Thesis Ref No: _____________

BIOMASS YIELD AND NUTRITIVE VALUE OF DESHO (*Pennisetum glaucifolium*) GRASS AS AFFECTED BY FORAGE STAND HEIGHT UNDER CENTRAL HIGHLAND CONDITION OF ETHIOPIA

MSc THESIS

BY

HAILEGABRIEL AJEMA DESALEGN

ADDIS ABABA UNIVERSITY COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE, DEPARTMENT OF ANIMAL PRODUCTION STUDIES

JULY, 2022

BISHOFTU, ETHIOPIA

Biomass Yield and Nutritive Value of Desho (*Pennisetum Glaucifolium*) Grass as Affected by Forage Stand Height under Central Highland Condition of Ethiopia

A Thesis Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Production

By

Hailegabriel Ajema Desalegn

Department of Animal Production Studies MSc Program in Animal Production

Major Advisor: Gebreyohannes Berhane (PhD, Assoc. Prof)

Co-Advisor: Gezehagn Kebede (PhD candidate, EIAR)

July, 2022

Bishoftu, Ethiopia

SIGNATURE PAGE

Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

Biomass Yield and Nutritive Value of Desho (*Pennisetum Glaucifolium*) Grass as Affected by Forage Stand Height under Central Highland Condition of Ethiopia

Submitted by: Hailegabriel Ajema Desalegn ______________ _______________

Name of student Signature Date

Approved for submittal to a thesis assessment committee

1. Dr. Gebreyohannes Berhane (PhD, Assoc. Prof) ____________ ____________
   Major Advisor Signature Date

2. Gezehagn Kebede (PhD, Candidate) _______________ ________
   Co- Advisor Signature Date

3. Dr. Gebreyohannes Berhane (PhD, Assoc.Prof) _____________ ___________
   Department Head Signature Date

Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

As members of the examining board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by Mr. Hailegabriel Ajema Desalegn entitled: "Biomass Yield and Nutritive Value of Desho (*Pennisetum Glaucifolium*) Grass as Affected by Forage Stand Height under Central Highland Condition of Ethiopia", and recommend that it be accepted as fulfilling the thesis requirement for the degree of Masters in Animal Production.

Alemayehu Lema (Professor) ________________ ___________________

Chairperson Signature Date

Diriba Diba (PhD,Assoc. Professor) _______________ ____________

External Examiner Signature Date

BerhanTamir (Professor) _________________ __________

Internal Examiner Signature Date

I hereby certify that I have read the revised version of this thesis prepared under my direction and recommend that it be accepted as fulfilling the thesis requirement.

Gebreyohannes Berhane (PhD, Associate Professor) ________________ ____

Major advisor Signature Date

Gezahign Kebede (PhD, candidate EIAR) ________________ _______

Co-advisor Signature Date

Gebreyohannes Berhane (PhD, Associate Professor) ________________

____

Department chairperson Signature Date

DEDICATION

This dissertation is dedicated to Dr. Muluneh Minta, my colleague who passed away after the Covid19 pandemic. A special feeling of gratitude to my loving parents, my father Ajema Desalegn, My mother Obse Bulbula and My brother Bedada Ajema whose words of encouragement and push for tenacity ring in my ears.

STATEMENT OF THE AUTHOR

I confirm that this work is my original work, and that all sources of information used in it have been correctly acknowledged. This thesis was submitted as part of the requirements for an MSc degree at Addis Ababa University's College of Veterinary Medicine and Agriculture, and it has been put in the College Library to be made available to borrowers in accordance with the library's regulations. I declare that this thesis is never submitted to any other institution for the intention of obtaining any an academic degree, diploma, or certificate. Brief extracts from this work are permitted without specific permission as long as the source is properly acknowledged. When the planned use of the material is in the interests of research, the head of the major department or the Dean of the College may grant permission for a lengthy quotation from or reproduction of this material in whole or in part. In all other cases, however, authorization from the author is required.

Name: Hailegabriel Ajema Desalegn Signature: _______________

Place: Addis Ababa University, College of Veterinary Medicine and Agriculture, Bishoftu.

Date of Submission: __________________________

BIOGRAPHICAL SKETCH

The author was born in Chelliya district, West Shewa zone of Oromia Regional State, Ethiopia, on January 22, 1991. He attended his elementary education in Gedo Dire Gudina Primary School and completed his high school studies at Gedo Senior Secondary and Preparatory School respectively. After passing Ethiopian Higher Education Entrance Examination successfully, he joined Hawassa University in the 2013 academic year and graduated with a B.Sc. degree (Distinction) in Animal and Range Sciences in July 2015. In April 2017, he was employed to the Ethiopian Institute of Agricultural Research and served as a Field Assistant and Junior Researcher for three years at Holetta Agricultural Research Center/Ada'a Barga Sub-center. Subsequently, in September 2021 he enrolled to Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Animal Production for the MSc study Program in Animal Production.

ACKNOWLEDGMENTS

I would like to thank almighty God for strength, commitment, health, and skill. I express my deepest thanks to my major advisor Dr.Gebreyohannes Berhane (Associate Professor) for his unreserved technical advice, guidance, and follow-up from Proposal development to Thesis write-up. I am also very grateful to my Co-advisor Mr.Gezehagn Kebede for his kind supervision and technical comments from the very beginning of proposal development to the final thesis write-up. My earnest thank is extended to the EIAR Livestock Research Director Dr. Fekede Feyissa for his unreserved follow-up and motivation. I would like to thank Dr. Bimrew Asmare for his major contribution to research on Desho grass which I used as reference in this thesis writing.

I am thankful to Addis Ababa University for hosting me and for financial support. My sincere thanks are also extended to the Ethiopian Institute of Agricultural Research for providing me with an Education opportunity with sponsorship during my study leave and Holetta Agricultural Research Center, especially the Dairy Cattle Breeding Program. My special thanks also go to the HARC Animal Feeds and Nutrition Research Program and particularly to Mr. Deraje Fikadu for his generous assistance in the laboratory Analysis and Mr. Kibret Hailu and Gebremedhin Hagos for their assistance in data collection sample preparation for Laboratory Analysis (Grinding). Last but not least gratitude goes to my brother Bedada Ajema who never forgets me in any situation, unreserved backup, and moral support during my study. After this thesis, I must express my heartfelt gratitude to those who, in one way or another, contributed to my success.

LIST OF ACRONYMS AND SYMBOLS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
AOAC	Association of Analytical chemists
AvDMY	Average dry matter yield
BMPRH1	Biomass production rate of harvest 1&2
CBD	Convention on Biological Diversity
CP	Crude protein
CV	Coefficient of variation
DAP	Di-ammonium Phosphate
OMD	Dry organic matter digestibility
DM	Dry matter
DMY	Dry matter yield
DMYTPH	Dry matter yield ton per hectare
HA	Harvesting Area
HT	Harvesting time
INL	Internode length
IVDMD	*In-vitro* dry matter digestibility
LDMY	Leaf dry matter yield
LLPP	Leaf length per plant
LP	Leaf percent
LSD	Least significant difference

LSR	Leaf to stem ratio
NDF	Neutral detergent fiber
NLPP	Number of leaves per plant
NNPP	Number of nodes per plant
NTPP	Number tiller per plant
OM	Organic matter
PH	Plant height
RCBD	Randomized complete block design
SDMY	Stem dry matter yield
SP	Stem percent
SSDW	Subsample dry weight
TDMY	Total dry matter yield
TFW	Total fresh weight

TABLE OF CONTENTS

Contents **Pages**

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

Figures Pages

LIST OF APPENDICES

TABLE PAGES

BIOMASS YIELD AND NUTRITIVE VALUE OF DESHO (*Pennisetum glaucifolium*) GRASS AS AFFECTED BY FORAGE STAND HEIGHT UNDER CENTRAL HIGHLAND CONDITION OF ETHIOPIA

By

Hailegabriel Ajema: (BSc) - Holetta Agricultural Research Center

Major Advisor- Gebreyohannes Berhane (PhD, Associate Professor) - Collage of Veterinary Medicine and Agriculture

Co-advisor-Gezehagn Kebede (MSc)-Holetta Agricultural Research Center

ABSTRACT

The study was conducted to evaluate biomass yield and nutritive value of Desho (Pennisetum glaucifolium) grass as affected by forage stand height under central highland condition of Ethiopia. A randomized complete block design with three replications was used. Cutting heights considered were 50cm, 60cm, 70cm, 80cm, 90cm, 100cm, 110cm and 120cm respectively. The combined analysis result shows the number of leaves per plant, number of nodes per plant, leaf length, internode length and dry matter yield were affected by cutting height(P<0.001). The highest number of leaves per plant was recorded for cutting height of 120cm with a mean of 8.15 followed by 100cm (7.20). The highest mean total dry matter yield were recorded for cutting height of 120cm (20.13t/ha), 110cm (18.22t/ha) and 100cm (18.18t/ha). All chemical analysis parameters (Ash, CP, NDF, ADL, IVDMD, OMD, and ME) tested for quality of Desho grass showed significantly affected by cutting heights (P<0.001), with DM and ADF at (P<0.05). CP% decreased as cutting height extended from 12.16-8.54% at 50cm-120cm cutting. Fiber contents showed an increasing trend with extended cutting height, except for late cutting (110cm and 120cm) of ADF% and recorded mean values of (73.5% NDF, 41.38% ADF, and 4.52% ADL. IVDMD, OMD, and ME, recorded 66.75%, 62.58%, and 10.01MJ respectively. Taking into consideration the mean values of agronomic parameters, yield, and nutritional quality, demonstrates that cutting Desho grass at 100 is recommended and it's the good harvesting height of Desho grass at Holetta.

Keywords: Biomass yield, Central highland, Cutting heights, chemical composition, Desho grass

1. INTRODUCTION

Livestock is an integral part of the agriculture in Ethiopia and contributes about 40% to the agricultural economy in live and their products (Asresie *et al*., 2015). Ethiopia holds Africa's richest animal population, with 70.29 million cattle and 42.9 million sheep, 52.5 million goats, 57 million chickens, 8.1 million camels, 6.9 million bee colonies, and 12.9 million equines, according to estimates by CSA, (2021). But, in proportion to its potential livestock population, the country has the least livestock productivity levels, even when compared to Sub-Saharan African countries(Adugna *et al*., 2012), while the contribution of livestock to agricultural GDP is the most commonly quoted single measure of livestock's importance to the overall national economy(IGAD Centre for Pastoral Areas and Livestock Development, ICPALD (2009).

Inadequate supply of feed for the existing livestock population and poor quality of the available feed resources are the two main factors that contribute to the low production and productivity of livestock in Ethiopia (Asresie *et al*., 2015). Tibbo, (2000), ranked feed shortage as the first among livestock diseases, to the low genetic potential of indigenous livestock, lack of marketing infrastructure, and water shortages. Tilahun *et al*., (2005) also ranked poor animal nutrition top among four important constraints; disease, poor livestock management, and breeds. In Ethiopia, natural pasture holds the major source of feed for livestock (Alemayehu *et al*., 2017). Main feed for livestock is entirely based on natural pasture, browse species, and crop residues (Tibbo, 2000). Most of the feed in the Ethiopian highlands is obtained from natural pasture and crop residues (Tilahun *et al*., 2005).

Ethiopia has a net annual fodder biomass production of 144.5 million tons, with ME and CP values of 890 x 109 MJ and 7.49 million tons, respectively (Aranguiz & Creemers, 2019). Except in the Harari region, where improved forages account for 1.68 percent of the diet, hay and crop residues together with natural grass account for more than 90 percent of all animal diets(Aranguiz & Creemers, 2019). Even though the feed is available to a certain extent, in the majority of cases, it is not in a position to satisfy the quality for higher productivity of our livestock sector in Ethiopia. Available concentrate feeds and agro-industrial by-products are still at a very low level of supply to feed the present livestock population. In addition to availability, it is also true that prices attached to livestock feeds are still very high; hence, accessibility of feeds for most smallholder farmers is a question of the day (Getnet *et al*., 2012). For this reason, sustaining improved forage production through environmentally feasible means and research is essential to be able to boost livestock productivity in the country at both small-scale and commercial levels.

One of the recommended profitable options to address this challenge of feed shortage is improved forage production using strategies suitable for a given farming system (Adugna, 2012). The utilization of locally accessible forage plants as feed resources is highly suggested to address existing livestock nutritional limits because they are familiar to smallholder farmers, grow with minimal input and adapt to local environments (Bimrew *et al*., 2017). Although grasses provide more energy than legumes, research on forage grasses for the highlands has underperformed (Tilahun *et al*., 2005).

In Ethiopia, both public and transnational exploration organizations have performed investigations on fodder products and consumption. Nonetheless, the investigations focused on the agronomic and nutritional features of feed sources, as well as animal responses to different feeds and feeding strategies (Seyoum *et al*., 2001) and recommended an alternative solution to overcome feed shortage and improve livestock productivity would be to introduce improved forage technologies into the farming systems. Shortage of green forages can be alleviated by the introduction of high-yielding new multi-cut forages which can supply green herbage in adequate quantities during periods of scarcity (Mohamed & Gebeyew, 2018). Due to forage plant characteristics being most sensitive to changes over time, forage must be analyzed regularly to determine if it meets the animals' daily nutritional needs (Newman *et al*., 2006). Forage intake and forage nutritive value are two forage-related parameters that influence animal performance and these components work together to influence the forage's quality (Adesogan *et al*., 2009). Determining the best height to harvest Desho grass will require striking a balance between productivity and feed quality (Tilahun *et* *al*., 2017). Understanding a forage growth and developmental behavior is thus beneficial in estimating optimum plant growth, optimum timeframe for defoliation, and optimum timing and rate of nutrient administration (Mekasha & Mengistu, 2007).

In Ethiopia, certain information on Desho (*Pennisetum glaucifolium*) grass is generated in the form of publications and working papers (Smith, 2010; Leta et al., 2013,;Bimrew,2016). Desho grass is a multipurpose grass that plays an important role in soil and water conservation (Welle *et al*., 2006). No suitably informative attempt has been undertaken to identify superior yield and nutritional value within the context of the relevance of Desho grass. Lukuyu *et al*., (2011) raised concern about this and stated that to incorporate locally accessible feed resources into animal feeding systems, it is necessary to understand the chemical composition and use the information of such resources. As a result, research into the impact of cutting height when harvesting, on agronomic features, yield, and nutritional value of Desho grass in Ethiopia's Central highlands is critical. As a result, the following objectives were established for this study:

- Determining the appropriate cutting of Desho grass harvesting height that ensures optimum dry matter yield and nutritive value
- Assess the agronomic characteristics of Desho (*Pennisetum glaucifolium*) grass grown in central highlands

2. LITERATURE REVIEW

2.1. Livestock feed resources in Ethiopia

There are different kinds of animal feed resources in Ethiopia (Bimrew, 2016). Natural pasture (54.4%) and crop residues (31.13%) are the largest contributors to feed livestock among feed resources (Sere *et al*., 2008; Hassen *et al*., 2010), which is the reality in the majority of developing nations. The contribution of all feed supplies are dependent on crop types, agro-ecology, production system, and accessibility of the feeds (Alemayehu *et al*., 2017). According to Seyoum *et al*., (2001), the mode and intensity of crop product, agro-ecology, population pressure, season, and climatic circumstances, such as rainfall distribution, all influence feed resources. Alemayehu, (2005) classified Ethiopian animal feed supplies as pastureland, crop residue, improved pasturage, fodder trees, forage crops, agro-industrial byproducts, and some non-conventional feeds. Most of the feed in the Ethiopian elevations is attained from natural pasture and crop remainders (Tilahun *et al*., 2005).

2.2 Feed resources and distribution over seasons

Feed deficit is critical during the dry time of year (Tilahun et al., 2005). Crop residues from the cereal fields are abundant during the dry season and low in metabolizable energy and protein content. This problem is addressed to some extent by mixing crop residues with varied forage legumes like beats which are important protein suppliers' adjuncts to energy-rich cereal crop residues (Tilahun *et al*., 2005). Some improved forages like Rhodes grass exist in the highlands of Ethiopia. The most extensively grown forage grass is Napier (*Pennisetum purpureum*) which is commonly planted in fodder banks or on strips to mark boundaries of plots (Tilahun *et al*., 2005). According to Husen *et al*., (2016), 8.89% of the repliers in Jimma zone use wild browse/ fodder trees and shrubs as the main sources of livestock feeds substantially during the dry season with the stubble grazing as one of the ways by which stock keepers more depend. Desho grass is among the most accessible type of forage in Ethiopia, with Elephant/Napier grass, Oat, Vetch, Cowpea, Lablab (Shiferaw *et al*., 2011).

2.2.1 Natural pasture

Natural pasture is the primary source of roughage feed (Adugna *et al*., 2012). Livestock grazing is the principal shape of land use in pastoral regions, while inside the densely populated highland and mid-latitude regions the upper soils are used for cropping, and best the hilly and seasonally waterlogged areas are allotted for grazing. Rangelands represent more than 60% of Ethiopia's land area (Adugna *et al*., 2012).

Many experts believe that natural pasture is the most important feed resource, yet estimates of its contribution vary substantially (Alemayehu, 2004). The case for this is because the quantity and quality of natural pasture change with altitude, rainfall, soil, and cropping intensity. Ethiopia's grassland region covers 30.5 percent of the country's total area, with the western, southern, and southeastern semi-arid lowlands being the most extensive (Alemayehu *et al*., 2017). According to information gathered from feed owners in rural parts of Ethiopia, green forage (grass) is the most significant type of feed (54.54%)(CSA,2021). With the rapid growth of the human population and rising need for food, grazing pastures are being converted to arable land, and are now limited to locations with little value or farming potential, such as hilltops, swampy areas, roadsides, and other marginal lands (Alemayehu *et al*.,2017). This is especially true in Ethiopia's mixed-farming highlands and mid-altitudes. Ethiopia's grassland region covers 30.5 percent of the country's total area, with the western, southern, and southeastern semi-arid lowlands being the most extensive (Alemayehu *et al*., 2017). According to information gathered from feed owners in rural parts of Ethiopia, green forage (grass) is the most significant type of feed 54.54% (CSA, (2021).

2.2.2 Indigenous and improved forages

Desho (*Pennisetum pedicellatum*) grass is a locally available, versatile, and promising feed resource in Ethiopia, likewise as tropical Africa, and is found across the continent from West to East (Leta *et al*., 2013). According to (Welle *et al*., 2006), is an essential grass that is used to prevent soil loss by 43 percent in the Jigjiga area, as well as being used as cattle fodder. In pastoral and agro-pastoral areas, local Acacia tree species, as well as selected non-leguminous species are sources of feed for cattle (Derero & Kitaw, 2018). Rhodes grass (*Chloris gayana*) is a tropical and subtropical African perennial grass that has remained one of the most important forage grass (Melese, 2021) and it is a versatile grass that can be utilized as a pasture, hay, or ley crop. Napier grass is a tall, deep-rooted perennial bunch of grass that is mostly utilized in cut-and-carry feeding systems because of its great yielding capabilities (FAO, 2015). It grows best at high temperatures, but can endure low air temperatures with lower yields, and ceases to develop at temperatures below 10°C, according to (Fekede *et al*., 2005). With proper agronomic and management techniques, Napier grass might play an important role in delivering a considerable quantity of biomass production of 20- 30 t DM/ha/year, which is one of the improved fodder crops recommended in Ethiopia (Farrell *et al*., 2002). Chifir Bequa (*Pennisetum Polystachion*) is a fast-growing tropical grass fodder variety selected from locally available prospective collections by the Ethiopian Institute of Agricultural Research, Pawe Research Center (Getnet *et al*., 2020). Under the present Ethiopian conditions, cultivated fodder crops like Oats, Vetch, Alfalfa, and Fodder beet aren't well grown (Getnet and Ledin, 2001; Alemayehu, 2005). A number of the identified causes for the limited adoption of enhanced forage production include an absence of land within the mixed crop-livestock production system, technical issues like planting and managing seedlings, insect damage, and farmers' lack of enthusiasm (Abebe *et al*., 2008). Some indigenous multipurpose plants, such as *Vernonia amygdalina*, *Buddleja polystachya*, *Maesa lanceolata*, *Enset ventricosum*, and *Bambusa spp*., have been identified as potential animal feed resources in smallholder traditional farming systems in various parts of the country (Aynalem and Taye, 2008; Beyene *et al*., 2010).

2.2.3 Crop residues

The significant reliance on crop residues as livestock feed is anticipated to expand as additional grazing lands are farmed to supply the grain needs of the rapidly growing human population (Bimrew, 2016). The recent report of CSA, (2021) put use of crop residue as a feed for livestock in Ethiopia (31.13%). Crop residues are high in fiber content, low digestion, and low intake. Crop residues and aftermath grazing make for more than 60-70 percent of ruminant animals' basal diet in the most widely cultivated areas, according to reports (Seyoum *et al*., 2001). Endale *et al*., (2021) reported that crop residues are fed to dairy cattle by the majority of responders in Ada'a Berga, Dirre Inchinni, and Walmara. Crop residues alone accounted for 78.72 percent of livestock feed supplies Alaba disctrict of Ethiopia (Yeshitila, 2008).

2.2.4 Agro-industrial by-products

Concentrate feeds are most commonly made from agro-industrial by-products, grain, and grain screens. Agro-industrial by-products include flour mill by-products, oil-processing plant by-products, breweries by-products, and sugar factory by-products, to name a few (FAO, 2018). Wheat bran is the most prevalent by-product of Ethiopian flour mills, and it is used to feed livestock. The flour mill business produces wheat middling, wheat short, rice bran, bean bran, bean hull, lentil bran, and lentil hull as by-products (Adugna *et al*., 2012). Molasses is the most common by-product of sugar mills, but bagasse and sugar cane tops are alternative by-products that can be used as roughage. Agro-industrial by-products make up a minor percentage of animal feed (2.03%) and are mostly employed by commercial livestock operations and small-scale livestock farmers in urban and peri-urban regions(CSA,2021). The annual supply of agro-industrial by-products is insufficient to meet the rising demand for these products in farm animal diets. Wheat milling by-products and oilseed cakes are estimated to yield 269,238 and 102,225 tons, respectively, every year (Adugna *et al*., 2012). Flour mills and oil processing plants are operating at less than half their capacity due to a paucity of raw materials and the non-competitiveness of the goods (Adugna *et al*., 2012). The principal agro-industrial by-products in Ethiopia nowadays include residues left behind after oil seed and grain processing (Firew and Getnet, 2010) and they are influenced by amino acid availability and digestibility, mineral and vitamin concentrations, and moisture, fiber, and urease levels. Ethiopia has the potential to produce 567 thousand tons of oilseed cakes and the highest potential availability is Noug cake (34.2%), followed by sesame, but sesame seeds are exported, there is no contribution of sesame seed cake to animal feed (FAO,2018). Similarly, FAO, (2018) reported Ethiopia's potential to produce 2041 thousand tons of cereal bran per year which is nearly 3.6 times higher than oilseed cakes, while crop-based forages are 25.8 times lower

2.3. Forage yield and quality

Forage quality is influenced by a combination of environmental and genetic factors (Van Soest, 1982). The ability of forage to support desired levels of animal performance is referred to as forage quality (e.g., daily gain or milk production) and voluntary intake, as well as nutritional value (nutrient content and digestibility), determine it (Hancock, 2017). According to the FAO, (2018), the difference between the availability of feed resources as DM, ME, and CP, and requirements of all animal species, feed deficiency in the country is 9% as DM, while ME and CP deficiencies are 45% and 42% respectively. Genotype, maturity, season, management, and anti-quality components all have an impact on forage quality and because of all of these aspects and their interconnections, tables of forage quality and nutritional value are unlikely to provide valuable information about a single forage (FAO, 2018).

Reduced cell soluble are caused by increased fiber (cellulose, hemicellulose, and lignin), movement of nutrients from leaves to roots, and leaching of cell soluble by rain and snow during dormancy (Lyons *et al*., 2000). According to (Diribi, 2022) the dry matter content increases as the harvesting stage progressed and reported the highest 92.98% at DM content was obtained from the harvesting stage of 90 days while the lowest was from 45(92.78%) and 60(92.79%) days harvesting stage of bracharia grass. DM, as well as the OM, NDF, cellulose, and hemicellulose contents, increased while ash and CP contents decreased as the harvesting age of *Pennisetum clandestinum* increased from 30,45 and 60 days (Muhindo *et al*., 2018). Eniyew *et al*., (2021) reported a dry matter percentage of 91.08 for Desho grass, which was lower than the higher dry matter percentage of 91.96 percent for Buffel and Setaria (91.42 percent). The dry matter yield of Desho grass increased with increasing cutting intervals, according to (Tilahun *et al*., 2017; Kefyalew *et al*., 2020). Between the harvesting dates of 75,105 and 135, the DM concentration exhibited minimal change, ranging from 88.2 to 89.1 percent (Tilahun *et al*., 2017). Mulisa *et al*., (2021) also reported a 91.64 dry matter percentage for Desho grass. Yirgu *et al*., (2017) reported (41.48 and 38.48) Dry matter percent for Kulumsa and Kindo kosha variety of Desho grass during the second harvest. Denbela *et al*., (2020) reported 89.67%, 89.33%, 90%, and 90.33% of Dry matter percent content for Kulumsa, Areka, Kindokisha DZF92, and Kindokisha DZF589 varieties of Desho grass respectively; the increase in DM content from the first to the last cutting in this study should be explained by the fact that as the plant matures, its water absorption capacity decreases. As a result, dry matter accumulates more in plant cells.

Ash is a leftover of a feed sample comprising inorganic mineral elements that is evaluated in a laboratory by burning the sample at a high temperature (removing the organic matter) and weighing the residue (Hancock, 2017). Mulisa *et al*., (2021) reported 15.87% ash content for Desho grass tested in mid altitude Holetta. As harvesting age increased, ash concentrations decrease significantly, with values at 75 days exceeding those at 105 and 135 days and this was linked to progressive increases in plant spacing, which resulted in significant ash concentration increases (Tilahun *et al*., 2017). Minson, (1997) reported for Desho grass a 13.92 percent ash content, and that the ash content decreased as harvesting time increased. Mineral concentration declines with age, according to McDonald *et al*., (2002), and is influenced by soil type, soil nutrient levels, and seasonal conditions. This could be due to the diffusion and remobilization of minerals attributed with the leaf's vegetative portion as it matures. A reduced ash level is advantageous for feeding animals because it reduces silica, which interferes with feed digestion. Berhanu *et al*., (2007) and Terefe, (2017) reported a decreasing trend in total ash concentration as plant age rose, which is consistent with this finding. Denbela *et al*., (2020) reported 7.33, 7.29, 10.22, and 7.85 ash content for Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 Desho grass respectively.

Protein supplements are necessary when the protein content of forages, silages, or grains used in animal feeding is insufficient to meet the needs of the animal type(Hancock, 2017), and as a result, total protein or crude protein analysis in a feed sample is critical. Desho grass harvesting age had a significant effect on crude protein (CP) concentration, dropping from 10.9% at 75 days to 9.3% at 135 days (Tilahun *et al*., 2017). According Mulisa *et al*., (2022), crude protein yield differed considerably among accessions, with the maximum crude protein output was produced by Desho grass, followed by B. decumbens (accession ILRI-13205), B. decumbens (accession ILRI-14721), and S. sphacelata (accession 6543. Tilahun *et al*., (2017) reported that Desho grass cut at a young age exhibited great nutritional value, with a high CP concentration (10.9% CP), which is a limiting nutrient in tropical forages. Even at 135 days of age, crude protein concentrations were significantly more than 7.0%, which means it was 9.3%; and 7% is the minimum voluntary intake of ruminants that can be reduced. According to (Muhindo *et al*., 2018), crude protein (CP) contents decreased from the first mow to last. Diribi, (2022) report revealed CP decreased as the harvesting stage extended but increased with increasing NPS fertilizer levels for Bracharia Mulato II grass. Cattle require a minimum CP of 15% for lactation and growth (Norton 1982; Van Soest 1982). Zewdu, T. (2005) reported 15.7% CP for Napier grass accessions (16791), 13.9 % (16853), and 13.2% CP for the local variety of Napier grass. According to Demlew *et al*., (2019) on harvesting time of 90days, the highest CP content (20.51%) was found, while at 150days, the lowest (15.13%) CP was found. Harvesting times 90days had higher CP content than 120days and 150days, while harvesting days 150 had significantly lower CP content than 90days and 120days for Buffel grass and silver desmodium (Demlew *et al*., 2019). This finding showed that as plant age increased, CP content in samples collected during the trial period reduced significantly. This could be attributed to an increase in structural carbohydrate content diluting the CP concentration of forage materials gathered at late maturity. In immature herbage, higher proportions of vegetative grass tillers are linked to higher CP concentration than after extended growth (Steinshamn *et al*., 2016). This finding supports the findings of (Bimrew, 2016; Terefe, 2017; Genet *et al*., 2017), who found that CP content decreases as plants grow. Desho grass varieties; Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 had Crude protein content of 11.84, 14.12, 13.39, and 9.57 percent, respectively (Denbela *et al*., 2020).

According to Lepcha & Naumann, (2021), a greater proportion of forage mass was consistently partitioned to the stem as crop biomass increased and the leaf-stem ratio decreased. The total fiber (NDF) concentration in the stem increases as the structural tissue proportion occupies a larger portion of the stem than the leaves. As a result, the stem received a lower proportion of the forage nutrients than the leaves. The NDF value should be as low as possible. A high NDF level in forage indicates a high total fiber content (Newman *et al*., 2006). According to (Demlew *et al*., 2019), forage stand and harvesting time showed extremely significant effects on NDF respectively. Demlew *et al*., (2019) reported NDF content increased as harvesting time increased, with the highest mean NDF content (54.46%) reported at the later harvesting period (150 days) and the lowest (46.38%) at the shortest harvesting time (45 days) (90 days). Comparable trend by (Minson, 1997), at 150 days after harvesting, the highest value (52.68 percent) was observed, while the lowest value (44.66 percent) was reported at 90 days following harvesting. As the grass grows older, this could be due to an increase in fiber content, which is accompanied by a decrease in CP content, as well as an increase in the percentage of lignified structural tissue (Van Soest, 1982; McDonald *et al*., 2002). The findings of (Taye *et al*., 2007; Bimrew, 2016; Genet *et al*., 2017; and Terefe, 2017), report indicated that pasture maturity increased NDF content. Feeds with NDF values less than 45 percent are considered high-quality, those with values between 45 and 65 percent are considered medium-quality, and those having a value of more than 65% are considered low-quality (Singh and Oosting, 1992). The amount of NDF in tropical grass that affects cattle's dry matter intake is 60% (Meissner *et al*. 1991). Desho grass lines of Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 had 57.73, 55.12, 56.7, and 63.42 percent Neutral detergent fiber content (Denbela *et al*., 2020).

The indigestible component of forage is made up of lignin, cellulose, silica, and insoluble nitrogen forms. Forages with a greater ADF have less digestible energy than forages with a lower ADF, hence the digestible energy level drops as the ADF level rises (Hancock, 2017). The harvest age has a significant impact on the fibrous material concentration. This could be due to an increase in ADF concentration with a decrease in the leaf to stem ratio and an increase in cell wall lignification as the plant progresses through the stages of development (Gebrehiwot *et al*., 1996). With advanced harvesting age, ADF has a close relationship with a drop in leaf-to-stem ratio and a rise in cell well lignification could be explained by the increase in ADF content as plants mature (Berhanu *et al*., 2007; Taye *et al*., 2007; Bimrew, 2016) and Genet *et al*., 2017) in Desho grass and Terefe, (2017) in Rhodes grass, respectively, found that as plants matured, their ADF content increased. As plants age, photosynthetic products are converted more quickly to structural components, resulting in a drop in protein and soluble glucose and an increase in structural cell wall components (Ammar *et al*., 2004). The ADF concentration decreased as the harvesting stage was extended, with the lowest ADF concentration being 45 days after total clearing (Diribi, 2022), and reported the mean value (31.77 %) of ADF.

Because lignin is indigestible, it decreases cellulose's digestibility. The digestibility of cellulose decreases as the amount of lignin in a diet increases, limiting the amount of energy accessible to the animal (Hancock, 2017). Lignin is an essentially indigestible component of fiber that builds up largely at maturity and acts as a barrier to rumen microorganisms degrading fiber, is one of the main chemicals deposited internally in the plant cell walls as the plant matures (Newman *et al*., 2006). According to (Diribi, 2022) Acid detergent Lignin was affected by the harvesting stage of the plant and increased with the extended harvesting stage. Minson, (1997) reported the highest ADL (10.03%) content was found in the third harvesting time(150 days), compared to the first harvesting time(90 days) (7.70%) and second harvesting time(120 days) (8.73%), indicating the occurrence of rapid lignification's as forages species developed. The lignin concentration of the cell wall increased exponentially as the total cell wall concentration of the grasses increased (Jung & Vogel, 1986). By reducing nutrient availability, forages with higher ADL concentration had lower overall digestibility of the meal (Van Soest, 1994). As a result, Van Soest (1982) found that lignin content above 6% harms fodder digestibility.

2.3. Improved forage crops production in Ethiopia

Aranguiz & Creemers, (2019) listed the most common improved species of forage crops in Ethiopia are; Oats, Vetch, Desho, Napier grass, Fodder beet (*Beta vulgaris*), Siratro (*Macroptilium atropurpureum*), Desmodium species, Cowpea (*Vigna unguiculata*), Lablab (*Lablab purpureus)*, Sweet lupine (*Lupinus angustifolius L*.), Rhodes grass (*Chloris gayana)*, Lucerne (*Medicago sativa*), Phalaris species, Trifolium species, Sesbania species, Leucaena species, Tree Lucerne(*Cytisus proliferous*). Some smallholder farms have begun to employ enhanced fodder, but it accounts for only 0.2

percent of total animal feed (Yilma *et al*., 2011) and presently increased to 0.57% (CSA, 2021). According to CBD Ethiopia's 4th Country Report,(2014), there are 736 kinds of grasses, 358 types of legumes, and 179 species of browsing trees suitable for animal grazing. Feyissa et al. (2022) recommended Desho grass (var. Kulumsa) as among the evaluated grass species performance to be used as alternative forage grass for the central highland Holetta area and similar agro-ecologies.

2.4. Desho grass production and utilization

Desho grass is a perennial plant that first appeared in Chencha in 1991 in the Southern Nations, Nationalities, and Peoples Regional State (Welle *et al*., 2006). It is regarded as an improved forage. Desho grass demands the allocation of resources such as land, fertilizer, and labor, as well as management practices (Bimrew *et al*., 2017). Desho grass (*Pennisetum pedicellatum*) is a Poaceae family perennial grass native to Ethiopia (Hidosa & Getaneh, 2021). Desho grass is comparatively more used under a cut-and-carry system (Bimrew *et al*., 2016). Desho grass is more commonly employed in a cut-and-carry system, and it is primarily used for cattle with the highest nutritional needs, such as lactating cows, regardless of other considerations (Bimrew *et al*., 2016). Desho grass has the ability to meet feed scarcity problems since it delivers more forage per unit area and maintains a consistent supply of forage due to its multi-cut nature (Ecocrop, 2010). Similarly, Desho grass grown well at altitudes ranging from 1500 to 2800 meters above sea level and is appropriate for intensive treatment (Leta *et al*., 2013).

2.5. Agronomic performance of Desho grass lines

Desho grass agronomic performance varies depending on the agro environment and season of the production system. The huge disparities in height, physic-chemical properties of the soil, temperature, differences in both the amount and distribution of yearly rainfall and other agro-climatic parameters might be attributable to the highly significant environment effect and its high variance component. The higher forage yield could also be related to the good rainfall, temperature, and nutrient availability in the soil (Bimrew *et al*., 2017; Gezehagn *et al*., 2016).

Desho grass yield varies among varieties; the Areka-DZF590 variety yielded more dry matter than KindoKisha-DZF591 and Areka local check varieties, although it was equivalent to the Kulimisa-DZF590 variety in a study conducted under irrigation in Ethiopia's South Omo zone (Hidosa & Getaneh, 2021). According to Yirgu *et al*.,(2017) research in Wondogenet, the agronomic performances of height, vigor, dry matter ratio (DMR), dry matter yield in (t/ha), and dry matter, leaf to stem ratio were not significantly different among four Desho grass lines. Kindo kosha-DZF591 and Kindo kosha-DZF589 lines exhibited substantially lower cover than Kulumsa-DZF592. Birmaduma et al., (2019) reported from Mechara that the agronomic performance of regeneration %, plot cover, stand vigor, and leaf to stem ratio between Desho grass lines included in their experiment did not reveal a significant difference. However, there was a significant difference in the analytical variance for plant height (cm) and dry matter yield (t/ha) between Desho grass lines.

According to Bimrew *et al*., (2018a), the stage of harvest had a greater impact on plant features and productivity of Desho grass. The quality of the forage decreases as it matures, with lower CP concentrations and higher NDF, ADF, and ADL concentrations. While delayed harvesting yields more DMY, it does so at the expense of quality. Harvesting time has a considerable impact on all agronomic characteristics. With advanced plant maturity, plant height, number of leaves, number of tillers, and leaf area tended to increase, while leaf to stem ratios tended to decrease. Therefore plant age, despite greater values in most parameters, harmed the agronomic performance of forage grasses and legumes (Yegrem *et al*., 2019). According to Hidosa & Getaneh, (2021), the Areka-DZF590 Desho grass variety produced higher dry matter and crude protein in the South Omo area. Hidosa & Getaneh, (2021) also reported, the Areka-DZF590 variety produced a higher dry matter yield than the KindoKisha-DZF591 and Areka local check varieties, but it was comparable to the Kulimisa-DZF590 variety. Harvesting time and forage stands had a substantial impact on plant height (Yegrem *et al*., 2019). According to (Bimrew *et al*., 2017b; Bimrew *et al*., 2018a ;), altitude and harvesting dates had a substantial impact on plant height (PH). In terms of harvesting dates, the maximum plant height was found at mid-altitude, and as the date of harvesting grew, so did the height of the plant. In contrast to this (Hidosa &

Getaneh, 2021) reported that the cutting height above ground was unaffected by the locations. The variation is likely due to differences in soil type and harvesting times.

The number of tillers per plant, increases with increasing harvesting age, while the leaf to stem ratio (LSR) decreased with fertilization application (Kefyalew *et al*., 2020). Species, harvesting time, and their interactions all had a substantial impact on the number of tillers and branches per plant (Yegrem *et al*., 2019). The mid-altitude location had the most tillers per plant, and the number of tillers per plant grew as the harvesting date approached (Bimrew, *et al*., 2018a). The number of tillers per plant was affected by location. Hidosa & Getaneh (2021), reported that the Dassench area produced substantially more tillers per plant than the Hamer area. The number of tillers per plant is affected by spaces between plants; (Worku *et al*., 2017), reported there is a substantial difference in the number of tillers in planting spaces, suggesting that as planting space grows, the number of tillers per plant grows. As a result, biomass production increases as the number of tillers per plant increases.

Altitude and harvesting date had an effect on the number of leaves per plant (NLPP), but the interaction of these factors had no effect and for mid-altitude, the bigger NLPP (273.24) was observed (Bimrew, *et al*., 2018a). The mid-harvesting date (105) had the highest NLPP, whereas the early harvesting date (75 days) had the lowest (Bimrew, et al., 2018a). Harvesting periods, forage stands, and their interaction had a substantial effect on the number of leaves per plant, according to (Yegrem *et al*., 2019). At 90, 120, and 150 days after harvesting, the number of leaves per plant was 84.8, 242, and 362, respectively. The third harvesting time produced much more leaves per plant than the first and second harvesting times.

Harvesting periods had a considerable effect on the leaf to stem ratio, but harvesting times did not affect forage stands or their interaction with harvesting time. The highest leaf to stem ratio (2.04) was found on the 90th day of harvesting, while the lowest (1.14) was found on the 150th day (Yegrem *et al*., 2019). According to research from two locations (Hidosa & Getaneh, 2021) the leaf to stem ratio was significantly higher in Dassench than in Hamer; showed that location affect the leaf to stem ratio of the forage grass. According to Lepcha & Naumann, (2021) a greater proportion of forage mass was consistently partitioned to the stem as crop biomass increased and the leaf-stem ratio decreased.

Harvesting periods and forage stands both had an impact on dry matter yield per hectare. According to Yegrem *et al*., (2019), the maximum Dry matter yield (6.08 t/ha) was recorded at the third harvesting time (150 days), while the lowest (2.45 t/ha) value was recorded at the first harvesting time, indicating that harvesting time can affect dry matter production. The dry matter yield was not considerably affected by the investigation locations (Hidosa & Getaneh, 2021). This could be related to the plant's suitability to temperature and favorable soil parameters, which cause faster plant growth and trigger more leaves per plats, as a result, the dry matter yield, cutting height, and the number of tillers per plant are all higher. According to Gezahagn *et al*.,(2017) the tested genotypes of Napier grass differed significantly in terms of plant height and forage DM yield in different locations.

2.6. Factors affecting preference of Desho grass for livestock

Maturity of the grass, feeding value and agronomic ecology all influence the preference of Desho grass utilized for livestock feed. Farmers would like to cut and carry more due to agroecology and terrain (Bimrew *et al.*, 2016). Because the topography is mountainous and grazing is restricted, farmers would choose to cut and carry. In animal evaluation research, Bimrew (2016) found that Desho grass hay had a superior chemical composition, especially in crude protein (CP) content, higher intake, and palatability by sheep than a mixed sward natural pasture hay. However, Seid *et al*., (2021) found that lambs fed on Desho grass alone had poorer dry matter intake, live weight growth, carcass yield, and feed cost per unit live weight gain than lambs fed on supplemented grass. Additionally, increasing the proportion of Desho grass hay in Washera lambs' baseline diet from 0 to 100% increased DM intake, nutrient digestibility, body weight, and feed conversion efficiency, resulting in overall better performance at the high level of grass-feeding(Bimrew,2016). When compared to control and 40% poultry feeding level, Desho grass ensiled inside 20% to 30% broiler litter enhanced Crude protein (CP) content and intake by Kaffa goat intake(Zeleke,2017).

Varied harvesting dates affected the chemical makeup and herbage yield of the grass; as harvesting dates were extended from 60 to 120 days following planting, plant DM, OM, NDF, ADF, ADL, and hemicellulose content increased, whereas crude protein levels decreased (Taye *et al*., 2007; Peiretti, 2009). With an increase in harvesting days after planting, the number of tillers increases, leaf formation, leaf elongation, and stem growth could be linked to an increase in herbage output (Ansah *et al*., 2010). Increases in plant height during later harvest stages, according to (Melke, 2005), could be attributed to extensive root development and efficient nutrient uptake, allowing the plant to continue to grow.

In forage crops, plant height is an essential factor that influences yield. Desho grass produces a lot of biomasses and grows upright, reaching 90 cm to 120 cm in height depending on soil richness (Shiferew *et al*., 2011). Increases in plant height during later harvest stages, according to (Melkie, 2005), is attributed to extensive root development and efficient nutrient uptake, allowing the plant to continue to grow. Plant height increased significantly with harvesting age, 46.2 cm at 75 days to 69.8 cm at 105 days and 83.1 cm at 135 days (Tilahun *et al*., 2017). According to a report by Yakob *et al*., (2015), the height of Desho grass harvested at the first and second harvests was 122cm and 120cm, respectively. Mulisa *et al*., (2021) recommend harvesting Desho grass at a height of >40cm as the initial cutting height. Desho grass lines were harvested at 50 cm maturity at 10 cm above ground for the goal of evaluating herbage yield and quality under irrigation at Wondogenet, Ethiopia (Yirgu *et al*., 2017). Tessema *et al*., (2010) found that cutting heights (5cm, 10cm, 15cm, 20cm, and 25cm) above ground had a significant effect on total ash and CP, but no significant effect on other chemical components or IVDMD content in Napier (*Pennisetum purpureum*) grass, which is closely related to Desho grass

3. MATERIALS AND METHODS

3.1 Description of study area

The highland agro-ecology in Ethiopia, is defined by an altitude of more than 1500 m *a.s.l*, cover around 44% of the country and support 70% of cattle production and the central Ethiopian highlands are above 1800 m *a.s.l*, with an annual mean rainfall of more than 800 mm (Tilahun *et al.*, 2005).The research was carried out at Holetta Agricultural Research Center (HARC) under rain-fed conditions over the main cropping seasons of 2019 to 2021. HARC is located at 9°00'N latitude and 38°30'E longitude, at an elevation of 2400 m *a.s.l*. With an average annual rainfall of 1055.0 mm, relative humidity of 60.6%, and average maximum and lowest air temperatures of 25°C and 4.6°C, respectively. It is located 34 kilometers west of Addis Ababa on the road to Ambo. The rainy and dry seasons are the two major seasons in the research region. Rainfall is bimodal, with almost 70% falling between June and September and the remaining 30% falling between March and May. (EIAR, 2005). The research area's soil type is Nitosol with a Clay textural class. The soil pH of Holetta is 5.51 with a total Organic Carbon of 1.94%. It has the total nitrogen of 0.18 percent and 7.46ppm available Phosphorus EIAR, (2022). CEC is an acronym for "cation exchange capacity" and refers to a soilless medium or soil's capacity to hold and exchange mineral nutrients. Map of study area is indicated in Figure 1.

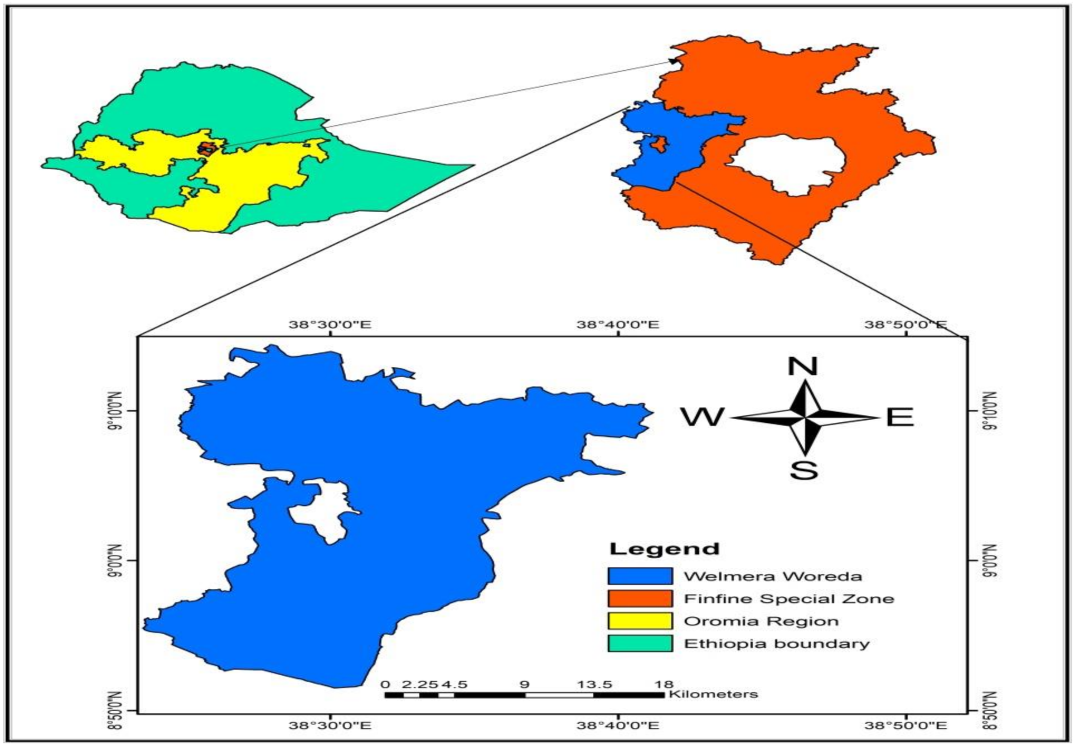

Figure 1 Map of the study area

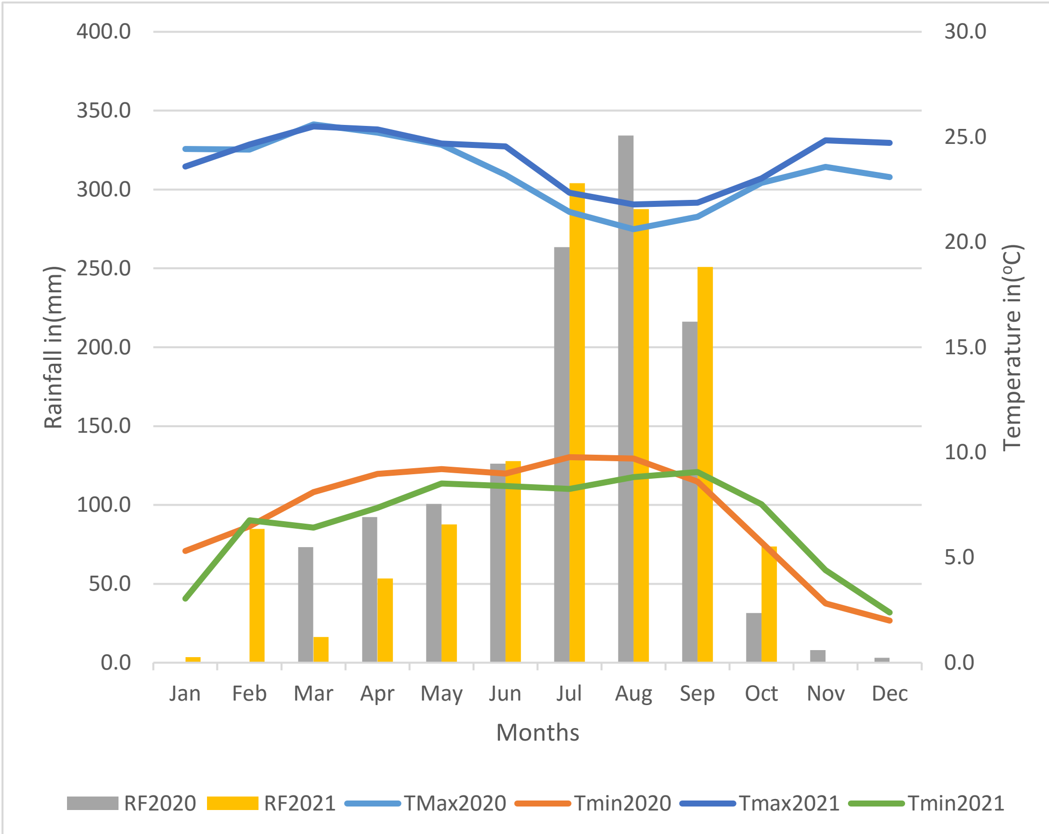

Figure 2. Weather condition of the area during the study duration

Table 1. Soil characteristics of the study area (EIAR (2022).

Ser.No	Parameters	Value
1	pH	5.51
2	OC (%)	1.94
3	P(ppm)	7.46
4	TN%	0.18
5	CEC(meg/100g	24.33
Texture		
6	Clay%	57.50
7	Silt%	29.17
8	Sand%	13.3
Textural class		
9	Clay	

Note: **OC**= organic carbon, **TN**= total nitrogen, **CEC**= cation exchange capacity

3.2. Experimental layout, design and treatments

Planting material (Desho grass) and eight harvesting heights (50cm, 60cm, 70cm, 80cm, 90cm, 100cm, 110cm and 120cm) was considered as factors. The research was carried out employing a three times replicated randomized complete block design (RCBD). Root splits of Desho grass using inter and intra spacing of 50 cm by 25 cm were used for establishment, respectively. The spacing between blocks and plots were 1.5 m and 1 m, respectively. Each experimental unit had 3*4 m with a total area of 12 $m^{2,}$ from which 2*4m total $8m^2$ was used for sample collection. The total experimental area was 465 m^2 (31 *15). Each plot had 6 rows on which plantings was done uniformly. The treatments are indicated in Table 2.

Table 2. Treatment arrangements

Treatment	Cutting height	Treatment	Cutting height
T1	50cm	T5	90cm
T2	60cm	T6	100cm
T3	70cm	T7	110cm
T4	80cm	T8	120cm

3.3. Land preparation and management

After site selection was accomplished seedbed preparation was done; with plowing, disc, leveling, and row making. Fertilizer was applied to the grass as recommended for normal conditions or control management. This had been calculated from 100kg di-ammonium phosphate (DAP, 18% N; 20% P; 1.5% S) per hectare at planting and 50kg (46% N/ha) in the form of urea. The released Desho grass (*Pennisetum glaucifolium*), Kulumsa variety was used as a test crop under the highland condition of Ethiopia. Desho (*Pennisetum glaucifolium*) grass was established during the onset of the main rainy season (15, July, 2019) and all agronomic management (fertilizer, weeding, and draining excess water from each plots) were done. The treatment consists of forage harvesting at different stages based on plant heights during the main rainy season. During these periods, one or more harvests can be taken depending on the regrowth of the plant. Harvesting was done by hand with a sickle, leaving an 8 cm stubble height as per the recommended practice by (Leta *et al*., 2013).

3.4 Data collection, sampling and measurements

The establishment year (2019) and production years (2020-2021) of this study were involved to collect all agronomic and morphological characteristics of Desho grass.

Plant height

A continuous follow up was done to measure the plant height. A steel tape was used to measure plant height immediately before biomass harvesting, after each of the corresponding cutting heights of 60cm, 70cm, 80cm, 90cm, 100cm, 110cm, and 120cm and the heights were taken from the ground to the tip. Four rows were randomly selected from a total of six rows within each plot to measure plant height, excluding the two border rows on each side, and then five tillers were randomly selected for plant height measurement and then the average height was taken.

Number of tillers per plant

The number of tillers was counted and recorded on the same tagged plants. After transplanting from the net plot area, the number of tillers per plant was counted from a randomly selected five plants in the middle row of each plot at each cutting height, and the mean was obtained.

Number of leaves per plant and internode length

On an experimental plot area, the number of leaves per tiller was counted in 10 randomly selected tillers at each cutting height of harvesting. By multiplying the number of leaves per tiller by the number of tillers per plant, the total number of leaves per plant was obtained. Five randomly selected plants per plot of each row were measured for internode length.

Leaf Length

Leaf length was measured from the base of the collar area to the tip of the leaf for each plant. It was computed from the mean of five randomly selected plants from the middle rows at each harvesting cutting height.

Leaf-to-stem ratio

LSR was determined by cutting plants from randomly selected middle succeeding rows. The plants were taken from the plot's central sections. After carefully mixing the net harvested plant, samples obtained from each plot at each harvesting cutting height were precisely measured, and fresh leaves and stems of each harvested sample were separated and weighed. Stems and leaves were obtained after the measurements for DM Analysis. The (LSR) was computed after oven-dried (65^{o}C for 72 hours) each leaf and stem sample by dividing leaf dry weight by stem dry weight.

Dry matter yield

At the end of each harvesting cutting height of each plot, the dry matter yield (DMY) was calculated. Desho grass was cut at 8cm from the ground level to determine biomass yield from the rows adjacent to the guard rows. A sensitive balance was used to assess fresh biomass, and then subsamples of roughly 500 g of fresh plants were obtained from the net harvested plant sample. Finally, to acquire dry weights, these subsamples were oven-dried. The leaf and stem dry weights are calculated by dividing the leaf and stem fresh weights by 100 to calculate the DM percent for each sample. Based on this, total dry matter yields for each plot were calculated using DM percent and fresh biomass yield from the sample area of each plot and then converted to metric tons per hectare. After drying the samples in a forced drying oven set at 65°C for 72 hours, the dry matter yield was determined as follows:

DMY (t/ha) - (10 x TFW x SSDW) / (HA x SSFW) (James et al., 2008).

Where: 10 - constant for conversion of yields in (kg/m^2) to (t/ha)

TFW - total fresh weight (kg)

SSDW - sub-sample dry weight (g)

HA - harvest area (m^2)

SSFW - sub-sample fresh weight (g)

Biomass production rate

The biomass production rate was calculated for the total dry matter yield of the first and second harvest of each year by dividing the total dry matter yield by the number of days it took to reach each cutting height of harvest. Then the result was multiplied by 1000 to convert yield into Kg/ha/day. The clearing date (July) was taken as an initial growing period for the first year harvest and June (the first showering month) as an initial growing period for the second year harvest.

Number of nodes per plant and stem basal diameter

Stem width at harvest (base level stem thickness will be measured using caliper for five selected plants) and the number of nodes per plant was counted and recorded from 10 randomly selected plants from each plot.

3.5. Chemical analysis

A fresh herbage yield of the grass was measured immediately after each cutting height and weighed by sensitive balance on the field soon after cutting. About 500g of Oven dried samples dried at a temperature of 65°C for 72 hours was used for laboratory analysis. Then dried samples were ground to pass a 1-mm sieve and the ground samples had been used for laboratory analysis. The samples were dried at 60°C overnight in an oven to standardize the moisture These samples were analyzed in % DM basis for ash%, crude protein (CP), neutral detergent fiber (NDF), acid detergent lignin (ADL), acid detergent fiber (ADF), organic matter digestibility (OMD) and metabolizable energy (ME) at Animal Nutrition Laboratory, Holetta Agricultural Research Center. The total ash concentration was obtained by combusting the samples for 6 hours at 550 degrees Celsius in a muffle furnace (AOAC, 1990). Nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation and titration procedures (AOAC, 1995); in order to calculate the amount of protein in a sample, the nitrogen in the sample is multiplied by the fact that true protein is composed of amino acids, which contain about 16% nitrogen. Therefore, 100% divided by 16% equals 6.25xN. Van Soest and Robertson, (1985) procedures was used to determine the structural plant components (NDF, ADL, and ADF). Tilley and Terry procedure (1963) where used to determine the OMD (48 h pepsin HCl, 48 h rumen fluid) with the only main modification that residues are combusted to get OM digestibility) and IVDMD. The prediction equation devised by McCormick et al. (McDowell, L.R, 1985), ME (MJ)/kg of DM=0.016x OMD, was used to estimate the ME of dry matter.

3.6. Statistical Analysis

The Analysis of variance (ANOVA) procedures of R software was done using general linear model (GLM). For the comparison of means, the least significant difference (LSD) at a 5% significance level was utilized. The model used for the Analysis was:

Yij= μ+Bi+Tj+Yk+Eij

Where:

Yij-Response of parameters

μ- Overall mean

$\mathbf{B}_i$- ith block effect

$\mathbf{T}_j$- jth treatment effect

$\mathbf{Y}_k$ _ kth year effect

$\mathbf{E}_{ij}$- Random error

4. RESULTS

4.1 Effect of cutting height on agro-morphological characteristics

4.1.1 Number of leaves per plant, leaf length and stem basal diameter

The result for agronomic performance traits; number of leaves per plant, leaf length, and stem basal diameter are shown in Table 3. The two years average result showed that the number of leaves per plant and the leaf length were significantly affected by cutting height ($P<0.001$). Leaf length was affected by the interaction of treatment and year ($P<0.001$). But stem basal diameter was not significantly affected by cutting height ($P>0.05$). The number of leaves per plant showed no consistent change with maturity. The same trend was observed for leaf length (Table 3). Desho grass harvested at 120cm had higher number of leafs per plant followed by that harvested at 100cm. The highest leaf length was recorded when Desho grass was harvested at 120cm followed by harvest height of 100 cm. Desho grass harvested at 60cm and 70cm recorded higher basal diameter than the rest of treatments.

Table 3. Morphological characteristics (NLPP, LL and SBD) of Desho grass harvested at different cutting heights for the two years.

Treatments/cutting heights	**Parameters**								
	NLPP			**LL**			**SBD**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1:50cm	5.13^{c}	7.20^{cd}	6.17^{cd}	31.13^{e}	31.80	31.46^{c}	21.87	31.43	26.65
T2:60cm	5.87^{bc}	7.00^{cd}	6.43^{bcd}	33.33^{de}	34.20	33.76^{bc}	25.67	20.70	23.18
T3:70cm	5.60^{bc}	6.20^{d}	5.90^{d}	31.90^{e}	31.13	31.52^{c}	29.06	17.90	23.48
T4:80cm	5.20^{bc}	7.50^{bc}	6.35^{cd}	39.73^{cd}	30.10	34.92^{bc}	19.30	18.46	18.88
T5:90cm	6.23^{b}	7.20^{cd}	6.72^{bc}	41.50^{c}	31.10	36.30^{bc}	18.62	19.66	19.14
T6:100cm	5.90^{bc}	8.50^{ab}	7.20^{b}	50.17^{b}	33.36	41.76^{ab}	19.96	18.30	19.13
T7:110cm	6.13^{bc}	7.50^{bc}	6.82^{bc}	44.00^{bc}	30.96	37.48^{bc}	17.43	21.80	19.61
T8:120cm	7.37^{a}	8.93^{a}	8.15^{a}	63.20^{a}	29.66	46.43^{a}	18.71	19.80	19.25
Mean	5.93	7.50	6.72	41.87	31.54	36.71	21.33	21.01	21.17
LSD	1.06	1.06	0.79	7.74	4.60	8.18	9.62	9.06	7.07
CV%	10.25	8.03	10.08	10.56	8.32	19.04	25.74	24.63	28.56
SL	*	**	***	***	ns	***	ns	ns	ns
T:Y			**ns**			***			ns

SL=significance level**, *=P<0.05, **=P<0.01, ***=P<0.001, ns=**not significant**, NLPP**=Number of leaves per plant, **LL**=Leaf length, **SBD**=Stem basal diameter, **LSD=**Least significant difference, **C.V**= Coefficient of variation. **Aver**= average of the combined two years data. **T: Y** = significance level of year by treatment interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.1.2 ***Number of nodes per plant, number of tiller per plant and internode length for the two years.***

The analysis result for the number of nodes per plant, number of tillers per plant, and internode length of Desho grass are shown in (Table 4). The result from the analysis showed that the number of nodes per plant was significantly affected by cutting height during the first year of harvesting and the second year of harvesting (P<0.001). Except for the cutting height of 60 cm and 70cm, the rest number of nodes per plant showed an increasing trend with maturity (Table 4). The number of tillers per plant during the first harvesting year showed insignificant (P>0.05), but it was significant during the second year of harvest (P<0.05) (Table 4). The number of tillers per plant showed no consistent change; but harvesting height 50cm recorded the highest of all followed by

70cm. The internode length for Desho grass showed significant difference (P<0.001) for harvesting height in both years and combined analysis. Harvesting height above 80cm showed an increasing trend for internode length (Table 4). Number of tillers per plant and internode length are both affected by interaction of treatment with year. The number of nodes per plant and internode length during earlier cutting heights of 50cm, 60cm, 70cm, 80cm and 90cm were not recorded due to undeveloped.

Table 4. Morphological characteristics (NNPP, NTPP and INL) of Desho grass affected by different cutting heights for the two years.

Treatments /Cutting heights	**Parameters**								
	NNPP			**NTPP**			**INL**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1:50cm	0.00[c]	3.17[d]	1.58[c]	139.67	111.90[bc]	125.78	0.00[c]	6.67[c]	3.33[d]
T2:60cm	0.00[c]	3.90[cd]	1.95[c]	85.93	100.27[bc]	93.10	0.00[c]	9.93[abc]	4.96[cd]
T3:70cm	0.00[c]	3.90[cd]	1.95[c]	82.13	96.93[c]	89.53	0.00[c]	8.20[bc]	4.10[d]
T4:80cm	2.37[b]	5.20[bc]	3.78[b]	83.67	135.73[a]	109.70	0.00[c]	10.13[ab]	5.06[cd]
T5:90cm	3.10[ab]	6.20[ab]	4.65[a]	89.17	104.53[bc]	96.85	0.00[c]	10.40[ab]	5.20[cd]
T6:100cm	3.50[a]	6.27[ab]	4.88[a]	94.12	112.60[bc]	103.36	3.50[c]	12.27[a]	7.88[bc]
T7:110cm	3.63[a]	6.43[ab]	5.03[a]	87.67	117.33[abc]	102.50	8.77[b]	11.97[a]	10.36[ab]
T8:120cm	3.73[a]	7.00[a]	5.37[a]	96.27	119.53[ab]	107.90	11.23[a]	11.67[a]	11.45[a]
Mean	2.04	5.26	3.65	94.83	112.35	103.59	2.94	10.15	6.54
LSD	0.75	1.39	0.75	36.50	20.44	22.88	2.21	3.33	2.93
C.V%	20.18	15.14	17.51	21.98	21.98	18.88	42.90	18.74	38.30
SL	***	***	***	ns	*	ns	***	*	***
T:Y			ns			*			***

SL=significance level, *=P<0.05, **=P<0.01, ***=P<0.001, **NNPP**=number of nodes per plant, **NTPP**=number of tiller per plant, **INL**= inter node length, **LSD**= least significant difference, **C.V**= coefficient of variation. **Aver**= average of the combined two years data. **T: Y** = significance level of year by treatment interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly.

4.1.3 Leaf percent, stem percent and leaf to stem ratio for the two years

The analysis result for leaf percent, stem percent and leaf to stem ratio of Desho grass is presented in (Table 5). All leaf percent, stem percent and leaf to stem ratio were not significantly affected by different cutting heights (Table 5). Cutting height of 120cm produced the highest leaf percent followed by Desho grass harvested at 80 cm height. The combined analysis result showed that the stem content of Desho grass harvested at 60cm gave the highest value followed by 90cm harvesting height. Cutting height of Desho grass at 50cm produced the highest leaf to stem ratio followed by 60 cm and (Table 5). Generally when compared over the year of study there was a reduction for leaf percentage in 2021 and an increase for stem percentage and leaf to stem ratio in each harvesting heights (Table 5).

Table 5. Morphological characteristics (LP, SP and LSR) affected by different cutting heights for the two years.

Treatments/ Cutting height	Parameters								
	LP			SP			LSR		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1:50cm	71.53	48.78	60.15	28.47	51.22	39.84	0.47	1.29	0.90
T2:60cm	57.83	54.12	55.97	42.17	45.88	44.02	0.73	0.91	0.82
T3:70cm	69.80	54.61	62.20	30.20	45.38	37.79	0.47	0.84	0.65
T4:80cm	71.58	55.22	63.40	28.42	44.78	36.60	0.42	0.81	0.62
T5:90cm	70.24	49.63	59.93	29.76	50.37	40.06	0.48	1.04	0.76
T6:100cm	70.00	53.88	61.94	30.00	46.12	38.06	0.45	0.86	0.65
T7:110cm	71.37	55.02	63.19	28.63	44.98	36.80	0.46	0.82	0.64
T8:120cm	76.00	51.84	63.92	24.00	48.15	36.08	0.32	0.93	0.62
Mean	69.79	52.89	61.34	30.21	47.11	38.66	0.48	0.94	0.71
LSD	16.81	15.15	10.84	16.81	15.15	10.84	0.37	0.59	0.32
C.V%	13.76	16.36	15.11	31.79	18.36	23.97	44.56	36.26	38.99
SL	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
T:Y			**ns**			**ns**			**ns**

SL= significance level**, ns=** not significant**, LP**=leaf percentage, **SP**=stem percentage, **LSR**= leaf to stem ratio, **LSD**=least significant difference, **C.V**= coefficient of variation. **Aver**= average of the combined two years data. **T: Y** = significance level of year by treatment interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.1.4 Leaf, stem and first harvest dry matter yield for the two years

The analysis result for leaf dry matter yield, stem dry matter yield and Frist harvest dry matter yield are indicated in Table 6. The result from analysis showed that leaf dry matter yield, stem dry matter yield and first harvest dry matter yield were significantly affected by cutting height(P<0.001)(Table 6). The combined analysis showed that Desho grass harvested at 120cm height gave the highest leaf dry matter yield followed by the grass harvested at 110 cm. The grass harvested at 120 cm gave the highest dry matter yield at first harvest followed by the grass harvested at 110 cm (Table 6). Despite no consistent either increasing or decreasing trend was showed in LDMY, SDMY and first harvest DMY all recorded highest at later cutting heights (120cm,110cm and 100cm) respectively. From combined analysis, the result for first harvest Dry matter yield of Desho grass harvested at 120cm,110cm,100 and 80cm produced yields of 18.62,14.84,14.56 and 9.48 t/ha, respectively (Table 6). Cutting height at 50cm, 60cm, 70cm and 90cm produced yields of 6.13, 8.48, 7.45 and 8.68 t/ha, respectively (Table 6). Both stem dry matter yield and first harvest total dry matter yield are affected by interaction effect of treatment with year (P<0.05), but leaf dry matter yield is not affected by the treatment-year interaction

Table 6. Agronomic performance **(**LDMY, SDMY and H1DMY) as affected by different cutting heights during first harvest cycle.

Treatments/cutting heights	**Parameters**								
	LDMY(t/ha)			**SDMY(t/ha)**			**H1DMY(t/ha)**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1:50cm	3.12^{c}	4.00^{c}	3.56^{d}	1.31^{c}	3.83^{d}	2.57^{d}	4.44^{c}	7.83^{d}	6.13^{c}
T2:60cm	4.23^{c}	5.36^{c}	4.80^{cd}	3.02^{ab}	4.35^{d}	3.69^{d}	7.26^{b}	9.71^{d}	8.48^{c}
T3:70cm	4.09^{c}	4.88^{c}	4.48^{cd}	1.92^{bc}	4.02^{d}	2.97^{bcd}	6.017^{bc}	8.90^{d}	7.45^{c}
T4:80cm	4.96^{c}	6.58^{bc}	5.77^{c}	2.09^{abc}	5.34^{bcd}	3.72^{bcd}	7.05^{b}	11.92^{cd}	9.48^{bc}
T5:90cm	5.07^{c}	4.95^{c}	5.01^{cd}	2.20^{abc}	5.13^{cd}	3.66^{cd}	7.27^{b}	10.08^{d}	8.68^{c}
T6:100cm	7.15^{b}	10.08^{ab}	8.61^{b}	3.23^{ab}	8.66^{b}	5.95^{ab}	10.38^{a}	18.73^{ab}	14.56^{ab}
T7:110cm	8.17^{ab}	9.89^{ab}	9.03^{b}	3.56^{a}	8.07^{bc}	5.81^{abc}	11.72^{a}	17.96^{bc}	14.84^{a}
T8:120cm	9.22^{a}	12.94^{a}	11.08^{a}	2.89^{ab}	12.19^{a}	7.54^{a}	12.11^{a}	25.14^{a}	18.62^{a}
Mean	5.75	7.34	6.54	2.53	6.45	4.49	8.28	13.78	11.03
LSD	2.05	3.59	1.93	1.48	3.44	2.26	2.07	6.48	3.72
C.V%	20.33	27.95	25.25	33.41	30.48	43.06	14.29	26.85	28.86
SL	***	***	***	***	**	***	***	***	***
T:Y			ns			*			*

SL= significance level**, ns=** not significant**, **=P<0.01, ***=P<0.001, LDMY**=leaf dry matter yield, **SDMY**=stem dry matter yield, **H1DMY**=first harvest dry matter yield, **LSD**=least significant difference, **C.V**= coefficient of variation. **Aver**= average of the combined two years data. **T: Y** = significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.1.5 Biomass production rate and Dry matter yield of second harvest for the two years.

The analysis result for biomass production rate and dry matter yield of second harvest is presented in Table 7. There is a big difference in biomass production rate across treatments over the study years. Biomass production rate for first harvest varied significantly by cutting height ($P<0.05$) (Table 7); it was only significant for first year harvest. Desho grass harvested at 100cm, 120cm, 80cm, 110cm and 60cm produced 190.79, 180.82, 162.98, 156.29 and 132.1 kg/ha/day biomass yield, respectively for the first harvest. The dry matter yield harvested at second round varied significantly ($P<0.001$) with cutting height. The combined analysis result for second harvest dry matter yield showed Desho grass harvested at 60cm had the highest dry matter yield followed by 50cm cutting height with 6.2 and 6.1 t/ha, respectively. Biomass production rate for second harvest dry matter yield was highly affected by cutting height ($P<0.001$). Biomass production rate decreases as cutting height increase from 50cm to 120cm (Table 7). Cutting height at 50cm produced the highest biomass production rate (85.57 Kg/ha/day) while the lowest rate was recorded for the highest cutting height.

Table 7. Agronomic performances (BMPRH1, H2DMY and BMPRH2) as affected by different cutting heights for first (H1) and second harvest (H2).

Treatments/cutting heights	**Parameters**								
	BMPRH1Kg/ha/day			**H2DMY(t/ha)**			**BMPRH2Kg/ha/day**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1:50cm	75.19^{d}	126.34	100.76	6.30^{a}	5.91^{a}	6.10^{ab}	82.19^{a}	88.95^{a}	85.57^{a}
T2:60cm	107.48^{abc}	156.72	132.10	6.27^{a}	6.13^{a}	6.20^{a}	85.25^{a}	72.97^{ab}	79.11^{ab}
T3:70cm	85.95^{cd}	128.98	107.47	4.46^{b}	6.11^{a}	5.28^{ab}	47.48^{bc}	72.74^{ab}	60.11^{bc}
T4:80cm	96.57^{bcd}	229.38	162.98	4.93^{ab}	4.55^{ab}	4.74^{bc}	60.82^{b}	48.45^{bc}	54.63^{cd}
T5:90cm	90.92^{cd}	121.52	106.22	3.72^{b}	2.55^{bc}	3.13^{d}	46.46^{bc}	30.39^{c}	38.43^{d}
T6:100cm	119.38^{ab}	262.19	190.79	4.06^{b}	3.18^{bc}	3.62^{cd}	41.85^{bc}	33.37^{bc}	37.61^{d}
T7:110cm	127.43^{a}	185.15	156.29	3.98^{b}	2.77^{bc}	3.38^{cd}	39.86^{cd}	33.05^{bc}	36.46^{de}
T8:120cm	119.93^{ab}	241.69	180.82	1.91^{c}	1.11^{c}	1.50^{e}	19.49^{d}	13.09^{c}	16.29^{e}
Mean	102.86	181.5	142.18	4.45	4.04	4.25	52.93	49.13	51.03
LSD	24.10	115.63	78.02	1.73	2.41	1.37	20.74	40.32	20.34
C.V%	13.38	36.38	46.94	22.19	34.16	27.69	22.37	46.87	34.10
SL	**	ns	ns	**	**	***	***	*	***
T:Y			ns			ns			ns

Sig.level= significance level, **ns=**not significant**, *=P<0.05, **=P<0.01, ***=P<0.001, BMPRH1**=biomass production rate of first harvest, **H2DMY**=second harvest dry matter yield, **BMPRH2=**biomass production rate of second harvest, **LSD=** Least significant difference, **C.V**=coefficient of variation. **Aver**= average of the combined two years data. **T: Y**= significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly.

4.1.6 Total dry matter and Average dry matter yield

Total dry matter yield, and average dry matter yield of Desho grass harvested at different cutting height are shown in Table 8. The average of the two years result for total dry matter yield, and average dry matter yield varied significantly with cutting height (P<0.001). Cutting height at 120cm, 110cm and 100cm produced higher total dry matter yield of 20.13, 18.22 and 18.18t/ha, respectively (Table 8).

Table 8. Agronomic performances (TDMY and AvDMY) as affected by different cutting heights

Treatments/cutting heights	Parameters					
	TDMY(t/ha)			AvDMY(t/ha)		
	Years					
	2020	2021	Aver	2020	2021	Aver
T1:50cm	10.74^{c}	13.74^{cd}	12.24^{c}	5.37^{c}	6.87^{cd}	6.12^{c}
T2:60cm	13.53^{ab}	15.84^{bcd}	14.68^{bc}	6.76^{ab}	7.92^{bcd}	7.34^{bc}
T3:70cm	10.48^{c}	15.01^{bcd}	12.74^{c}	5.24^{c}	7.50^{bcd}	6.37^{c}
T4:80cm	11.97^{bc}	16.48^{bcd}	14.23^{bc}	5.98^{bc}	8.24^{bcd}	7.11^{bc}
T5:90cm	10.99^{c}	12.64^{d}	11.81^{c}	5.49^{c}	6.32^{d}	5.90^{c}
T6:100cm	14.45^{a}	21.92^{ab}	18.18^{ab}	7.22^{a}	10.95^{ab}	9.09^{ab}
T7:110cm	15.71^{a}	20.74^{abc}	18.22^{ab}	7.85^{a}	10.37^{abc}	9.11^{ab}
T8:120cm	14.02^{ab}	26.24^{a}	20.13^{a}	7.01^{ab}	13.12^{a}	10.06^{a}
Mean	12.74	17.83	15.28	6.37	8.91	7.64
LSD	2.45	7.68	4.09	1.23	3.84	2.04
C.V%	11.01	24.62	22.88	11.00	24.62	22.88
SL	**	*	***	**	*	***
T:Y			ns			ns

SL= significance level, *****=P<0.05, ******=P<0.01, *******=P<0.001, **AvDMY**=average dry matter yield, **LSD**=least significant difference, **C.V**= coefficient of variation. Treatments with the same superscript letter/s at each column do not differ significantly. **Aver**= average of the combined two years data. **T: Y**= significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.2 Chemical composition

4.2.1 Dry matter, ash and crude protein of Desho grass as affected by cutting height for first harvest

Dry matter, ash and crude protein content of Desho grass were presented in Table 9. The combined analysis showed that dry matter varied significantly by cutting height (P<0.05). The first year harvest was not affected by cutting height but the second year harvest was highly affected by cutting height (P<0.001). The mean dry matter (DM) content from combined analysis was 92.84% (Table 9).The dry matter content of the present study was not highly significant and it's almost related *i.e*. between 92 and 93 range (Table 9). Desho grass ash content was highly affected by cutting height

(P<0.001). The ash content was the highest in the second year of harvest. The mean ash content obtained in the first and second year was 5.11% and 6.12%, respectively (Table 9). The highest Ash content was found for cutting height of 50cm (6.81%) followed by 60cm (6.48%) and 80cm (6.08%) while the least was for cutting height of 120cm (4.34%) followed by 90cm (4.78%). Crude protein (CP) content was highly affected by cutting height (P<0.001). The first year harvest had less Crude protein content than the second year harvest with the mean CP content of 8.36% and 12.58%, respectively (Table 9). From combined analysis result, the highest CP content was found for cutting height of 50cm (12.16%) and the least for cutting height of 120cm (8.54%). Crude protein content decreases with increasing harvesting height. The mean CP content from the combined analysis result was 10.47% (Table 9). Cutting height 80cm and 90cm had intermediate CP content (10.93% and 10.21%), respectively (Table 9), while cutting height 50cm and 120cm had the highest and lowest CP content. Dry matter yield is significantly affected by interaction of year-treatment (P<0.001).

Table 9. DM, Ash and CP of Desho grass as affected by cutting height for each year

Treatments /Cutting heights	Parameters								
	DM%			**Ash%**			**CP%**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1-50cm	93.25	92.89^{ab}	93.07^{a}	5.98^{a}	7.64^{a}	6.81^{a}	9.59^{a}	14.73^{a}	12.16^{a}
T2-60cm	93.00	93.09^{a}	93.05^{a}	5.43^{ab}	7.53^{ab}	6.48^{ab}	9.14^{b}	13.49^{ab}	11.31^{b}
T3-70cm	93.10	92.75^{ab}	92.91^{a}	5.03^{abc}	6.41^{c}	5.71^{bcd}	8.67^{c}	13.58^{ab}	11.13^{b}
T4-80cm	93.01	92.68^{ab}	92.84^{a}	5.62^{ab}	6.55^{bc}	6.08^{abc}	8.50^{cd}	13.35^{ab}	10.93^{bc}
T5-90cm	93.00	92.67^{ab}	92.84^{a}	4.54^{bc}	5.01^{d}	4.78^{ef}	8.32^{de}	12.10^{bc}	10.21^{cd}
T6-100cm	93.16	91.51^{c}	92.33^{b}	5.19^{ab}	5.78^{cd}	5.48^{cde}	8.11^{e}	11.57^{cd}	9.84^{d}
T7-110cm	93.00	92.44^{b}	92.72^{ab}	5.14^{abc}	5.31^{d}	5.23^{de}	7.71^{f}	11.57^{cd}	9.64^{d}
T8-120cm	93.08	92.90^{ab}	92.97^{a}	3.95^{c}	4.73^{d}	4.34^{f}	6.86^{g}	10.22^{d}	8.54^{e}
Mean	93.07	92.61	92.84	5.11	6.12	5.62	8.36	12.58	10.47
CV%	0.19	0.29	0.37	13.85	9.99	12.29	1.79	7.36	6.68
LSD	0.31	0.48	0.41	1.24	1.07	0.81	0.26	1.62	0.82
SL	ns	***	*	ns	***	***	***	***	***
T:Y			***			ns			ns

SL= significance level, *= P<0.05, ***=P<0.001, DM%- dry matter, CP%-crude protein, ns= not significant, LSD=least significant difference, CV%=coefficient of variation. **Aver**= average of the combined two years data. **T: Y** = significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.2.2 Neutral detergent fiber, acid detergent fiber and acid detergent lignin of Desho grass as affected by cutting height for first harvest

Neutral detergent fiber, acid detergent fiber and acid detergent lignin were presented in Table 10. Neutral detergent fiber (NDF) content was highly affected by cutting height (P<0.001). The current result showed that the NDF content ranged from 71.34 to75%. The mean NDF content of the current result was 73.5%. Generally the NDF content was higher in the first year of production (Table 10). Acid detergent fiber (ADF) content was significantly affected by cutting height (P<0.05). The first year harvest was not significantly affected for ADF% by harvesting heights. The value of the current study revealed that ADF% ranged between 40.5% for 60cm and 42.73% for 100cm cutting heights. The highest ADF content recorded when Desho grass was harvested at cutting height of 100cm (42.73%) followed by 90cm (42.06%) (Table 10). Acid detergent lignin (ADL) content was significantly affected by cutting height (P<0.001). The ADL content increase with increasing cutting height. It ranged from 4.13% and 4.93% in increasing order from 50cm to 120cm cutting height (Table 10). All NDF, ADF and ADL were significantly affected by interaction of treatment-year effect (Table 10).

Table 10. NDF, ADF and ADL contents of Desho grass as affected by cutting height for first harvest

Treatments/cutting heights	**Parameters**								
	NDF%			**ADF%**			**ADL%**		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1-50cm	73.56^{h}	69.13^{d}	71.34^{f}	41.72	39.94^{c}	40.83^{bc}	4.19^{d}	4.06^{d}	4.13^{d}
T2-60cm	74.61^{g}	69.52^{cd}	72.07^{ef}	41.26	39.74^{c}	40.50^{c}	4.31^{d}	4.04^{d}	4.17^{cd}
T3-70cm	74.87^{f}	71.14^{bc}	73.01^{de}	41.34	40.18^{c}	40.76^{bc}	4.48^{c}	4.10^{cd}	4.29^{bcd}
T4-80cm	75.15^{e}	72.37^{ab}	73.76^{bcd}	41.67	39.89^{c}	40.78^{bc}	4.57^{bc}	4.26^{cd}	4.41^{bc}
T5-90cm	75.39^{d}	73.59^{a}	74.49^{abc}	42.27	41.85^{b}	42.06^{ab}	4.63^{bc}	4.39^{c}	4.51^{b}
T6-100cm	75.61^{c}	71.50^{b}	73.55^{cd}	41.99	43.47^{a}	42.73^{a}	4.65^{b}	4.98^{ab}	4.81^{a}
T7-110cm	76.02^{b}	73.99^{a}	75.00^{a}	40.13	42.76^{ab}	41.44^{abc}	4.68^{b}	5.16^{a}	4.92^{a}
T8-120cm	76.62^{a}	72.88^{ab}	74.75^{ab}	42.08	41.75^{b}	41.91^{ab}	5.04^{a}	4.82^{b}	4.93^{a}
Mean	75.23	71.76	73.50	41.56	41.20	41.38	4.57	4.47	4.52
CV%	0.08	1.52	1.31	1.91	2.14	2.79	1.94	4.06	4.76
LSD	0.16	1.91	1.13	1.39	1.55	1.35	0.15	0.32	0.25
SL	***	***	***	ns	***	*	***	***	***
T:Y			*			***			***

SL=significance level, **NDF%**- neutral detergent fiber, **ADF%-** acid detergent fiber and **ADL%-** Acid detergent lignin, **ns**=not significant, *****=P<0.05, *******=P<0.001, **LSD**=least significant difference**, CV%=**coefficient of variation, **Aver**= average of the combined two years data. **T: Y** = significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

4.2.3 In-vitro dry matter digestibility and metabolizable energy of Desho grass as affected by cutting height for first harvest

In-vitro dry matter digestibility, dry organic matter digestibility and metabolizable energy are presented in Table 11. *In-vitro* dry matter digestibility (IVDMD) was highly affected by cutting heights (P<0.001). The least IVDMD was found for cutting height of 100cm (61.68%) followed by 120cm (63.25%) and the highest was found for cutting height 80cm (69.52%), followed by 60cm (69.23%) and 70cm (69.16%) (Table 11). Generally the highest IVDMD was recorded for the first year of harvest. Organic matter digestibility (OMD) was significantly affected by cutting heights (P<0.001). The overall mean OMD of the present study was 62.58%. The highest OMD was recorded in the first year of harvest than in the second year of harvest (Table 11). The highest OMD was recorded for cutting height of 80cm (65.18%) and the least for 100cm (57.83%). Metabolizable energy was highly affected by cutting height (P<0.001). Metabolizable energy was highly affected by cutting height (P<0.001). Metabolizable energy was higher for lower cutting heights than later cutting heights. Cutting heights greater than 100cm where low(less than 10%) in ME than the rest of treatments or cutting heights in which they had almost had related values and ranges between 10.02% and 10.42 %(Table 11).The combined analysis mean Metabolizable energy of the present study was 10.01MJ/kg DM. IVDMD,OMD and ME were significantly affected by treatment-year effect(P<0.001).

Table 11. IVDMD, OMD and M E content of Desho grass as affected by cutting height for first harvest

Treatments/Cutting heights	Parameters								
	IVDMD%			**OMD%**			**ME** MJ/kg DM		
	Year								
	2020	2021	Aver	2020	2021	Aver	2020	2021	Aver
T1-50cm	64.95^{a}	72.55^{bc}	68.75^{a}	60.89^{a}	68.02^{bc}	64.45^{a}	9.74^{a}	10.88^{bc}	10.31^{a}
T2-60cm	64.27^{ab}	74.19^{ab}	69.23^{a}	60.25^{ab}	69.56^{ab}	64.90^{a}	9.64^{ab}	11.13^{ab}	10.38^{a}
T3-70cm	63.35^{bc}	74.97^{ab}	69.16^{a}	59.39^{bc}	70.28^{ab}	64.83^{a}	9.50^{bc}	11.24^{ab}	10.37^{a}
T4-80cm	62.55^{c}	76.49^{a}	69.52^{a}	58.65^{c}	71.71^{a}	65.18^{a}	9.38^{c}	11.47^{a}	10.42^{a}
T5-90cm	62.13^{cd}	71.55^{bc}	66.84^{ab}	58.25^{cd}	67.08^{bc}	62.66^{ab}	9.32^{cd}	10.73^{bc}	10.02^{ab}
T6-100cm	61.14^{d}	62.22^{d}	61.68^{d}	57.32^{d}	58.33^{d}	57.83^{d}	9.17^{d}	9.33^{d}	9.25^{d}
T7-110cm	60.88^{d}	70.35^{c}	65.61^{bc}	57.08^{d}	65.95^{c}	61.51^{bc}	9.13^{d}	10.55^{c}	9.84^{bc}
T8-120cm	57.53^{e}	68.96^{c}	63.25^{cd}	53.94^{e}	64.65^{c}	59.29^{cd}	8.63^{e}	10.34^{c}	9.48^{cd}
Mean	62.10	71.41	66.75	58.22	66.95	62.58	9.31	10.71	10.01
CV%	1.25	2.92	3.69	1.24	2.92	3.69	1.25	2.92	3.70
LSD	1.35	3.65	2.88	1.27	3.42	2.70	0.20	0.54	0.43
SL	***	***	***	***	***	***	***	***	***
T:Y			***			***			***

SL= significance level, IVDMD= in vitro dry matter digestibility, OMD= dry organic matter digestibility and ME=metabolizable energy, ns=not significant, ***=P<0.001, LSD=least significant difference, CV%=coefficient of variation, **Aver**= average of the combined two years data. **T: Y** = significance level of treatment by year interaction for average. Treatments in each column with the same superscript letter/s do not differ significantly

5. DISCUSSIONS

5.1 Effect of cutting height on number of leaves per plant, leaf length and stem basal diameter

The analysis result from average of the two years showed cutting height had a significant effect on the number of leaves per plant, which controls the plants' photosynthetic capability. The highest number of leaves per plant was recorded for later cutting height 120cm. According to Tsegaye, (2021) in unpublished report found a significant effect of cutting interval on the total number of leaves per plant of Desho grass in all harvesting dates of 90d,120d and 150d. But in contrast (Tessema *et al*., 2010) reported cutting height has no significant effect on the number of leaves per plant and increased with maturity following 120 d of Napier grass defoliation. From the present study result, Desho grass harvested at 120cm had higher number of leaves per plant followed by cutting at 90cm and 110cm. Tesemma, (2012) reported that the number of leaf per plant and leaf length were affected by the interaction effect of growing agro-ecology and cutting height which ranged from 21.95cm-55.01cm having leaves number of 6.92 and 12.2, respectively. The leaf length of Desho grass in the present study is in line with Tesemma's result (31.46cm-46.43cm) but the number of leaves per plant goes below the range (5.9-8.15) he reported. This could be due to the difference in harvesting time of the experiment and environmental factors like temperature, soil nutrient and management. Bimrew *et al*. (2018) also found that the mid harvesting date (105) had the maximum amount of leaves per plant, whereas the early harvesting date had the lowest (75 days). The highest leaf count per plant was found in *Brachiaria mutica* grass harvested at 60, 90, and 120 days (143.5, 412.9, and 894.5 leaves, respectively), with a mean of 483.6. Desho grass had a moderate number of leaves (110.75, 389.8, and 854.87) with a mean of 451.8 at harvesting ages of 60, 90, and 120 days. Napier grass had the lowest leaves count (69, 145, and 197.76) with a mean of 137.245 at harvesting ages of 60, 90, and 120 days, respectively (Bantihun *et al*., 2022).

In forage production, leaf length is an important component in determining the economic value of different grass species and cultivars. It's also critical for individual plants' survival within a sward. The result from present study showed that leaf length was affected by cutting height; In line with this result (Tessema *et al*., 2010) reported that cutting height had a significant effect on leaf of Napier grass. Kefyalew *et al.* ,(2020) reported leaf length was significantly affected by harvesting age (90d, 120d and150d with 20.91cm, 23.37cm and 23.38cm), respectively, for each harvesting date. This showed that leaf length increase with maturity. The leaf length from the analysis result showed that Desho grass harvested at 120cm was longest (46.63cm) among the other treatments followed by 100cm (41.76cm) cutting height, in contrast to Kefyalew *et al*., (2020) result. Bimrew *et al*. (2017) reported that leaf length was highly affected by harvesting date and showed an increase with maturity; the higher cutting height requires enough time to growth, and later cutting height recorded higher leaf length than others in this case in line with Bimrew *et al*. (2017). In contrast to the present result, the mean leaf length was substantially longer at 75 and 105 days than it was at 135 days (Tilahun *et al*., 2017).

According to Bantihun *et al*., (2022) at 60, 90, and 120 days after harvesting, Desho grass had 23 cm, 21.5 cm, and 26.2 cm and Napier grass had 45.03 cm, 60.3 cm, and 82.6 cm with mean of 23.5 cm and 62.64cm which indicated intermediate to largest leaf length, respectively, for each grass species. In both grasses (Desho and Napier), the longest mean leaf length per plant (LLPP) (44 cm) was recorded at the late harvesting stage (120 days), while the shortest leaf length per plant (27.8 cm) was recorded at the early harvesting stage (60 days) and the intermediate leaf length per plant (34.1 cm) was recorded at the 90 day harvesting stage (Bantihun *et al*., 2022). The current result indicated that the highest leaf length was recorded at 120cm cutting height (46.43cm) and shortest at 50cm (31.13cm) and intermediate at 90cm (41.5cm) which showed all are greater than the result reported by Bantihun *et al*., (2022). This might be due to developmental stage of the plant, whether reproductive or vegetative, and environmental differences have a big impact on leaf length in grasses. The combined analysis result showed that stem basal diameter was not significantly affected by cutting height. Tessema *et al*. (2010) also reported that basal circumference of Napier grass was not affected by cutting height. Desho grass cutting at 50cm showed higher record of basal diameter (26.65cm) followed by 70cm and 60cm cutting height having 23.48cm, 23.18cm basal diameter, respectively, and the least was 18.88 cm harvested at 80cm.

5.2 Effect of cutting height on total dry matter yield, leaf dry matter yield and stem dry matter yield each years.

The enhanced total dry matter yield (TDMY) during later phases of cutting height was expected since plants were physiologically activated, resulting in more tillers and leaves per plant. All of these traits would promote better photosynthetic activity and, as a result, higher DM synthesis. The increase in yield could be attributed to the growth of more tillers, which resulted in increased leaf creation, leaf elongation, and stem development (Bimrew *et al*., 2017; Diribi, 2022).

The result from analysis showed leaf, stem and total dry matter yield all were significantly affected by cutting height. The second-year harvesting cycle produced a higher biomass yield with mean TDMY of (17.83 t/ha) than the first-year harvesting cycle (12.74 t/ha). This result could be attributed to the fact that the number of tillers has been increased to allow for optimal plant tissue growth. In line with the finding of Yirgu *et al*., (2017), dry matter yield was significantly higher during the second harvest than the first, with a large amount of dry matter yield of 28.83 t/ha produced. The highest yield of forage harvested at late stage of maturity could be attributed to the availability of favorable rainfall, temperature and soil nutrient over the extended growing period (Bimrew, 2016).

This could be also due to Desho grass produced much more forage dry matter and grew more vigorously, resulting in a well-established root structure that allowed the grass to draw more growth resources from the soil (Mulisa *et al*., 2021). In line with the present study, the greater biomass yield (30.98 t/ha) was produced at the second harvesting cycle than the first cycle (26.14 t/ha) of the same Desho grass variety at Machara area which is in lined with the previous report (Birmaduma *et al*., 2019). The grass harvested at later heading were yielded higher dry matter than those harvested at earlier heading, for (*Pennisetum Polystachion*) grass (Getnet *et al*., 2020). The current dry matter yield for cutting height at 120cm (20.13 t/ha) was comparable to Denbela *et al*., (2020) who were reported (20.77 t/ha) for Kulumsa Desho grass variety but the overall mean of the current study result (15.28 t/ha) was less than their report but comparable to Kindo Kisha DZF591 variety of Desho grass (15.45 t/ha).

The taller plant has more tillers per plant, and has more leaves per plant, hence higher dry matter yields are expected at later stages of harvesting. The present result is higher than (Bantihun *et al*., 2022) report for *Brachiaria mutica* grass, (11.8 t/ha), and Napier grass, which had a mean DMY of 9.8 t/ha.

Total herbage in Napier grass increased with increasing harvesting age (60,90,120 days) due to increases in tiller number, leaf formation, leaf elongation, and stem growth (Ansah *et al*., 2010). Melkie (2005) found that as the harvesting stage progressed, the yield of Bana grass enhanced. The result could be attributable to the fact that forage dry matter yield is directly related to plant height during the forage harvesting stage, since forage dry matter yield increases as plant height at forage harvesting increases. According to Mulisa *et al*., (2022), Desho grass out performs Panicum, Setaria accessions, and B. *decumbens* (ILRI 10871) in terms of dry matter yield. Under additional irrigation, dry biomass production (t/ha) ranged from 11.54 to 20.32, with no statistically significant differences amongst Napier accession types (Aman & Diribi, 2021).

Taylor *et al*. (2009) reported that the influence of cutting height on dry matter yield of Napier grass in the central highlands of Ethiopia, and found that harvesting at 100cm and 150cm cutting heights produced maximum dry matter yields. Cutting heights of 50cm and 100cm, on the other hand, resulted in higher yields of CP and digestible dry matter and recommended cutting Napier grass at a young stage (below one meter in height) produced better nutritional composition. Sumran Wijjitphan, (2009) found that total dry matter yield and average dry matter yield for cutting heights of 15cm was greater than 0cm (65,707.5; 67,070; 69,697.5 and 71,403.1Kg/ha/year;5,973.4, 6,096.4, 6,336.2 and 6,491.2 Kg/ha/year, respectively) for Napier grass above ground cutting height (0cm, 5cm, 10cm, and 15cm). The present TDMY result for Desho grass cutting height studied were higher than the finding of (Werner *et al*.,1966) that cutting

Napier grass at 1-3, 30-40, and 70-80cm above ground height for four weeks cutting interval resulted in 4.5, 11.9, and 13.1t/ha DMY, respectively.

In contrast to the current overall result, Figueira *et al*.,(2016) reported leaf dry matter yield and stem dry matter yield were not affected by cutting height harvest times(30, 40, 50 and 60cm; harvested on January, March and May, 2011). Combined Analysis result from the current study shows the cutting height of 120cm and 100cm produced a higher leaf dry matter yield than the rest of the treatments. As for cutting height increase, dry matter yield also increase, except for cutting height at 90cm which showed a decreasing trend. Taylor *et al*.,(2009) reported for Napier grass that the average dry matter (DM) yield per cut was 8.21t ha-1, although it rose as plant height increased through(50cm, 100cm, and 150cm) and N fertilization increased. Jorgensen *et al*.,(2010) reported 11 621 kg DM ha-1 TDMY of cumulative cutting height for Tangashima variety Napier grass and lower yield of 5930 kg DM ha-1 TDMY for Taiwan A25 at 0 cm cutting(without any stem left). Cutting height, as well as the interaction between cutting height and frequency of defoliation had no significant influence on Napier grass DM yield (Tessema *et al*., 2010). Generally total dry matter yield was higher in later harvesting heights. These findings could be explained by the fact that as a plant grows and ages, its structural carbohydrate and lignin contents increase as the cell wall expands, contributing to an increase in DM content (Lima *et al*., 2010).

According to (Bimrew *et al*., 2017) there were significant differences in dry matter yield due to harvesting period, with the highest total dry matter yield (20.75 t/ha) produced by the longest harvesting period (150d), and the shortest harvesting period had the lowest total dry matter yield (12.71 t/ha) (90d). Wadi *et al*., (2004) reported that Napier and King grass harvested at a 90-day interval had higher % dry matter than those harvested at a 60-day interval, while plants harvested at a 30-cm height had higher percentage dry matter than those harvested at a 0-cm height. The present study showed that cutting height of Desho grass at 120cm, 110cm and 100cm produced 20.13, 18.22 and 18.18 t/ha dry matter yield, respectively. Santos *et al*. (2001a) looked at the proportion of leaves and stems in elephant grass cv. Purple was harvested at four residual heights (0, 15, 30, and 45 cm) during two harvest seasons (dry and wet), with a mean proportion of leaves of 70.96, 73.91, 78.66, and 76.64 percent for each cutting height, and a mean proportion of stems of 29.04, 26.09, 21.34, and 23.36 percent for each cutting height, respectively. Jorgenson *et al*. (2010) reported that as cutting height increased dry matter yield for leaf also increase; and found with a maximum leaf DM yield of 7927 kg /ha, Dwarf Napier harvested at 30 cm had the highest overall leaf DM production in their study.

Cutting height at 90cm had the least dry matter yield which was 11.81 t/ha from combined analysis result. Lounglawan *et al*. (2014) reported that cutting a King Napier grass stand every 45 to 60 days resulted in higher dry matter and nutrient yields than cutting in every 30 days. The harvesting height of King Napier grass, whether 5, 10, or 15cm above ground level, had no effect on dry matter or nutrient yields. Tilahun *et al*. (2017) in their report stated that early harvesting resulted in poor DM yields at the time of harvest. Allowing the plants to grow until they were 135 days old resulted in considerably larger yields with little quality loss, despite a decrease in CP concentration and an increase in NDF for Desho grass (Tilahun et al., 2017). Stem dry matter showed significantly affected by cutting heights. In contrast to the present result, (Figueira et al., 2016) reported that stem dry matter yield was not affected by cutting height.

5.3 Effect of cutting height on first and second harvest biomass production rate

Both the first and second harvest biomass production rate were highly affected by cutting height. There is a big difference between the first and second harvest; the highest biomass production rate was recorded for the first harvest but when compared with the second harvest except for cutting height at 50cm it was shown decreasing trend specially highly reduced for the highest cutting height of 120cm.This was due to it takes a long time to regrow for longer cutting height than those harvested at shorter heights. The same trend was observed for 2021 harvesting year; but for combined analysis result, all cutting heights had shown a consistent decreasing trend.

5.4 Effect of cutting height on number of nodes per plant, and internode length

The number of nodes per plant was affected significantly with cutting heights. The highest number of nodes per plant was recorded in the first year harvest. This could attributed to the growth of Desho grass that resulted in several tillers developed.

The combined analysis result showed that internode length was affected by cutting height. In line with this finding Bantihun *et al*., (2022) reported that the interaction between grass species and harvesting age had significant effect on the number of nodes per plant. According to Bantihun *et al*., (2022), the highest number of nodes per plant were recorded (7.3, 14.68, & 4.96) in the late (120 days) harvesting, followed by the intermediate number of nodes (6.025, 9.025, and 0) in (90 days) harvesting, and the lowest number of nodes (3, 6.25, and 0) in the early (60 days) harvesting in Desho, Brachiaria, and Napier grass species, respectively. This indicates that the number of nodes per plant varies among with different grass species. This could be due to variation in genetic and environmental condition. The current mean result (3.65 nodes) was less than the report of Bantihun *et al*., (2022) for Desho grass and Brachiaria grass mean number of nodes per plant (5.4 and 10 nodes, respectively), while Napier grass produced the lowest (1.65). This might be due to weather condition, soil characteristics and overall management applied in the area during the study time.

In contrast to the present finding, Ebrahim *et al*., (2020) found that cutting height has no effect on internode length in Napier grass. But when came to the analysis result of each year growth, internode length was highly affected by cutting height during 2020 and also significantly affected on 2021 year. In line with this result internodes length per plant differed statistically among Napier grass accessions, and the least internodes length per plant of 12.9 cm was obtained from accession 15743 and the most internodes length per plant of 14.94 cm from accession 16819 (Aman & Diribi, 2021). Except for cutting height at 50cm and 70cm, all others were shown an increasing trend. Cutting height at 120cm was the longest internode length (11.45cm) followed by 110cm (10.36cm). According to (Zewdu, 2005), the highest (16.6cm) internode length was recorded for local accession of Napier grass followed by 14983 (16.1cm) and the least internode length was for 16836 accession (7.5cm) followed by accession 15743 (8cm).

From the present result, only cutting height above 100cm were comparable to the least result (Zewdu, 2005). This could be due to the genetic difference even though both are under same species of *Pennisetum*. This could be because the tiller or stem remains vegetative as the harvesting age increases; the inflorescence has an endless number of nodes and leaves and can theoretically produce an enormous number of new nodes and leaves. Stem elongation is influenced by soil type, temperature, rainfall amount and distribution, genotypes, and harvesting stage interaction effects, just like other agronomic traits.

5.5 Effect of cutting height on number tillers per plant, leaf to stem ratio, leaf and stem percent

The number of tillers per plant is insignificant during the first harvesting year, but significant during the second harvesting year. There is inconsistency of record for all cutting heights neither increasing nor decreasing number of tillers per plant across the treatments. Shahin *et al*. (2013) reported that cutting height affect the number of tillers per plant for Pearl millet (*Pennisetum galucum*). The highest number of tiller per plant was recorded for cutting heights of 50cm, 80cm, 100cm, 110cm and 120cm, respectively. The rest cutting heights were produced the least number of tillers. The reduction in number of buds which cause for tiller formation might be the reason for those produced less number of tillers (Shahin *et al*., 2013). According to Bimrew *et al*., (2018), the number of tillers per plant increased as the harvesting date approached. Bantihun *et al*., (2022) found that Desho grass had the higher number of tillers (46.45), whereas *Brachiaria mutica* and Napier grass had the intermediate (39.48) and minimum (14.45) numbers of tillers respectively, which are related perennial grasses.

From the present study the leaf to stem ratio of Desho grass was not affected by cutting height. This was consistent with the report for (*Andropogon Gayanus*) and the three grass species viz., *Panicum virgatum*, *Andropogon geradii*, and *Bromus inermisleyss produced the lowest* leaf to stem ratio with advancing maturity (Arega *et al*., 2020; Alexander *et al*., 1998). The reported (Getnet *et al*., 2020) leaf to stem ratio (1.29) harvested at 10% heading for Chifir Beqoa (*Pennisetum Polystachion*) was consistent with the current reported value. Leaf to stem ratio increased with increasing maturity.

According to Tessema *et al*., (2010), the leaf-to-stem ratio of Napier grass increased as the frequency of defoliation increased, probably due to undisturbed development for a longer duration. The current result was also in line with (Zewdu, 2005 and Butt *et al*., 1993) that the highest leaf to stem ratio was found from the shortest accession (15743) of Napier grass. The current higher leaf to stem ratio was found for cutting height at 50cm. The Leaf to stem ratio is an indicator of high forage nutritional value since leaf has a higher nutritive value than other parts of the plant (Tudsri *et al*., 2002), and animal performance is proportional to the amount of leaf in the diet. The longer periods of physiological growth with reduced defoliation frequency stimulate stem growth at the expense of leaf formation, resulting in a decrease in leaf to stem ratio with longer cutting intervals (Butt *et al*. 1993).

Many factors affect the leaf and stem fraction of the grass including tillering performance, plant height, and harvesting age and all had an impact on the leaf to stem fractions. Because leaves contain higher levels of minerals and less fiber than stems, the leaf fraction has a considerable impact on the nutritional quality of the forage (Denbela. H, 2015). The leaf percentage is a significant component regulating meal selection, quality, and forage intake (Kidanemariam *et al*., 2012). Because leaf is normally of higher nutritional value *(*Fekede *et al*., 2008), and animal performance is directly related to the amount of leaf in the diet, the leaf fraction is associated with high nutritive content of the forage. Combined analysis result for leaf to stem ratio showed a decreasing trend as cutting height increase from 50cm to 120cm except for cutting height at 90cm. Bimrew *et al*., (2017) reported that leaf to stem ratio was highly affected by harvesting date and when compared to the late harvesting date(150d), early harvesting at 90d and 120d resulted in a higher leaf to stem ratio. Denbela *et al*., (2020) reported that higher leaf to stem ratio was obtained from cropping year two even though leaf to stem ratio was not significantly affected by cropping year. Birmaduma *et al*. (2019) reported that the second harvesting cycle generated significantly more leaf to stem ratio than the first. This was due to the plant's tendency to produce more leaves (prolific tiller) and lie horizontally rather than uprightly.

Cutting height of Desho grass had no effect on leaf percentage and stem percentage. Generally leaf percentage showed a decreasing trend from first year harvest to second year harvest, but in case of stem percentage it showed an increasing trend from first to second year harvest. Cutting height of 120cm, 80cm and 110cm gave better leaf percentage (63.92%, 63.40% and 63.19%), respectively and cutting height at 60cm produced the least leaf percentage (55.97%). In case of stem percentage, cutting height at 60cm and 90cm gave the highest stem proportion of 44.02% and 40.08%, respectively and cutting height at 120cm produced the least stem proportion (36.08%). This could be due to directly related to leaf to stem ratio and all are not affected by cutting heights.

5.6 Effect of cutting height on first and second harvest and average dry matter yield

According to Yirgu *et al*., (2017), dry matter yield was significantly higher during the second harvest than the first year. The first harvest dry matter yield of Desho grass was highly affected by cutting height. Cutting height at 120cm gave the highest dry matter yield (18.62 t/ha) on average followed by cutting height at110cm and 100cm (14.84 and 14.56 t/ha), respectively. The least dry matter yield was recorded for cutting height at 50cm (6.13t/ha) on average.

Cutting height at 60cm and 90cm produced comparable biomass yield (8.48 and 8.68 t/ha), respectively but cutting height of 80cm gave higher yield (9.48t/ha) than cutting height at 50cm, 60cm and 90cm. The first and second harvest dry matter yield was highly affected by cutting height. The first harvest yields increased with increased cutting height, the second harvest dry matter yield was decreased with increasing cutting height. The least (1.5t/ha) dry matter yield was harvested for 120cm cutting height and the highest (6.2 and 6.1 t/ha) dry matter yield for 60cm and 50cm, respectively. This might be due to the difference in regrowth period required for longer (120cm) cutting height than shorter (50cm and 60cm) cutting heights.

Generally second harvest dry matter yield showed a decreasing trend from 2020 to 2021 year of harvest. Cutting height at 50cm and 60cm (6.1 and 6.2 t/ha) produced better yield than those harvested at 70cm, 80cm, 90cm,100cm,110cm and120cm. After first harvest of first year, the mother plant is continued to grow during dry periods of

December to May; so before the onset of the main rainy season all treatments were harvested uniformly. During the harvesting period the plant height vary significantly due to the cutting effect of the previous harvest. The present study result revealed that average dry matter yield was affected by cutting height. Generally average dry matter yield showed an increasing trend over years. Combined analysis result showed the same increasing trend as maturity increase except for some treatments. Cutting height at120cm recorded the highest average dry matter yield while cutting at 50cm produced the least dry matter yield. In contrast to the present result (Yirgu *et al*., 2017) reported that the average dry matter yield of the second harvest was higher than the first (21.76 and 24.99 kg/ha for first and 31.29 and 31.72 kg/ha for second) for Kulumsa and Areka variety , respectively. The present result showed that 6.37 t/ha and 8.91 t/ha average dry matter yield was recorded for the first and second year harvest, respectively.

5.7. Effect of cutting height on dry matter, ash and crude protein

The current study revealed that the overall mean DM content of 92.84% was recorded for Desho grass. This was comparable to the report of (Diribi, 2022) who stated that the dry matter content rose as the harvesting stage progressed and reported the highest 92.98% DM content at harvesting stage of 90 days while the lowest was from 45 (92.78%) and 60 (92.79%) days to harvesting for bracharia grass. It was higher than Eniyew *et al*., (2021) who reported (91.08%DM) for Desho grass and higher (91.96%DM), and (91.42%DM) for Buffel and Setaria grass respectively. Tilahun *et al*., (2017) and Kefyalew *et al*., (2020) reported that the dry matter yield of Desho grass increased with increased cutting intervals opposite to this study in which there was no clear increase or decreasing trend but minimal change observed. In contrast to the present study (Muhindo *et al*., 2018) reported independently to the cutting frequency, dry matter (DM) content increased from the first to the last cutting. Between the harvesting dates of 75,105 and 135, the DM concentration exhibited minimal change, ranging from 88.2 to 89.1 percent (Tilahun *et al*., 2017), in line with the present result. The present result was also higher than the report of (Denbela *et al*., 2020) 89.67% DM for Desho grass in the South Omo area, Ethiopia. The recent report by (Geberemariyam & Gezahegne, 2022) for DM% is 90.82%DM which is less than the present study result, but a comparable result was reported for Bracharia, Napier, and Rhodes grasses. The variation could be attributable to differences in the environment where the experiment was conducted.

Bimrew,(2016) reported a significant difference in dry matter percentage for Desho grass, and dry matter percentage of (31.42%) at mid-altitude of Ethiopia which was far less than the current result(92.84%) and the reason might be associated with environmental differences such as temperature, moisture, and soil characteristics. Yirgu *et al*.,(2017) also got 30.91 dry matter percent on average from the first and second harvest of Kulumsa variety Desho grass under irrigation conditions. Comparable to this study result Mulisa *et al*.,(2021) also reported a 91.64% dry matter for Desho grass. Yirgu *et al*.,(2017) reported (41.48 and 38.48) Dry matter percent for Kulumsa and Kindo kosha variety of Desho grass during the second harvest. Less than the current result Denbela *et al*.,(2020) also reported 89.67%, 89.33%, 90%, and 90.33% of Dry matter percent content for Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 varieties of Desho grass respectively.

Ash percentage was highly affected by cutting height .The ash content of the current study (5.11%-6.12%) was much less than the report of Mulisa *et al*. (2021) which was 15.87% ash content for Desho grass tested at Holetta. This could be attributed to variation to weather conditions (temperature, rainfall, humidity) during the growing period of the plant and soil fertility change and management of the plant. In line with the present result (Tilahun *et al*., 2017) reported that ash concentration declined significantly as harvesting age increased. This was associated with progressive increases in plant spacing resulted in significant increases in ash concentration (Tilahun *et al*., 2017). In addition, Demlew *et al*., (2019) also reported a linear decrease in ash content with an increase in harvesting days . According to Demlew *et al*., (2019), for other grass species (Buffel grass and Silver leaf *Desmodium*), the highest mean ash percentage (12.71%) was found at 90days for Buffel grass harvesting, while the lowest (9.89%) was found at 120days. In contrast to the extreme harvesting days, intermediate ash content (11.74 percent) was attained at 120 days. High Ash content in forage could be an indication of high mineral concentration(Pratt & Lewis Smith, 1982). The decrease in total ash as harvesting time increases could be related to a decrease in total ash content of forages, resulting in earlier dilution and translocation of different minerals linked with the vegetative component of the leaf at a later maturity time. A reduced ash level is advantageous for feeding animals because it reduces silica, which interferes with feed digestion. This result is also in line with the findings of (Berhanu *et al*., 2007) and (Terefe, 2017), who observed that total ash concentration decreased as plant age increased.

The current result(5.62%) is also less than the report of (Denbela *et al*., 2020) who reported 7.33, 7.29, 10.22, and 7.85% of ash content for Kulumsa, Areka, Kindokisha DZF592 and Kindokisha DZF589 varieties of Desho grass respectively. Total ash content was considerably affected by forage species and the ash content of pure grass was substantially greater than that of pure legume, but not significantly higher than that of the mixture(Demlew *et al*., 2019).

The current result reveals that crude protein was highly affected by cutting height (P<0.001). There is a big difference between the two harvesting years in the present study; the mean crude protein content was 8.36CP %(2020) and 12.58CP %(2021) each year respectively. Crude protein decrease with cutting height increase. In comparable with this result Tilahun *et al*., (2017) stated that crude protein (CP) concentration was significantly affected by harvesting age, and declined from 10.9% at 75 days to 9.3% at 135 days of Desho grass harvesting. According to a study report by (Mulisa *et al*., 2022), crude protein yield differed considerably among accessions, and Desho grass produced the highest crude protein, followed by *B. decumbens* (accession ILRI-13205), *B. decumbens* (accession ILRI-14721), and *S. sphacelata* (accession 6543).The current result was also higher than the finding of (Geberemariyam & Gezahegne, 2022) for Desho grass(9.85%CP), Bracharia, Napier, and Rhodes grass. In line with the present result Tilahun *et al*.,(2017) reported Desho grass cut at a young age exhibited great nutritional value, with a high CP concentration (10.9% CP), which is a limiting nutrient in tropical forages. Even at 135 days of age, crude protein concentrations were significantly more than 7.0 percent, which means it was 9.3 percent; below this threshold(7%CP), ruminant voluntary intake may be reduced(Tilahun *et al*., 2017). This was true of the present result for cutting height of 50cm which records (12.16CP %) higher than the rest of the treatments. Diribi, (2022) also reported CP decreased as the harvesting stage extended but increased with increasing NPS fertilizer levels for *Bracharia Mulato II* grass. A minimum CP content of 15% is required for cow lactation and growth (Van Soest 1982; Norton 1982; NRC, 2001), although no cutting height examined in the current study exceeded this figure. The present result was less than the report (Zewdu, 2005) which reported 15.7% CP for Napier grass accessions (16791), 13.9 %(16853), and 13.2% CP for varieties of Napier grass; all other accessions were less than 13% CP content. But the present result was higher than those (Bimrew, 2016) who reported CP% of 8.17%,7.55%, and 5.61% for harvesting dates of 90d,120d, and 150d respectively. This may be due to differences in grass species as well as environmental conditions. Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 had crude protein content of 11.84, 14.12, 13.39, and 9.57%, respectively(Denbela *et al*., 2020). Accordingly, the current combined Analysis result of 10.47% was lower compared to the report by (Denbela *et al*., 2020). Desho grass cut at a young age from the present study has great nutritional content in line with (Tilahun *et al*., 2017), particularly high CP concentration, a limiting nutrient in tropical forages. CP concentrations were well above 7.0 percent in forage cut at 135 days of age, which is the level below which ruminant voluntary intake may be depressed(Tilahun *et al*., 2017). Plant species, plant morphological components, plant maturity stage, and climatic conditions such as rainfall, temperature, and soil type all affect the nutritional content of fodder and forage crops (Papachristou and Papanastasis, 1994).

5.8 Neutral detergent fiber, Acid detergent fiber and Acid detergent lignin

The neutral detergent fiber was significantly affected by cutting height from the present study result. It was increased with increasing cutting height or maturity except for cutting height at 100cm and 120cm in which they didn’t showed change. This is in line with Demlew *et al*. (2019) who stated that forage stand and harvesting time showed extremely significant effects on NDF . As the harvesting period grew, the NDF content increased as well; the highest mean 54.46 %NDF content was recorded at the later harvesting period (150 d) and the lowest 46.38%NDF recorded at the shortest harvesting period (90 d) (Demlew *et al*., 2019). The NDF level of the mid-harvesting (120 days) was significantly higher than that of the early harvesting (90 days), but significantly lower than that of harvested at 150 days (Demlew *et al*., 2019). Bimrew, (2016) found that Desho grass harvested at 90, 120, and 150 days produced 70.38, 72.17 and 78.22% NDF. These findings showed that the NDF content rose as the harvesting days increased and 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 as the immature plant grows older (Van Soest, 1982; McDonald *et al*., 2002). Environmental conditions such as temperature and water stress may also impact cell content, resulting in reduced carbohydrate accumulation (Whiteman, 1980). The present result was consistent with the result of Bimrew, (2016) who stated that significant increase of NDF concentration with harvesting height and who found that NDF concentration increased from 72.8 percent at 90 days to 77.7 percent at 150 days for the same grass species (Desho), except for cutting height 100cm. For Napier grass was harvested at 60, 90, and 120 days, Bayble *et al*. (2007) observed a similar tendency. The current result also corresponds to the findings of Taye *et al*. (2007), Bimrew (2016), Genet *et al*. (2017), and Terefe (2017)), who found that NDF content of natural pasture increased with advancing maturity. Feeds with NDF values less than 45 percent are considered high-quality, those with values between 45 and 65 percent are considered medium-quality, and those with values greater than 65 percent are considered low-quality (Singh and Oosting, 1992). The level of NDF content above 60% in tropical grass affects the DM intake (Meissner *et al*. 1991). In opposite to this result Kulumsa, Areka, Kindokisha DZF592, and Kindokisha DZF589 had 57.73, 55.12, 56.7, and 63.42% neutral detergent fiber content, according to (Denbela *et al*., 2020).

The close relationship of ADF with a decrease in leaf-to-stem ratio and an increase in cell well lignification with advanced harvesting age could explain the increase in ADF content as plants mature (Berhanu *et al*., 2007; Taye *et al*., 2007). In line with the current result (Bimrew, 2016) and (Genet *et al*., 2017) in Desho and (Terefe, 2017) in Rhodes grass, respectively, found that as plants matured, their ADF content increased, except for cutting height at 110cm and 120cm that they didn’t show change. This might be due to photosynthetic products are converted to structural components more quickly as plants age, as a result, protein and soluble glucose levels drop while structural cell wall components rise (Ammar *et al*., 2004). The maturity stage of the plant has a substantial impact on acid detergent fiber (ADF). The ADF rose as the harvesting stage was extended, with the lowest ADF concentration at 45 days following total clearing (Diribi, 2022) and reported the mean value of 31.77 % ADF for Desho grass. The present result of 42.73% was lower than the report of Tilahun *et al*., (2017) in which Desho grass collected at 135 days had a 48.1% ADF content. The present result (41.38%) was also less than (Denbela *et al*., 2020) report 44.63% ADF for Kulumsa variety Desho grass in South Omo area. This could be attributed to the environment in which the experiment was done and weather condition of the area.

The present study showed that the ADL content increase with extended cutting height of Desho grass and ranged between 4.13% and 4.93 %. Acid detergent Lignin was affected by harvesting stage of the plant and increased with extended harvesting stage (Diribi, 2022). The composition and digestibility of grass species altered as expected (Jung & Vogel, 1986), with rising cell wall content and decreased digestibility as maturity progressed. The lignin concentration of the cell wall rose dramatically as the overall cell wall concentration of the grasses increased.

The increase in ADL content with age was most likely due to a rise in cell wall concentration with maturity. By reducing nutrient availability, forages with higher ADL concentration had lower overall digestibility of the meal (Van Soest, 1994). As a result, Van Soest (1982) found that lignin content above 6% has a negative impact on fodder digestibility. The present result was below this value and it’s acceptable and had less impact on digestibility of Desho grass by livestock. As a result, the study's total mean (4.52 percent) was within the acceptable range. According to (Zewdu, 2005) report, 3.46, 4.61,and 3.34 percent of ADL was recorded for (14983,149884 and Local) accessions of Napier grass.

5.9 *In vitro* dry matter digestibility, organic matter digestibility and metabolizable energy

In vitro dry matter digestibility was highly affected by cutting heights. Generally, IVDMD showed an increase from year 2020 to 2021. The overall mean of the current study result for IVDMD is 66.75 %. This result was much higher than (Getnet *et al*., 2020) the reported value for *Pennisetum Polystachion* grass species in Pawe area. This could be attributed to species difference and environmental condition of the area. The present result is higher than the report of (Geberemariyam & Gezahegne, 2022) who reported 63.08%IVDMD for Desho grass. This could be due to the area's environmental conditions and species differences. It’s also higher than the report of (Arega *et al*., 2020) the combined mean value of IVDMD content of the Dirk Ayifera (*Andropogon Gayanus*) at different stage of cutting were 36.53%. This could be attributed to high content of fiber specially (NDF %) in the treatments negatively affect the digestibility of the sample. According to Van Soest, (1982), lignin content more than 60 g/kg DM has a negative impact on forage digestion. The current result(66.75%) was comparable to the finding of (Zewdu, 2005) that mean In vitro dry matter digestibility for ILRI accessions of Napier(*Pennisetum purpurum*) grass (68.94%) and higher than local variety of Napier grass.

Organic matter digestibility was highly affected by cutting heights. The combined analysis result found that the overall mean organic matter digestibility was 62.58%. The current result is higher than the report of (Bimrew, 2016) mean 44.81% in highland altitude for Desho grass tested at different harvesting dates. In contrast to this *Tilahun et al*., (2017) reported that organic matter (OM) concentration increased progressively as harvesting age increased. The OMD content showed significant variation at Holetta (Gezahagn *et al*., 2017a) The highest OMD was recorded for Cutting height at 80cm followed by 60cm, 70cm and 50cm, respectively which were above 64% OMD. The least recorded for cutting height at 100cm followed by 120cm, 110cm and 90cm which were below 63%OMD. This is due to the higher organic matter demand of grass for reproduction at advanced maturity stages, which results in an increase in the concentration of OM. 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 chemical composition and digestibility of Napier grass (Gezahagn, *et al*,. 2017a).

Metabolizable energy was highly affected by cutting height. The current result found for all cutting heights is higher than the report (Bimrew, 2016), which were 6.69,6.13 and 5.87 MJ/Kg DM for 90d,120d, and 150d harvesting days of Desho grass respectively. High and low-energy feeds are defined as feeds containing more than 12.0 MJ/kg of dry matter of ME and feed containing less than 9.0 MJ/kg of dry matter of ME, respectively (Lonsdale, 1989). Hence, according to this classification, the currently tested Desho grass cutting heights at the highland area of Holetta are classified as intermediate energy feed. The present result ranges between 9 and 11 which was the intermediate result between high and low-quality parameters with a mean (10.01 MJ/Kg DM) which is higher than the report (Bimrew, 2016; Bimrew *et al*., 2017). The present result was also higher than the finding (Zewdu, 2005) for Napier grass accessions. In contrast to the current finding (Bimrew, 2016) result shows a decreasing trend of Metabolizable energy with maturity. The current combined Analysis result shows an increasing trend up to a cutting height of 80cm and began to decline for later cutting heights. This could be due to an increase in fiber content as the cutting height in this study increased. The present finding mean (10.01 MJ/KgDM) also is higher than the report of (Maleko *et al*., 2019) who reported the mean ME values of 7.94MJ/KgDM, and (Turano *et al*.,2016) reported 7.1MJ/KgDM for *Pennisetum purpurium* grass species from Tanzania. However, the current mean result fulfills the NRC, (2001) recommendation of minimum metabolizable energy (10 MJ/KgDM), the requirement for dairy cattle. This is the indication that supplementary protein-energy-rich feed sources are required for optimal milk production if the Desho grass under the study is used to be the basal dairy cattle feed in the central highland of Ethiopia.

6. CONCLUSIONS AND RECOMMENDATION

Dry matter yield and nutritive value of Desho grass harvested at different cutting heights respond differently for the tested agronomic and chemical parameters across the study years. Number of leaves per plant, number of nodes per plant, leaf length, and internode length were affected with cutting height. But stem basal diameter, leaf to stem ratio and the number of tillers per plant were not significantly different. The later stage/cutting heights harvesting, dry matter yield and fiber contents of Desho grass is higher while Ash and CP content is decreased. Crude protein decreased as cutting height extended from 12.16-8.54% at 50cm-120cm cutting. The highest mean total dry matter yield were recorded for cutting height of 120cm (20.13t/ha), 110cm (18.22t/ha) and 100cm (18.18t/ha) in descending order. It is recommended that Desho grass should be harvested at an appropriate cutting height in order to have better nutritive value with relatively higher biomass yield. So in this study cutting height which record good nutritive value of Desho grass with higher biomass yield was selected. Hence, out of all cutting heights, agronomic and nutritive value parameters tested, cutting Desho grass at 100cm is better both in terms of biomass yield and nutritive value. Further research should be done by animal feeding trial to confirm this cutting height through observing the response of animal.

7. REFERENCES

Abebe, M., Oosting, S. J., Fernandez-Rivera, S., & Van der Zijpp, A. J. (2008). Farmers' perceptions about exotic multipurpose fodder trees and constraints to their adoption. *Agroforestry systems*, ***73***(2): 141-153.

Adesogan, A. T., Sollenberger, L. E., Moore, J. E., Newman, Y. C., & Vendramini, J. M. B. (2009). Factors Affecting Forage Quality. *Edis*. **5**:1–5.

Adugna, T. (2012). Potential for Development of Alternative Feed Resources in Ethiopia. *An Assessment Report prepared for ACDI/VOCA. Addis Ababa Ethiopia. pp20.*

Adugna, T., Alemu, Y., Alemayehu, M., Dawit, G. A., Diriba, A. G., Lemma, G. & Yirdaw, W. (2012). Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation: Main issues, Conclusions and Recommendations. *Ethiopia Animal Feed Industry Association, Addis Ababa, Ethiopia. P*, *135*.

Alemayehu, M. (2004). Pasture and forage resource profiles of Ethiopia. *Ethiopia/FAO. Addis Ababa, Ethiopia*, **19**

Alemayehu, M. (2005). Feed resources base of Ethiopia: Status, limitations and opportunities for integrated development. Proceedings of the 12th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 12-14, 2004, Addis Ababa, 410p.

Alemayehu, M., Gezahagn, K., Getnet, A. and, & Fekede, F. (2017). Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities Farming System Dynamism in Ethiopia View project African Chicken Genetic Gains View project. *Academic Research Journal of Agricultural Science and Research.* **5**(3):176–185. https://doi.org/10.14662/ARJASR2017.013

Alexander, J. Smart., Walter Ii. Schacht. Jeffrey, F., Pedersen, Daniel. J. Under sander, and Lowell E. Moser. (1998). Prediction of leaf: stem ratio in grasses using near infrared reflectance spectroscopy, *Journal of range management*.**51**:447-449.

Aman, G., & Diribi, M. (2021). Performance Evaluation of Napier Grass (*Penisetum Purpuruem* (*L*.) *Schumach*) accessions under rain fed and Irrigation System at Wondo Genet. *Global Journal of Ecology,* **6**: 028–033. https://doi.org/10.17352/gje.000041

Ammar, H., López, S., González, J. S., & Ranilla, M. J. (2004). Chemical composition and in vitro digestibility of some Spanish browse plant species. *Journal of the Science of Food and Agriculture*, ***84***(2): 197-204.

Ansah, T., Osafo, E. L. K., & Hansen, H. H. (2010). Herbage yield and chemical composition of four varieties of Napier (Pennisetum purpureum) grass harvested at three different days after planting.

AOAC (Association of Official Analytical Chemists). (1990). Official methods of analysis. 15th ed. Washington, DC.

AOAC as Ed. By Cunniff, P. (1995). Official methods of analysis. *Association of Official Analytical Chemists (AOAC). 16th ed. Arlington, Virginia, USA*.

Aranguiz, A. A., & Creemers, J. (2019). *Quick scan of Ethiopia's forage sub-sector*. Working paper, Wageningen, Wageningen UR-Livestock Research.

Arega, H., Shitaneh, E., Getnet, M., & Worku, B. (2020). Determination of Appropriate Cutting time of Perennial Elite Lowland Adaptive Forage Grass Species of Dirk Ayifera/Andropogon Gayanus/for Optimum Yield and Quality of Hay in Metekel Zone of Benishangul Gumuz. *International Journal of Scientific Engineering and Science*, **4**(9): 41–49

Asresie, A., Zemedu, L., & Adigrat, E. (2015). The contribution of livestock sector in Ethiopian economy. *A Review. Advances in Life Science and Technology*, ***29***.

Bantihun, A., Asmare, B., & Mekuriaw, Y. (2022). Comparative Evaluation of Selected Grass Species for Agronomic Performance, Forage Yield, and Chemical Composition in the Highlands of Ethiopia. *Advances in Agriculture*, *2022*.

Bayble, T., Melaku, S., & Prasad, N. K. (2007). Effects of cutting dates on nutritive value of Napier (Pennisetum purpureum) grass planted sole and in association with Desmodium

(Desmodium intortum) or Lablab (Lablab purpureus). *Livestock Research for Rural Development*, ***19***(1), 120-136.

Berhanu, A., Melaku, S. and Prasad, N. K. (2007). Effects of varying seed proportions and harvesting stages on biological compatibility and forage yield of oats (*Avena sativa L*.) and vetch (*Vicia villosa R*.) mixtures. *Livestock Research for Rural Development*, ***19***(1): 12.

Beyene, T., Tegene, N. and Ayana, A. (2010). Effects of farming systems on floristic composition, yield and nutrient content of forages at the natural pasture of Assosa zone (western Ethiopia). *Tropical and Subtropical Agroecosystems*, ***12***(3): 583-592.

Bimrew, A. (2016). Asmare, B. (2016). Evaluation of the agronomic, utilization, nutritive and feeding value of desho grass (*Pennisetum pedicellatum*) (PhD dissertation, Jimma University).

Bimrew, A., Demeke, S., Tolemariam, T., Tegegne, F., & Jane, W. (2018a). Appraisal of mineral content of Desho grass (*Pennisetum pedicellatum Trin*.) as affected by stage of maturity and agro-ecologies in Ethiopia. *J. Agric. Environ. Sci*, **3**(1): 56.

Bimrew, A., Demeke, S., Taye, T., Tegegne, F., Haile, A., & Wamatu, J. (2017). Effects of altitude and harvesting dates on morphological characteristics, yield and nutritive value of Desho grass (*Pennisetum pedicellatum Trin*.) in Ethiopia. *Agriculture and Natural Resources*, **51**(3):148–153. https://doi.org/10.1016/j.anres.2016.11.001

Bimrew, A., Demeke, S., Taye, T., Tegegne, F., Wamatu, J., & Rischkowsky, B. (2016). Determinants of the utilization of desho grass (*Pennisetum pedicellatum*) by farmers in Ethiopia. *Tropical Grasslands-Forrajes Tropicales*, ***4***(2): 112-121.

Bimrew, A., Mekuriaw, Y., & Tekliye, I. (2018b). Desho grass (*Pennisetum pedicellatum Trin*.) evaluation based on plant characteristics, yield and chemical composition under irrigation in Northwestern Ethiopia. *Journal of Agriculture and Environment for International Development*, **112**(2): 241–251. https://doi.org/10.12895/jaeid.20182.704

Birmaduma, G., Tamrat, D. and, & Muleta, D. (2019). Evaluation of Desho Grass (*Pennisetum pedicellatumTrin*) lines for their adaptability at Mechara Research Station, Eastern Oromia, Ethiopia.*Journal of Ecology and the Natural Environment*, **11**(3):26–32. https://doi.org/10.5897/jene2019.0742

Butt, N. M., Donart, G. B., Southwara, M. G., & Pieper, R. D. (1993). Effect of defoliation on plant growth of Napier grass. *Tropical Science London*, ***33***:111-111.

Convention on Biological Diversity, (2009). Report, C. E. 4th C. Ethiopia's 4th Country Report.

CSA (Central statistical agency), (2021). Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey 2020 / 21 report on livestock and livestock characteristics. II (February).

Demlew, M., Alemu, B., & Awuk, A. (2019). Nutritive value Evaluation of Buffel grass and Silver leaf Desmodium Grown in Pure Stands and in Mixture at Different Harvesting Times in Gozamen District, East Gojjam Zone, Ethiopia. *Greener Journal of Agricultural Sciences*, *9*(3), 315-321.

Denbela, H., Berako, B., & Sintayehu, K. (2020). Evaluation of Desho (Pennisetum pedicellatum) grass varieties for dry matter yield and chemical composition in South Omo Zone, South Western Ethiopia. *Agricultural Research and Technology*, ***25***(2): 001-008.

Denbela. H, B. A. and Mengistu. M. (2015). Participatory On-Farm Evaluation and Demonstration of Improved Legume Forage Species in Benatsemay Woreda of South Omo Zone. ***5***(21):127–131.

Derero, A., & Kitaw, G. (2018). Nutritive values of seven high priority indigenous fodder tree species in pastoral and agro-pastoral areas in Eastern Ethiopia. *Agriculture and Food Security*, **7**(1):1–9. https://doi.org/10.1186/s40066-018-0216-y

Ebrahim, H., Negussie, F., & Animut, G. (2020). Effects of Nitrogen Fertilizer Rate and Cutting Height on Morphological Characteristics and Yield of Elephant Grass (*Pennisetum purpureum L*.). *East African Journal of Sciences*, **14**:141–150

Eco crop, (2010). Eco crop database. Food and Agricultural Organization.

EIAR (2022). Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Center, soil laboratory reported data

Endale, Y., Nibo, B., Million, T., Ulfina, G., Lemma, F., H/Gabriel, A. & Beksisa, U. (2021). Evaluation of Management Levels and Performance of Crossbred Dairy Cattle Demonstrated to Smallholder Farmers in the Central Highlands of Ethiopia. **1**:19–29.

Eniyew, Y., Alemu, B., & Ayele, S. (2021). Effects of Fertilizer Type and Grass Species on Agronomic Performances and Chemical Composition in Gozamin District, East Gojjam Zone, Ethiopia. **6**(4): 103–110. https://doi.org/10.11648/j.ajere.20210604.11

FAO, (2018). Report on feed inventory and feed balance in Ethiopia.

FAO, (2015). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.

Farrell, G., Simons, S., & Hillocks, R.J. (2002). Pests, diseases and weeds of Napier grass, Pennisetum purpureum: a review. *International Journal of Pest Management*, ***48***(1): 39-48.

Fekede, F., Adugna, T., & Melaku, S. (2008). Proportions of morphological fractions of oats (*Avena sativa L*.) as affected by variety and growth stage. *Livestock Research for Rural Development*, **20**(6).

Fekede, F., Getnet A., Lulseged G., Muluneh, M. and Tadesse, T. (2005). Evaluation of Napier grass-vetch mixture to improve total herbage yield in the central highlands. In: Proceedings of the 13th annual conference of the Ethiopian Society of Animal Production (ESAP), August 25 – 26, 2005, Addis Ababa, Ethiopia.

Figueira, D. N., Neumann, M., Ueno, R. K., Galbeiro, S., & Bueno, A. V. I. (2016). Forage yield and quality in elephant grass cv. Pioneiro harvested at different cutting height sand times. Semina: Ciencias Agrarias, **37**(2):1017–1028.

Firew, T., & Assefa, G. (2010). Feed resources assessment in Amhara National Regional State. Ethiopia Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM, Texas Agricultural Experiment Station (TAES). Final Report, Bahir Dar, Ethiopia. 2010: 81–94.

Geberemariyam, T., & Gezahegne, M. (2022). Nutritional Value and in Situ Degradability of Selected Forages, Browse Trees and Agro Industrial By-Products. *Online Journal of Animal and Feed Research*, March. https://doi.org/10.51227/ojafr.2022.13

Gebrehiwot, L., R. L. McGraw. and Getinet A. (1996). "Forage yield and quality profile of three annual legumes in the tropical highlands of Ethiopia." *Tropical agriculture* **73**:2.

Genet, T., Bimrew, A. and Yeshambel, M. (2017). Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of Desho grass (*Pennisetum pedicellatum Trin*.) in the highlands of Ethiopia. *Tropical Grasslands-Forrajes Tropicales*. **5**(2): 77-84.

Getnet, A. and Inger, L. (2001). Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures, *Animal Feed Science and Technology*. **92**: 95-111.

Getnet, A., Mesfin, D., Hanson, J., Getachewu, A., Solomon, M., & Alemayehu, M. (2012). Forage seed research and development in Ethiopia.

Getnet, M., Arega, H., Shitaneh, E. & Worku, B. (2020). Determination of Appropriate Cutting Date of Perennial Elite Lowland Adaptive Forage Grass Species : Chifir Bequa (*Pennisetum Polystachion*), **4**(8):1–3.

Gezahagn K., Fekede F., Getnet A., Mengistu A., Alemayehu M., Aemiro K., Kassahun M., Solomon M., Estifanos T., Shewangizaw W. & Mergia A. (2017). Agronomic performance, dry matter yield stability and herbage quality of Napier grass (*Pennisetum purpureum (L.) Schumach*) accessions in different agro-ecological zones of Ethiopia. *J. Agric. Crop Res*., **5**(4): 49–65.

Hall, A. & Rasheed, S. (2007). Reframing Technical Change: Livestock Fodder Scarcity Revisited as Innovation Capacity Scarcity.

Hancock, D. (2017). Common Terms Used in Animal feeding and Nutrition. University of Georgia, 1367.

Hassen, A., Ebro, A., Kurtu, M., & Treydte, A. C. (2010). Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. *Livestock research for rural development*, ***22***(229).

Hidosa, D. & Getaneh, D. (2021). Evaluation of Desho (*Pennisetum pedicellatum*) Grass Varieties for Dry Matter Yield and Chemical Composition under Irrigation in two Districts of South Omo Zone, Southwestern Ethiopia. *East African Journal of Sciences* **15**:71–78.

Husen, M., Kechero, Y., & Molla, M. (2016). Assessment of Livestock Feed Resources Utilization in Jimma Zone, Southwest Ethiopia. *Academic Journal of Nutrition*, **5**(1):1–17.

IGAD Center for Pastoral Areas and Livestock Development (ICPALD) ICPALD, (2009). The contribution of Livestock to The Ethiopian Economy. Policy Brief, 02.

James, K. M., Daniel, N. M., V.Verchot, L., & James B.Kung'u. (2008). Combining Napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. *Agroforestry Systems*, **74**(1): 37–49.

Jorgensen, S. T., Pookpakdi, A., Tudsri, S., Stölen, O., & Ortiz, R. (2010). Acta Agriculturae Scandinavica Section B –Soil and Plant Science Cultivar-by-cutting height interactions in Napier grass (*Pennisetum purpureum Schumach*) grown in a tropical rain-fed environment. 4710. https://doi.org/10.1080/09064710902817954

Jung, H. G., & Vogel, K. P. (1986). Influence of lignin on digestibility of forage cell wall material. *Journal of animal science*, ***62***(6): 1703-1712.

Kefyalew, A., Alemu, B., & Tsegaye, A. (2020). Effects of Fertilization and Harvesting Age on Yield and Quality of Desho (*Pennisetum pedicellatum*) Grass Under Irrigation, in Dehana District, Wag Hemra Zone, Ethiopia. *Agriculture, Forestry and Fisheries*, **9**(4):113. https://doi.org/10.11648/j.aff.20200904.13

Kidanemariam, A., Gebrekidan, H., Mamo, T., & Kibret, K. (2012). Impact of Altitude and Land Use Type on Some Physical and Chemical Properties of Acidic Soils in Tsegede. *Open Journal of Soil Science*, 223–233.

Lepcha, I., & Naumann, H. D. (2021). Partitioning of Forage Mass and Nutritive Value in Sunn Hemp.

Leta, G., Duncan, A. and Asebe, A. (2013). Desho grass (*Pennisetum pedicellatum*) for livestock feed, grazing land and soil and water management on small-scale farms. NBDC Brief 11, *International Livestock Research Institute*. Nairobi, Kenya.

Lima, E. da S., da Silva, J. F. C., Vásquez, H. M., de Andrade, E. N., Deminicis, B. B., de Morais, J. P. G., da Costa, D. P. B., & Araújo, S. A. do C. (2010). Agronomic and nutritional characteristics of the main varieties of elephant grass. *Veterinária e Zootecnia*, **17**:324–335.

Lonsdale, C., 1989. Raw Materials for Animal Feeds Compounders and Farmers. *Chalcombe Publications Great Britain*. Pp. 17-47.

Lounglawan, P., Lounglawan, W., & Suksombat, W. (2014). Effect of Cutting Interval and Cutting Height on Yield and Chemical Composition of King Napier Grass (*Pennisetum Purpureum*x*PennisetumAmericanum*).APCBEEProcedia.**8**:27–31. https://doi.org/10.1016/j.apcbee.2014.01.075

Lukuyu, B., Franzel, S., Ongadi, P.M. and Duncan, A. J. (2011). Livestock feed resources: Current production and management practices in central and northern rift valley provinces of Kenya. *Liv. Res. Rur. Dev*. **23**: 1–12.

Lyons, R. K., Machen, R., & Forbes, T. D. A. (2000). Why Range Forage Quality Changes.

Maleko, D., Mwilawa, A., Msalya, G., Pasape, L., & Mtei, K. (2019). Forage growth, yield and nutritional characteristics of four varieties of napier grass (*Pennisetum purpureum Schumach*) in the west Usambara highlands, Tanzania. *Scientific African*, 6. https://doi.org/10.1016/j.sciaf.2019.e00214

McDonald P, R.A Edwards, J.F.D Greenhalgh, and C.A Morgan. (2002). Animal Nutrition 6th Edition. Pearson Educational Limited. Edinburgh, Great Britain. pp. 255-657

McDowell, L.R. (1985). Nutrition of grazing ruminants in warm climates. Animal feeding and Nutrition, Academic press, Inc., London, UK. 443p.

Meissner, H.H., Koster, H.H., Nieuwoudt, S.H. and Coetze, R.J. (1991). Effects of energy supplementation on intake and digestion of early and mid-season ryegrass and

Panicum/Smuts finger hay, and on in Sacco disappearance of various forage species. *South African Journal of Animal Science* **21**: 33–42.

Mekasha, A., & Mengistu, A. (2007). Measurements in Pasture and Forage in Cropping Systems.

Melese, F. (2021). On-farm Performance Evaluation of Rhodes Grass (Chloris gayana) Cultivars Under Rain-fed Condition at Babile District of East Hararghe, Oromia, Ethiopia. *Journal of Biology, Agriculture and Healthcare*, **11**(3): 19–24. https://doi.org/10.7176/jbah/11-3-03

Melkie, B. (2005). Effect of Planting Patterns and Harvesting Days on Yield and Quality of Bana Grass [*Pennisetum purpureum* (L.) x *Pennisetum americanum* (L.)].M.Sc. Thesis Presented to the School of Graduate of Alemaya University. 111p.

Minson, D. J. (1997). Forage Composition. 1980.

Mohamed, A., & Gebeyewu, K. (2018). On-farm performance evaluation of selected perennial grass under rain-fed conditions at Deghabour District, Cherer Zone, Ethiopian Somali Region. *Poultry, Fisheries & Wildlife Sciences*, ***6***(2): 2-5.

Muhindo, Z. K., Tendonkeng, F., Miégoué, E., & Pamo, J. L. E. T. (2018). Effect of Harvesting Time on the Chemical Composition of *Pennisetum clandestinum*. **2**(2): 10–17.

Mulisa, F., Gezahagn, K., Fekede, F., Kedir, M., Muluneh, M., Solomon, M., & Tsegahun, A. (2021).Evaluation of ten perennial forage grasses for biomass and nutritional quality. *TropicalGrasslands-ForrajesTropicales*.**9**(3):292–299.

Mulisa, M., Gezahagn, K., Fekede, F., Kedir, M., & Gezahign, M. (2022). Yield, Yield Components, and Nutritive Value of Perennial Forage Grass Grown under Supplementary Irrigation.

Mulisa, M., Gezahegn, K., Muluneh, M., Fekede, F., Kedir, M., Solomon, M., & Aschalewu, T. (2022). Performance of different perennial forage grass species at Holetta Research Center, Central Highland of Ethiopia.Livestock Research Results.

Newman, Y. C., Lambert, B., & Muir, J. P. (2006). Defining Forage Quality. 1–13.

Norton, B.W. (1982). Differences between species in forage quality. In: Proceedings of an international symposium, St Lucia, Queensland, Australia, 1981, on nutritional limits to animal production from pastures. pp. 89–110.

NRC (National Research Council,2001), Nutrient requirements of dairy cattle, 7th revised ed. 542 National Academy Press, Washington, DC., USA.

Papachristou, T.G., and Papanastasis, V.P. (1994). Forage value of Mediterranean deciduous woody fodder species and its implication to management of silvo-pastoral systems for goats. *Agr. Sys*. **27**: 269–282

Peiretti, P. G. (2009). Effects of growth stage on chemical composition, organic matter digestibility, gross energy and fatty acid content of safflower (*Carthamus tinctorius L*.). *Livest. Res. Rural Dev*., **21** (12).

Pratt, R. M., & Lewis Smith, R. I. (1982). Seasonal trends in chemical composition of reindeer forage plants on South Georgia. *Polar Biology*, ***1***(1):13-32.

Santos, E. A. D., Silva, D. S. D., & Queiroz Filho, J. L. D. (2001a). Aspectos produtivos do capim-elefante (*Pennisetum purpureum, Schum*.) cv. Roxo no Brejo Paraibano. *Revista Brasileira de Zootecnia*, ***30***: 31-36.

Seid, W., Tsega, W., & Demisse, E. (2021). Growth Performance of Arsi-Bale Sheep Fed Desho Grass (*Pennisetum pedicellatum*) Hay Supplemented with Different Concentrate Levels. **31**(4): 89–98.

Seré Rabé, C., Ayantunde, A. A., Duncan, A. J., Freeman, H. A., Herrero, M. T., Tarawali, S. A., & Wright, I. A. (2008). Livestock production and poverty alleviation challenges and opportunities in arid and semi-arid tropical rangeland based systems.

Seyoum, B., Getnet, A., Tedla, A. and Fekadu, D. (2001). Present status and future directions in feed resources and nutrition research targeted for wheat-based crop–livestock production systems in Ethiopia

Shahin, M. G., Abdrabou, R. T., Abdelmoemn, W. R., & Hamada, M. M. (2013). Response of growth and forage yield of pearl millet (Pennisetum galucum) to nitrogen fertilization rates and cutting height. *Annals of Agricultural Sciences*, ***58***(2):153-162.

Shiferaw, A., Puskur, R., Tegegne, A., & Hoekstra, D. (2011). Innovation in forage development: empirical evidence from Alaba Special District, southern Ethiopia. Development in Practice, **21**(8):1138–1152. https://doi.org/10.1080/09614524.2011.591186

Singh, G.P, Oosting, S.J. (1992). A model for describing the energy value of straws. Indian dairyman.

Smith, G., (2010). Ethiopia: Local solutions to a global problem.

Steinshamn, H., Nesheim, L., and Bakken, A. K. (2016). "Grassland production in Norway," in The Multiple Roles of Grassland in the European Bio economy. Proceedings of the 26th General Meeting of the European Grassland Federation, Trondheim, Norway. (Wageningen: *Wageningen Academic Publishers*), 15–25.

Sumran Wijjitphan, P. L. (2009). Effect of Cutting Heights on Productivity and Quality of King Napier Grass (*Pennisetum purpureum cv*.King Grass) under Irrigation (pp. 1244–1250).

Taye, B., Solomon, M. and Prasad, N., K. (2007). Effects of cutting dates on nutritive value of Napier (*Pennisetum purpureum*) grass planted sole and in association with Desmodium (*Desmodium intortum*) or Lablab (*Lablab purpureus*). *Livestock Research for Rural Development*.**19** (11).

Taylor, P., Zewdu, T., Baars, R. M. T., & Yami, A. (2009). Effect of plant height at cutting, source and level of fertiliser on yield and nutritional quality of Napier grass (Pennisetum *purpureum*(L)*Schumach*nutritionalqualityofNapiergrass(*Pennisetumpurpureum*(L.)Schumach.).37–41. https://doi.org/10.2989/10220110209485783

Terefe, Tolcha. (2017). Effect of Nitrogen Fertilizer and Harvesting Days on Yield and Quality of Rhodes Grass (*Chloris gayana*) Under Irrigation at Gewane, North-Eastern, Ethiopia. MSc Thesis Haromaya University, Ethiopia. 80P

Tesemma, T. (2012). Preprint not err Preprinted. Research Gate/under Peer Review Paper, 1(January).

Tessema, Z. K., Mihret, J., & Solomon, M. (2010). Effect of defoliation frequency and cutting height on growth, dry-matter yield and nutritive value of Napier grass (*Pennisetum purpureum (L.) Schumach*). *Grass and forage science*, ***65***(4): 421-430

Tibbo, M. (2000, November). Livestock production constraints in a M2-2 sub-agro ecological zone with special reference to goat production. In *The Opportunities and Challenges of Enhancing Goat Production in East Africa. Proceedings of a conference held at Debub University, Awassa, Ethiopia*, **10**: 92-106.

Tilahun, A., Solomon, M., & Ralph, R. (2005). Intensification of livestock feed production in Ethiopian highlands: potential and experiences of the African highlands initiative. 19th EVA Annual Conference, August 2016. https://www.researchgate.net/profile/

Tilahun, G., Asmare, B., & Mekuriaw, Y. (2017). Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of desho grass (*Pennisetum pedicellatum Trin.*) in the highlands of Ethiopia. *Tropical Grasslands-Forrajes Tropicales*, ***5***(2):77-84.

Tilley J M A and Terry R A 1963. A two stage technique for the in vitro digestion of forage crops. J. *Brit.Grassl. Soc*. **18**: 104-111.

Tsegaye, T. (2021). Effects of cutting interval on morphological parameters, biomass yield and chemical composition of para (*brachairia muticastapf*), napier (*pennisetum purpureum*) and Desho (*pennisetum pedicellatum*) grasses grown under irrigation condition. Thesis Paper.

Tudsri, S., Jorgensen, S.T., Riddach, P., Pookpakdi, A. (2002). Effect of cutting height and dry season date on yield and quality of five Napier grass cultivars in Thailand. *Trop. Grassl*., **36**: 248-252

Turano, B., Tiwari, U. P. and R, Jha. (2016). Growth and nutritional evaluation of Napier grass hybrids as forage for ruminants. *Trop*. *Grasslands-Forrajes*

Van Soest, P. J and Robertson, J. B. (1985). Analysis of Forages and Fibrous Foods. A Laboratory Manual for Animal Science 613. Cornel University, Ithaca. New York, USA, 202p.

Van Soest, P. J. (1994). Nutritional ecology of the ruminant. (2nd Eds.). Cornell University Press, Ithaca. New York, USA. pp. 244-252.7

Van Soest, P.J. (1982). Nutritional ecology of the ruminant. O and B Books, Inc., Corvallis, Oregon, USA. 373p.

Wadi, A., Ishii, Y., & Idota, S. (2004). Effects of cutting interval and cutting height on dry matter yield and overwintering ability at the established year in *Pennisetum* species. *Plant Production Science*, **7**(1): 88–96. https://doi.org/10.1626/pps.7.88

Welle, S., Chantawarangul, K., Nontananandh, S., & Jantawat, S. (2006). Effectiveness of grass strips as barrier against runoff and soil loss in Jijiga area, northern part of Somali Region, Ethiopia. *Kasetsart Journal Natural Science*, **40**(2): 549–558.

Werner, J. C., Lima, F. P., & Martinelli, D. (1966). Studies of three different cutting heights on elephant grass Napier. *Bol. Ind. Anim*. **23**:161–168.

Whiteman, P.C. (1980). Tropical pastures science. Oxford University press, New York. 392p.

Worku. B, Denbela. H and T/yohanis. B. (2017). Effect of Planting Space and Fertilizer Rate on Productivity of Desho Grass (*Pennisetum Pedicellatum*) in Jinka Agricultural Research Center, Southern Ethiopia ", *International Journal of Research in Agriculture and Forestry*. **4** (11): 14-19.

Yakob, G., Gebremicheal, A., Aklilu, A. and Melaku, E. (2015). Participatory Evaluation of Different Multipurpose Grass Species for Graded Soil Bund Stabilization in Gimbo District, South West Ethiopia. *Open Access Library Journal*, **2**:1627. http://dx.doi.org/10.4236/oalib.1101627

Yegrem, M., Alemu, B., & Awuke, A. (2019). Agronomic Performance and Dry Matter Yield of Desho (*Pennisetum Pedicellatum*) and Setaria (*Setaria Sphacelata*) Grasses Mixed with Greenleaf Desmodium (*Desmodium Intortum*) at Different Harvesting Time. *International Journal of Research Studies in Agricultural Sciences*, **5**(8): 31–39. https://doi.org/10.20431/2454-6224.0508005

Yeshitila, A. (2008). Assessment of Livestock Feed Resources Utilization in Alaba district, southern Ethiopia, (M.Sc. Thesis Haramaya University. Haramaya, Ethiopia).

Yilma, Z., G.B., Emannuelle and S., Ameha. (2011). A Review of the Ethiopian Dairy Sector. Ed. Rudolf Fombad, Food and Agriculture Organization of the United Nations, Sub Regional Office for Eastern Africa (FAO/SFE), Addis Ababa, Ethiopia, pp 81.

Yirgu, T., Mengistu, S., Shanku, E., & Ijara, F. (2017). Desho Grass (Pennisetum *pedicellatum*) Lines Evaluation for Herbage Yield and Quality under Irrigation at Wondogenet. **17**(5): 427–431. https://doi.org/10.5829/idosi.aejaes.2017.427.431

Zeleke, M. (2017). The Nutritional Composition, Fermentative Characteristic and Palatability of Desho Grass (Pennisetum *pedicellatum*) Ensiled with Broiler Litter in Kaffa Goat. **7**(1):26–31.

Zewdu, T. (2005). Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass accessions (*Pennisetum purpureum*). *Tropical Sciences*, **45**: 67–73.

8. APPENDIXES

Appendix 1. Analysis of Variance Table for Number of leaf per plant

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>)
Replication	2	5.6267	2.8133	6.1307	0.005016
Treatment	7	20.8933	2.9848	6.5042	4.990e-05
Year	1	29.7675	29.7675	64.8676	1.174e-09
Residuals	37	16.9792	0.4589		
R square	**CV%**	**MSE**			
0.7056	10.08	0.4588964			

Appendix 2. Analysis of Variance Table for Leaf length

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	7.63	3.81	0.0780	0.925095
Trt	7	1123.33	160.48	3.2842	0.008135
Yr	1	1280.30	1280.30	26.2015	9.768e-06
Residuals	37	1807.95	48.86		
R square	**CV%**	**MSE**			
0.4557	19.04376	48.8636			

Appendix 3. Analysis of Variance Table for Stem basal diameter

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	115.88	57.942	1.5843	0.2187
Trt	7	354.18	50.597	1.3835	0.2413
Yr	1	1.24	1.242	0.0340	0.8548
Residuals	37	1353.16	36.572		
R square	**CV%**	**MSE**			
0.05787	28.56737	36.57194			

Appendix 4. Analysis of Variance Table for Number of nodes per plant

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	4.741	2.371	5.8042	0.006421
Trt	7	104.703	14.958	36.6218	9.345e-15
Yr	1	124.163	124.163	303.9980	< 2.2e-16
Residuals	37	15.112	0.408		

R square	**CV%**	**MSE**
0.9228	17.50929	0.408

Appendix 5. Analysis of Variance Table for Number of tiller per plant

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	1452.7	726.3	1.8982	0.164152
Trt	7	5416.5	773.8	2.0222	0.078212
Yr	1	3686.4	3686.4	9.6338	0.003652
Residuals	37	14158.1	382.7		

R square	**CV%**	**MSE**
0.2723	18.88	382.6514

Appendix 6. Analysis of Variance Table for inter node length

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	22.00	11.00	1.7502	0.1878
Trt	7	379.40	54.20	8.6219	3.064e-06
Yr	1	624.96	624.96	99.4160	4.969e-12
Residuals	37	232.59	6.29		

R square	**CV%**	**MSE**
0.7653	38.30	6.286

Appendix 7. Analysis of Variance Table for Leaf percent

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	1390.3	695.1	8.0946	0.001213
Trt	7	285.9	40.8	0.4756	0.845968
Yr	1	3428.9	3428.9	39.9287	2.326e-07
Residuals	37	3177.4	85.9		
R square	**CV%**	**MSE**			
0.5127	15.10699	85.87627			

Appendix 8. Analysis of Variance Table for Stem percent

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	1390.3	695.1	8.0946	0.001213
Trt	7	285.9	40.8	0.4756	0.845968
Yr	1	3428.9	3428.9	39.9287	2.326e-07
Residuals	37	3177.4	85.9		
R square	**CV%**	**MSE**			
0.5127	23.97167	85.87627			

Appendix 9. Analysis of Variance Table for Leaf to stem ratio

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.95867	0.47933	6.3045	0.004404
Trt	7	0.43473	0.06210	0.8168	0.579366
Yr	1	2.54764	2.54764	33.5083	1.214e-06
Residuals	37	2.81311	0.07603		
R square	**CV%**	**MSE**			
0.4709	38.99939	0.3225618			

Appendix 10. Analysis of Variance Table for Leaf dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	11.543	5.771	2.113	0.135226
Trt	7	300.908	42.987	15.738	2.267e-09
Yr	1	30.106	30.106	11.022	0.002031
Residuals	37	101.062	2.731		
R square	**CV%**	**MSE**			
0.7106	25.25	2.731396			

Appendix 11. Analysis of Variance Table for Stem dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	25.633	12.816	3.4299	0.0430023
Trt	7	126.647	18.092	4.8419	0.0006017
Yr	1	184.458	184.458	49.3651	2.617e-08
Residuals	37	138.255	3.737		
R square	**CV%**	**MSE**			
0.6303	43.06	3.736616			

Appendix 12. Analysis of Variance Table for First harvest dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	46.39	23.20	2.2867	0.1158
Trt	7	814.72	116.39	11.4730	1.222e-07
Yr	1	363.61	363.61	35.8424	6.541e-07
Residuals	37	375.35	10.14		
R square	**CV%**	**MSE**			
0.702	28.86	10.14457			

Appendix 13. Analysis of Variance Table for Biomass production rate of First harvest

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	2863	1431.4	1.3148	0.2805
Treatment	7	17590	2512.8	2.3080	0.0460
Residuals	38	41372	1088.7		
R square	**CV%**	**MSE**			
0.1723	42.90692	1088.729			

Appendix 14. Analysis of Variance Table for Second harvest dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	3.256	1.6280	1.1769	0.3195
Trt	7	111.000	15.8572	11.4638	1.234e-07
Yr	1	2.075	2.0750	1.5001	1.234e-07
Residuals	37	51.180	1.3832		
R square	**CV%**	**MSE**			
0.6119	27.69226	1.383243			

Appendix 15. Analysis of Variance Table for Biomass production rate of 2nd Harvest

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	398.7	199.3	0.6582	0.5236
Treatment	7	23011.0	3287.3	10.8553	1.963e-07
Residuals	38	11507.5	302.8		
R square	**CV%**	**MSE**			
0.5924	34.10233	302.8283			

Appendix 16. Analysis of Variance Table for Total dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	42.41	21.204	1.7341	0.1905958
Trt	7	418.41	59.773	4.8886	0.0005589
Yr	1	310.74	310.745	25.4142	1.242e-05
Residuals	37	452.41	12.227		
R square	**CV%**	**MSE**			
0.5305	22.88223	12.22718			

Appendix 17. Analysis of Variance Table for Average dry matter yield (t/ha)

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	10.602	5.301	1.7341	0.1905958
Trt	7	104.603	14.943	4.8886	0.0005589
Yr	1	77.686	77.686 25	25.4142	1.242e-05
Residuals	37	113.101	3.057		
R square	**CV%**	**MSE**			
0.5305	22.88	3.056796			

Appendix 18. Analysis of Variance Table for Dry Matter

Source of var	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.2472	0.12361	1.0102	0.37396
Trt	7	2.3413	0.33448	2.7336	0.02163
Yr	1	2.4707	2.47067	20.1925	6.659e-05
Residuals	37	4.5272	0.12236		
R square	**CV%**	**MSE**			
0.4001	0.3767531	0.1223559			

Appendix 19. Analysis of Variance Table for Ash

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	5.2037	2.6019	5.4504	0.008421
Trt	7	29.4378	4.2054	8.8096	2.436e-06
Yr	1	12.2715	12.2715	25.7066	1.135e-05
Residuals	37	17.6626	0.4774		
R square	**CV%**	**MSE**			
0.6526	12.29803	0.4773683			

Appendix 20. Analysis of Variance Table for Crude protein

Source of var.	Df	Sum Sq	Mean sq	F value	Pr(>F)
Rep	2	0.555	0.277	0.5664	0.5724
Trt	7	54.684	7.812	15.9481	1.901e-09
Yr	1	213.237	213.237	435.3201	< 2.2e-16
Residuals	37	18.124	0.490		
R square	**CV%**	**MSE**			
0.9197	6.684539	0.4898392			

Appendix 21. Analysis of Variance Table for Neutral detergent fiber

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	3.912	1.956	2.0936	0.1376
Trt	7	70.992	10.142	10.8562	2.348e-07
Yr	1	143.936	143.936	154.0769	9.298e-15
Residuals	37	34.565	0.934		
R square	**CV%**	**MSE**			
0.8267	1.315009	0.9341839			

Appendix 22. Analysis of Variance Table for Acid detergent Fiber

Source of var..	Df	Sum Sq	Mean Sq	F value	Pr(>)
Replication	2	3.459	1.7295	1.2939	0.28633
Trt	7	26.374	3.7677	2.8187	0.01857
Yr	1	1.552	1.5516	1.1608	0.28828
Residuals	37	49.458	1.3367		

R square	**CV%**	**MSE**
0.2229	2.793974	1.336715

Appendix 23. Analysis of Variance Table for Acid detergent lignin

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.0190	0.00948	0.2042	0.8162
Trt	7	4.5331	0.64759	13.9502	1.09e-08
Yr	1	0.1055	0.10547	2.2720	0.1402
Residuals	37	1.7176	0.04642		

R square	**CV**	**MSE**
0.6578	4.760371	0.04642145

Appendix 24. Analysis of Variance Table for Invitro dry matter digestibility

Source of var.	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	3.38	1.69	0.2775	0.7592
Trt	7	377.47	53.92	8.8633	2.283e-06
Yr	1	1039.83	1039.83	170.9142	1.932e-15
Residuals	37	225.11	6.08		

R square	**CV%**	**MSE**
0.8263	3.694759	6.083953

Appendix 25. Analysis of Variance Table for Dry organic matter digestibility

Source of var..	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	2.97	1.49	0.2778	0.759
Trt	7	331.73	47.39	8.8635	2.282e-06
Yr	1	913.86	913.86	170.9217	1.930e-15
Residuals	37	197.83	5.35		

R square	**CV%**	**MSE**
0.8263	3.69455	5.346639

Appendix 26. Analysis of Variance Table for Metabolizable energy

Source of var	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Rep	2	0.0759	0.0380	0.2763	0.7601
Trt	7	8.4664	1.2095	8.8056	2.448e-06
Yr	1	23.4081	23.4081	170.4223	2.019e-15
Residuals	37	5.0821	0.1374		

R square	**CV%**	**MSE**
0.8257	3.701037	0.1373537

Appendix 27. Long term weather condition of Holetta