EFFECTS OF FERTILIZER TYPES AND HARVESTING STAGES ON AGRONOMIC PERFORMANCE, BIOMASS YIELD, CHEMICAL COMPOSITIONS, AND IN VITRO DIGESTIBILITY OF RHODES GRASS (*Chloris Gayana K.)*

MSc. THESIS

BY:

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JUNE 2024

JIMMA, ETHIOPIA

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MSc. THESIS

Submitted to Department of Animal Sciences, College of Agriculture and Veterinary Medicine, Jimma University, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Nutrition

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June 2024

Jimma, Ethiopia

SCHOOL OF GRADUATE STUDIES

JIMMA UNIVERSITY

COLLEGE OF AGRICULTURE AND VETERINARY MEDICINE

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We, the undersigned, member of the Board of Examiners of the final open defense by **Tamiru Hailu** have read and evaluated his/her thesis entitled **"Effects of Fertilizer Type and Harvesting Stage on Agronomic Performance, Biomass Yield, Chemical Compositions, and In Vitro Digestibility of Rhodes Grass (*Chloris Gayana*)"** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Animal Nutrition**

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DEDICATION

I dedicate this work to my mom, Baye Yami, and my beloved wife, Bizunesh Girma, who stood beside me throughout my studies and sacrificed a lot for this work, which is one of my life's best accomplishments.

STATEMENT OF AUTHOR

I hereby declare that this thesis is my original work and that all sources of materials used for it have been duly acknowledged. Jimma University has received such a thesis for the partial fulfillment of the requirements for the Degree of Master of Science in Animal Nutrition and has deposited it in its library with the approval to permit borrowing under their regulations. I solemnly affirm that this thesis was not delivered to another institution anywhere in order to award any degree, diploma or certificate.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CBD	Convention on Biological Diversity
CP	Crude Protein
CPY	Crude Protein Yield
CSA	Central Statistical Agency
DM	Dry Matter content
DMY	Dry Matter Yield
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
GLM	General Linear Model
HARC	Holeta Agricultural Research Center
ILRI	International Livestock Research Institute
IVDMD	In vitro Dry Matter Digestibility
IVOMD	In Vitro Organic Matter Digestibility
LLPP	Leaf length Per Plant
LSR	Leaf to Stem Ratio
ME	Metabolizable Energy
MoA	Ministry of Agriculture
NDF	Neutral Detergent Fiber
NLPP	Number of Leaves per Plant
NPS	Nitrogen, Phosphate, and Sulfur
NTPP	Number of Tillers per Plant
RCBD	Randomized Complete Block Design
WARC	Werer Agricultural Research Center

BIOGRAPHICAL SKETCH

The author, Tamiru Hailu Geleta, was born on November 17, 1992, in Salale District, Oromia Regional State's North Shewa Zone. He attended his elementary education at Jati elementary school and Muka Turi secondary and preparatory school for his secondary and preparatory studies from 2008 to 2012 at Wacale Wereda. In the 2012/13 academic years, he joined Woldia University College of Agriculture and Veterinary Medicine and graduated with a BSc degree in animal production and technology on June 24, 2015.

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ACKNOWLEDGEMENT

First and foremost, I would like to thank the Almighty God for blessing me and supplying strength, hope, belief, love, and patience throughout my study. I would like to express my deepest respect, most sincere thanks, and heartfelt appreciation to my major advisor, Mr. Wasihun Hassen, and co-advisor, Mr. Abdo Mohammed, for their unreserved support, guidance, constant encouragement, valuable comments, and suggestions from the very beginning of the research idea until the successful completion of the thesis write-up.

I highly acknowledge Mizan A TVET College for giving me the chance to pursue an MSc study and for their willingness to provide experimental land and financial support. I would like to extend my sincere appreciation to Jimma University, the College of Agriculture and Veterinary Medicine, Animal Science Department, and the Graduate Program Directorate for their contribution to the completion of this study.

I would like to thank my friends Mulugeta W/mikael and Melash Tefera, who helped me throughout my thesis work by facilitating all the processes, starting from field experimental site selection to the end of the final thesis write-up, and for their overall encouragement during the whole study period. It is necessary to acknowledge the staff members of the animal feed analytical laboratory at Holeta Agricultural Research Center and Jimma University Animal Nutrition Laboratory for their support in conducting the in vitro digestibility and proximate analysis and Tepi Research Center's soil science laboratory for soil analysis.

The words are lacking to express my feelings for my beloved family and for their encouragement and financial and moral support throughout my life. Last but not least, my thanks are also due to my classmates, friends, and staff members of Mizan A TVET College for their cooperation and encouragement for the successful completion of my thesis work.

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Effects of Fertilizer Types and Harvesting Stages on Agronomic Performance, Biomass Yield, Nutritional value of Rhodes Grass (Chloris Gayana K.) at Mizan, South West Ethiopia

By: Tamiru Hailu Geleta

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ABSTRACT

The field experiment was conducted to determine the effects of fertilizer types and harvesting stages on agronomic performance, forage biomass yield, chemical composition, and in vitro dry matter digestibility of Rhodes grass (Chloris Gayana K) during the 2023 growing season in Mizan, Ethiopia under rain condition. A factorial arrangement with four fertilizer types (control, NPS, farmyard manure, and NPS + manure) and three harvesting stages (60, 90, and 120) with three replications was used. The data collected were morphological characteristics such as plant height, number of tillers per plant, leaf length per plant, leaf-to-stem ratio, number of leaves per plant, forage dry matter yield, chemical composition, and in vitro digestibility analysis of the grass sample at 60, 90, and 120 days after planting. Samples of grass were harvested, weighed, dried, chopped and then ground for analyses of crude protein (CP), ash, dry matter (DM), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), IVDMD, and IVOMD. All data were subjected to ANOVA procedures in SAS version 9.3. The results showed that the effects of fertilizer types and harvesting stage had a significant $p<0.05$ effect on all of the morphological characteristics, forage yields, chemical composition, and in vitro digestibility. Plant height (PH), number of tillers per plant (NTPP), number of leaves per plant (NLPP), number of leaves per tiller (NLPT), dry matter yield (DMY), crude protein yield (CPY), and leaf length (LL) were increased with increasing harvesting age, while leaf to stem ratio (LSR) showed a decreasing trend. The NDF, ADF, and ADL content also increased with increasing harvesting age, while crude protein and ash declined with age. In vitro dry matter digestibility, IVOMD, and metabolizable energy (ME) values decrease with advancement to harvesting ages. Fertilizer type also significantly affected the agronomic parameters of Rhodes grass. A mixture of 50% NPS and 50% FYM provided the highest NTPP, NLPP, LLPP, and DMY, while control was the lowest in all parameters. The highest NDF, ADF, and ADL content was recorded in the control group. But the crude protein, ash and In vitro dry matter digestibility, IVOMD and ME was lower in the control group. Based on the present findings, it can be concluded that the utilization of 50 kg of NPS fertilizer with 2,500 kg of manure per hectare at 90 days of harvest could be used in the cultivation of Rhodes grass to achieve higher agronomic performance, dry matter yield, crude protein yield, better nutritional value, and economic feasibility. Further investigation is needed with using different mixtures of organic and inorganic fertilizers at different levels in different agro-ecological zones across years under rained and irrigation conditions and using animal performance trials.

Keywords: Crude Protein, Dry Matter Yield, Farmyard manure, IVDMD, NPS

1. INTRODUCTION

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). Despite the sizeable population and significant importance of livestock in the country, animal productivity is low due to different constraints like inadequate feed, wide spread diseases, poor health care services, and poor genetic potential of indigenous animals and lack of good husbandry practices (Shapiro *et al*., 2015 and CSA, 2018). Among the mentioned factors, the most limiting one is shortage of feed in terms of quantity and quality (Shapiro *et al*., 2015). The natural grazing lands are gradually shrinking due to cultivation to satisfy the food needs of the increasing human population. Livestock are forced to graze on marginal areas, which combined with the use of low-quality crop residues as feed has resulted in poor livestock performance (Negasu *et al.*, 2020).

The most crucial input for producing livestock year-round in terms of both quantity and quality is feed. It is a necessary precondition for any significant and long-term increase in the production of livestock. The available feed resources in Ethiopia include natural pastures, crop residues, stubble grazing, cultivated forages, agro-industrial by-products, grain and grain screenings, and compound or formula feeds. Natural pasture accounts for the major share of feed supply (54.5%), followed by crop residues (31.1%) and hay, which contribute 7.4% of the total feed (CSA, 2021). Agro-industrial by-products, improved forage crops, and non-conventional feed resources like animal by-products and vegetable and fruit wastes contribute the remaining 2.0, 0.6, and 4.4% of the total feed, respectively. The contribution of improved forage as livestock feed in Ethiopia is very limited—less than one percent (0.60) despite more than four decades of research and development efforts in the country (CSA, 2021).

The grazing land is constantly converted to cropping land in response to the alarmingly increasing human population food demand. Then it is time to act on improving the existing grazing land through the introduction of improved grasses by studying their agronomic performance and chemical composition (FAO, 2012). Utilizing improved forage varieties has several advantages, like improving animal nutrition, resulting in better livestock products; it helps the livestock producers conserve forage for the dry season, protect the soil from erosion, and improve its fertility. Furthermore, planting improved grass could improve marginal lands, improve carbon sequestration to mitigate climate change, support systems substantially, and enhance natural assets and system reliance (Mimila *et al.,* 2020). The improved forage crops lead to more conserved forage, like hay, to mitigate the feed shortage gap facing the country (Beyadglign, 2019). So, the problem of feed shortage can be addressed through the identification, evaluation, and promotion of forage species with better forage yield and nutritive value, which are also adapted to drought and low soil fertility (Ghimire *et al.*, 2015).

Improved forage species growing in Ethiopia includes Buffel grass, Desho grass, Oats, Guinea grass, Rhodes grass, Elephant grass, Phalaris grasses from grass forage species. Herbaceous legume species includes: Axillaris, Green Leaf, Lablab, Cowpea, Vetch, Alfalfa, and White Clover, and *Leucaena*, *Susbania*, Pigeon Pea, and Tree Lucerne belongs to tree and shrub forages (Alemayehu *et al.,* 2017). Among the improved forage crops, Rhodes grass (*Chloris gayana)* was recommended for cultivation in Ethiopia by the Holeta Agricultural Research Center (HARC) in 1984 (MoA, 2013). Due to its high dry matter yield, high seed production ability, favorable economics of cultivation and superiority over most other perennial forage grasses, it could play an important role for smallholder farmers and intensive livestock production systems (WARC, 2014).

Rhodes grass (*Chloris gayana*) belongs to the family Poaceae (Gramineae). It is one possible perennially improved grass that is high-yielding on average 12.5 tons of dry matter (DM) per hectare, has a relatively high crude protein value (9–12%), is fast-growing, palatable, and deep-rooted, and can be widely grown on-farm and used by small-holder farmers (Terefe *et al.,* 2017). The seed production potential of some forage crops in sub-humid altitude areas of Ethiopia indicates that *Chloris gayana*, at an optimum seeding rate and row spacing, can yield up to 700 kg/ha of seed. *Chloris gayana* with proper agronomic practices such as hoeing, manuring, and mulching reflected in better restoration of degraded rangeland in Borana, Ethiopia (Tebeje *et al.*, 2014).

Improved forage development strategies have been practiced for about five decades in Ethiopia, but their adoption by the farming community and yield of improved forage species are low due to management information gaps such as application of fertilizer, irrigation, weeding, optimum spacing, harvesting days, and the high cost of planting materials (Getnet *et al.*, 2016). Amongst the major agronomic practices required, harvesting of grass at the appropriate harvesting date and fertilizer types are very important to improve the dry matter yield and nutritive value of forage grass. To enhance the yield and quality of Rhodes grass through fertilizer type and proper harvesting stages, the correct use of a relatively inexpensive fertilizer type and understanding the appropriate harvesting date can help increase the level of fodder production (Yasin *et al.*, 2003).

Nevertheless, there is no adequate information on the effect of fertilizer types (either alone or in combination), harvesting stages, and their interaction on agronomic performance, biomass yield, and nutritional qualities of *Chloris gayana K.*, which are not yet well studied under the conditions of the current study area.

Objectives

General objective

- to evaluate the effects of fertilizer types and harvesting stages on agronomic performance, forage biomass yields, chemical compositions and in vitro digestibility of Rhodes grass (*Chloris Gayana K.*) at Mizan, South west, Ethiopia

Specific objectives

- to evaluate the effects of fertilizer types and harvesting stages on agronomic performance and biomass yields of Rhodes grass (*Chloris Gayana K.*) under rain condition at study area
- to determine the effects of fertilizer types and harvesting stages on chemical composition and in vitro digestibility of Rhodes Grass (*Chloris Gayana K.*)
- to assess the economic feasibility of both organic and inorganic fertilizers used for experiment

2. LITERATURE REVIEW

2.1. Major Livestock Feed Resources in Ethiopia

Major livestock feed resources in Ethiopia include natural pasture, crop residues, agro-industrial byproducts, multipurpose trees and shrubs, stubble grazing, cultivated and conserved forages (Adugna *et al.*, 2012; Dawit *et al.*, 2013; CSA, 2020). The common feed resources available in the highland and midlands of Ethiopia are mainly natural pasture, crop residues, and stubbles (ILRI, 2010; Zewdie and Yoseph, 2014). Natural grazing land is a predominant feed source for livestock in Ethiopia. In the rural areas of the country, green fodder (grazing) is the major type of animal feeds followed by crops residue, hay and by-products (CSA, 2021). In the integrated crop-livestock production systems, crop residues are the main feed resources. Fallow lands, forests, and shrub lands are also the feed resources in different agro-ecologies of Ethiopia (Ahmed *et al.,* 2010).

In Ethiopia, most feed resources are characterized by inherent nutritional deficiencies, and are generally low in nitrogen, energy, vitamins and minerals (Solomon, 2001), which affects microbial growth and fermentation in the rumen, resulting in low feed intake and digestibility, leading to reduced reproductive capacity, decline in growth rates and increased mortality rates (Solomon *et al.*, 2004).

Table 1: Proportion of animal feed resources in Ethiopia

No	Feed source	Percentage
1	Grazing	54.5
2	Crop residue	31.1
3	Improved fodder or pasture	0.6
4	Hay	7.4
5	Agro-industrial byproducts	2
6	Non-conventional feeds	4.4

Source (CSA, 2021)

2.1.1. Natural pasture

Natural pasture is the primary source of roughage feed (Adugna *et al.,* 2012). Livestock grazing is the principal form of land use in pastoral regions, while inside the densely populated highland and mid-latitude regions, the upper soils are used for cropping, and 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% of the country's total area, with the western, southern, and south-eastern semi-arid lowlands being the most extensive (Alemayehu *et al.,* 2017).

According to CSA (2021), green forage, or grass, is the most important type of feed, according to data collected from feed owners in rural Ethiopia (54.54%). Grazing pastures are being converted to arable land due to the world's population expansion and increasing need for food. These regions are now only found in places with low agricultural potential, such as hilltops, swamps, roadsides, and other marginal lands (Alemayehu *et al.,* 2017). This is particularly apparent in Ethiopia's mid-altitude and highland mixed-farming regions.

2.1.2. Crop residues

Crop residue is one of the main feeds used in animal production in Ethiopia, especially in those areas that practice livestock and crop production together as mixed farming. Apart from being a source of animal feed, residues are also used as fuel, sold as an income source, and are also used for house construction, particularly for plastering walls and thatching roofs in rural areas. Some farmers also use crop residues (wheat, teff, millet, maize, sorghum, etc.) for mulching purposes to enhance the fertility of the soil (Dereje *et al.*, 2013). It provides a considerable quantity of dry-season feed supply during the dry seasons of the year in most farming areas of the country. They are important in filling feed gaps during periods of acute shortages of other feed resources. The amount of crop residue produced is closely related to grain production, the farming system, the type of crops produced, and the intensity of cultivation. The potential and abundance of crop residues that could be used for livestock feeding in Ethiopia in most cases drown from grain yield, using a multiplier of 13.7 million tons per year (13.6 million tons in rural areas and 136 thousand tons in urban areas) from cereals with CP values ranging from 3.1-6.7% and digestibility levels of about 40.7 to 54.1% (Malede and Takele, 2014).

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 crop residue as a feed for livestock in Ethiopia (31.13%). Crop residues are high in fiber content, have low digestion, and have low intake. Crop residues and aftermath grazing make up more than 60–70% 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% of livestock feed supplies in the in the Alaba district of Ethiopia (Yeshitila, 2008).

2.1.3. 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, brewery 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).

Agro-industrial by-products have a special value and high quality in feeding livestock mainly in the urban and peri-urban livestock production system, as well as in situations where the productive potential of the animals is relatively high and require high nutrient supply (Shimelis, 2018). Agro industrial by products are mainly used for dairy, fattening and commercial poultry production and the scope for their wider use by smallholder producers is low due to availability and price (Yoseph *et al.,* 2010). Natural pasture and crop residues are naturally of low quality and do not fulfill the nutrient requirement of animals. Hence, high producing animals such as dairy cattle and fattening animals should be supplemented with high energy and/or protein concentrates (Beyadglign, 2019).

2.1.4. Improved forage crops production in Ethiopia

Aranguiz & Creemers (2019) listed the most common improved species of forage crops in Ethiopia: oats, vetch, desho, naper 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, and Tree Lucerne (*Cytisus proliferous*). Some smallholder farms have begun to employ enhanced fodder, but it accounts for only 0.213 percent of total animal feed (Yilma *et al.,* 2011) and has 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. Rhodes grass (*Chloris gayana*) is a tropical and subtropical African perennial grass that has remained one of the most important forage grasses, and it is a versatile grass that can be utilized as a pasture, hay, or ley crop (Melese, 2021).

Utilizing improved forage varieties has several advantages, like improving animal nutrition, resulting in higher-producing livestock, and helping livestock producers conserve forage for the dry season. Not only this, but it also complements crop production by maintaining soil fertility through nitrogen fixation (Etsubdink, 2014). While grazing depletes the fertility of the land, forage growing improves soil health. Improved fodder species generally have higher herbage yield potential than natural pasture: about 13, 8, and 10.5 t/ha DM yield for grasses, herbaceous legumes, and browse trees, respectively, while the average herbage DM yield obtained from seasonally rested pasture and continuously grazed pasture was 4 and 1 t/ha, respectively (Getnet *et al.,* 2016).

The overall average productivity of the improved fodder crops per unit area has been found to exceed the productivities of seasonally rested and continuously grazed natural pastures by about 3-fold and 10-fold, respectively (Fekede *et al.,* 2015). The use of improved forages would reduce pressure on natural pasture, improve soil fertility and erosion of marginal lands, improve carbon sequestration to mitigate climate change, support system substantially and enhance natural assets and system reliance (Etsubdink, 2014). However, the adoption of improved forages at farmers' level and contribution in national feed supply has been very low, because of factors such as lack and unadoptable forage technologies, scarcity of forage seed, poor extension services, shortage of land, lack and high cost of planting materials, reluctance of most smallholder farmers and size of livestock ownership and farm size (Alemayehu and Getnet, 2012; Beshir, 2014).

Improved forage crop production has diversified advantages. The primary benefits are to produce high amount of quality forage to be used as feed for farm animals. On the other hand, they complement crop production through maintaining soil fertility by fixing nitrogen or when used as mulch. In addition, forage crops could be grown as a component in integrated natural resource management to prevent soil erosion and to control weeds, and pests and diseases. Generally improved forage crop production could provide useful nutrients especially in the rural areas where availability and accessibility of agro-industrial by-products is a problem (Muluye, 2019).

2.2. Constraints of Improved Forage Production in Ethiopia

In spite of its long history and existence of some exemplary forage production practices, the contribution of improved forage to the total feed resource is still low which is 0.67 % (CSA, 2020) due to its low adoption level in the farming community because of different constraints in the farming systems. A few studies have been conducted to identify factors that affect the adoption of these technologies, the highlands and lowlands hold similar constraints to adopt forage technologies. Land shortage, lack of capital to purchase inputs (improved forage seed), lack and high cost of planting materials, lack of knowledge or awareness, crop-dominated farming systems, and poor extension services were identified as major constraints for improved forage cultivation in the Ethiopian farming system (Zereu and Lijalem, 2016 and Melese *et al.*, 2018). Poor productivity of forage species used after expensed many resources by farmer was another problem and labour also mentioned as the least ranked challenges of improved forage production raised by the forage producers (Melese *et al.,* 2018). Family size, farm size, topography and distance from farmers' home (residence) to farmers training centers were the major factors which significantly affect the probability adoption of improved forage technologies (Bashe *et al.,* 2018).

2.3. Description of Rhodes Grass (*Chloris Gayana K.*)

2.3.1. Origin and distribution of Rhodes grass

Rhodes grass is a native of South Africa and was named Rhodes after the famous Cecil Rhodes, who popularized it (Trivedi, 2010). Rhodes is now widespread in tropical and subtropical areas worldwide. Rhodes grass was released into Ethiopia in 1984 by the Holeta Agricultural Research Center (HARC) and described by the center as a variety (*Masaba*) (MoA, 2013) for cultivation. Growing Rhodes grass is beneficial to increase feed production and boost livestock production and productivity. Livestock productivity will rise as Rhodes grass grows and provides more fodder for the animals. This ultimately leads to a rise in household income and the consumption of animal products (meat and milk). Compared to natural grasses, farmers can produce more feed by planting Rhodes grass. Farmers favored Rhodes grass because it functions better and helps with livestock feed shortages (Yenesew *et al.,* 2015).

2.3.2. Botanical description of Rhodes grass

Chloris gayana is a C4 species of grass known by the common name Rhodes grass. It belongs to the kingdom Plantae, order Poales, family *Poaceae*, subfamily *Chloridoideae*, genus *Chloris*, and species *C. gayana* (Luna *et al.*, 2002). As a tropical grass with the C4 type of photosynthesis, like corn and sugarcane, Rhodes grass efficiently uses solar radiation and the available soil moisture to quickly accumulate a relatively high amount of biomass (Valenzuela and Smith, 2002). It is tufted perennial grass 1-2 m tall, spreading by looping runners, forming new plants along the stolen. Rhodes grass is a stoloniferous creeping or occasionally tufted perennial grass; its stem is fine and leafy (Mannetje and Kersten, 1992; Cook *et al.,* 2005).

Rhodes grass forms tufts and can spread into wide, monotypic stands. The stems are smooth and shiny, with creeping stems 0.4–0.5 cm in diameter and upright stems 0.2–0.4 cm in diameter. The inflorescence is a digitate or subdigitate panicle with 3–20 spikes, each 4–15 cm long. The two awned spikelets are best developed in the middle of each spike. It is 0.3–0.5 cm long with two to five overlapping florets along the central rachilla (Gibbs Russell *et al.,* 1990). The leaves are glabrous, 15–50 cm long and 0.3–0.9 cm wide, tapering to a point (Mannetje and Kersten, 1992). The seed heads are mostly a single circle of radiating light, greenish-brown (ripening to darker brown) branches 4–15 cm long. Due to its deep roots, Rhodes grass can withstand long dry periods (over six months) and up to 15 days of flooding and also respond well to irrigation (Mannetje and Kersten, 1992; Cook *et al.,* 2005; FAO, 2014).

2.3.3. Suitable agro-ecology

Rhodes grass (*Chloris gayana*) is a stoloniferous perennial grass that grows in a wide range of climates (rainfall and temperature) and soil types. It is grows better in areas where annual rainfall is above 600 mm and altitude ranges from 1400 to 2400 m. *C. gayana* grows on a wide range of soils. It grows well on well-drained, moderate- to high-fertility soils. It can also survive on infertile soils, although it is unproductive and may eventually die out, particularly if grazed regularly. It is not tolerant of waterlogging. Rhodes grass has some establishment problems on very acidic soils, but it is tolerant of saline conditions. Generally, Rhodes grass is a poor shade-tolerant forage crop. Once well established, Rhodes grass recovers well after fire. Due to its vigorous fibrous root system, it is moderately drought-resistant. In addition, due to its vigorous horizontal root (stoloniferous) growth and extensive roots, Rhodes grass has a great contribution to soil binding and soil erosion control (Bell *et al.,* 2001; Valenzuela and Smith, 2002).

Rhodes grass has an optimum temperature of 35°C for photosynthesis but is tolerant of a wide temperature range (0–50 °C). It is more tolerant of lower temperatures than other subtropical grasses. Due to its vigorous fibrous root system, Rhodes grass is moderately drought-resistant (Hassan *et al.,* 2010). An established plant can withstand a dry season of up to six months. This pasture crop responds well to irrigation and is moderately tolerant of flooding, but it is not shade-tolerant. It is a C4 species widely used as forage in tropical and subtropical areas and known for its ability to withstand dry conditions, soil salinity, and light frost. Rhodes grass efficiently uses solar radiation and the available soil moisture to quickly accumulate a relatively high amount of biomass, and it is a full-sun species that does not grow well under shade (Valenzuela and Smith, 2002).

2.4. Importance of Rhodes grass

In general, the main application of Rhodes grass is providing animal feed. Since Rhodes grass has a high survival rate, many farmers grow it in poor soil conditions and sell it to livestock at the market as feed (Dutton, 2013). In order to keep the soil from eroding and to help farmers preserve the quality of their land so they can cultivate the crops they want, Rhodes grass is also planted. When pastures are lacking in grass during dry seasons, Rhodes grass is dried and turned into hay, which is then made available for cattle. Prior to flowering, the grass should be chopped and dried, as this increases the nutritional content of the hay (FAO, 2014). Because of its high protein content (9–12%), rhizome grass is a suitable choice for cattle feed. It can also be used in conjunction with other crops, such as legumes and alfalfa, to increase crop yields Arshad (2015). According to Getnet and Gezahegn (2012), it can generate a substantial seed yield of 145–195 kg/ha and boost revenue from the selling of seeds.

Rhodes grass can be utilized as green forage or hay. It is very palatable and has good nutritive value. Rhodes grass makes good hay if it is cut at the beginning of flowering or a little earlier. Old stands give low quality hay. It is not suitable for silage making. When preparing hay appropriate hay making procedures should be followed. Rhodes grass can be grazed 4 - 6 months after planting CASCAPE (2015).

2.5. Management Practices for Rhodes Grass Establishment

2.5.1. Land preparation

The land should be cleared of weeds and trees before plowing. The land should be plowed two to three times to get a fine, leveled seedbed. As the Rhodes grass seed is very small, it needs a well-prepared seedbed. The seedbed should be prepared well. A well-prepared seedbed favors seed germination, seedling emergence, and growth (CASCAPE, 2015).

2.5.2. Planting time

Planting should be done at the start of the main rainy season, when the soil has received sufficient moisture to support germination and establishment. Seed germinates within 7 days after planting (Cook *et al.,* 2005). Sowing too deeply will result in failure or poor germination.

Rhodes grass seed will germinate under slightly cooler conditions than most summer-growing grasses (Yenesew *et al.,* 2015).

2.5.3. Seed rate and planting methods

Rhodes grass can be grown from seed or vegetatively (by splitting its roots). Seed quality (germination and purity), sowing technique, environmental factors, and land preparation all affect seed rate. General seed rate of between 3 and 15 kg/ha, taking into account the previously mentioned parameters. Higher altitudes and colder climates typically benefit from higher seed rates. Cook *et al.* (2005) recommend sowing seeds no deeper than two centimeters on the surface. *Chloris gayana* may be broadcast or row-sown. Seed can be combined with sand or soil for distribution. After planting, use tree branches to cover it with light soil. Another alternative is to drive animals both before and after the seed is sown in order to lighten the packing. Nevertheless, it can be planted in rows if labor is available. In this instance, planting should take place when the soil becomes moist, with care needed to evenly spread and drill the seeds over the prepared area (HARC, 2004; CASCAPE, 2015). Row spacing in this situation should be 20 cm.

2.5.4. Fertilizer application

Nitrogen deficiency may exert pronounced adverse effects on crop development and yield. Growth is stunted, and leaves become chlorotic because a lack of nitrogen limits the synthesis of proteins and chlorophyll. Lack of chlorophyll inhibits the capacity of the plant to assimilate carbon dioxide (CO_2) and synthesize carbohydrates, leading to poor and premature flowering and fructification and shortening of the growth cycle (ILRI, 2013).

Nitrogen-deficient plants respond quickly to the addition of nitrogen fertilizers if applied in a timely manner and properly. Application of high rates of nitrogen fertilization produced an extremely high yield of Rhodes grass, and the curvilinear effect of N-application rates on grass yield has been reported in tropical and subtropical regions (Gilbert and Clarkson, 1993). In general, grasses have a high requirement for nitrogen, phosphorus, and potassium elements. These nutrients should be applied at the time of sowing, after each cut or grazing. In addition to improving biomass, fertilizer application enhances both nutritive value and yield. Rhodes grass gives an increased response to phosphorus in some areas and usually a spectacular linear response to nitrogen in the presence of adequate phosphorus and potassium, both in yield and in CP content.

2.5.5. Weed control

The newly established pasture should be free from weeds. Removing weeds by hand is essential. Removing weeds reduces competition when the grass is weak, and it also minimizes the chances of further perpetuation of weeds by seed. Removing weeds at the early stage of Rhodes grass production is crucial. As the plant is weak at this stage, removing weeds makes establishment easier and enhances further survival. Weeding twice after planting at monthly intervals during establishment is recommended. Harvesting the grass and weeds together using a sickle when there is vigorous growth is another alternative to controlling weeds. Using an herbicide like 2-4-D is also effective to remove young broad-leaf weeds (HARC, 2004).

2.5.6. Harvesting and post-harvest handling

To obtain high-quality feed, the Rhodes grass should be harvested at the 50% flowering stage. Harvesting Rhodes grass at an early stage will ensure higher levels of CP in the harvested material. The grass's level of CP decreases as harvesting time increases. The newly established pasture through seed sowing can be utilized within 3 to 5 months after sowing. The harvested material can be fed to livestock as fresh or it can be made into hay for later feeding. If root split is used as a planting material, the first harvest can be done in two to three months, provided that there is adequate moisture and fertilizer application (Yenesew *et al.*, 2015).

2.6. Growth and Yield of Rhodes Grass (*Chloris gayana K.*)

The type of cultivar, plant age, and other environmental conditions all affect how well Rhode grass grows (FAO, 2009). According to a number of studies, Rhodes grass typically provides 7 to 25 tons of dry matter per hectare per year, depending on the type, soil fertility, climate, and frequency of cutting (HARC, 2004; Cook *et al.*, 2005). The second year's yields could treble those of the establishment year, but management and environmental factors also play a role. There have been reports of 35–60 tons of dry matter per hectare (Cook *et al.*, 2005).

When properly grazed and fertilized, Rhodes grass is tenacious and drought-resilient; nevertheless, if poorly maintained, it will vanish after a few years. It yields more seed as well. The delicate stems dry quickly and are simple to cut. Rhodes grass typically has a three-year productive life, though this can be prolonged with proper fertilization. Ecocrop (2014) stated that the average yield is between 10 and 16 tons of DMY/ha, with the greatest observed production being between 30 and 40 tons.

2.7. Productivity and Nutritive Value of Rhodes Grass

2.7.1. Forage dry matter productivity

Based on several studies, the dry matter yields of Rhodes grass generally ranges from 7 - 25 ton/ha per year, depending on variety, soil fertility, environmental conditions and cutting frequency (HARC, 2004; Cook *et al.,* 2005). Yields in the second year may be double that of the establishment year, but this also depends on management and environmental conditions. Yields of 35 - 60 ton/ha dry matter (DM) are reported (Cook *et al.*, 2005). Rhodes grass is persistent and drought tolerant when well grazed and fertilized, but disappears after a few years if not well managed. It also produces more seed. The fine stems are easy to cut and dry rapidly. The usual productive life of Rhodes grass is three years; this can be extended by optimum fertilization.

2.7.2. Nutritive value of grass

The nutritive value of Rhodes grass declines after flowering, and it is important to maintain the plant in a leafy condition by regular defoliation. Crude protein levels vary with age of material and level of available nitrogen and may range from 17% on a dry matter (DM) basis in very young leaf, to 3% in old leaves. The in vitro dry matter digestibility (IVDMD) varies from 40 - 80% (Cook *et al.*, 2005). Other sources report that crude protein content and digestibility of Rhodes grass range from 4 - 13 % and 40 - 60% of dry matter, respectively. Young growth is very palatable, but after the plants have seeded they are less attractive. Digestibility and crude protein content decrease as the grass matures and becomes steamy. To avoid over-maturity regular cutting or grazing should be practiced and over-mature pasture should be slashed or burned. There is no record of toxicity on Rhodes grass (Yenesew *et al.*, 2015).

2.8. Effects of Fertilizer Types and Harvesting Stages on Agronomic Performance of Forage

2.8.1. Plant height

Plant height is an important parameter contributing to biomass yield in forage crop and also it is an important component which helps determining the growth attained during the growing period (Tessema *et al.,* 2002). According to Baghdadi *et al.* (2018), Plant height of corn and soybean was significantly taller through a combined application of chemical fertilizer and chicken manure compared to sole chicken manure, but gave the same as sole NPK. And also Nebi *et al.* (2018) recorded at degraded grazing land; the plant height was significantly increased by chemical fertilizer and organic fertilizer application relative to the control plot. Short plant height was due to depletion of nutrients from control plots over time hence plants showed stunted growth owing to inadequate supply of nutrients. The higher plant height attributed to the gradual release of essential nutrient from organic and inorganic fertilizer as required by the forage. In contrast plant height of Rhodes grass was not significantly affected by different types of fertilizer (urea, farmyard and chicken manure) (Yossif and Ibrahim, 2013).

Plant height of forage grass was significantly affected by harvesting stage. However, different literature indicated that the height of the plant is dependent on the age of the plant at harvest. According to (Bimrew *et al.,* 2017) who reported that mean plant height was low in early age of growth, but for harvesting after 120 day, enhanced growth was observed in *Desho* grass.

2.8.2. Number and length of leaves per plant

Number of leaves per plant is one of important parameters that indicate the potential of photosynthetic capacity of the plants. Leaves are the major eco-physiological parts of a plant that interact with the atmosphere, absorbing and assimilating carbon dioxide, intercepting light necessary for photosynthesis, releasing oxygen that is formed as a byproduct of photosynthesis, being the site of water vapor loss during evapo-transpiration, which helps to build pressure to absorb water from the ground, intercepting rainfall and channeling water to branches and stems, and gradually to the roots (Scott Trimbel, 2019).

The number of leaves (NLPP) increased with an increase in harvesting day, and fewer total leaves per plant were produced from short harvesting intervals of grass due to cutting at the younger stage of growth, while leaf length per plant was highest at reduced harvesting intervals (Butt *et al.*, 1993). Genet *et al.* (2017) indicated that the number of leaves per plant and leaf length were significantly affected by harvesting age; the mean leaf length of desho grass was 19, 18.2, and 17.7 cm for 75, 105, and 135 harvesting days, respectively, while the mean number of leaves per plant significantly increased from 75 (249) to 105 (514) to 135 (710) harvesting days.

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 sword. Wubetie *et al.* (2018) found that the harvesting stages had a substantial impact on the leaf length of the Brachiaria cultivars. The longest leaf length per plant increased with the maturity of the grass (Rambau *et al.,* 2016). Ghiwot (2019), the length of leaf per plant (43.96 cm) observed at 60 days of harvesting was significantly lower as compared with 120 days in Buffel Grass (*Cenchrus ciliaris linn*).

Biniyam *et al.* (2018) revealed that NPS fertilizer and manure had a significant effect on the NLPP of desho grass. This means that the application of fertilizer augments the NLPP more than without fertilizer application in the experiment. Priyadarshani *et al.* (2013) reported that either combined use of compost and inorganic fertilizer or sole application significantly increased the number of leaves per plant compared to control on vetiver forage. Similarly, Mulata (2015) noted that the highest number of leaves were obtained at manure alone, mixed with urea, and urea alone than at nil (control) on the wheat crop. Similarly, mean leaf length was significantly higher (26.63 cm) when treated with a mixture of 50 kg of urea and 60 quintal compost/ha than control or without any fertilizer sources (18.53 cm), but there was no statistical difference between control and 120 quinol compost/ha on leaf length (Yibeltal *et al.,* 2021).

2.8.3. Number of tiller per plant

Tillers are new shoots of grass that grow from crown tissue buds, rhizomes, stolons, or above-ground nodes (aerial tillers). These segments, known as phytomers, are made up of successive parts called growing points (apical meristem which may become a seed head), a stem, leaves, roots nodes, and latent buds. One of the most crucial agronomic characteristics is the number of tillers per plant since it affects the forage grasses' biomass yield.

Ahmad et al. (2011), who stated the significant effect of organic and inorganic sources of fertilizer application used alone or in combination on the number of tillers per plant of oat grass, It was reported that the maximum number of tillers per plant (8.02) was observed in nitrogen and phosphorous, which were applied at 150 and 60 kg/ha, followed by N: P2O5 112:45+ Poultry manure (750 kg/ha) and N: P2O5 112:45+ FYM (1000 kg/ha), having 7.89 and 7.53, respectively. While the minimum number of tillers was 5.94, no fertilizers were applied. Also, Biniyam *et al.* (2018) reported that the application of organic and inorganic fertilizers (NPS, manure, and control) significantly differed.

Rambau *et al.* (2016) for Napier grass showed that the number of tillers increased with the increased maturity of the Napier grass. The number of tillers increases from 54.6 to 79.9 tillers per plant in Desho grass as the harvesting stage increases, as reported by Worku *et al.* (2017).

2.8.4. Leaf to stem ratio (LSR)

A plant with a high leaf to stem ratio also has excellent nutrition and digestibility because it is one of the best indicators of the quality of forages. However, the stem of grasses is more easily digested than the leaf sections of the plant in the early stages of growth; however, as the plant becomes older, the digestibility of the stem rapidly reduced, while the nutritional content of the leaf parts gradually decreased (McDonald *et al.,* 1988).

According to Bimrew *et al.* (2017), *Desho* grass had a greater leaf to stem ratio at earlier harvesting stages (90 and 120 days) than at a later date (150 days). Similar result from Awoke *et al.,* 2020, who stated that the highest leaf steam ration of desho grass recorded at 90 day of harvesting, while the lowest leaf steam ration observed from late harvesting stage (150 days). The decrease in leaf: stem ratio as harvesting date increased that showed reduction in leaf proportion and an increase in the stem fraction of the grass at the advanced harvesting date Yasin *et al.* (2003).

Leaf to stem ratio of Rhodes grass was significantly affected by nitrogen fertilizer applications in which the highest mean leaf to stem ratio was recorded at 69 kg/ha of N fertilizer rates and the lowest mean leaf to stem ratio was at 0 and 23 kg/ha of nitrogen fertilizer rates Terefe *et al.* (2017). The study also indicated that the leaf to stem ratio increased as the N fertilizer increased. *Brachiaria Hybrid Mulato II* applied with manure fertilizer application to get highest leaf to stem ratio than with NPS fertilizer application and control (Negasu *et al.*, 2020). The highest but statistically similar values of leaf to stem ratios 1.26 and 1.20 were recorded for (control) without fertilizer and 12,000 kg compost/ha, respectively, whereas the lowest leaf steam ration recorded from a mixture of 50 kg urea and 6,000 kg compost/ha application of desho grass (Awoke *et al.*,2020). The current result in contrast with Yossif and Ibrahim (2013), who stated that leaf to stem ratio of Rhodes grass was not significantly affected by different types of fertilizer (urea, farmyard and chicken manure).

2.9. Effects of Fertilizer Types and Harvesting Stages on Forage Yields

2.9.1. Dry matter yield

Dry matter yield (DMY) is the percentage of the forage that is not water. Grasses which yield the highest DM should be the most sought since they can supply the highest amount of forage to livestock. The highest DM yield (8.26 t/ha) of natural pasture was produced on urea fertilizer at 120 days of harvesting while the lowest dry matter yield was recorded from control groups (3.20, 3.29 t/ ha) at 90 and 120 days respectively (Shiferew *et al.*, 2020). And also Tessema *et al.* (2010) stated that DM yields of the grass component increased with the application of nitrogen fertilizer in the north-western parts of Ethiopia. Application of nitrogen fertilizer increased natural pasture DM content. This was due to grass vigorously responded to nitrogen fertilizer application and showed that content increases with increasing harvesting age. This indicates that the water content of plants in the pasture decreases as in advancing growth (Nemera, 2016).

A previous study by Terefe *et al.* (2017) found that varying the rate of inorganic fertilizer may greatly increase the number of leaves and length of leaves on Rhodes grass plants. Specifically, the length of leaves per plant increases gradually from 8.7 ton/ha at 0 kg/ha. Fertilizer rates for nitrogen to 16.5 tons/ha at 69 kg/ha nitrogen fertilizer: this suggests that applying more nitrogen fertilizer would have likely increased soil nitrogen availability, which would have improved meristematic growth and raised forage yield.

Regarding to harvesting stage, the yield and quality of grassland are significantly influenced by harvesting stages of grass .The higher DMY at later stages of harvesting was to be expected as plants were physiological trigger, which leads to the increased production of tillers and more leaves per plant. Wassie *et al.* (2018); Wubetie *et al.* (2018) reported, harvesting stages influence the dry matter yield of *Bracharia hybrid mulato II* in North western Ethiopia. The DMY of *Desho* grass significantly increased as the harvesting stage increased from 90 to 150 days in Ethiopia (Bimrew, 2016). The yield increments as harvesting stage extended might be due to the additional tillers developed, which brought an increase in leaf formation, leaf elongation and stem development (Nguku *et al.*, 2016 and Bimeraw *et al.*, 2017).

2.9.2. Crude protein yields

Hasan *et al.* (2010) observed that increasing doses of N fertilizer boosted the crude protein production of cowpea fodder. In a similar vein, Biniyam *et al.* (2018) found that applying NPS fertilizer to *desho* grass enhanced its CPY in comparison to manure and control experiments. These suggest that the use of nitrogen fertilizer may be the result of enhanced soil availability of nitrogen for plant tissue protein synthesis, which has been reflected in higher plant growth as measured by plant height as well as increased forage yield.

The effect of days of harvesting indicated an increasing trend in CPY of grass with extended days of harvesting. According to different authors, Wassie *et al.* (2018); Wubetie *et al.* (2019) reports, harvesting stages influence the crude protein yield (CPY) *of Bracharia hybrid mulato II* in North western Ethiopia. Additionally, Crude protein yields increased progressively and significantly as growth period increased (0.76 t/ha at 75 days to 2.36 t/ha at 135 days (Genet *et al.*, 2017; Bimrew *et al.*, 2017).

2.10. Effects of Fertilizer Types and Harvesting Stage on Chemical Composition of Forage Grasses

2.10.1. Dry matter content

According to Shiferew *et al.* (2020) who reported dry matter content of the natural pasture influenced by fertilizer type and harvesting stage in which the highest value of dry matter content was recorded by nitrogen fertilizer application (92.55%) at 120 days while the lowest value of dry matter content was recorded in compost (90.30%), mix (91.21 and control (90.35%) treatments at 90 days and the lowest groups were not showed significant different each other. Application of nitrogen fertilizer increased natural pasture dry matter content. This was due to grass vigorously responded to nitrogen fertilizer application and showed that content increases with increasing harvesting age. This indicates that the water content of plants in the pasture decreases as in advancing growth. Similarly, Terefe *et al.*, 2017 who stated that dry matter content increased with delayed harvesting which could be attributed to decreased moisture content in leaves as plants age and become lignified.

On the other hand at 120 days of harvesting age except for nitrogen fertilizer, the organic (91.21%), combined (nitrogen + compost) (91.30%), and the control treatments (91.20%) were statistically similar in dry matter content. This was due to grass vigorously responded to nitrogen fertilizer application and showed that content increases with increasing harvesting age Shiferew *et al.* (2020). This indicates that the water content of plants in the pasture decreases as in advancing growth. Rambau *et al.* (2016) who showed that the DM content increased as the grass matured.

2.10.2. Crude protein content

Protein content is one of the most important parameters affecting the nutritional value of fodder crops. Protein is commonly measured as crude protein (CP), which is 6.25 times the nitrogen content of forage. Crude protein is used because rumen microbes can convert non-protein nitrogen to microbial protein, which can then be used by the animal. However, this value should be used with some care, as it is not applicable to non-ruminants or when high levels of nitrate are present in the forage (Bell *et al.,* 2001).

According to Shiferaw *et al.* (2020) who sated that fertilizer type and harvesting age had significant effect on crude protein content of the natural pasture in which application of compost fertilizer resulted in the highest CP content of (15.13%) at 90 days of harvesting, while the lowest CP (7.23%) content was observed in the control plot from the late harvesting age (120 days). The nitrogen fertilizer (8.81%) was lower than compost (15.13%), combined treatment (12.06%) and the control (9.04%) at 90 days. Additionally, Negasu *et al.* (2020) who reported chemical fertilizer and manure were significantly affected crude protein content (CP %) of *brachiaria hybrid mulato II* grass. The highest mean crude protein (CP %) was observed for NPS fertilizer (11.08%) while the lowest value crude protein content (CP %) of *brachiaria hybrid mulato II* grass was recorded for the control plot (10.4%).

In terms of harvesting stage, in various *Bracharia* ecotypes in Ethiopia, the maximum CP concentration was obtained at the earliest stage of harvesting, with values dropping when harvesting was postponed (Wassie *et al.,* 2018). According to Limenih (2016), Desho grass (*Pennisetum pedicellatum*) in Ethiopia showed a substantial drop in CP content when the harvesting stage progressed from 90 to 150 days. Early plant growth age was strongly correlated with higher CP content contents in the first harvest; young leaves and flowers yield feed that is of higher quality. The leaf-to-stem ratio was lower in more mature plants. Thus, this plant's nutritional value was lower than its fodder quality (Caddel and Allen, 2010).

2.10.3. Acid detergent fiber

The part of the forage that is left over after being treated with a detergent in an acidic environment is known as acid detergent fiber (ADF). It consists of silica, cellulose, and lignin. According to Van Soest (1994), acid detergent fiber is a reliable measure of digestibility and hence energy intake. Acid detergent fiber is significant because studies have indicated a negative correlation between it and the potential digestibility of fed fodder. The digestibility of the feeds decreases as ADF increases.

Shiferaw *et al.* (2020) reported harvesting age and application of fertilizer type significantly affected the acid detergent fiber at and highest ADF was observed on unfertilized treatment at 120 days of harvesting age, the lowest was observed in all (compost, urea, and mix) treated treatments at (90 days) but treated were statistically similar with unfertilized treatment on the same harvesting age (90 days), while at 120 days of harvest compost, nitrogen and combined treatments were statically the same. The increased ADF contents with advanced age of harvesting might be associated with an increase in cell wall lignification's as forages get matured (McDonald *et al.*, 2010).

In contrast Fekadu *et al.* (2017) who reported the application of organic and inorganic fertilizer (chemical fertilizer, cattle manure, wood ash, lime and control) did not significantly affect the fiber content of natural pasture, in which the highest fiber obtained when a sole chemical fertilizer used and the lowest fiber cattle manure. This indicated fiber content of natural pasture is highly interconnected with the stages of growth or stages of maturity of the natural pasture than fertilizer treatments.

2.10.4. Neutral detergent fiber

Neutral detergent fibers are good indicators of fiber contents in forages; they do not measure how digestible that fiber is, but NDF is a good indicator of "bulk" and thus feed intake (Miraeoh *et al., 2016*). The insoluble portion of the forage (neutral detergent fiber) contains cellulose, hemicellulose, lignin, and silica. It is commonly referred to as the cell wall fraction. Neutral detergent fiber has been shown to be negatively correlated with dry matter intake. This means that, as the NDF in forages increases, animals will be able to consume less forage. A better prediction of forage intake can be made using NDF; therefore, better rations can be formulated (Schroeder, 2012).

The application of organic and inorganic fertilizer did not significantly affect the NDF content of natural pasture in other parts of Ethiopia (Nemera, 2016). However, Delevatti *et al*. (2019) stated that there was a significant effect on fiber contents due to the fertilizer effect. Similarly, Negasu *et al.* (2020), who stated fertilizer type significantly affected the NDF content of *Brachiaria hybrid Mulato II* grass, recorded the highest mean NDF content without fertilizer, so it indicates that as the application of fertilizer increases, the NDF decreases. This may elucidate that the urea fertilizer improves plant growth and raises new leaves and shoots, which minimizes the NDF content as the urea fertilizer level increases, but there is no rejuvenation of leaves and tillers in the non-fertilizer treatments, and as a result, plant tissue matures and accumulates more NDF.

The percentage of NDF was significantly impacted by the harvest stage. Plants become lignified as they mature, and Tessema *et al.* (2010) found that plants possessed the highest amount of NDF. According to Bimrew (2017), the NDF content of grass was less at early harvesting periods (72.78% at 90 days and 73.96% at 120 days), but it reached its maximum (77.68%) at late harvesting (150 days). According to Genet *et al.* (2017), there was a substantial rise in NDF concentration in desho grass with increasing plant spacing and harvest age.

2.10.5. Ash content

According to Mabu *et al*. (2019), the nitrogen fertilizer application affected the ash content of Rhodes grass. They found that using 160 kg/ha resulted in greater ash contents (6.36%), which is comparable to applying 120 and 140 kg/ha (6.23 and 5.91%) as opposed to applying 0 and 100 kg/ha (4.59 and 5.81%). Tefera *et al.* (2017) reported that the application of varying nitrogen fertilizer rates affected the ash content of Rhodes grass. They found that applying 69 kg/ha of nitrogen produced a higher total ash content, while applying 0 kg/ha of nitrogen produced the lowest mean ash content. The highest mean total ash content was obtained in manure fertilizer type, while the lowest value was recorded in without fertilizer and NPS fertilizer used, respectively. The present study indicated that total ash content was very low for the control treatment, but as the organic (manure) and inorganic (NPS) fertilizer increased, the ash content of the desho grass increased. The higher ash content of natural pasture in compost was due to the high mineral contents inherited from the manure fertilizer (Nemera, 2016).

The ash content of Para (*Brachiaria mutica*) grass was reduced with an increase in the stage of maturity (Mimila *et al.,* 2020). The majority of the six studied Brachiaria grasses in different locations had high mineral content at early harvesting (Wubetie *et al.,* 2018). The decrease in ash content with long harvesting interval is probably a normal phenomenon of maturity and may have been caused partly by the dilution effect of higher yields in the presence of a constant amount of available minerals in the soil Ullah *et al*. (2010). Ash reduction from 71.4 at 60 days of age to 55 at 120 days of age in case of Napier grass (Ansah *et al.,* 2010).

2.11. Effects of Fertilizer Types and Harvesting Stages on In Vitro Digestibility of Forage Grasses

2.11.1. In-vitro dry matter digestibility (IVDMD)

In vitro digestibility: the amount or percentage of food substances contained in food ingredients that, after being digested, are not wasted using artificial digestion techniques. In-vitro dry matter digestibility is one of many factors influencing animal productivity (Mathison *et al.*, 1995). This is also influenced by the availability of the degradable materials in the feed (Campos *et al.*, 2013).

The in vitro dry matter digestibility of grass reduces with age (longer harvesting period). The greatest IVDMD (64.88%) and lowest IVDMD (56.82%) were obtained when the study grass was harvested at 60 days and 120 days, respectively. An increment in the percentage of cell wall and its constituent parts could be one reason for the drop in IVDMD as foraging advanced. In other words, as the plant ages, the stem in the later phases of harvest becomes more reflective of the entire plant than the leaf (Ghiwot, 2019).

The basic determinant of forage digestibility is the plant anatomy; plant cell contents, being primarily soluble carbohydrates and proteins, are almost completely digestible; however, cell wall digestibility varies according to their degree of reinforcement with lignin and is also influenced by the proportion of leaf to stem ratio (McDonald *et al.*, 2002). Simachew (2016) demonstrated that as the stage of harvesting day increased, the IVDMD percentage of blue panic grass decreased constantly. As Owen and Jayasuriya (1989) explained that, 50% IVDMD for feeds is critical and acceptable threshold level.

3. MATERIAL AND METHODS

3.1. Description of the Study Area

The experiment was conducted during 2023 growing season (June-October) in Bench Sheko Zone, south west Region at Mizan Agricultural, Technical and Vocational Education Training College (ATVET College) at Kosokol demonstration site that has an altitude of 1560 m above sea level. The site is located 561km to south west of the capital city of Ethiopia, Addis Ababa.

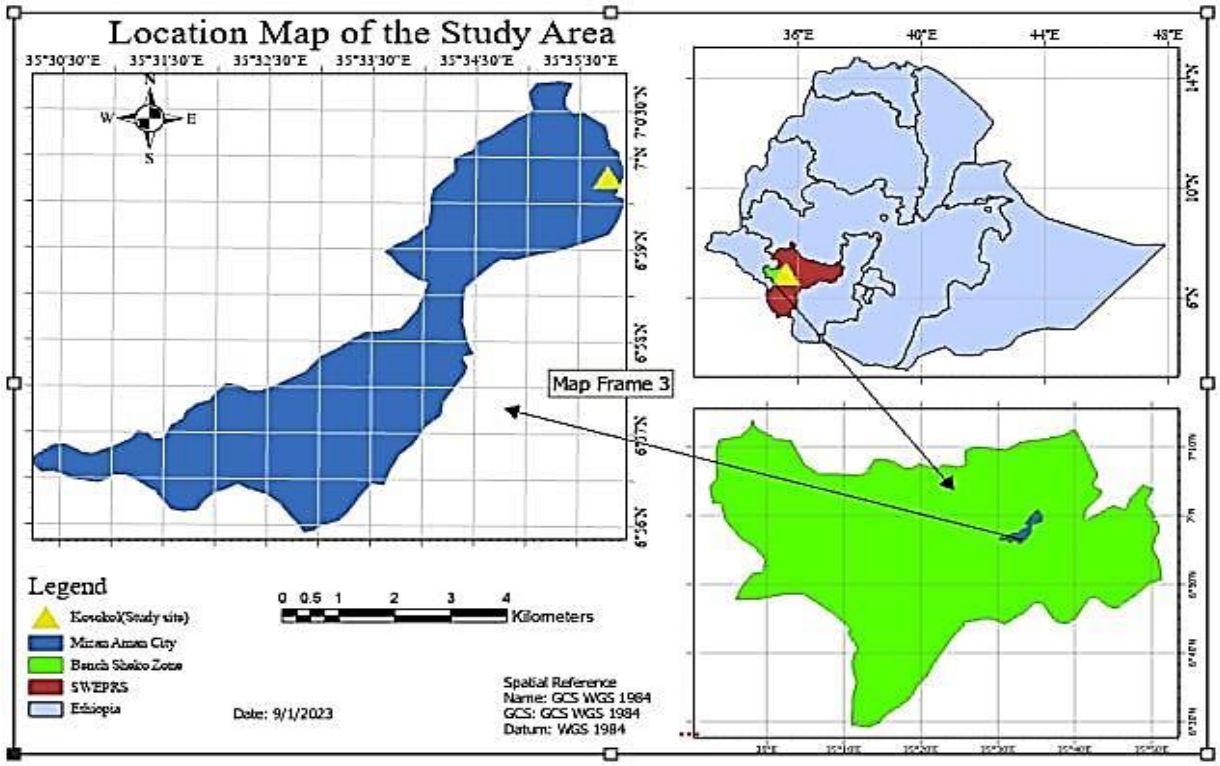


Figure 1: Map of study araea

The mean annual maximum and minimum temperature are 25.94 and 20.025 ^{o}C and the annual maximum and minimum rainfall 578mm, 51.8 mm, while the annual average rainfall of study area was 251.6 mm (NMSJE, 2023).

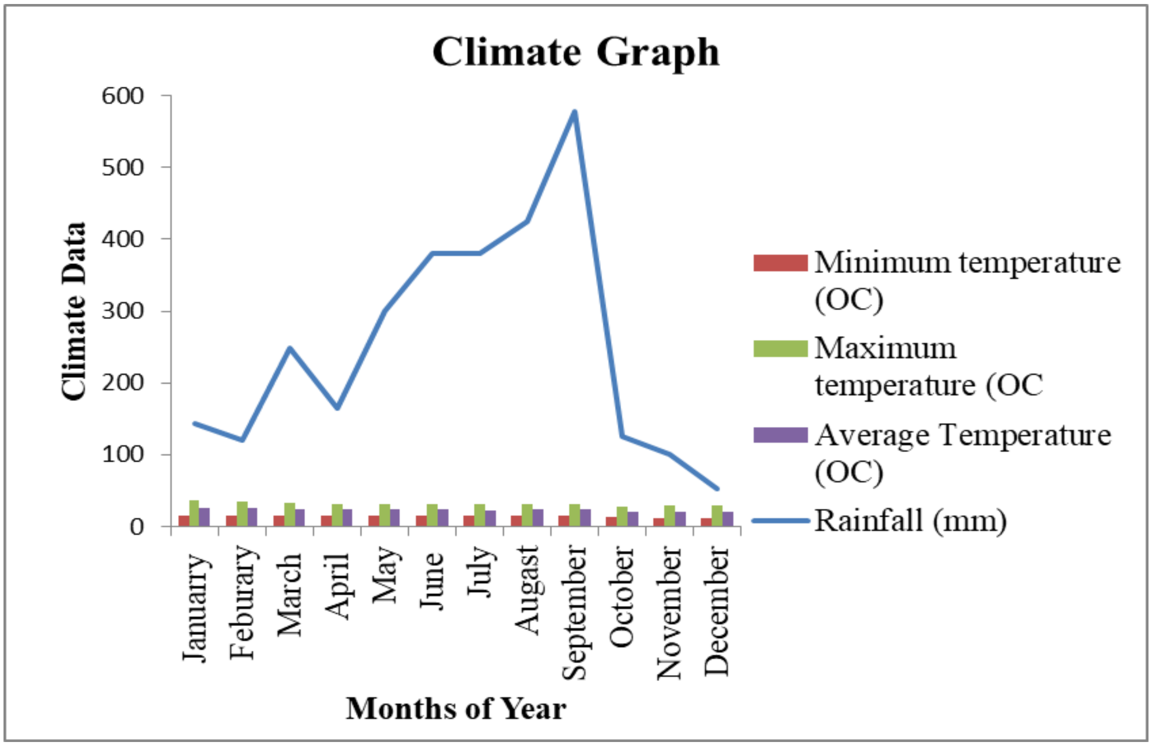


Figure 2: Annual rainfall (mm) and maximum and minimum temperature (^{O}C) of experimental site

Source: National Meteorological Services Jimma, Ethiopia (2023)

3.2. Experimental Layout, Design and Treatment

The experimental design used in the study was a factorial arrangement of treatments in a randomized complete block design (RCBD) consisting of two factors (fertilizer type and harvesting stage) with three replications each. The experiment had a total of twelve treatments, resulting in thirty-six plots in total with a factorial combination with four levels of fertilizer type (Ft_1: without fertilizer, Ft_2: 2,500 kg FYM + 50 kg NPS/ha, Ft_3: 100 kg NPS/ha, and Ft_4: 5000kg FYM/ha) combined with three harvesting stages (60, 90, and 120 days). The spacing between blocks and plots was 1 and 0.5 meters, respectively. Treatments were assigned to each plot randomly within a block. The total experimental area is 25 m x 8 m (200 m^2) with an individual plot size of 1.5 m × 1.5 m (2.25 m2) and the net plot area (harvestable area) 1 m² (1 m × 1 m) was used for sample taking and the remaining area for border effects for each plot.

Table 2: Treatments allocated randomly in different plots for the field experiment

	Treatment combination		
	Harvesting stages		
Fertilizer types	**H1**	**H2**	**H3**
Ft1	$Ft_1 \times H_1$=(T1)	$Ft_1 \times H_{2=}$ (T2)	$Ft_1 \times H_3$ =(T3)
Ft2	$Ft_2 \times H_1$ =(T4)	$Ft_2 \times H_2$=T5	$Ft_2 \times H_3$=(T6)
Ft3	$Ft_3 \times H_1$=(T7)	$Ft_3 \times H_2$=T8	$Ft_3 \times H_3$=(T9)
Ft4	$Ft_4 \times H_1$=(T10)	$Ft_4 \times H_2$=T11	$Ft_4 \times H_3$=(T12)

*(**Ft_1** (without fertilizer); **Ft_2** (2,500 kg FYM + 50 kg NPS); **Ft_3** (100 kg NPS fertilizer) and **Ft_4** (5,000 kg/ha FYM)); **H_1**= 60 days harvesting; **H_2**=90 days harvesting; and **H_3**= 120 days harvesting*

3.3. Land Preparation and Experimental Materials

The land was cleared, plowed, and leveled manually. *The Massaba* variety of *Chloris gayana* was used for the experiment, and the grass seed used was collected from the Holeta Agricultural Research Center. The NPS fertilizer (19% N, 38% P_2O_5, and 7% S) was used as the source of inorganic fertilizers and purchased from the farmer's union association. Farmyard manure was collected from Mizan A TVET College and used as a source of organic input. Based on the recommendation of Tesfaye *et al.* (2020), manure can be applied at a rate of 5000kg per hectare for Rhodes grass.

3.4. Cropping History of Experimental Land

The experimental land utilized for the study was cultivated with a variety of crops, especially maize, under both rain and irrigation conditions, and the land was also used as a demonstration site for soil and water resource conservation before the experiment took place on it. However, the area was left fallow for one growing season prior to the execution of current experiment.

3.5. Sampling and Analysis of Soil

Composite soil samples were collected from 0–30 cm of depth following the standard soil sampling procedures before application of the treatments. Uniformly cut slices and adequate volumes of soil were collected in each sub-sample by the vertical insertion of an auger. Then the collected composite soil sample was air dried and grounded to pass through a 2 mm sieve, except for the analysis of organic carbon and nitrogen, where the sample was passed through a 0.5 mm sieve (Anderson, 2010). The composite samples of soil were analyzed for selected physico-chemical properties for soil pH and texture, nitrogen, organic carbon, available phosphorus, and cations exchange capacity (CEC). Total nitrogen in the soil was determined by the wet acid Kjeldahl digestion method (Thomas, 1967). As recommended by Sahlemedhin and Taye (2000) for most Ethiopian soils, the available phosphorus in the soil in the soil was determined by the Olsen extraction method.

A sample was also taken from farmyard manure and subjected to chemical analysis using the same procedures with soil analysis before being incorporated into the soil. The soil and farmyard manure samples were analyzed at the JUCAVM and Tepi research centers, soil science laboratories.

Table 3: Chemical composition of the experimental soil and farmyard manure

Parameter	Soil	Farmyard manure
pH	4.98	7.28
Organic carbon (%)	1.96	16.57
Total nitrogen (%)	0.19	0.54
Available phosphorus (mg kg^{-1})	7.96	11.28
Cation exchange capacity*(cmol+kg^{-1})*	16.96	0.33
Soil texture		
Sand (%)	46%	
Silt (%)	24%	
Clay (%)	30%	-
Soil textural class	**Sandy**	-

3.6. Establishment and Management Practices

The Rhodes grass seed was sown in mid-June 2023 in a rainy season according to the recommendation of Cameron and Lemcke (2008), broadcasted at a depth of 2 cm on the ground on a well-prepared seedbed; the seed covered with soil slightly. The seed rate used for the experiment was 15 kg/ha (Cook *et al.,* 2005). Ten days before grass seeds were sown; farmyard manure was manually ground and combined with the soil by stirring the plot to facilitate decomposition. Farmyard manure was applied at a rate of 5000kg per hectare, and NPS was applied at a rate of 100 kg per hectare during planting. Weeding was controlled by hand weeding twice after planting at monthly intervals during establishment to avoid competition.

3.7. Data Collection and Analytical Procedure

3.7.1. Morphological parameters

Plant morphological traits were calculated by taking six plants that were randomly selected from each plot on a 1 m2 quadrant (within 1 × 1 m, the remaining area for border effects) throughout the experimental period (120 days) to be recorded to estimate mean plant height (PH), number of tillers per plant (NTPP), number of leaves per plant (NLPP), leaf length per plant (LLPP), and leaf-to-stem ratio (LSR) at different fertilizer types during all harvesting stages.

Plant height and leaf length were measured by using meter tape from the 1 m2 quadrant mean of six randomly selected plants. The number of tillers and leaves per plant was counted from six plants that were randomly selected and recorded from each plot on 1 m2 quadrants before the time of biomass harvest. Leaf stem ratio is determined by harvesting a fresh sample weight of about 500 grams from each plot in the 1 m2 quadrant, followed by partitioning the harvested biomass into leaf and stem fractions and drying. Then, the leaf-to stem ratio was determined by the ratio of the dry weight of leaves to the dry weight of stem at each fixed harvesting stage.

3.7.2. Forage dry matter yield

At the end of all harvesting stages for each fertilizer type, the DM yield was calculated. The grass was mowed about five cm above the ground from all the treatments, excluding border effects, to determine biomass yield. A sensitive balance was used to weight fresh biomass, and then subsamples of 300 grams of fresh plants were taken 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)

$$\text{Crude protein yield} = \frac{\text{Dry matter yield tons/ ha X crude protein (\%)}}{100}$$

3.7.3. Chemical Composition Analyses

The chemical compositions of all samples of feed collected during agronomy were conducted at the Jimma University College of Agricultural and Veterinary Medicine Animal Nutrition Laboratory. The oven-dried samples at a temperature of 65 ^{o}C for 72 hours were used for laboratory analysis to determine the chemical composition and in vitro dry matter digestibility of Rhodes grass. The dried samples were then ground through a 1-mm sieve, and the ground samples were used for laboratory analysis. The samples were analyzed on a % DM basis for ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL).

Total ash content was determined by oven-drying the samples at 105 °C overnight and by combusting the samples in a muffle furnace at 550 °C for 6 hours. Nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation, and titration procedures (AOAC, 1995), and the CP content will be estimated by multiplying the N content by 6.25. The structural plant constituents (NDF, ADF, and ADL) were determined according to the Van Soest and Robertson procedure (1985).

3.7.4. In vitro digestibility determination

The samples that were oven-dried and utilized for chemical analysis are used to determine in vitro digestibility. The IVOMD (48 hours pepsin, hydrochloric acid and 48 hours rumen fluid) and IVDMD were determined using the two steps of the Tilley and Terry techniques (1963), with the primary difference being that residues are combusted to obtain IVOM digestibility. In vitro digestibility analyses were carried out at the Holeta Agricultural Research Center, Animal Nutrition Laboratory.

IVDMD was calculated (Jeans and Yolande, 2007) as:

$$\frac{\text{Dry sample weight-(residue-blank)}*100}{\text{Dry sample weight}}$$

The IVOMD was calculated as:

$$\frac{\text{OM in feed-(OM in residue-blank)}*100}{\text{OM in feed}}$$

Where OM=DM -Ash

The metabolizable energy (ME) of the feed was estimated according to the equation below:

$$\text{ME (MJ Kg/DM)} = 0.15*\text{IVOMD (Pinkerton, 2005)}$$

3.8. Economic Analysis

An economic analysis was used to compare the economic benefits of food and forage crops using the partial budget analysis (CIMMYT, 1988). Information on all costs of production, including fertilizer purchases and labor costs, was collected. The price of fresh Rhodes grass was estimated by farmers on a plot with a fixed area, and after the price estimation, the forage in the fixed area was harvested, weighed, and dried to convert to dry matter in kilograms per hectare. Costs of pre-basic seed, inorganic and organic fertilizers, and labor costs for land preparation, weeding, and threshing were considered for the estimation of production costs. The benefits (income from selling the grass) of each treatment were also calculated on a hectare basis in birr.

The DMY obtained as the combined mean of the three harvests was used to calculate the gross income from the grass. To get an adjusted yield, 10% of the DMY was deducted from the combined mean yield because the yield at the farm is less than 10% when compared with the yield at the research station. The total cost, gross income, net-benefit ratio, and cost-benefit ratio of all treatments were calculated as follows:

Total cost=Total variable cost + Total fixed cost

Total variable cost= Fertilizer cost

Total fixed cost= Cost expended from planting to the end of the experiment

Gross income (GI): - Income from the sale of the grass. Considering the local market sells prices of *Rhodes* grass (1kg = 3.75 birr) on a dry matter basis.

Net Benefit (NB): - was calculated as the amount of money left when the total costs (TC) for each treatment deducted from the gross income (GI).

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Total cost}}$$

3.9. Statistical Analysis

The General Linear Model (GLM) procedure of SAS was used to analyze morphological characteristics, DM yield, and chemical composition parameters, and significant mean differences were separated using the LSD (Least Significant Difference) test. The effect of different fertilizer types and harvesting stages on morphological characteristics, biomass yield, in vitro digestibility, and chemical composition was determined by using the following model:

$$Yijk = \mu + F_i + H_j + (Ft*H)_{ij} + E_{ijk}$$

Whereas,

Yij: Total observations

μ: overall mean

Fi: effect of fertilizer type (NPS, FYM, farmyard manure + NPS, and control)

Hj: effect of harvesting stage (at 60, 90 and 120 days)

Fi*Hj: the interaction of fertilizer type and harvesting stage

Eij: the error mean

4. RESULTS AND DISCUSION

4.1. Effects of Fertilizer Types and Harvesting Stages on Agronomic Performance of Rhodes Grass

4.1.1. Plant height

The effect of fertilizer type, harvesting stage, and their interaction had a significant ($p<0.05$) effect on the plant height of Rhodes grass, as presented in Table 4. The late harvesting stage (120 days) showed significantly higher (105.5cm) plant height, while 60 days of harvesting showed lowest (75.9cm) values of plant height in the current result. The highest plant height (102.8 cm) was measured from the 50kg NPS+2500kg FYM, whereas the lowest (76.7cm) value was from 0kg fertilizer/ha. PH was significantly affected by the interactions, in which the tallest plant (120.8cm) was recorded from the application of 50 kg of NPS + 2,500 kg of farmyard manure/ha, which was no significant difference from the sole NPS fertilizer application (117.27cm), was harvested at the 120-day harvesting stage. However, the shortest plant height (64.5cm) was from a non-fertilized plot at 60 days of harvesting.

The increase in plant height of Rhodes grass observed by combined application of NPS fertilizer and FYM is in agreement with previous finding of Anteneh *et al.* (2022), who reported that application of different fertilizers had a significant effect on the plant height of Rhodes grass, and the longest mean plant height (108.07cm) was recorded at a mixing of bio-slurry with NPS fertilizer application and the shortest mean (83.475cm) was observed without added fertilizer. The reason could be due to the improved physical, chemical, and biological properties of the soil that ultimately increased water absorption and nutrient utilization and thus plant heights. Moreover, application of NPS and FYM may provide balanced micro and macronutrients as well as enhanced availability of plant nutrients, which would help to enhance the improvement of plant growth. This finding supported by Awoke *et al.* (2021), who found that the highest PH of oat grass was observed for NPK fertilizer (140 cm), while the lowest (120 cm) value was recorded for control. The result of Yossif and Ibrahim (2013) was disagreed with this result that the plant height of Rhodes grass was significantly affected by different types of fertilizer (urea, farmyard manure, and chicken manure).

The plant height increase as the stage of grass increased might be due to the well-established root development and nutrient uptake ability of the grasses, which in turn could be manifested by the increment of plant height. This was supported by Dawit *et al. (2024),* who reported that the tallest plant height (124cm) of *C. gayana* was recorded from 120 days of harvesting, while the shortest plant heights of 0.49 cm were obtained from the early harvesting stage (60 days); relatively, their report is higher than PH observed in the current study. The difference might be due to management practices, type of fertilizer, soil, and climatic conditions. Other similar findings were reported by Ansah *et al.* (2010), who reported that plant height increased with increased harvest days. Similarly, cutting interval had significant effects on plant height, with height increasing progressively as cutting interval increased (Wangchuk *et al.*, 2015).

4.1.2. Number of leaves per plant

Fertilizer types, harvesting stages, and their interactions had a significant ($p<0.05$) effect on the NLPP of Rhodes grass, as shown in Table 4. Harvesting at the stage of 120 days gave the highest number of leaves per plant (123) compared to harvesting at the stages of 90 and 60 days. Fertilizer type significantly affected ($p<0.05$) the number of leaves, with the highest leaf number (105.2) recorded when 50 kg NPS + 2,500kg farmyard manure/ha were applied, whereas the least 66.1 leaves were obtained at control plots (without fertilizer). For the interaction effects, significantly higher (144) leaf numbers were recorded for the application of a mixture of 50 kg NPS with 2,500kg farmyard manure/ha, which was statistically similar to the sole NPS (139 leaves) application at the late harvesting stage (120 days), while the lowest number (49 leaves) was recorded from the control (without fertilizer) at 60 days of harvesting.

A large number of leaves per plant were counted at the application of a mixture of 50 kg of NPS with 2,500 kg of farmyard manure/ha. This may be due to all forms of fertilizer used to positively increase tillers, which might improve soil physical condition and provide plant growth requirements through the availability of nutrients, especially nitrogen, even at the early stage of forage growth. The result of Anteneh *et al.* (2022) was in line with the present finding, who reported that the different fertilizer applications had a significant effect on the number of leaves per plant of Rhodes grass, whereas the maximum number of leaves per plant (173.05) were obtained from a mixing of 50% bio-slurry with 50% NPS fertilizer, while the minimum number of leaves per plant (86.1) was observed in the control group, but their report is higher than the current finding. The reason for these differences might be associated with the environmental conditions (type and fertility of soil, temperature, rainfall, and altitude), harvesting stage, and management practices applied to the plant.

The increment in the NLPP as the harvesting stage extended in this experiment was in line with the findings of Dawit *et al.* (2024), who stated that the number of leaves per plant of Rhodes grass increased with the advancement of the harvesting date, and the highest number (170 leaves) was observed at 120 days of harvesting and the lowest number of leaves per plant (83 leaves) was observed at 60 days of harvest, but their report is higher than the current finding. The reason behind this variation is associated with fertilizer, weather, soil type, and management practices. However, in this study, it was observed that with the increase in the stage of maturity, a greater number of leaves, which are important for the photosynthetic and transpiration surfaces, were produced from the newly emerging tillers, which resulted in a greater number of leaves as the plant matured. Bimrew *et al.* (2017) reported that the number of leaves per plant (NLPP) significantly increased as the harvesting stage increased from 90 to 150 days for desho grass.

4.1.3. Leaf length per plant

Both fertilizer type and harvesting days had a highly significant ($p<0.05$) effect on the length of leaves per plant of Rhodes grass, and their interaction had no effect (Table 4). The largest leaf length per plant (36.8 cm) was measured from a mixture of 50kg NPS with 2,500kg farmyard manure/ha application, which had a statistically similar value (34.5cm) to the sole NPS application, whereas the lowest leaf length per plant (25.2 cm) was recorded from the control group (0 kg/ha fertilizer). However, the application of sole farmyard manure showed an intermediate value between sole NPS and the control group. The late harvesting stage (120 days) showed significantly higher (38.5cm) leaf length, whereas 60 days of harvesting showed lower (24.3 cm) values of leaf length per plant in the current result.

The results show that a combination of organic and inorganic fertilizer had the highest LLPP and a lower value without fertilizer, which is in line with Tefera *et al.* (2017), who reported that Rhodes grass with the application of fertilizer had significantly longer leaf length than non-fertilizer treatments. The same result was reported by Anteneh *et al.* (2022), who reported that the longest LLPP (45.9 cm) of Rhodes grass was obtained from a mixture application of 50% bio-slurry with 50% NPS fertilizer, while the shortest leaf length per plant (37.37cm) was observed in the control group. This might be due to the integrated use of NPS with farmyard manure, which improves soil fertility and therefore increases nutrient absorption by grass roots, which leads to better leaf development. A similar trend was stated by Getahun *et al.* (2021), who stated that the LLPP of *Desho* grass was significantly higher with the application of NPK than with the intermediate and without fertilizer.

The increase in leaf length at the later harvesting stage is consistent with other observations by Dawit *et al.* (2024), who stated that the longest day of harvesting (120 days) showed 48 cm of leaf length, followed by 90 days (33 cm of leaf length), and the lowest at 60 days (29 cm of leaf length) of harvest for Rhodes grass. The present results are also supported by the findings of Wubetie *et al.* (2018) and Rambau *et al.* (2016), who reported that the longest leaf length per plant increased with the maturity of different grasses. The advantage of extended harvesting time is that it gives opportunity for the growth of different parts of the plant that attain maximum leaf length.

4.1.4. Number of tillers per plant

As presented in Table 4, the number of tillers per plants of Rhodes grass was significantly affected ($p<0.05$) by the fertilizer types, harvesting stage, and their interactions. The application of a mixture of 50 kg NPS and 2500kg farmyard manure fertilizer showed significantly higher (20.6) NTPP, whereas the control treatments showed lower (15.5) values of NTPP. The highest tillers per plant (79.84) were counted at the late harvesting stage (120 days), while the least tiller number (42.23) was counted at 60 days of harvesting. The higher (27.53) tillers per plant were counted from the application of 50kg NPS + 2,500kg farmyard manure/ha at late harvesting days, followed by sole NPS application (25 tillers), but significantly no differences, whereas the least value of NTPP was counted from non-fertilized (13.47 tillers) when grass harvested at 60 days after sowing.

The highest tillers per plant were counted at a mixture application of 50kg NPS + 2,500 kg farmyard manure/ha and a sole NPS application. The reason might be that the integrated use of inorganic fertilizers with organic fertilizers is a sustainable method for efficient nutrient usage, which enhances the efficiency of the chemical fertilizers and also can improve the properties of the soil Schoebitz *et al.* (2016). Therefore, the release of nutrients to plants at different times indicates enhanced development of new shoots and new tillers. The present finding is in line with Antenah *et al*. (2022), who noted that the maximum number of tillers (27.5) of Rhodes grass was obtained from a mixing of 50% bio-slurry with 50% NPS fertilizer, while the minimum tiller number (17.67) was observed in the control group. In addition, the present result is in line with Getahun *et al.* (2021), who found that the fertilizer type significantly affected *($p<0.0001$)* the number of tillers per plant of oat grass. The highest mean NTPP was observed at the application of NPK fertilizer and the lower value count of NTPP was recorded for the control group.

The number of tillers per plant increases as days of harvesting increase in the current study, which is in agreement with the report of Terefe *et al.* (2017), who reported that the number of tillers per plant of Rhodes grass increased with the advancement of harvesting ages. This might be due to the enhanced development of new shoots and encouragement in the development of new tillers. And this finding is also supported by Bimrew *et al*. (2017), who noted that the number of tillers per plant of Desho grass was significantly affected by harvesting date. The largest number of tillers (50.92) was observed at the later (150 days) stage of harvest, while early harvesting (90 days) showed a relatively low (40.75) number of tillers per plant.

4.1.5. Leaf to stem ratio

Leaf to stem ratio of Rhodes grass was significantly ($p<0.05$) affected by the stage of harvesting, not by the application of different fertilizers, but there was a significant ($p<0.05$) difference between the control treatment and others fertilizers (Table 4). The highest LSR (1.062) was observed from the application of 50 kg of NPS + 2,500 kg of farmyard manure/ha, which is no significant difference from sole NPS and farmyard manure (1.053 and 1.047, respectively), whereas the lowest leaf stem ratio was recorded without fertilizer application. The highest leaf stem ratio (1.24) was recorded at the 60-day harvesting stage, while the lowest LSR was recorded at the 90-day (1.071) and late harvesting stages (0.79).

The reason for the increase in LSR within the application of fertilizer compared to the non-fertilized group might be because fertilizer increases leafiness, fodder yield, and digestibility of plants. The present finding is in line with Terefe *et al.* (2017), who reported that Rhodes grass with the application of fertilizer had a significantly higher leaf-to-stem ratio than the control treatment. And the same result by Anteneh *et al. (2022):* the application of different fertilizers had no significant effect on the leaf-to-stem ratio of Rhodes grass, but there was a significant difference from the control group without fertilizer application. Similarly, the current result agreed with Yossif and Ibrahim (2013), who stated that the leaf-to-stem ratio of Rhodes grass was not significantly affected by different types of fertilizer.

The analysis indicated that the declining leaf-to-stem ratio with the advancement of the harvesting stage indicated an inverse relationship between the growth of the plant and LSR. This could be due to the reduction of plants in leaf proportion and an increase in stem fractions of the grass at the advanced stage of harvesting. LSR is the best indication of the quality of forages; hence, a plant with a high leaf-to-stem ratio also has high nutrition and digestibility. But, at the early stages of plant growth, the stem of grasses is easier to digest than the leaf parts of the plant, but as growth advanced, the digestibility of the stem rapidly declined while the nutritive value of the leaf parts slowly decreased (McDonald *et al.,* 1988). A similar trend conducted by Ghiwot (2019) showed that there was a significant effect observed in the leaf-to-stem ratio of *Cenchrus ciliaris* due to the different harvesting days. The stages of growth of *Cenchrus ciliaris* increased, and LSR became reduced. The current result is also in agreement with Mergia (2021), who noted that the leaf-to-stem ratio of Desho grass showed a significant decrease with the increasing date of harvesting.

The overall mean leaf-to-stem ratio (1.035) of Rhodes grass in the current study was comparable with (1.09) earlier reports by Yossif and Ibrahim (2013) but lower than (1.16) earlier reports by Antenah *et al.* (2022) for the same variety. The reason behind variation is associated with differences in the nutrient contents of fertilizer, weather, soil type, and management practices.

Table 4: Effects of fertilizer types and harvesting stages on the agronomic performance of Rhodes grass

Factors	**Parameters**				
	PH(cm)	**NLPP(count)**	**LLPP(cm)**	**NTPP(count)**	**LSR**
Fertilizer types					
FYM	86.9^{b}	80.4^{c}	28.8^{b}	17.3^{b}	1.05^{a}
NPS	99.8^{a}	95.9^{b}	34.5^{a}	20.6^{a}	1.06^{a}
FYM+NPS	102.8^{a}	105.2^{a}	36.8^{a}	21.2^{a}	1.05^{a}
Control	76.7^{c}	66.1^{d}	25.2^{c}	15.5^{c}	0.98^{b}
p-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	0.0157
Harvesting stages					
60 days	75.9^{c}	62.3^{c}	24.3^{c}	15.1^{c}	1.24^{a}
90 days	93.2^{b}	76^{b}	31.2^{b}	18.4^{b}	1.07^{b}
120 days	105.5^{a}	122.6^{a}	38.5^{a}	22.5^{a}	0.79^{c}
p-value	*<.0001*	*<.0001*	*<.0001*	*<.0001*	<.0001
Interaction effect					
Control *60 day	64.5^{f}	48.2^{g}	18.33	13.47^{f}	1.21
Control *90 day	78^{f}	54.1^{g}	25.9	15.67^{ef}	0.99
Control *120 day	87.6^{ed}	96.13^{c}	31.26	17.4^{ced}	0.74
FYM+NPS*60 day	81.93^{ef}	74.8^{ed}	27.86	16.53^{efd}	1.26
FYM+NPS*90 day	105.53^{b}	97.13^{c}	35.33	19.4^{cbd}	1.11
FYM+NPS*120 day	120.8^{a}	143.73^{a}	47.06	27.53^{a}	0.79
NPS*60 day	80.67^{ef}	68.33^{ef}	28.13	16.13^{ef}	1.26
NPS*90 day	101.47^{cb}	80.93^{d}	34.86	20.7^{b}	1.09
NPS*120 day	117.27^{a}	138.67^{a}	40.6	25^{a}	0.83
FYM*60 day	76.8^{f}	57.67^{gf}	22.93	14.13^{f}	1.24
FYM*90 day	87.73^{ed}	71.87^{ed}	28.53	17.73^{cebd}	1.1
FYM*120 day	96.13^{cd}	111.8^{b}	34.86	20^{cb}	0.8
p-value	*0.0175*	*0.0453*	*0.4790*	*0.0291*	0.83
Overall mean	91.5	86.9	31.3	18.64	1.035
CV%	5.09	7.63	10.7	9.3	5.41
SE	2.68	3.83	1.93	1.004	0.032

$^{a\text{-}g}$ means followed by different letter with the same column are statistically not significant ($p<0.05$). PH=plant height; LLPP=leaf length per plant; NTPP= number of tiller per plant; NLPP= number of leave per plant; LSR= leaf steam ratio; NPS=Nitrogen phosphate sulfur; FYM=farmyard manure; CV=Coefficient of variation; SE=standard error

4.2. Effects of Fertilizer Types and Harvesting Stages on Dry Matter Yields of Rhodes Grass

4.2.1. Dry matter yield (t/ha)

The DM yields of Rhodes grass were significantly affected ($p<0.05$) by the type of fertilizer and the stage at which it was harvested, but not by interaction, as indicated in Table 5. The combination of 50 kg NPS with 2,500kg farmyard manure/ha resulted in a maximum DM production of 9.50 t/ha, followed by the application of sole NPS, which yielded 9.46 t/ha. Conversely, the control group (without fertilizer) had the lowest DMY value of 7.07 t/ha. The highest mean of DMY was observed after 120 days of harvesting, followed by 90 days and 60 days of harvesting stages (11.37 tons/ha, 8.93 tons/ha, and 5.33 tons/ha), respectively.

The result shows that a plot treated with a combined fertilizer treatment produced a significant increase in dry matter yield. The reason might be that such fertilizer mixtures have the highest soil fertility improvement capacity compared to the rest of the fertilizer types. The findings align with the study conducted by Anteneh *et al.* (2022), who found that the highest DMY (12.63 t/ha) of Rhodes grass was achieved when 50% bio-slurry was mixed with 50% NPS fertilizer in northern part of Ethiopia. In contrast, the control group yielded the lowest DM yield (7.69 t/ha), but their report is higher than the current finding. Differences in the agro-ecology of the study sites, the stage of harvesting, type of fertilizer applied, and the agronomic management of the grass could be responsible for the observed differences.

The DM yields of the grass increased as harvesting stages increased. The reason might be attributed to the emergence of new tillers, the production of more leaves, the elongation of existing leaves, the development of the stem, and the overall vegetative growth of the plant. The present result is supported by Dawit *et al.* (2024), who stated that the DM yield of Rhodes grass collected at the longest harvesting period (120 days) was significantly (9.25) higher than 90 and 60 days of harvest. Wubetie *et al.* (2019), which reported comparable findings on various types of *Brachiaria* grasses in Ethiopia. A similar result was found by Mamila *et al.* (2020), who found that the highest DM yield (20.19 t/ha) was recorded after 120 days of harvesting. The observed variation could be attributed to disparities in the agro-ecology of the research locations, type of grasses, the stage of harvesting, and the agronomic treatment of the grass.

4.2.2. Crude protein yield

The type of fertilizer and the stage of harvesting had a significant effect ($p<0.05$) on the yield of crude protein of Rhodes grass, while their interaction did not show a significant difference, as indicated in Table 5. The plant treated with a mixture of 50 kg NPS and 2,500 kg farmyard manure/ha yielded 0.98 tons/ha of CP yield, which was ~~much~~ higher than the plant treated with NPS alone, which produced 0.97 tons/ha. The lowest CP yield (0.68 tons/ha) was reported from the control plot (0kg fertilizer/ha). The late harvesting stage (120 days) showed significantly higher (1.07 t/ha) crude protein yield, while 60 days of harvesting showed lower (0.59 t/ha) values of crude protein yield.

The application of different fertilizers can significantly affect the yield of CP. During the growing season, plants absorb most of the nitrogen, leading to higher CP content and dry matter yield. Consequently, CPY is determined by multiplying the total dry matter yield with the CP concentration in the plant. Consistent with the recent study by Anteneh *et al.* (2022), the greatest production of crude protein yield (1.42 t/ha) for *C. gayana* was observed when a mixture of 50% bio-slurry and 50% NPS fertilizer was applied, while the lowest crude protein output (0.68 t/ha) was observed in the control group. Negasu *et al.* (2020) found a similar outcome, observing that chemical fertilizer and manure had a significant impact on the CPY of *Brachiaria hybrid Mulato II* grass, and the highest average CPY was reported for NPS, while the control group had the lowest value.

The increase in crude protein yields as the harvesting stage advanced may be attributed to the corresponding increase in dry matter yield (DMY) with the advancing age. The result of Awoke *et al.*, 2020, was in line with the current finding, which reported that the CPY of *Desho* grass was significantly affected by harvesting age. They found that CPY increased as the harvesting stage was prolonged. A similar result was obtained by Mergia (2021), who found that the CPY was higher when the *Desho* grass was harvested 154 days after planting than at the other two harvesting stages. The average crude protein yield of Rhodes grass in this study (0.86 ton/ha) was significantly lower compared to previous findings by Yossif and

Yassin (2013), who reported crude protein yields of 1.22 t/ha for the same grass type. The observed variation may be attributed to differences in the agro-ecology of the research regions, the stage of plant maturity, and the agronomic management of the grass.

Table 5: Effects of fertilizer type and harvesting ages on dry matter and crude protein yields of Rhodes grass

Factors	**Parameters**	
	DMY (ton/ha)	**CPY (ton/ha)**
Fertilizer types		
FYM	8.14[b]	0.81[b]
NPS	9.46[a]	0.97[a]
FYM+NPS	9.50[a]	0.98[a]
Control	7.07[c]	0.68[c]
p- value	*0.0001*	*<.0001*
SE	0.135	0.013
Harvesting stage		
60 days	5.33[c]	0.59[c]
90 days	8.93[b]	0.91[b]
120 days	11.37[a]	1.07[a]
p-value	*<.0001*	*<.0001*
SE	0.117	0.012
Overall mean	8.54	0.86
CV%	4.73	4.66
Interaction effect *(p-value)*	0.1636	0.1253

Means within column followed by the same letters are not significantly different; (p<0.05)= significant; NPS=Nitrogen phosphate sulfur; SE: standard error: CV=coefficient of variation; DMY=dry matter yield; CPY=crude protein yield: FYM=farmyard manure

4.3. Effects of Fertilizers Types and Harvesting Stages on Chemical Composition of Rhodes Grass.

4.3.1. Dry matter content

As presented in Table 6, both harvesting stages and fertilizer type had significant (*$p<0.001$*) effects on the dry matter percentage of Rhodes grass, while the interaction effect showed a non-significant (*$p>0.05$*) effect. The highest DM content (94.15%) was recorded from a combination of 50 kg of NPS fertilizer and 2,500 kg of farmyard manure/ha, followed by a sole NPS application, whereas the lowest DM percentage (93.56%) was obtained from the control group (0kg of fertilizer/ha). The late harvesting stage showed significantly higher (94.22%) dry matter content, while 60 days of harvesting showed lower (93.35%) values of dry matter content.

The higher DM% recorded from a combination fertilizer group than others were due to the fact that grass vigorously responded to fertilizer application. This trend is in agreement with Negasu *et al.* (2020), who report that there was a significant effect between fertilizer types on the dry matter content of *Brachiaria hybrid Mulato* II grass, in which the highest dry matter content was observed for NPS fertilizer compared to manure and control experiments. A similar result was reported by Getahun *et al.* (2021), who reported that the dry matter content of the oat grass influenced by the application of fertilizer (NPK, compost, and unfertilized) was significantly different. The current finding disagrees with Anteneh *et al. (*2022), who stated that the dry matter content of Rhodes grass was not significantly affected by different types of fertilizer.

The result shows that the increment in DM% with the advancement of the harvesting stage might be due to the decline in moisture content of the grass as age advanced. The current result was in agreement with Terefe *et al.* (2017), who suggested that the dry matter content of Rhodes grass increased with delayed harvesting, which could be attributed to decreased moisture content in leaves as plants age and become lignified. Similar trends by Wubetie *et al.* (2018) and Mamila *et al.* (2020) in *Brachiaria* grass and Bimrew (2016) in *Desho* grass show that DM content increases linearly with an increase in harvesting age.

The overall mean DM (93.86%) of current findings is higher than the earlier reports of Anteneh *et al. (*2022) and Geberemariyam & Gezahegne (2022), who reported 92.37% and 91.16% dry matter content of similar grass. The reason behind this variation might be the soil structure, stage of plant maturity, management practices, and weather conditions, which are major factors that influence the nutritional quality of grasses.

4.3.2. Crude protein (CP %)

Fertilizer type, harvesting stage, and their interaction had a significant ($p<0.05$) effect on the CP content of the Rhodes grass, as indicated in Table 6. The 50 kg NPS + 2500kg farmyard manure fertilizer showed significantly higher CP (10.48%), whereas the control treatments showed lower (9.88%) values of CP in the present study. The highest CP was obtained at the first harvesting stage (11.08%), whereas the lowest CP was obtained at the late harvesting stage (9.42%). Plants received a mixture of 50 kg NPS and 2,500kg farmyard manure/ha and sole NPS fertilizer, which resulted in the highest CP content but statistically similar values (11.37% and 11.29%, respectively) at 60 days of harvesting, while the lowest CP (8.96%) content was observed in the control plot from the late harvesting stage (120 days), followed by sole farmyard manure (9.35%) application.

The result of the highest CP content in the combination of NPS fertilizer with farmyard manure treatment could be due to the fact that integrated use of NPS with organic fertilizer improved soil fertility and therefore nutrient absorption by grass roots, which led to continuous sprouting of the vegetation until harvest. The current finding is supported by Anteneh *et al.* (2022), who found that all fertilizer applications had significantly higher CP content than control treatments, which means higher CP contents of Rhodes grass (11.25%) were observed when mixing 50% of the bio-slurry with 50% of fertilizer, while the lowest CP (8.9%) content was observed in the control group (0kg fertilizers), but the overall mean (10.34%) of their report is comparable with the present result. Similarly, as Awoke *et al.* (2021) reported, the CP content of *Desho* grass was significantly affected by fertilizer type, in which the application of 100 kg Urea/ha was significantly higher (11.70) than the other fertilizers, while non-fertilizer (control) was provided with the lowest CP content (8.74).

The reason for the declination of CP content as the harvesting stage advances may be due to the fact that the CP content of plants generally declines with advanced maturity. As the age increased, the grass became lignified, causing a decline in CP content. The present result is in line with Dawit *et al.* (2024), who reported Rhodes grass harvested at 60 days showed significantly the highest CP (13.85%) value, followed by 90 and 120 days of harvest (12.36% and 10.30%, respectively), which was higher than the average of the current CP result (10.23%). The variation might be due to the soil structure, management practices, weather conditions, and type of fertilizer, which are major factors that influence the nutritional quality of grasses. The current finding of declining CP concentration with delayed harvesting is again in line with the finding of Wassie *et al.* (2018), who stated the highest CP concentration was obtained at the earliest stage of harvesting, with values declining as harvesting was delayed in different *Bracharia* ecotypes in Ethiopia.

The CP content of the feed has to be at least 7% to 7.5% to satisfy the maintenance requirements of the ruminants (Van Soest, 1994). The CP content value of Rhodes grass obtained in the current study under all treatments was above or equal to the threshold level of 7% required for normal rumen microbial function and feed intake, whereas the present result of CP% was below the minimum 15% CP needed for lactation and growth of cattle described by Norton (1982).

4.3.3. Ash content (%)

As indicated in Table 6, the effect of fertilizer type, harvesting stage, and their interaction significantly ($p<0.05$) affected the ash percentage of Rhodes grass. The 50 kg NPS + 2500kg farmyard manure fertilizer/ha showed significantly higher (10.02%) ash content, whereas the control treatments showed lower (8.78%) values of ash. The highest ash content (10.17%) was recorded from 60 days of harvesting, while the lowest (8.58%) was at late harvesting stages. The ash was also significantly affected by the interactions, with the highest ash content (11.4%) observed under the combined fertilizer 50 kg NPS x 2,500kg farmyard manure/ha, which was statistically similar to the sole NPS fertilizer application (10.38%) on the early harvesting days (60), whereas the lower result (8.39%) was observed in the unfertilized plot at 120 days of harvesting.

Increased ash content with the application of combined fertilizer compared to other treatments due to the combination of organic and inorganic fertilizer application enhanced the phosphor and potassium uptake by plants compared to sole application (Almaz, 2016). The result of this study agreed with the findings of Anteneh *et al*. (2022), who stated that the highest ash content (11.81%) was observed at the mixing of 50% of the bio-slurry with 50% of NPS fertilizer, while the lowest ash (9.78%) content was observed at the control group (without fertilizer) application. On the contrary, Abdi (2014) noted that the lowest mean ash content was obtained at treated levels of nitrogen fertilizer, while the highest ash content was recorded from control groups on Buffel and Guinea grass species. This difference might be because ash content in forages varies with soil fertility, stage of plant maturity, and management practice.

On the other hand, total ash content decreased as the harvesting days of grass advanced, and this might be due to natural dilution and translocation of nutrients to roots, the agro-ecology of the area, and poor soil fertility during the growth and development of plant tissue, resulting in a decline in mineral concentration in the grass (McDonald *et al.*, 2002). The current finding is supported by Dawit *et al.* (2024), who found that the highest total ash of Rhodes grass was observed at 90 days (11.19%), while there was no significant difference between 60 and 120 days of harvesting. A similar result was reported by Ghiwot (2019), who reported that the highest total ash content was obtained in Buffel grass that was harvested at 60 days, while the lowest value was recorded at 120 days of harvesting.

4.3.4. Neutral detergent fiber

The effect of fertilizer type, harvesting stage, and their interaction had a significant ($p<0.05$) effect on the neutral detergent fiber content of Rhodes grass, as indicated in Table 6. The 50 kg NPS + 2500kg farmyard manure fertilizer showed significantly lower NDF (56.8%), whereas the control treatments showed higher values of NDF (59.49%) in the current study. Rhodes grass harvested at 60 days showed significantly the lowest NDF value, followed by 90 and 120 days of harvest. The highest value of NDF (61.64%) was recorded at late harvesting (120) days from 0kg fertilizer/ha (control), whereas the least value of neutral detergent fiber was recorded from a sole NPS and a combination of 50kg NPS + 2,500kg farmyard manure/ha application (53.66% and 54.5%, respectively) when grass harvested at 60 days after sowing, but there was no significant difference.

The lowest NDF content of the combination of NPS and farmyard manure received ~~in~~ plots compared to the fertilized groups might be due to the fact that NPS fertilizer and its mixture with farmyard manure improved plant growth and raised new leaves and shoots, which could minimize the NDF content. But there is no renewal of leaves and tillers in the non-fertilized treatments as a result of mature tissue plants accumulating more NDF. The result of the present study is in line with Anteneh *et al*. (2022), who reported that the NDF content of Rhodes grass obtained from different types of fertilizer application (NPS, NPS + bio-slurry, and sole bio-slurry) is almost similar but significantly lower than from the control group or without added fertilizer application (68.07%). The result of the present study is consistent with Baghdadi *et al.* (2019), who reported that a combination of chemical and organic manure fertilizer application resulted in a reduced NDF concentration of corn-soybean forage over without fertilizer application but was similar to sole chicken manure treatment.

The current result indicates that the content of NDF increased as the grass matured. This is due to the fact that as the plant matures, the cellulose, hemicelluloses, lignin, and silica, which are found in the insoluble portion of the forage, increase. Also, more seeds are produced at the time of plant maturity; there is a translocation of protein from leaf and stem to seed; therefore, high fiber is remaining on the plant. The present finding is consistent with Dawit *et al.* (2024), who noted the NDF content of the highest harvesting date was significantly higher than 90 and 60 days of harvesting of Rhodes grass. Additionally, the current result agrees with the findings of Diribi (2022), who reported that NDF content increased with extended harvesting stages. The NDF obtained in the present study was lower (59.44%) than the results of Ansah *et al. (*2010), who reported that NDF for Napier grass was 76.5% at 120 days of harvesting. The differences in NDF could be attributed to the nature of the grass, soil and climatic conditions, harvesting stage, and management systems.

According to Singh and Oosting (1992), roughage feeds with a NDF content of less than 45% were grouped as high-quality feeds, while feeds with a NDF content of 45–65% were categorized as medium-quality feeds. Therefore, the current result shows that it can be categorized as a medium-quality feed.

4.3.5. Acid detergent fiber

Effects of fertilizer type as well as harvesting stage and interactions (*$p<0.05$*) were significant on acid detergent fiber in Rhodes grass, as shown in Table 6. ADF was significantly affected (*$p<0.05$*) by harvesting stage, in which ADF increased from 36.57% at 60 days of stage to 39.14% at 120 days of stage. ADF was also significantly affected by the interactions, with the highest ADF (39.76%) observed from the unfertilized treatment at 120 days of harvesting and the lowest observed in all NPS, a mixture of 50kg NPS and 2,500kg farmyard manure/ha, and sole farmyard manure-treated treatments at 60 days of harvesting (35.64%, 35.91%, and 36.87%, respectively).

The highest ADF was recorded from unfertilized plots, while the least value was recorded from combinations of NPS and farmyard manure fertilizer. This might be due to fertilizer improving plant growth and raising new leaves and shoots, which minimize the ADF content of the grass. The current findings are supported by Anteneh *et al.* (2022), who reported that the highest ADF (55.43%) was obtained when non-fertilizer was applied, and the lowest ADF was obtained at bio-slurry (52.44%) and mixed (52.97%). The present result is also supported by Baghdadi *et al.* (2019), who reported that the ADF concentration of soybean forage with the application of chicken manure and NPK produced a lower ADF concentration than without fertilizer treatment.

An increasing trend in ADF content was observed as the harvesting stage was delayed. The reason may be due to the development of the structural components and cell wall constituents of the grass as age increased. The result is in line with Dawit *et al.* (2024), who stated the ADF content increased as the maturity of the plant increased, indicating significantly higher ADF contents of Rhodes grass were observed at 90 and 120 days of harvest (56.37% and 51.50%, respectively), whereas the lowest ADF (38.72%) was recorded at 60 days of harvest, which was higher than the current ADF result. This difference might be because of soil fertility, fertilizer type, and management practices. ADF is the percentage of highly indigestible and slowly digestible material in a feed or forage. Higher forage ADF results in reduced digestible dry matter as a consequence of increased lignification of cellulose in the later stages of the plant (DePeters, 1993). Contrary to the current finding, Rambau *et al.* (2016) showed plant maturity had no effect on the ADF content of Napier grass.

Kellems and Church (1998) characterized roughages with less than 40% ADF as high quality and those above 40% as low quality. Based on the current finding, the means of ADF% of Rhodes grass under all fertilized treatments as well as controls were found to be categorized as medium- to high-quality forage. As a result, it showed positive responses to intake and digestibility for animal productivity.

4.3.6. Acid detergent lignin

The ADL of Rhodes grass was significantly ($p<0.05$) affected by fertilizer types and stages of harvesting but not by their interaction (Table 6). The highest ADL recorded from control plots was 10.07%, and the lowest (9.52%) ADL was obtained for the application of a mixture of 50kg NPS and 2,500kg farmyard manure/ha. The current result also revealed that the lowest ADL content (8.84%) of Rhodes grass was recorded at 60 days of harvesting, whereas the highest ADL content (10.58%) was recorded at 120 days of harvesting.

The lowest ADL was recorded from a combined application of NPS and FYM compared to the unfertilized groups. This is because fertilizers promote the growth of new leaves and shoots, resulting in low lignin content, which compensates for the increased lignin content of the other tissue. When lignin is lowered, it has always produced a marked increase in the digestibility of the plants, and lignin is highly resistant to chemical and enzymatic degradation and is not appreciably broken down by the micro-flora in the ruminant digestive tract (Ranjhan SK 1993). Similar trends were reported by Biniyam *et al. (2018)* and Awoke *et al*. (2020), who reported that the ADL of *desho* grass was significantly affected by fertilizer types, with the highest ADL recorded in the control group and the lowest ADL content obtained from fertilized plots. A similar result was reported by Abdi (2014), who reported that the ADL content of *Panicum maximum* and *Cenchrus ciliaris* decreased with increasing levels of urea fertilizer. This finding disagrees with Anteneh *et al.* (2022), who noted that the effects of different fertilizer applications had no significant effect on the ADL content of Rhodes grass.

The ADL content result indicated that with the stage increase, the level of lignin in grass also increased, which showed rapid lignification to occur in late development stages, and the presence of insoluble fiber, particularly lignin, lowers the overall digestibility of the feed by limiting nutrient availability (Van Soest, 1994). A similar report by Dawit *et al.* (2024) found that the highest ADL (13.58%) content was observed at 120 days of harvest, while the earlier harvests (60 and 90 days) were the lowest (10.58% and 11.23%, respectively), but their finding is higher than the current result. The reason might be associated with differences in the nutrient contents of fertilizer, weather, soil type, and management practices. Additionally, the current result is similar to Terefe *et al*. (2017), who reported an increase in ADL content along with an increment in harvesting age in Rhodes grass. Similarly, Mamila *et al.* (2020), Genet *et al.* (2017), and Ghiwot (2019) reported increased ADL with progressive stages of maturity.

Table 6: Effects of fertilizer types and harvesting stages on chemical compositions of Rhodes grass

Factors	**Parameters**					
	DM%	**Ash%**	**CP%**	**NDF**	**ADF**	**ADL**
Fertilizer types						
FYM	93.8^{ba}	9.18^{b}	10.16^{b}	58.27^{b}	37.56^{b}	9.86^{ba}
NPS	93.93^{ba}	9.49^{b}	10.42^{a}	56.89^{c}	37.41^{b}	9.61^{bc}
FYM+NPS	94.15^{a}	10.02^{a}	10.48^{a}	56.8c	37.49^{b}	9.52^{c}
Control	93.56^{b}	8.78^{c}	9.88^{c}	59.49^{a}	38.81^{a}	10.07^{a}
p- value	0.0402	*<.0001*	*<.0001*	*<.0001*	<.0001	*0.0025*
Harvesting stage						
60 day	93.35^{b}	10.17^{a}	11.08^{a}	55.95^{c}	36.57^{c}	8.84^{c}
90 day	93.97^{a}	9.36^{b}	10.19^{b}	58.21^{b}	37.75^{b}	9.87^{b}
120 day	94.27^{a}	8.58^{c}	9.42^{c}	59.44^{a}	39.14^{a}	10.58^{a}
p- value	<.0001	*<.0001*	*<.0001*	*<.0001*	<.0001	*<.0001*
Interaction effect						
Control *60 day	92.78	9.09^{fde}	10.74^{c}	57.71^{d}	37.85^{ed}	9.11
Control *90 day	93.89	8.86^{fge}	9.93^{f}	59.12^{b}	38.83^{bc}	10.17
Control *120 day	94.01	8.39^{g}	8.96^{h}	61.64^{a}	39.76^{a}	10.94
FYM+NPS *60 day	93.4	11.4^{a}	11.37^{a}	54.5^{e}	35.91^{f}	8.52
FYM+NPS *90 day	94.29	9.67^{cd}	10.35^{d}	57.72^{cd}	37.36^{ef}	9.59
FYM+NPS *120 day	94.75	8.99^{fge}	9.71^{f}	58.19^{cbd}	39.19^{ba}	10.43
NPS *60 day	93.72	10.38^{b}	11.29^{a}	53.66e	35.64f	8.82
NPS*90 day	93.82	9.68^{cd}	10.3^{d}	57.93^{cd}	37.47^{ef}	9.56
NPS*120 day	94.26	8.44^{g}	9.67^{f}	59.08^{b}	39.14^{bac}	10.45
FYM*60 day	93.5	9.82^{cb}	10.92^{b}	57.92^{cd}	36.87^{f}	8.91
FYM*90 day	93.87	9.24^{cde}	10.19^{d}	58.05^{cbd}	37.36^{ef}	10.16
FYM*120 day	94.04	8.49^{fg}	9.35^{g}	58.83^{cb}	38.45^{dc}	10.51
p- value	0.286	*0.003*	*0.0462*	*0.*0001	*0.0066*	*0.611*
Overall mean	93.86	9.37	10.23	57.86	37.82	9.76
CV%	0.43	3.61	1.017	1.02	1.11	3
SE	0.23	0.19	0.06	0.34	0.24	0.16

$^{a-g}$ Means with different letters in a column are significantly different (p<0.05); CV=Coefficient variance, SEM = standard error of mean; DM=Dry matter content, CP = Crude protein; ADF=Acid detergent fibre, ADL=Acid detergent lignin, NDF= Neutral Detergent Fiber. NPS=Nitrogen phosphate sulfur: FYM=farmyard manure

4.4. Effects of Fertilizers Types and Harvesting Stages on In Vitro Digestibility of Rhodes Grass.

4.4.1. In-vitro dry matter digestibility (IVDMD)

The in-vitro dry matter digestibility of Rhodes grass was significantly ($p<0.05$) affected by both fertilizer types and harvesting stages, but not by interactions, as presented in Table 7. The application of a mixture of 50 kg of NPS plus 2,500kg of farmyard manure/ha had the highest value (54.03%) of IVDMD. The application of sole farmyard manure had the second-highest value, whereas the control plot (0 kg fertilizer/ha) had the lowest value (52.41%) of IVDMD. The IVDMD was higher (54.54%) at the early (60 days) harvesting stage than at the intermediate (90 days) and late (120 days) harvesting dates (52.89% and 52.77%, respectively).

The high content of IVDMD in the group treated with fertilizer can be attributed to the addition of nitrogen to the soil, which promotes the growth of new tillers, shoots, and leaves. This accelerates stem development and increases the CP content of plants, resulting in lower levels of cell wall and lignin contents (Van Soest, 1982). The current finding is supported by Diribi (2022), who observed that there was an increase in in vitro dry matter digestibility when the level of NPS fertilizer increased.

The in-vitro dry matter digestibility decreases as the harvesting stage increases due to the deposition of lignin in the cell wall with increasing maturity and the increasing proportion of stem, which becomes less digestible when compared with the leaf portion at advanced maturity (McDonald *et al.,* 1995). This finding is consistent with Ghiwot's (2019) research, which states that the IVDMD decreases as the harvesting period increases, and the maximum and lowest in-vitro dry matter digestibility values were achieved when the grass was harvested at 60 days and 120 days, respectively. Simachew's (2016) study found that the IVDMD% of blue panic grass consistently decreased as the harvesting day stage increased.

The current average IVDMD (54.26%) of Rhodes grass is higher than the finding of Geberemariyam & Gezahegne (2022), who recorded an IVDMD of 51.35%, while the average result of this study was lower (56.9%) than the published value of Kebede *et al.* (2024). The observed variation may be attributed to disparities in the agro-ecology of the research sites, the stage of harvesting, grass species, fertilizer types, and the agronomic management of the plants.

Owen and Jayasuriya (1989) said that a 50% IVDMD for feeds is considered a critical and acceptable threshold level. Hence, the IVDMD percentage found in *Chloris gayana* in the present study is deemed satisfactory.

4.4.2. In vitro organic matter digestibility

Fertilizer type and harvesting stage had a significant ($p<0.05$) effect on the in vitro organic matter digestibility of Rhodes grass, while the interaction effect did not show a significant difference, as shown in Table 7. The highest (54.53%) IVOMD of Rhodes grass was recorded at the mixture of 50kg NPS and 2,500kg farmyard manure/ha, followed by sole farmyard manure (53.92%) application, while the lowest value (52.35%) of IVOMD was recorded from a non-fertilized plot. IVOMD increased with the application of a combination fertilizer type when compared with other fertilizer types. Regarding harvesting time, the highest (54.75%) IVOMD was obtained at 60 days of harvesting, whereas the lowest (53.025) was recorded at the late harvesting stage.

The reason for the increase in IVOMD with increasing fertilizer levels might be because IVOMD is a function of IVDMD and also a decline in the leaf-to-stem ratio. Current findings are in agreement with Diribi (2022), who stated fertilizer level had a significant effect on the in vitro organic matter digestibility of *Bracharia* mulato II grass, in which the highest IVOMD was obtained from a 200 kg/ha fertilizer application while the least was from the control group.

The analysis also revealed that in vitro organic matter digestibility decreased with extended harvesting stages. This might be due to the deposition of lignin in the cell wall with increasing maturity and the increasing proportion of stem, which becomes less digestible when compared with the leaf portion at advanced maturity (McDonald *et al.*, 1995). A similar finding was reported by Agza *et al.* (2013), who reported that IVOMD showed a declining trend in advancing maturity. Current findings disagree with Bimirew *et al. (2017),* who noted that the IVOMD of *desho* grass was not affected by the harvesting period.

4.4.3. Metabolizable energy

As shown in Table 7, the metabolizable energy of Rhodes grass was significantly affected by both the type of fertilizer and the stage of harvesting ($p<0.05$), but there was no significant difference observed in their interaction. A combination of 50kg NPS and 2,500kg farmyard manure/ha application achieved the maximum metabolizable energy of 8.18 MJ kg DM. The second-best ME was obtained from the sole application of farmyard manure, whereas the lowest ME of 7.85 MJ kg DM was recorded in the control plot (0kg fertilizer/ha). The highest metabolizable energy of 8.21 MJ per kilogram of DM was obtained at the 60-day harvesting stage, while the lowest ME of 7.95 MJ per kilogram of DM was recorded during the 120-day harvesting stage, which had a statistically similar value to the 90-day harvesting stage.

A combined application of NPS and farmyard manure had the highest metabolizable energy. The reason might be the function of IVOMD. The present result is in line with the findings of Diribi (2022), who observed that the metabolizable energy of *Bracharia mulato II* grass was significantly affected by the level of NPS fertilizer. Specifically, the plants receiving 150 and 200 kg/ha of NPS fertilizer exhibited significantly higher metabolizable energy content compared to those receiving 0 and 50 kg/ha of NPS fertilizer.

The delaying of the cutting date results in a greater dry matter yield (DMY) due to an increase in indigestible plant parts, specifically cell wall components. This decrease in digestibility of the pasture is also reflected in the lower metabolizable energy (ME) value of the grasses, according to McDonald et al. (2002). Similar findings were reported by Ghiwot (2019), who observed that the highest and lowest levels of metabolizable energy in *Cenchrus ciliaris* were documented at 60 and 120 days after harvesting, respectively. Current research contradicts the findings of Bimirew *et al.* (2017), who observed that the energy content (MJ/kg) of desho grass was not influenced by the time of harvest.

The average metabolizable energy of Rhodes grass (8.04 MJ/kg DM) recorded in this study is higher than that of an earlier report (7.7 MJ/kg DM) by Kebede *et al.* (2024). The variation in the findings could be due to environmental conditions such as soil, temperature, and moisture, management systems, type of fertilizer application, harvesting stage, and management systems.

Table 7: The in vitro digestibility and metabolizable energy content of Rhodes grass are affected by fertilizer types and harvesting stages.

Factors	**Parameters**		
	IVDMD (%)	**IVOMD (%)**	**ME** (MJ /kg DM)
Fertilizer types			
FYM	53.48[b]	53.92[b]	8.09[b]
NPS	53.69[b]	53.71[c]	8.06[c]
FYM+NPS	54.03[a]	54.53[a]	8.18[a]
Control	52.41[c]	52.35[d]	7.85[d]
p value	*<.0001*	*<.0001*	*<.0001*
SE	0.085	0.050	0.0076
Harvesting stage			
60 days	54.54[a]	54.75a	8.21[a]
90 days	52.89[b]	53.11[b]	7.97[b]
120 days	52.77[b]	53.025[b]	7.95[b]
***p* value**	*<.0001*	*<.0001*	*<.0001*
SE	0.074	0.043	0.0066
Overall mean	53.40	53.63	8.04
CV%	0.48	0.28	0.28
Interaction effect *(p value)*	**0.94**	**0.35**	**0.36**

Means followed by the same letters within a column are not significantly different. CV=Coefficient variance; SEM = standard error; IVDMD=In vitro dry matter digestibility; IVOMD=In vitro-organic matter digestibility; ME=Metabolizable energy; NPS=Nitrogen phosphate sulfur: FYM=farmyard manure

4.5. Correlation among Agronomic Parameters, Chemical Composition, and Digestibility of Rhodes Grass

The relationship between yield, nutritive value, agronomic parameters, and digestibility of *Chloris gayana* is presented in Table 8. Plant height was positively correlated ($p<0.05$) with NTPP, the NLPP, CPY, and fibers, while it was negatively correlated with LSR, ash, and CP. LSR is an important factor associated with digestibility and had a negative correlation to the number of leaves per plant, DM yield, CP yield, NDF, and ADF in the current study. The direct relationship between LSR and CP content, ash content, and in vitro digestibility, as well as the inverse association between LSR and fiber content, were also previously observed by Tessema *et al.* (2002) for Napier grass.

The DM yield of Rhodes grass was positively correlated ($p<0.05$) with CPY, NDF, ADF, and ADL and some morphological parameters, but it was negatively associated with LSR. Increases in DMY, a few morphological characteristics, and fiber content might be associated with harvesting stages. The positive association of DM yield with some of the morphological parameters (PH, LLPP, and NLPP) is similar to Biniyam *et al.* (2018).

The crude protein content of Rhodes grass was negatively correlated with all fiber contents (NDF, ADF, and ADL). This indicated that the cell wall contents contributed to the increment of plant parts, which eventually led to a decrease in total crude protein content (CP). The positive relationship between CP content and IVDMD, IVOMD, ME, and ash content might be due to the to the high crude protein concentration obtained at the early harvesting stage with the application of different fertilizer types. Similarly, IVDMD, IVOMD, ME, ash content, and crude protein content are related to the quality and digestibility of feed parameters.

Ash content was positively correlated ($p<0.05$) with IVDMD, IVOMD, ME, while negatively correlated with fiber components, and DM yield. The fiber components of Rhodes grass, NDF, ADF, and lignin (ADL), were positively correlated with each other‘s. This indicated that there was a high relationship among the different cell wall contents. In vitro dry matter digestibility, LSR, CP, IVOMD, and ME were positively correlated (p<0.0001) with each other’s, while negatively correlated with other parameters.

Table 8: Correlation coefficient among agronomic performances, biomass yields, chemical composition, and in vitro digestibility of Rhodes grass

	DMY	CPY	CP	Ash	NDF	ADF	ADL	PH	NTPP	NLPP	LSR	IVDMD	IVOMD	ME
DMY	1	0.99***	-0.82***	-0.60**	0.58***	0.69***	0.83***	0.81***	0.78***	0.81**	-0.83*	-0.61***	-0.50**	-0.50**
CPY		1	-0.75***	-0.53***	0.51***	0.61***	0.77***	0.85***	0.81***	0.81***	-0.76*	-0.54***	-0.44**	-0.44**
CP			1	0.83***	-0.84**	-0.88**	-0.92**	-0.46**	-0.44**	-0.57**	0.93***	0.84**	0.78**	0.79**
Ash				1	-0.78**	-0.85	-0.78	-0.29	-0.27 ns	-0.36**	0.75***	0.75**	0.76**	0.76**
NDF					1	0.85**	0.79**	0.22 ns	0.20 ns	0.27 ns	-0.73*	-0.84**	-0.77**	-0.77**
ADF						1	0.82*	0.41*	0.42*	0.48*	-0.86*	-0.81**	-0.76*	-0.76*
ADL							1	0.47***	0.47**	0.57**	-0.87*	-0.81**	-0.76**	-0.76**
PH								1	0.89**	0.86**	-0.55*	-0.17 ns	-0.084 ns	-0.08 ns
NTPP									1	0.87*	-0.57*	-0.18 ns	-0.09 ns	-0.09 ns
NLPP										1	-0.70*	-0.20ns	-0.13 ns	-0.13 ns
LSR											1	0.70***	0.63***	0.63***
IVDMD												1	0.93***	0.93***
IVOMD													1	0.99***
ME														1

*Level of significance:**=p<0.01;*=p<0.05; ***=p<0.001; DMY=dry matter yield; CP=crude protein%; Ash=ash%;IVDMD=In vitro dry matter Digestibility; IVOMD=In vitro-organic matter digestibility, ME=Metabolizable energy yield; NDF=neutral detergent fibre%; ADF=acid detergent fibre%; ADL=acid detergent lignin%; LLPP=leaf length per plant; NTPP=number of tiller per plant; NLPP=number of leaf per plant; PH=plant height; LSR=leaf to stem ratio*; *CPY= crude protein yield.*

4.6. Partial Budget Analysis

The economic analysis result has been shown in Table 9. The result indicated that the highest benefit-cost ratio and net-benefit was obtained from 50 Kg/ha NPS: 2,500kg farmyard manure/ha applied at 120 days of harvesting stage gave the highest benefit cost ratio (1.86) while control group (0 Kg/ha fertilizer application) at 60 days of harvest gave the least (1.11) benefit-cost ratio with (1466.25 birr) net-benefit. A recommendation was determined by comparing the benefit-cost ratio of a therapy modification to the minimum benefit-cost ratio and then switching to the other treatment. Nevertheless, it was clear from the results that treatment receiving 50 Kg/ha NPS + 2,500 kg farmyard manure/ha at 120 days of harvest were more profitable than the other treatment combinations. All of the treatments with positive benefit-cost ratios were advantageous from an economic perspective.

Table 9: Partial budget analysis on per hectare basis of Rhodes grass as affected by fertilizer type and harvesting stage

Treatment	TVC	TFC	TC	GI	NB	BCR
Ft1 × H1	0	12900	12900	14366.25	1466.25	1.11
Ft1× H2	0	17250	17250	25042.5	7792.5	1.45
Ft1 × H3	0	19400	19400	32175	12774.99	1.66
Ft2 × H1	3250.45	12900	16150.45	20711.25	4560.80	1.28
Ft2 × H2	3250.45	17250	20500.45	33345	12844.55	1.63
Ft2× H3	3250.45	19400	22650.45	42153.75	19503.3	1.86
Ft3 × H1	4850.9	12900	17900.9	19946.25	2195.35	1.12
Ft3× H2	4850.9	17250	22250.9	33963.75	11862.85	1.54
Ft3 × H3	4850.9	19400	24400.9	41872.5	17621.60	1.73
Ft4× H1	1800	12900	15100	16953.75	2253.75	1.15
Ft4 × H2	2200	17250	19450	28203.75	8753.75	1.45
Ft4 × H3	2400	19400	21800	37282.5	15482.50	1.71

TFC=Total fixed cost, TVC=Total variable cost, TC=Total cost, GI=Gross income, NB=Net benefit, BCR=Benefit cost ratio; Ft=fertilizer type; H=harvesting stage

5. SUMMARY AND CONCLUSION

The result of the experiment pointed out that most of the morphological parameters, above-ground biomass yield, chemical composition and dry matter digestibility of Rhodes grass were significantly affected by the effects of fertilizer type and harvesting days.

The study concluded that the application of 50kg NPS fertilizer mixed with 2,500kg farmyard manure/ha yielded the maximum forage biomass yield, agronomic performances, and nutritional value (CP and ash, IVDMD) of Rhodes grass, whereas the application of 50 kg NPS + 2500kg farmyard manure/ha fertilizer produced the lowest NDF, ADF, and ADL. The sole inorganic fertilizer (NPS) and farmyard manure were used in the order of priority to produce the highest dry matter yield, better nutritional value, and good digestibility of Rhodes grass. Application of combined NPS with farmyard manure fertilizer increased the height of the plants, their number of leaves per plant, the number of tillers per plant, the dry matter output, and the chemical composition of the Rhodes grass when compared with others fertilizer types. Generally, the results obtained from a combination of NPS and farmyard manure and sole NPS fertilizer application showed no significant difference in most parameters.

The analysis showed that the highest plant height, leaf length per plant, number of leaves per plant, and number of tillers per plant, crude protein yields, and NDF, ADF, and ADL were recorded from late harvesting stages. The maximum DMY and CPY was also found in the grasses harvested as they matured; however, the crude protein, leaf steam ratio, IVDMD, IVOMD, and ME declined as the harvesting stage increased. The partial budget analysis confirms that the treatment applying 50 kg NPS mixed with 2,500kg farmyard manure/ha harvested at 120 days had the highest benefit-cost ratio and net benefit per harvest, while the control group harvested at 60 hays of harvest had the lowest benefit-cost ratio. All of the treatments with positive cost-benefit ratios were advantageous from an economic perspective.

6. RECOMMENDATIONS

From the present study, the following points are recommended;

- The application of integrated use of farmyard manure and inorganic fertilizer can be best recommended in equal proportion, specifically in 2,500kg FYM with 50kg NPS for improvement of agronomic performance, biomass yield, and nutritional quality, as well as the economic feasibility of grass. 90 days of harvest could be used to enable the production of *Chloris Gayana K.* grass with an optimal dry matter yield and a moderate nutritional value.
- Further research is needed on different types and percentages of organic-inorganic fertilizer mixtures in different agro-ecological zones under different rainfall and irrigation conditions within different harvesting stages and frequencies, and the cost-benefit and environmental impact of different fertilizer types are also needed to be verified.
- As the grass is relatively good in terms of biomass yield, chemical composition and digestibility, animal performance evaluations should be the area of future research.

7. REFERENCES

Abdi H. (2014). Effect of nitrogen fertilizer application on agronomic traits, biomass yield and nutritive value of Buffel grass and *Panicum maximum* grown under irrigation at Gode, Somali Region. MSc Thesis. Haramaya University, Ethiopia, 42p.

Adugna, T. Alemu, Y. and Dawit, Al. (2012). Livestock feed resources in Ethiopia: challenges, opportunities and the need for transformation.

Agza, B., Binyam, K., Solomon, Z., Eskinder, A., Ferede, A. (2013). Forage yield and nutritive value of natural pastures at varying levels of maturity in North west Lowlands of Ethiopia. World J. Agric. Sci. **1(3):**106-112.

Ahmed, AH. Wahid, A. Khalid, F. Fiaz N. and Zamir, M.S.I. (2011). Impact of organic and inorganic sources of nitrogen and phosphorus fertilizers on growth, yield and quality of forage Oat (*Avena sativa L.)* Cercetari Agronomic in Moldova. 39 - 49.

Alemayehu M. & Getnet A., (2012). The evolution of forage seed production in Ethiopia: Forage Seed Research and Development in Ethiopia, Ethiopian Institute of Agricultural Research,pp: 15-32

Alemayehu M. (2012). Keynote address. In: Getnet Assefa, Mesfin Dejene, Jean Hanson, Getachew Anemut, Solomon Mengistu And Alemayehu Mengistu (eds), Forage seed research and development in Ethiopia. Ethiopia institute of agricultural research, Addis Ababa, Ethiopia. Pp 3-5.

Alemayehu, M. Gezahagn, K. Fekede, F. and Getnet, A. (2017). Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities. Academic Research Journal of Agricultural Science and Research Vol. **5(3)**, pp. 176- 185

Almaz, M. (2016). Integrated Nutrient Management for Maize-Soybean Cropping System, PhD Dissertation, University of Putra Malaysia, 192

Anderson, N.P., Hart, J.M., Horneck, D.A., Sullivan, D.M., Christensen, N.W. and Pirelli, G.J. (2010). Evaluating soil nutrients and pH by depth in situations of limited or no tillage in western Oregon.

Ansah, T., Osafo, E. L. K and Hansen H. (2010). Herbage yield and chemical composition of four varieties of Napier (*Pennisetum purpureum*) grass harvested at three different days after planting. Agric. Biol. J. N. Am., 1 (5): 923-929.

Anteneh, G. Bimrew, A. and Yeshambel, M. (2022). Effects of Fertilizer Type on Morphological Characterstics, Forage Yield, Seed Yield and Qualities of Rhodes Grass (*Chloris gayana K.*) in North-western Ethiopia. Anim Sci and Bio, **55 (1).**

AOAC (1995). Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Arlington, VA.

Aranguiz, A.A. and Creemers, J.J.H.M. (2019). Quick Scan of Ethiopia's Forage Sub-Sector: Netherlands East African Dairy Partnership (NEADAP) Working Paper.

Arshad I. (2015). Performance of different Rhodes grass varieties under the agro climatic conditions of sindh, Pakistan. International journal for research in applied science and engineering technology. 267-273.

Awoke, K. Berhanu, A. Alemu T. (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. Vol. 9, No. 4, pp. 113-121.

Baghdadi, A. Halim RA., Ghasemzadeh A., Ramlan MF. and Sakimin SZ. (2018). Impact of organic and inorganic fertilizers on the yield and quality of silage corn intercropped with soybean. University of Putra, Malaysia. Peerj 6:5280.

Bashe, A. Bassa, Z. and Tyohannis, S. (2018). The determinants of probability in improved forage technology adoption in Wolaita zone: The case of Sodo Zuria district, Southern Nations and Nationalities Peoples state of Ethiopia. Open Access Journal of Science, **2(4)**, 228-231.

Bell M.J., Bridge B.J., Harch G. R., Want P. S., Orange D.N. and Connolly R. D. (2001). Soil structure affects water balance of ferrosol cropping systems, proceedings of the Australian agronomy Conference, Australian society of agronomy, Australia.

Beshir, H. (2014). Factors affecting the adoption and intensity of use of improved forages in north east highlands of Ethiopia. American journal of experimental agriculture.

Beyadglign H. (2019). Effects of Fertilizer and Soil Types on Different Cultivars of Brachiaria Species Biomass Yield and Quality and Farmers'perception in West Gojam Zone, Ethiopia (MS.c. thesis).

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

Bimrew A., Demeke S., Tolemariyam T., Tegegne F., Haile A., Jane W. (2017). Effects of altitude and harvesting dates on morphological traits, yield and nutritive value of Desho grass (*Pennisetum pedicellatum Trin.)* in Ethiopia Agriculture and Natural Resources **51 (3)**: 148–153.

Biniyam, M. Bimerew, A. and Yeshambele M. (2018). Effect of fertilizer type and plant spacing on plant morphological characteristics, yield and chemical composition of desho grass (*Pennisetum pedicellatum trin.*). M.Sc thesis, BahirDar University, in North-western Ethiopia. Agricultural science and technology Vol. 10, pp 107-114.

Butt N. M., Donart G. B., Southward M. G., Pieper R. D., Mohammad N. (1993) Effect of defoliation on plant growth of Napier grass Tropical Science 33:101–120.

Caddel J, Allen E. (2010). Forage quality interpretations.

Cameron A. G., Lemcke B. (2008) Para grass: a pasture grass for wet and flooded soils, no. E30.

Campos, F. P., Sarmento, P., Nussio, L. G., Lugão, S. M. B., Lima, C. G., and Daniel, J. L. P. (2013). Fiber monosaccharides and digestibility of Milenio grass under N fertilization. Animal Feed Science and Technology, **183(1-2)**, 17-21.

CASCAPE (2015). Capacity building for Scaling up of evidence-based practices in Agricultural Production in Ethiopia.

CSA (Central Statistics Agency) (2020). Agricultural sample survey Livestock and livestock characteristics (private peasant holding), Ethiopia. Stat. Bull.585: 2.

CSA (2018). Agricultural sample survey. Volume II report on livestock and livestock characteristics, Federal Democratic Republic of Ethiopia, Central Statistical Agency; Statistical bulletin number 587.

CIMMYT (International Maize and Wheat Improvement Center) (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition (Mexico).

Cook BG, Pengelly BC, Brown SD, Donnelly JL, Eagles DA (2005). Tropical Forages: an interactive selection tool, [CD-ROM], CSIRO, DPI&F (Qld), CIAT and ILRI, Brisbane, Australia.

CSA (Central Statistical Agency) (2021) Agricultural sample survey. Volume ii. Report on livestock and livestock traits. Addis Ababa, Ethiopia

Datt, C. Datta, M. S. N. P. and Singh, N. P. (2008). Assessment of fodder quality of leaves of multipurpose trees in subtropical humid climate of India. Jour of F R, **19(3)**, 209-214.

Dawit, A. Ajebu, N. and Sandip B. (2013). Assessment of feed resource availability and livestock production constraints in selected Kebeles of Adami Tullu Jiddo Kombolcha District. African Journal of Agricultural Research, **8(29).**

Dawit, A. and Teklu, W. (2014) Determination of Optimum Seed and Fertilizer Rate for Fodder Oat in Bale Highland South Eastern Ethiopia. In J of Soil and Crop Sci **2(7).**

Dawit, B. Yeshambel, M. Bimrew, A. (2024). Effects of Seed Rate and Harvesting Stage on Agronomic Performance and Quality Traits of Rhodes Grass (*Chloris gayana K.*) in Northwestern Ethiopia. Journal of Rangeland Sci. Vol 14, Issue 1, 142402 (1-12).

Delevatti LM, Cardoso AS, Barbero RP, Leite RG, Romanzini EP, Ruggieri AC, Reis RA. (2019). Effect of nitrogen application rate on yield, forage quality, and animal performance in a tropical pasture. Sci Rep **9 (1)**: 1-9.

DePeters E. (1993) Forage quality and its implications. In proceedings of the 23rd California alfalfa symposium at fresno, California, USA Department of Agronomy and Range Science Extension, 93–146.

Dereje, D. Debela, K. Wakgari, K. Zelalem, D. Gutema, B. Gerba, L. (2013). Rainwater management for resilient livelihoods in Ethiopia. Proceedings of the Nile Basin Development Challenge science meeting, Addis Ababa. NBDC Technical Report 5. Nairobi, Kenya: International Livestock Research Institute.

Diribi, M. (2022). Effect NPS fertilizer and harvesting stage on agronomic performance and nutritional quality of Bracharia grass under supplementary irrigation at Wondogenet, Southern Ethiopia. MSc. Thesis. Ambo University, Ethiopia.

Ecocrop. (2010). Ecocrop database. FAO. http://ecocrop.fao.org/ecocrop/srven/home. (Accessed 02 February 2015).

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.

Etsubdink T. (2014). Forage seed systems in Ethiopia: A scoping study. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

FAO (2009). Rhodes grass (Chloris gayana Kunth). Food and Agricultural Organization of the United Nations (FAO).

FAO (2012). Food and agriculture organization of the United Nations, Improving grazing land in Ethiopia.

FAO (2014). Grass land Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy.

FAO (2018). Ethiopia: Report on feed inventory and feed balance, 2018. Rome, Italy. 160pages. License: CC BY-NC-SA 3.0 IGO.

Fekadu, N. Zewdu, K. Tessema and Abule E. (2017). Effect of organic and inorganic fertilizer application on improvement of degraded grazing land in the central highland of Ethiopia. M.Sc thesis, Haramaya University, Ethiopia. Livestock Research for Rural Development **29(3)**.

Fekede ,F. Getu, K. and Getnet, A. (2015). Nutritional Qualities of Agro-Industrial By-Products and Local Supplementary Feeds for Dairy Cattle Feeding. Ethiopian journal of agricultural science. 26: 13-26.

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.

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 (2017) Vol. **5(2)**:77–84.

Getahun, W. Bimrew, A. Yeshambel, M. (2021) Effects of Fertilizer Types on the Agronomic, Forage Yield and Nutritional Value of Forage Oat Accessions in the Highlands of Ethiopia. Animal Science and Biotechnologies, **54 (1).**

Getnet A. and Gezagne K. (2012). Seed research and development of perennial forage crops in the central highlands. Forage Seed Research and Development in Ethiopia.95- 109.

Getnet Assefa. (2012). Retrospects and prospects of forage and pasture crop research in Ethiopia. In: Getnet Assefa, Mesfin Dejene, Jean Hanson, Getachew Anemut, Solomon Mengistu And Alemayehu Mengistu (eds), Forage seed research and development in Ethiopia. Ethiopia institute of agricultural research, Addis Ababa, Ethiopia. Pp 7-14.

Getnet, A. Solomon M. Seyoum B. and Fekede F. (2016). Animal feed resources research in Ethiopi. Achievements, challenges and future direction. Ethiopian journal of agricultural sciences. 1:141-55.

Ghimire S., Donald N., Mupenzi M., Juan C., Linda Johnson Elias Gichangi, Suliana T., Kennedy O., John Caradus, I. Rao and Appolinaire D. (2015). Climate-smart Brachiaria for improving livestock production in East Africa: Emerging opportunities.

Ghiwot W. (2019). Effect of Harvesting Stage on Yield and Nutritive Value of Buffel Grass (*Cenchrus ciliaris linn*) Under Irrigation at Gewane District, North Eastern Ethiopia. Journal of Scientific and Innovative Research 2019; **8(1)**: 7-12

Gibbs Russell G.E., Watson L., Koekemoer M., Smook L., Barker N.P., Anderson H.M. and Dall-witz. M.J. (1990). Grasses of southern Africa. Mem Botany survey and science Africa 58. Botanical research institute, Pretoria, South Africa. Grasses of southern Africa (No. 58).

Gilbert M.A. and Clarkson, N.M. (1993). Effect of nitrogen fertilizer strategies for tropical beef and dairy production using summer rainfall and SOI analysis. Summaries of the papers presented at international grasslands congress, Hamilton, New Zealand. Pp 24.

HARC (Holetta Agricultural Research Center) (2004). Feed resources development and utilization possible options and recommendations under Ethiopia condition

Hassen, A., Tessema, Z., Mengistu, U., Sisay, F. (2015). Effect of nitrogen fertilizer application on Agronomic traits, biomass yield and nutritive Value of cenchrus ciliaris and panicum maximum grown under irrigation at gode, Somali region, J. Nutr. Food Sci.

ILRI (International Livestock Research Institute). (2013). Rhodes grass (Chloris gayana) for livestock feed on small-scale farms. Fact sheet.

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.

Kebede G, Faji M, Feyissa F, Mengistu G, Kehaliew A, Mohammed K, Dejene M, Geleti D, Minta M, Balehegn M, Boote KJ, Dubeux JCB Jr and Adesogan AT (2024). Productivity and economic feasibility of cultivated forage and food crops in the central highlands of Ethiopia. Front. Anim. Sci. 5:1338621.

Kellems, R. O., Church, D. C., Livestock Feeds and feeding (4th edition.) (1998). Prentice-Hall, Inc. New Jersey, USA, p. 573.

Luna C., De Luca M. and Taleisnik. E. (2002). Physiological causes for decreased productivity under high salinity in Boma, a tetraploid Chloris gayana cultivar. II. Oxidative stress. Australia journal of agricultural research. 53: 663-669.

Mabu Isa.M., Galadima D., Musa and Sani Usman B. (2019). Effect of nitrogen fertilization and spacing on chemical composition of Rhodes grass (*Chloris gayana tan*) in dry sub humid zone of Sokoto, Nigeria. Asian journal of advanced research and reports.

Malede B. and Takele A. (2014). Livestock feed resources assessment, constraints and improvement strategies in Ethiopia. Middle-East J of Scientific Research, **21 (4)**: 616-622.Management in the Ethiopian Highlands. Working Paper 2002-04.

Mannetje, L. T. and Kersten, S.M.M. 1992. *Chloris gayana* Kunth. In Mannet je L. and Jones R.M. plant resources of South-East Asia No 4. Forages. Pudoc-DLO Wageningen, the Netherlands. 90-92.

Mathison, G. W., Okine, E. K., Vaage, A. S., Kaske, M., and Millingan, L. P. (1995). Current understanding of the contribution of the propulsive activities in the fore stomach to the flow of digesta. Proceedings of the eighth International Symposium on Ruminant Physiology, Berlin. Herstellung: Schröders, Agentur, D-14199, Berlin, pp, 23 41

McDonald PR, Edwards A, Greenhalgh JF, Morgan CA (1995). Animal Nutrition, 5 th edition, Longman, United Kingdom.Minitab Inc. Minitab Statistical Software for Windows Release 12, 1998, Minitab Inc. State College, PA., USA.

McDonald, Edwards PR, Green Halgh JFD, Morgon CA. (2002). Animal nutrition 6th (ed). Longman Group UK Ltd, England; 693p.

McDonald, P., Edwards, R. A, Greenhalgh, J. F. D., Morgan, C. A. (2010). Animal Nutrition 7th ed. Longman Group UK Ltd, England, pp. 693.

McDonald, P., R. A. Edwards and J. F. D. Greenhalgh. (1988). Animal Nutrition, fourth (ed).

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.

Melese, W., Assefa, A., and Dehninet, K. (2018). Improved forage production practice and challenges in Libokemkem District, Ethiopia. Agricultural Science Digest-A Research Journal, **38(4)**, 280-284.

Mergia A. (2021). Production Status, Biomass Yield under Different Management Practices and Nutritional Values of Desho grass (*Pennisetum Pedicellatum*) In Southern Ethiopia. PhD Dissertation, Hawassa University

Mimila Z., Yeshambel M., Bimrew A. (2020). Effect of Plant Spacing and Harvesting Age on Plant Characteristics, Yield and Chemical composition of Para grass (*Brachiaria mutica*) at Bahir Dar, Ethiopia. Scienti Papers Anim Sci and Bio, **53(2)**, pp.137-145.

Miraeoh, Heeok Hong, Hong Liang Li, Byong Tae Jeon, Cheong Hee Choi, Yu Ling Ding, Yu Jiao Tang, Eun Kyung Kim, Se Young Jang, Hye Jin Seong, and Sang Ho Moon. (2016). Effects of Physically Effective Neutral Detergent Fiber Content on Intake, Digestibility, and Chewing Activity in Fattening Heifer Fed Total Mixed Ration.v.29

MoA (Ministry of Agriculture) (2013). Crop Variety Register Issue No.16. Plant Variety Release, protection and seed quality control directorate. Addis Ababa, Ethiopia.

Muluye F. (2019). Improved Forage Production in Ethiopia: Utilization, Challenges and Prospects for Adoption: A Review. Journal of Biology, Agri. and Healthcare. 9: 1-7.

Nebi, H. Tessema, Z. and Melkamu, D. (2019). Effects of different sources of fertilizer application on species composition, herbage yield, nutritional quality and soil fertility of degraded grazing lands in central rift valley of Ethiopia. Msc Thesis Haramaya University Addis Ababa, Ethiopia. Pp.72.

Negasu, Y. Yeshambel, M. and Bimrew, A. (2020). Effects of Fertilizer Types and Plant Spacings on Plant Morphology, Biomass Yield and Chemical Composition of *Brachiaria Hybrid Mulato* II Grass Grown in Lowlands of Northwest Ethiopia. Msc Thesis Bahir Dar University, Ethiopia. Animal Sci and Biotechnologies. **53(1).**

Nemera, F. Zewdu TK and Ebro, A. (2016). Effect of organic and inorganic fertilizer application on improvement of degraded grazing land in the central highland of Ethiopia. Livestock Research for Rural Development, 3, 29.

Nguku, S., Musimba, N., Njarui, D., Mwobobia, R. and Kaindi, E. (2016). Effects of Acid Scarification on germination of the genus Brachiaria grass Cultivars. International J Sci Res Innov Technol, 3, 45-50.

Norton (1982). Differences between species in forage quality. In: Hacker JB (eds), Nutritional limits to animal production from pastures. Farnham Royal: Commonwealth Agricultural Bureaux. pp 89–110.

Owen, E. and M.C.N. Jayasuriya. (1989). Use of crop residues as animal feeds in developing countries: areview. Research and Development in Agriculture, **6(3)**: 129-138.

Pinkerton, B. (2005). Forage quality. Clemson University Cooperative Extension Service. Forage fact sheet 2. Cooperative Extension Service, Clemson University

Priyadarshani, N. D. A., Amarasinghe, M. K. T. K., Subasinghe, S., Palihakkara, I. R., Kumarasinghe, H. K. M. S. (2013). Effect of organic and inorganic fertilizers on biomass production, oil yield and quality of vetiver (*Vetiveria zizanioides*), Journal of Agricultural Sciences, 8, 1.

Rambau MD, Fushai F, Baloyi JJ. (2016). Productivity, chemical composition and ruminal degradability of irrigated Napier grass leaves harvested at three stages of maturity. South Afr J Anim Sci **46 (4)**: 398-408.

Ranjhan SK (1993). Animal Nutrition in the Tropics (3rd ed). Vikas Publishing House Pvt. Ltd., New Delhi.

Sahlemedhin S, Taye B. (2000). Procedures for soil and plant analysis. National Soil Research Center, EARO, Technical Paper NO. 74. Addis Ababa, Ethiopia. p. 110.

SAS. Statistical Analysis System, User's Guide. Statistical. Version 7th ed. SAS. Inst. Inc. Cary. N.C. USA. 2004.

Schoebitz, M., Vidal, G., 2016. Microbial consortium and pig slurry to improve chemical properties of degraded soil and nutrient plant uptake. Journal of soil science and plant nutrition, 16(1), 226-236

Schroeder, J. (2012). Interpreting Forage Analysis. North Dakota: NDSU Extension Service

Scott Trimble (2019). The Importance of Leaf Area Index (LAI) in Environmental and Crop Research. 1-360-833-8835.

Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., and Mechal, H. (2015). Ethiopia livestock master plan. ILRI Project Report. *International Livestock Research Institute (ILRI), Nairobi*.

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.

Shimelis M. (2018). Assessment of forage production, feed resource utilization and substitution effect of oat-vetch forage for concentrate mix on performance of sheep fed desho grass as a basal diet in Damote Gale District of Wolaita Zone, SNNPR (Doctoral dissertation, Hawassa University).

Simachew F. (2016). Impact of urea rate and cutting days on biomass and nutritive value of blue panic grass (*Panicum anti dotal Retz*) under irrigation at Gewane district, Afar. MSc. Thesis. Hawassa, University, Ethiopia; 89p.

Singh, G. P., and Oosting, S. J. (1992). A model for describing the energy value of straws. Indian Dairyman XLI: 322-327.

Solomon M. (2001). Evaluation of selected multipurpose trees as feed supplements in tef (*Eragrostis tef*) straw based feeding of Menz sheep. PhD. dissertation. Humboldt University, Berlin, Germany. 88p.

Solomon M., Kurt J. Peters, Azage T. (2004). Feed intake, live weight gain and reproductive performance of Menz ewes supplemented with Lablab purpureus, graded levels of Leucaena pallida 14203 and Sesbania sesban 1198. Livestock Production Science 87(1): 131-142.

Tebeje B. E., Gilo B. N., Kawo S. T., Liban J. D. (2014). Effect of reseeding of Rhodes grass on the restoration of degraded rangeland of Borana, Southern Ethiopia Direct Research Journal of Agriculture and Food Science **2(7)**: 102–106.

Terefe T., Tessema Z. and Mengistu U. (2017). Effects of nitrogen fertilizer and harvesting days on yield and quality of Rhodes grass (*Chloris gayana*) under irrigation at gewanne, eastern, Ethiopia. Msc thesis, Haramaya University. Pp 1-80.

Tesfaye, A. Girma, C. Daniel, W. Dawit, A. (2020). Effect of Different Levels of Cattle Manure on Biomass, Seed Yield and Crude Protein Content of Rhodes Grass. Journal of Natural Sciences Research. Vol.10, No.9.

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.

Tessema, Z., Baars, R., Alemu, Y. (2002). Effect of plant height at cutting, source and level of fertilizer on yield and nutritional quality of Napier grass (*Pennisetum purpureum (L.) Schumach*). Afr. J. Rang. Forag. Sci. 19, 123e128.

Thomas RL, Sheard RW, Moyer JP. (1967). Comparison of conventional and automated procedures for nitrogen, phosphorus, and potassium analysis of plant material using a single digest. Agron J.;59:240–3

Tilley J.M.A. and Terry R.A. (1963). A two-stage technique for the in-vitro digestion of forage crops. Journal of British Grassland Society **18(1)**: 104-111.

Trivedi BK (2010) Grasses and Legumes for Tropical Pasture. Indian agricultural research institute, India.

Ullah, M. A., Anwar, M and Rana, A. S. (2010). Effect of nitrogen fertilization and harvesting intervals on the yield and forage quality of elephant grass (pennisetum purpureum) under mesic climate of pothowar plateau. Pak. J. Agri. Sci., 47 (3), 231-234.

Valenzucla, H. and Smith, J. (2002). Rhodes grass, sustainable Agriculture, cover crops/SA-CC3. Cooperative Extension Service, collage of tropical agriculture and human resources. University of hawaii at Manoa.

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.

Wangchuk K., Rai K., Nirola H., Dendup C., Mongar D. (2015) Forage growth, yield and quality responses of Napier hybrid grass cultivars to three cutting inter vals in the Himalayan foothills Tropical Grasslands Forrajes Tropicales 3 (3): 142–150.

Wassie, W. A. Tsegay, B. A., Wolde, A. T., and Limeneh, B. A. (2018). Evaluation of morphological characteristics, yield and nutritive value of Brachiaria grass ecotypes in northwestern Ethiopia. Agriculture & Food Security, **7(1),** 1-10.

Werer Agricultural Research Center (WARC) (2014). Forage and Pasture research program progress report. Werer, Ethiopia.

Worku B., Denbela H., Tyohanis 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.

Wubetie A. (2019). Evaluation of Utilization Status, Agronomic Performance and Nutritive Value of Brachiaria (Hybrid, Cultivars and Ecotypes) Grass in Ethiopia.

Wubetie A., Berhanu A., Asaminew T., and Bimrew A. (2018). Evaluation of morphological characteristics, yield and nutritive value of Brachiaria grass ecotypes in northwestern Ethiopia. Agriculture & Food Security, **7(1)**, pp.1-10.

Yasin, M., Malik M.A., Nazir M.S. (2003). Effect of different spatial arrangements on forage yield, yield components and quality of Mott Elephant grass. Pakistan Journal of Agronomy 2(1): 52-58.

Yenesew A., Molla T., Shiferaw D., Mekonen T., Yihenew G., Agraw A., and Dessalegn M. (2015). Best fit practice manual for Rhodes grass (*Chloris gayana*) production. Capacity building for scaling up of evidence-based practices in agricultural production in Ethiopia. BahirDar University-CASCAPE Working. Paper, 10.

Yeshitila A. (2008). Efficiency of livestock feed resources utilization and forage development in Alaba Woreda, Southern Ethiopia. MSc. Thesis, Haramaya University, Dire Dawa Ethiopia. 128p.

Yibeltal, E. Berhanu, A. and Shashe, A. (2021). Effects of Fertilizer Type and Grass Species on Agronomic Performances and Chemical Composition in Gozamin District, East Gojjam Zone, Ethiopia. American J of Env and Resource Economics; **6(4)**: 103-110.

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.

Yoseph, M. Mengistu, U. Mohammed Y. Kurtu and Merga B. (2010). Effect of harvesting stage on yield and quality of natural pasture in the central high lands of Ethiopia. In: Proceedings of 3rd national conference of the Ethiopian society of animal production.27-29, April 1995. pp.316-322. Addis Ababa, Ethiopia.

Yossif A. M. and Yassin I. M. (2013). Effect of fertilizers (urea, farmyard and chicken manure) on growth and yield of Rhodes grass (*chloris gayana L. kunth*). Agronomy department, faculty of agricultural studies, Sudan University of science and technology Khartoum, Shambat, Sudan. Universal jour. of plant sci.: 1:137-140.

Zereu, G., and Lijalem, T. (2016). Status of improved forage production, utilization and constraints for adoption in Wolaita Zone, Southern Ethiopia. Livestock research for rural development, **28(78)**.

Zewdie W. and Yoseph M. (2014). Feed resources availability and livestock production in the Central Rift Valley of Ethiopia. International Journal of Livestock Production.

8. APPENDEX

List of appendix tables

Appendix table 1: Mean square of ANOVA for Agronomic Performance of Rhodes grass affected by fertilizer type, harvesting stage, and their interactions

Source	**DF**	**Mean square**				
		PH	NTPP	NLPP	LLPP	LSR
Rep	2	124.77*	9.76^{ns}	91.23111^{ns}	33.45*	0.0021 ^{ns}
FT	3	1308.61***	65.61**	2673.09**	252.18**	0.013*
HD	2	2632.3***	165.63**	11998.36***	599.44**	0.625***
FT*HD	6	72.03*	9.65*	115.4*	10.69^{ns}	0.0014
Error	22	21.68	3.02	44.05	11.22	0.0031
Total	35					
CV (%)		5.08	3.0274747	7.63	10.7	5.4

***, ns= Significant and non-significant (p<0.05); DF=degree of freedom; CV = coefficient of variation; PH=plant height; NTPP=number of tillers per plant; NLPP=number of leaves per plant; LLPP leaves length per plant; LSR=Leaf to stem ratio; Rep=Replication; HD=harvesting day; FT=fertilizer type*

Appendix table 2: Mean square of ANOVA for yields of Rhodes grass affected by fertilizer type harvesting age, and their interactions

Source	**DF**	**Mean square**	
		DMY	**CPY**
Rep	2	0.074^{ns}	0.00065^{ns}
FT	3	12.27***	0.178***
HD	2	110.69***	0.721***
FT*HD	6	0.28^{ns}	0.0031^{ns}
Error	22	0.163	0.0016
Total	35		
CV (%)		4.73	4.66

***, ns= Significant and non-significant (p<0.05); DF=degree of freedom; CV = coefficient of variation; DMY=dry matter yield; CPY=crude protein yield; Rep=Replication; HD=harvesting day; FT=fertilizer type*

Appendix Table 3: Mean square of ANOVA for chemical composition of Rhodes grass affected by fertilizer type harvesting stages, and their interactions

Source	DF	Mean square					
		DM	CP	Ash	NDF	ADF	ADL
Rep	2	0.09^{ns}	0.012^{ns}	0.50^{ns}	1.46^{*}	0.108^{ns}	0.103^{ns}
FT	3	0.53^{*}	0.68^{**}	2.45^{**}	14.66^{**}	3.98^{***}	0.56^{**}
HD	2	2.61^{***}	8.29^{***}	7.65^{***}	37.61^{***}	19.79^{***}	9.18^{***}
FT*HD	6	0.218^{ns}	0.028^{*}	0.54^{**}	3.87^{**}	0.72^{**}	0.064^{ns}
Error	22	0.164	0.0108	0.114	0.35	0.177	0.085
Total	35						
CV (%)		0.34	1.01	3.61	1.02	1.11	3.0

***, ns= Significant and non-significant (p<0.05); DF=degree of freedom; CV = coefficient of variation; DM=dry matter; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent lignin; Rep=Replication; HD=harvesting day; FT=fertilizer type*

Appendix table 4: Mean square of ANOVA for In-vitro digestibility of Rhodes grass affected by fertilizer type harvesting stages, and their interactions

Source	DF	Mean square		
		IVDMD	**IVOMD**	**ME**
Rep	2	0.08^{ns}	0.42^{**}	0.0096^{**}
FT	3	4.40^{**}	7.62^{***}	0.1715^{**}
HD	2	11.62^{***}	11.4^{***}	0.2567^{***}
FT*HD	6	0.019^{ns}	0.027^{ns}	0.000613^{ns}
Error	22	0.066	0.023	0.00052
Total	35			
CV (%)		0.481	0.284	0.28

***, ns= Significant and non-significant (p<0.05); DF=degree of freedom; CV = coefficient of variation; IVDMD=In vitro dry matter digestibility; IVOMD=in vitro organic matter digestibility; ME=Metabolizable energy; Rep=Replication; HD=harvesting day; FT=fertilizer type*

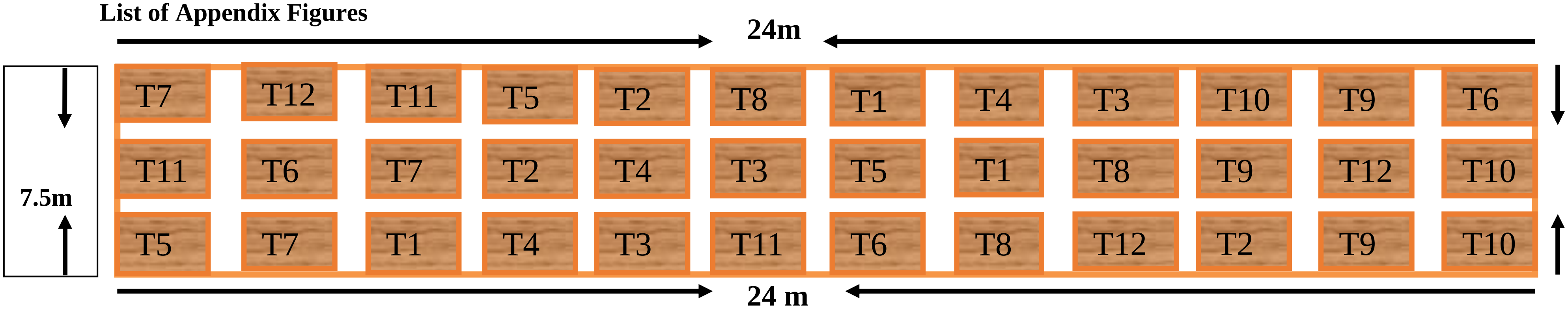
Appendix table 5: Climate data of growing season of study area.

Months	Maximum temperature	Minimum temperature	Average temperature	Rainfall (mm)
January	36.84	15.04	25.94	143.1
February	35.3	15.09	25.195	120.5
March	31.88	15.41	23.645	248.8
April	31.42	15.17	23.295	164.1
May	31.22	15.14	23.18	299.6
June	30.93	15.51	23.22	380.3
July	30.34	15.4	22.87	380
August	31.13	15.43	23.28	425.6
September	31.46	15.5	23.48	578.6
October	27.75	12.96	20.355	126.2
November	29.46	11.76	20.61	100.8
December	28.54	11.51	20.025	51.8

Source: National metrology service Jimma, Ethiopia.

Appendix Figure 1: Experimental Design Setup

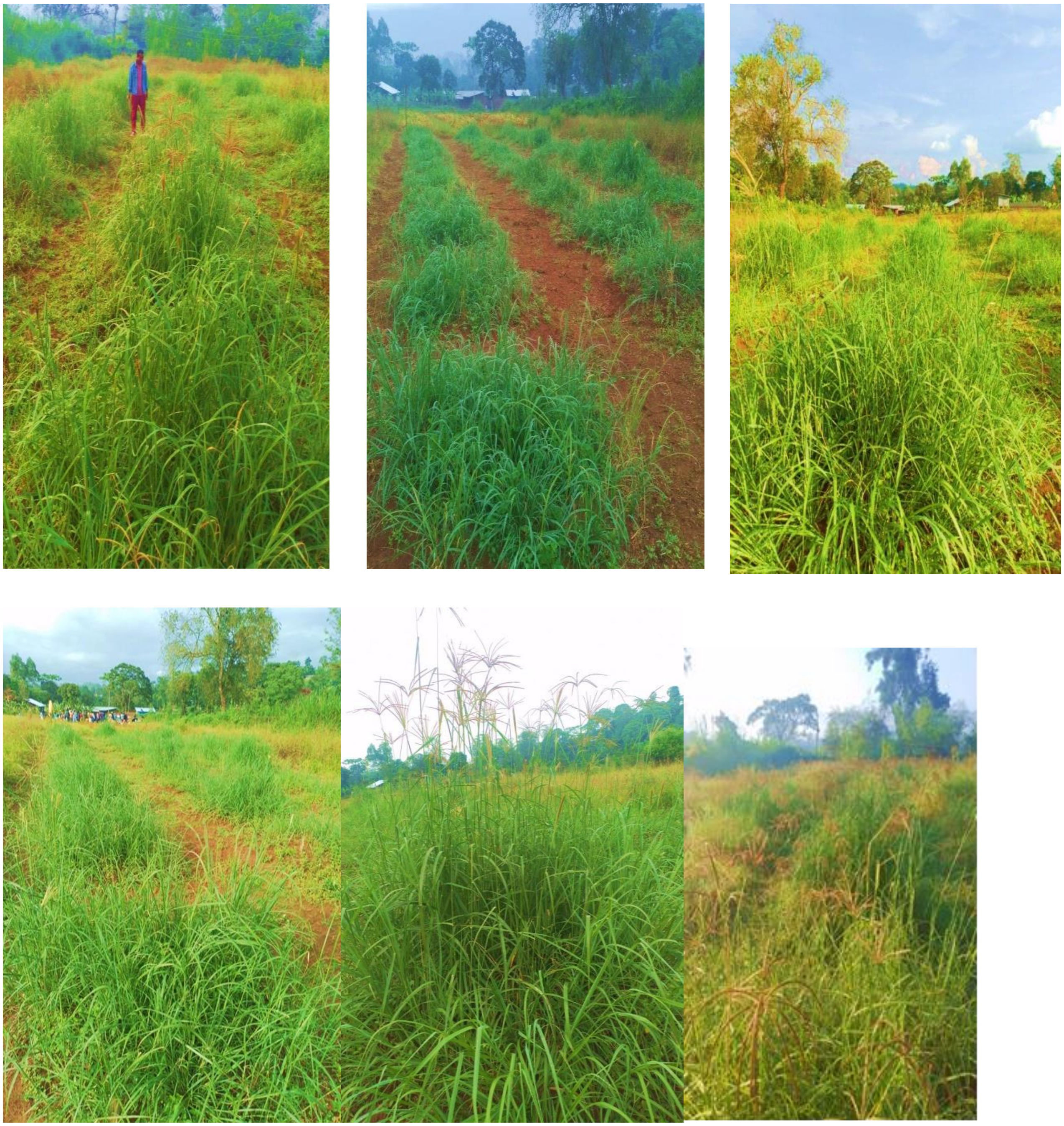
List of Appendix Figures



Treatments	Fertilizer type	Harvesting stage
T1	Control	60 day
T2	FYM+NPS	60 day
T3	NPS	60 day
T4	FYM	60 days
T5	Control	90 days
T6	FYM+NPS	90 days
T7	NPS	90 days
T8	FYM	90 days
T9	Control	120 days
T10	FYM+NPS	120 days
T11	NPS	120 days
T12	FYM	120 days

Appendix Figure 2: Experimental land and farmyard manure preparation, Application, and seed sowing.

Appendix figure 3: Some of the pictures the pictures taken during sampling



Appendix figure 4: Overall status of Rhodes grass in the study area during experimental times