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Agronomical and Quality Performance of Rhodes Grass (*Chloirs gayana*Kunth) Cultivars Under Different Nitrogen Levels and Production Systems in the Sudan

الأداء المحصولي و النوعي لأصناف من حشيشة الرودس تحت مستويات مختلفة من النيتروجين ونظم الإنتاج في السودان

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الآية

قال تعالى:

(فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ وَلَا تَعْجَلْ بِالْقُرْآنِ مِنْ قَبْلِ أَنْ يُقْضَى إِلَيْكَ وَحْيُهُ وَقُلْ رَبِّ زِدْنِي عِلْمًا)

صدق الله العظيم

سورة طه الآية (114)

DEDICATION

To my father and mother

To the soul of my sister (Hala)

To those who are sharing my life

My dear wife and beloved children

With faithful love

Hani Ahmed

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Abstract

Research experiment and field survey were conducted during 2016 – 2018 to study the effect of variety and nitrogen fertilization on the agronomic and quality performance of Rhodes grass and to investigate the husbandry practices of Rhodes grass in the major production systems in the Sudan. The experiment was conducted in Shambat (2016-2017) in the demonstration farm of the College of Agricultural Studies, Sudan University of Science and Technology. Two Rhodess grass varieties (Fine Cut and Reclaimer) and three nitrogen levels (60kg N /ha, 120kg N /ha and 0.0kg N /ha (Control) were studied across seven cuts. The treatments were replicated four times in split plot experiment with fertilizer doses assigned to the main plots and the varieties to the sub-plots. The data collected included agronomic (forage yield and related traits) and quality traits (NDF, ADF, CP). The field survey (2017-2018) was conducted in 15 projects covering Khartoum, River Nile and Northern States. The questionnaire was designed to comprehend the major features of Rhodes grass production as compared to Alfalfa under two production systems based on Pivot and surface (Border) irrigation method The questionnaire data were subjected to descriptive and regression analysis. Differences between varieties and their interaction with cuts were not significant for forage yield. Differences between fertilizer doses for dry yield and their interaction with cuts were highly significant. The nitrogen dose 120kgN/ha significantly increased forage yield and plant height over 60kgN/ha and the control with yield increment of 118%. The dose 60kgN/ha failed to show significant increase in yield over the control. The highest forage yield was obtained in the first cut after establishment then started to decease. The nitrogen dose 120kgN/ha maintained comparatively high forage yield throughout the subsequent cuts.

Differences between varieties were not significant for Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Crude protein (CP). Nitrogen dose

and cutting age have significant effect on NDF and ADF. Crude protein was significantly affected by cutting age but not nitrogen dose. The interaction effect of nitrogen dose and cutting age was significant for NDF and ADF. The dose 60kgN/ha gave desirable ADF percentage compared to 120kgN/ha whereas the opposite is true for NDF. Cutting age at 182 and 268 days resulted in desirable ADF percentage compared to 75 day whereas the opposite is true for NDF. Crude protein was the best at cutting age of 75 day compared to 182 day.

The field survey study provided data on dry yield, plant height, fertilization, seed rate, sowing method, days to zero (seed) cut, number of cuts per year, cutting interval and farm size. The results pointed to the possibility of further increasing the yield in farmer's field as it was lower than that obtained at the experimental level. Reduction in yield due to poor permeable soils (Sundos Scheme) was lower for Rhodes grass (32.1%) than Alfalfa (63.6%).The survey study reported different dosage used in the farmer's fields for Nitrogen (Urea), Diammonium phosphate (DAP), Triple Super Phosphate (TSP), Potassium sulfate (K2SO4), Ammonium sulfate (NH4)2SO4), Micro elements and humic acid. Unlike Alfalfa, Rhodes grass yield responded positively to nitrogen (Urea) whereas it's response to phosphorous was lesser than that of Alfalfa. Rhodes grass yield showed little or no response to fertilization with micro-elements. The yield of Rhodes grass showed negative response to seed rate, no response to number of cuts/year and number of days taken to zero cut whereas that of Alfalfa responded negatively to number of cuts/year and positively to days to zero cut. Unlike Alfalfa, Rhodes grass yield responded positively to plant height.

Lack of significant differences between Rhodes grass varieties in forage yield was due to the narrow genetic base of the diploid group. More attention should be given to Tetraploid varieties (Callide, Samford) to enhance productivity of the dairy farms. Nitrogen application has significant positive impact on productivity of Rhodes grass. Future research should focus on optimizing management of nitrogen dose across cuts, fine-tuning of seed rate and investigating strengths and weaknesses of Rhodes grass production under surface (Border) irrigation system especially in soils of low permeability.

المستخلص

تم إجراء تجارب بحثية ومسح حقلي خلال 2016-2018 لدراسة تأثير الصنف والتسميد النيتروجيني على الأداء المحصولي و النوعي لحشيشة الرودس بالاضافة الى إستقصاء العمليات الفلاحية لحشيشة الرودس في نظم الانتاج الرئيسة بالسودان. أجريت التجربة في شمبات (2016-2017) بالمزرعة الإيضاحية لكلية الدراسات الزراعية / حامعة السودان للعلوم و التكنولوجيا. تم على مدى سبعة قطعات دراسة صنفين من حشيشة الرودس (فاين كت و ريكليمر) وثلاث مستويات من التسميد النيتروجيني (60 كجم نيتروجين /هكتار ، 120 كجم نيتروجين /هكتار و 0.0 كجم نيتروجين /هكتار (شاهد)). تم اختبار المعاملات عشوائيا في اربعة مكررات باستخدام تصميم القطع المنشقة Split plot مع تعيين القطاع الرئيسي (main plot) للجرعة السمادية و القطاع التحتي (sub-plot) للأصناف. تم جمع بيانات الانتاجية والصفات ذات الصلة بالاضافة للصفات النوعية: نسبة البروتين الخام CP والهضمية ADF والعلف المأكول إراديا NDF . تم إجراء المسح الحقلي (2017-2018) في 15 عشر مشروعا تغطي ولايات الخرطوم ، نهر النيل و الولاية الشمالية. تم تصميم الاستبيان للتعرف على الملامح الاساسية لإنتاج حشيشة الرودس مقارنة بمحصول البرسيم تحت نظامي إنتاج يعتمدان على الري المحوري (Pivot) والري السطحي (Border). تم إخضاع بيانات المسح للتحليل الوصفي (Descriptive) و تحليل الارتداد (Regression).

الاختلافات بين الأصناف وتفاعلها مع القطعات بالنسبة لإنتاجية العلف لم تكن معنوية. الاختلافات بين الجرعات السمادية وتفاعلها مع القطعات كانت معنوية بصورة عالية بالنسبة لإنتاجية العلف الجاف. الجرعة 120 كجم نيتروجين /هكتار زادت إنتاجية العلف وطول النبات بصورة معنوية مقارنة ب 60 كجم نيتروجين /هكتار و الشاهد مع زيادة في الإنتاجية بلغت118%. الجرعة 60 كجم نيتروجين /هكتار لم تتفوق معنويا في الانتاجية على الشاهد. أعلى إنتاجية علف كانت في القطعة الأولى بعد التأسيس و من ثم بدأت في التدني. الجرعة 120 كجم نيتروجين /هكتار حافظت بصورة نسبية على إنتاجية عالية للعلف عبر القطعات المتلاحقة.

الاختلافات بين الأصناف لم تكن معنوية بالنسبة للعلف المأكول إراديا NDF والهضمية ADF ونسبة البروتين الخام CP. الجرعة النيتروجينية والعمر عند القطع كان لهما تأثيرا معنويا على العلف المأكول إراديا NDF والهضمية ADF. تأثرت نسبة البروتين الخام CP بصورة معنوية بالعمر عند القطع ولم تتأثر معنويا بجرعة النيتروجين. تأثير تفاعل جرعة النيتروجين مع العمر عند القطع كان معنويا بالنسبة للعلف المأكول إراديا NDF والهضمية ADF. الجرعة 60 كجم نيتروجين /هكتار أعطت نسبة مئوية أفضل للهضمية ADF مقارنة ب 120 كجم نيتروجين /هكتار بينما العكس

هوالصحيح بالنسبة للعلف المأكول إراديا NDF . القطع عند 182 و 268 يوم أعطى نسبة مئوية أفضل للهضمية ADF مقارنة بالقطع عند 75 يوم بينما العكس هوالصحيح بالنسبة للعلف المأكول إراديا NDF . نسبة البروتين الخام CP كانت أفضل عند القطع في عمر 75 يوم مقارنة ب 182 يوم.

أعطت دراسة المسح الحقلي معلومات عن الإنتاجية الجافة، طول النبات، التسميد، معدل التقاوي، طريقة الزراعة، عدد الأيام للقطعة الصفرية (قطعة البذرة)، عدد القطعات في السنة، فترة القطع ومساحة المزرعة. أشارت النتائج إلى إمكانية زيادة الإنتاجية على مستوى حقل المزارع بالنظر إلى تدنيها عن مستوى الإنتاجية في التجربة البحثية. تدني الإنتاجية في الأراضي سيئة النفاذية (مشروع سندس) كان أقل بالنسبة لحشيشة الرودس (32.1%) مقارنة بالبرسيم (63.6%). أوضحت دراسة المسح تطبيق جرعات مختلفة في حقول المزارعين من النيتروجين (يوريا)، دايامونيوم فوسفيت (DAP) سيوبر فوسفيت الثلاثي (TSP)، سلفات البوتاسيوم (K_2SO_4) سلفات الامونيوم ($(NH_4)_2SO_4$)، العناصر الصغرى و حمض الهيوميك (Humic acid). على عكس البرسيم، إستجابت حشيشة الرودس إيجابيا للتسميد النيتروجيني (يوريا) بينما كانت استجابتها للفوسفور أقل من البرسيم. إستجابة انتاجية حشيشة الرودس للعناصر الصغرى كانت قليلة أو معدومة. إستجابة انتاجية حشيشة الرودس كانت سالبة لمعدل التقاوي ولا توجد إستجابة لعدد القطعات/سنة وعدد الأيام للقطعة الصفرية بينما إستجابة البرسيم كانت سالبة لعدد القطعات/سنة و موجبة لعدد الأيام للقطعة الصفرية. إستجابت انتاجية حشيشة الرودس بصورة إيجابية لطول النبات، على عكس البرسيم.

عدم وجود إختلافات معنوية بين أصناف حشيشة الرودس تم إرجاعه لضيق القاعدة الوراثية للمجموعة الثنائية للطاقم الكروموسومي (Diploid group). يجب إعطاء إنتباه أكبر لأصناف مجموعة الطاقم الكروموسومي الرباعي (Tetraploid) مثل كالايدي Callide وسامفورد Samford لتطوير إنتاجية مزارع الألبان. إضافة النيتروجين كان لها تأثير إيجابي على إنتاجية حشيشة الرودس. الأبحاث المستقبلية يجب أن تركز على ضبط الجرعة السمادية عبر القطعات، ضبط معدل التقاوي و إستقصاء نقاط القوة و الضعف لنظام إنتاج حشيشة الرودس تحت الري السطحي (Border) خاصة في الأراضي متدنية النفاذية.

CHAPTER ONE

INTRODUCTION

Rhodes grass (*Chloris gayana*) is an important forage crop originated in east Africa and had been widely cultivated in the tropical and sub-tropical regions of the world (Ubi*et al.,* 2001). In Western Australia, Rhodes grass is one of the most widely sown sub-tropical grasses since 2000 (Moore, 2006).

Rhodes grass is a perennial plant primarily used as forage. It can be grazed, cut for hay or used as deferred feed, with moderate to high feed quality. Rhodes grass is also used as a cover crop to improve fertility and soil structure and decrease nematode numbers (Cook *et a*l., 2005). Many Rhodes cultivars have been developed in the world to suit different cultivation conditions or end-uses: for example cultivars with varying flowering duration, prostrate cultivars suitable for grazing or erect ones for hay production (FAO, 2014; Quattrocchi, 2006;Cook *et al.,* 2005; NSWDPI, 2004;Duke, 1983; Göhl, 1982).

The Rhodes plant ranges from 60- 160 cm tall, forms strong bunch types stools with runners that rapidly cover the ground surface. It spreads by rooting stolons, rhizomes or seeds. Rhodes grass is suitable to tropical and subtropical areas with rainfall ranging from 600-1600 mmanually when grown on pasture. The crop is grown in awide range of soils; from clays to sandy loam. It does not do well on very heavy clays. The soil pH for Rhodes grass range between 5 and 8.3. The crop responds well to irrigation and moderately tolerant to flooding but not to shading . It has high salt tolerance and can accumulate large amount of sodium without harm. The crop is palatable to animals with good nutritive value in early growth stages (Loch *et al,* 2004).

Cultivation of Rhodes grass is relatively new in Sudan. According to the records of the National Seed Administration (2018) importation of Rhodes grass seed increased steadily since 2012 through 2016 pointing to growing importance of Rhodes grass cultivation in the country. Based on total seed imported from 2012 up to 2017 (Appendix I) the area cropped to Rhodes grass in Sudan could be estimated around 75 thousand fed (=32000 ha). The major production system is the fully mechanized pivot irrigation system utilizing water pumped from artesian wells established in the sandy soils of Northern Sudan. The crop is essentially grown for export to the Gulf States where it can fetch high prices justifying the huge initial costs of the pivot system. Recently, a low cost production system employing surface irrigation has been attempted under the clayey soils using Nile water (Mohammed, 2018). However, most of the areas covered by this system are problematic soils suffering from water logging due to sodicity (low permeability).

Sudan is endowed with huge animal wealth ranking first in the Arab World and second in Africa. The national herd is greatly dependen to n the natural vegetationas the major source of feed for maintenance and production. This attitude is clearly reflected in poor performance of animalsdue to poor quality for age and problems of over and under grazing. One of the possible solutions to support the natural pasturesisto encourage Irrigated fodder production . The green chopping system has been able in the past to meet the need for fodder ; now adays, in view of the rapid pace to wards urbanization it is no longer capable of playing that role as it doesn’t allow employing modern means of production that facilitate wide scale production of forage crop. Introducing perennial fodder crops with attributes supporting grazing and/or hay making systems will help greatly in alleviating bottlenecks of fodder production in the Sudan. Of these, Rhodes grass appears to be one of the most promising under irrigated sector as it allows production of huge quantities of fodder under fully mechanized hay making system.

The earthiest attempt to introduce Rhodes grass to Sudan was made in 1970s by the Range and Forage Administration . Another attempt was done by the Arab Authority for Investment and Agricultural Development during 1980s.

The results achieved were said to be encouraging. Research works carried on Rhodes grass are not coping with its growing importance in the Sudan. Some works on the husbandry practices (Abuswar, 2005; Abdelrahman, 2007; Elnazier, 2010) and variety performance (Maarouf, 2008) have been attempted. However, research works following the wide adoption of Rhodes cultivation in the Sudan (i.e. 2012 onwards) are very few or lacking. Hence the ultimate objectives of this study were to provide information on the basic factors affecting yield and quality performance of Rhodes grass in the Sudan. The specific objectives were to:

1. Investigate the effect of variety, nitrogen fertilization and their interaction on the agronomic performance of Rhodes grass.
2. Study the quality performance of Rhodes grass as affected by cutting age, nitrogen dose, variety and their interaction.
3. Conduct a field survey to study the agronomic performance and husbandry practices of Rhodes grass in the major production systems in the Sudan.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

Rhodes grass 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. It belongs to the family Poaceae and sub tribe Chloridoideae (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 relatively high amount of biomass. (Valenzuela and Smith, 2002)

Valenzuela and Smith (2002) described the benefits and uses of Rhodes grass as excellent for erosion control and weed suppression, well adapted for quick growth, although establishment may be relatively slow, tolerates drought and saline conditions, but not shade. Fair forage production, nutritional quality, and palatability are additional merits. The crop is used in plantation and orchard cropping systems such as coffee, and papaya , and as "living sod" in vegetable production.

2.2 Origin and early history

The plant occurs naturally in most tropical and subtropical parts of Africa , including all of eastern and central Africa , much of southern Africa , and the eastern section of West Africa (Bogdan, 1969; Bogdan, 1977). It is found in open grassland or in grassland with scattered bush or trees, lake margins, or seasonally water logged plains up to 2000 m altitude (rarely higher). It is also often preset in fallow ground or abandoned cultivation where it acts as a pioneer species coming in after the initial weedy phase.

The crop was first cultivated in South Africa, probably in 1895, by Cecil John Rhodes, hence the common name. This was apparently a diploid form, possibly from Zimbabwe, though accounts of its early history vary (Chippindall, 1955). In one story, Cecil Rhodes found the grass growing wild on the veld. In another, it was taken to India and later re-introduced by French Moravian missionaries to the Eastern Cape area where Rhodes noticed it flourishing on an adjoining farm. Whatever the origin , it is clear that Cecil Rhodes recognized the economic potential of Rhodes grass and was the first to propagate and distribute it in cultivation . The first published record of its agricultural use , however, was a letter in October 1902 issue of the Cape Agricultural Journal giving advice on the best time , locality and conditions for planting Rhodes grass (Stent and Melle, 1921).

Rhodes grass was introduced to Australia in about 1902 by soldiers returning from the Boer War (Cameron, 1967). This accession was originally sown in the Hunter Valley of New South Wales (NSW), but quickly spread north, reaching Queensland about 1905. It is now widely sown and naturalized in coastal and sub- coastal districts from northern NSW through to central Queensland and on the Atherton Tableland in north Queensland. Rhodes grass was first imported into the USA in 1903, and most early plantings were from Australian seed (Potts and Hensel, 1947). However, by the 1950s, seed production in Texas was well organized (Wheeler and Hill, 1957) . Rhodes Grass is now mainly sown in the southern parts of Florida and Texas. Rhodes grass has also been introduced to most other tropical and subtropical countries, and even some warm temperate countries. It is of particular importance in the Middle East and to a lesser extent in Japan and Argentina.

2.3 Genetics and Cultivars

Number of chromosomes are 2n=20, 30, 40 (Fedorov, 1974). The diploids (2n=20) include cvs. Pioneer and Katambora and the tetraploids

(2n=40) include cvs. Callide and Samfrod . Breeding and selection aims at plants that are leafier and late flowering. Rhodes grass is a cross-pollinated crop. Skerman and Riveros, (1990); Partirdge, (2003) described that two new varieties have been selected from Katambora and Pioneer for hay production for the Middle East market . Finecut is derived from Katambora and Topcut from Pioneer. They have finer leaves and stems than Pioneer and higher yielding. Luna *etal*. (2002) pointed that the diploid and tetraploid cultivars are available in the market ; the latter are more productive but also less salt tolerant.

According to FAO (2003), there are some other African varieties, namely: Giant Rhodes including Mbarara from Uganda , Rongai , Nzoia , Pokot and Masaba are grown In Kenya and Karpedo suited to the drier areas of Kenya.

2.4 Taxonomy and morphology

Taxonomists place Rhodes grass in the grass subfamily Chloridoideae , but current phylogenetic opinion precludes further subdivision into the classically recognized tribes and subtribes . Morphologically, Rhodes grass is a variable species, best described as a stoloniferous creeping and tufted perennial with erect or ascending stems 0.5- to 2.2 m high and glabrous leaf blades 150- to >500mm long by 2- to 20-mm wide. Leaves on the stolons are shorter and arise in groups of two to four from each node. The inflorescence is a digitize or sub digitize panicle with 3 to 20 spikes, each 40- to 150-mm long.

The two-owned spikelet is best developed in the middle of each spike . They are 3- to 5-mm long with two to five overlapping florets along the central rachilla (Chippindall , 1955; Bogdan, 1966, 1977; Clayton *et al*., 1974; Gibbs Russell *et al.*, 1990). Florets are laterally compressed, narrowing at both ends with a hairy point (or callus) at the base and two sharp lobes at the top with a rigid awn (I - to 10- mm long) arising between the lobes. The lemma of the lowest floret is hinged with hairs forming a ‘brush’ near the top, with a short prominent nerve (Usually hairy) in the middle of each side. Upper florets are glabrous and progressively reduced in coin plexity: they become shorter, more oblong in outline narrowing abruptly towards the top, and have a shorter awn (floret 2) or are awn less. Spikelet end with an undeveloped floret shaped like a minute club.

Rhodes grass caryopses vary in size and shape depending on variety, but are generally spindle-shaped, about 2-mm long by 0.5-mm wide, glossy and transfused, and easily detached from the floret (Bogdan, 1966). Because of this, occasional spikelet contains more than one caryopsis.

Rhodes grass ranging from 60- 160 cm tall, forms strong bunch type stools with runners that rapidly cover the ground surface. It spreads by rhizomes, rooting stolen and seeds. Leaf blades are flat or folded and are 12.5- 45 cm long and 1- 2cm wide. Inflorescences consists of 6- 15 one sided spikes that are clustered at the end of the stem. Spikes are 5- 10 cm long with numerous spikes that are green when immature turning to copper-brown at maturity (Bogdan, 1966).

2.5 Abiotic adaptation

The natural distribution of Rhodes grass through much of Africa, and the extensive sowings and naturalized stands elsewhere demonstrate the wide environmental adaptation of the species as a whole. At the same time, this also reflects the tremendous range of intra-specific variation, such that different forms can exploit certain environmental niches where other would fail. Where it is well adapted, Rhodes grass normally persists well unless over grazed. A lack of persistence usually reflects more basic problems of adaptation, such as inadequate soil nutrients, low winter temperatures, marginal rainfall, and drought. As would be expected for a grass from the African savannas, Rhodes grass is tolerant to fire (Skerman and Riveros, 1990), although a heavy fire may thin the stand by killing some of the smaller rooted stolon nodes (Loch *et al*, 2004). It is also not shade tolerant (Skerman and Riveros, 1990), as expected from its origin in open woodlands and grasslands.

2.5.1 Rainfall

The forage is suitable to tropical and subtropical areas with rainfall ranging from 600- 1600 mm annually when grown on pasture. This pastures crop response well to irrigation and is moderately tolerant to flooding. Early Australian experience with Pioneer suggested that Rhodes grass is best suited to about 600 to 1200 mm rainfall belt (Cameron, 1967), though the tetraploids have extended this into wetter districts (to 1500 mm average rainfall) where Callide is now the major grass sown in dairy pastures. Experience in South Africa is similar, with the diploid Katambora mainly recommended towards the drier end and the tetraploid Giant towards the wetter end of the range (Cross, 1979; Dannhauser, 1991). In the drier parts of its native African range, Rhodes grass tends to be restricted to river banks, the margins of flood areas and valley bottoms (Van Rensburg, 1948) and has been successfully cultivated in wetter soils under as little as 450 rainfall (Dannhauser , 1991) . In arid areas (e.g., the Middle East), Rhodes grass is grown under irrigation.

Rhodes grass has moderate drought tolerance, but is less persistent under drought conditions than Green Panic (*Panicum maximum* Jacq.) and Buffel grass (*Cenchrus ciliaris* L.) (Cameron, 1967; Fair, 1989; Dickinson *et al*., 1990; Jones *etal*., 1995) . In Australia , for example, Rhodes grass died out at 600 mm average rainfall in the southern zone and did not regenerate following a severe 2 year drought with only 33% to 53% of annual rainfall , unlike Green Panic and Buffelgrass which survived and recovered (Coaldrake *et al*., 1969).

2.5.2 Temperature

Like other tropical/subtropical grasses, Rhodes grass grows best at high temperatures, as shown by growth chamber studies reporting an optimum of ~35°C for photosynthesis (Murata *etal*., 1965), an almost six fold increase in dry matter (DM) production of Samford between 20 and 30°C (Ludlow and Wilson, 1970), and a plateauing of relative growth rate for Pioneer above 30/25°C (Sweeney and Hopkinson, 1975). It has a lower critical daily mean temperature threshold for growth (8°C) than that for Buffelgrass and Green panic (12°C), and is also more tolerant to frost (Jones, .1969; Ivory, 1976). Data summarized by Bogdan (1969) showed that Rhodes grass was killed by temperatures of about - 10°C, which accords with its lack of persistence on the cold South African Highveld (>1400 m above sea level) (Scott, 1955; Fair, 1989; Rethman and de Witt, 1991) . Despite this, Rhodes grass has become an important short-term component of pasture sowings on the Highveld , acting as a nurse crop for 1 to 3 year (Rethman, 2000). In controlled environment chambers , Ivory and White- man (1978) showed that four diploid accessions (Nzoia, Pioneer, CPI 27211 and CPI 43949) were more resistant to foliar freezing than the tetraploids Pokot and Samford. Similarly, Loch and Butler (1987) found seed set in Callide (tetraploid) more sensitive to the damaging effects of low night temperatures than in Pioneer. Altitude of origin can have a modifying effect on temperature response (Kawanabe and Neal— Smith, 1979). Under their lowest controlled temperature regime (15/10°C) , the high altitude tetraploid Masaba (along with the diploids Pioneer and Nzoia) had a higher net assimilation rate and produced more leaves than Mpwapwa (tetraploid) and a second low altitude ecotype from Serere, Uganda.

2.5.3 Edaphic factors

The grass is adapted to a wide range of soil types; from clays to sandy loam . It does not do well on very heavy clays. The soil pH for Rhodes grass is between 5- 8.3. It grows best in fertile loams, ranging from sandy-textured and red volcanic soils to clay loams , but is also reasonably tolerant to less fertile, more poorly drained situations (Cameron, 1967; Bogdan , 1969 ; Loch, 1980). Although it will grow once established , Rhodes grass is not seriously difficult to establish on heavy cracking clay soils (Cameron,1967; Dannhauser, 1991) because of rapid drying of the surface layers causing moisture stress (Leslie, 1965) and poor primary root development of seedlings (Watt and Whalley, l982b ; Watt, 1983). It is widely grown and naturalized on moderately acid soils in Australia , but does not grow well on highly acid soils (Scott, 1955; Bogdan, 1969) and does not tolerate manganese (Mn) toxicity (Smith, 1979). Although it prefers better-drained soils (Bryan and Evans, 1973), Rhodes grass tolerates temporary water logging (up to 10-15 day) (Bogdan, 1958,. 1969; Dannhauser, 1991; Kretschmer and Wilson, 1995). Plants are killed by deep flooding (>30 cm ;) (Colman and Wilson, 1960) but limited seedling regeneration can occur after flooding (Anderson, 1974).

2.5.4 Salinity

Rhodes grass is one of the more salt-tolerant C4 forage grasses . It has high salt tolerance ability and can accumulate large amounts of sodium without harm. It occurs naturally on saline sites (Chippendall, 1955; Bogdan, 1958, 1969), and numerous authors have commented on its growth and persistence on saline soils or when grown with salty irrigation water. Critical U.S. studies rated Rhodes grass as moderately salt tolerant relative to other pasture plants (Maas, 1986), though it has been suggested that the tetraploids Callide and Boma might be less salt tolerant than the diploids (Perez *etal*., 1999) .

Rhodes grass germinates under higher salinity levels (Abd El-Rahman and El-Monayeri, 1967) and tolerates , high sodium levels better than alternative grasses (Bower and Wadleigh , 1948; Gauch and Wadleigh , 1951; Russell, 1976; Brauer and Wolfson, 1986)., For example, Pasternak *et al*. (1993) calculated that the DM yield of Pioneer was reduced by about 6% per unit increase in soil salinity between 4 and 12 dS m^{-1}.However, it is less tolerant to salinity during germination than as established plants (Tariq and Tayab, 1984).

Rhodes grass uses a range of physiological mechanisms to mediate salt toxicity (de Luca *et al*., 2001). Rhodes grass also accumulates higher Na^+ levels in plant tissues (tops > roots) as the concentration in the growing medium increases (Bower and Wadleigh, 1948; Gauch and Wadleiglh, 1951; Ando *et al*., 1985), but this is accompanied by progressively reduced plant potassium (K^+) levels (Smith, 1974, 1981). Andrew and Robins (1971) recorded higher Na^+ levels (58% of total cations) in Pioneer Rhodes grass than in eight other C_4 grasses. This, in turn, was balanced by low K^+ levels (20% of total cations) in plant tops. Cu1tivars from the East African group, however, typically contain lower levels of Na (Jones et al., 1995; Taleisnik *et al*., 1997) and are less tolerant to salinity than others (Taleisnik and Grunberg , 1993; Taleisnik *et al*., 1997). Within a cultivar, salt-tolerant plants also selectively exclude saline ions, and so accumulate less Na in their shoots than salt-sensitive clones under salt stress (de Luca *et al*., 2001; Luna *et al*., 2002). While the suggestion that susceptibility to high salinity could be related to oxidative stress , it has not been , proven conclusively (Luna *et al*., 2002). There is evidence that, at the cellular level, Rhodesgrass can compartmentalize saline ions within the vacuole while maintaining cytoplasmic osmotic potential through the accumulation of compatible organic solutes (Storey and Jones, 1977).

2.6 Biotic adaptation

2.6.1 Insect pests

Rhodes grass can be damaged at times by a number of different insects , none of which presents major problems. Typically, these pests also affect other grasses to a greater or lesser extent. Rhodes grass scale (*Antonina graminis*) warrants further mentioning because it was of specific concern in the USA prior to the introduction of effective predators during the 1950s. Biological control is the most effective long-term solution, and has been achieved in different U.S. states and in different countries with at least two separate parasitoids (*Anagvrusantoninae, Neodusmetiasangwani*), which differ in their environmental adaptation (Questel and Genung, 1957; Gerson *et al*., 1975; Dean *et al*., 1979).

2.6.2 Diseases

Numerous fungal , bacterial , and viral diseases are reported to infect Rhodes grass , either naturally or through laboratory inoculation, though few cause significant economic damage. Largely through erosion of susceptible ecotypes (e.g., Nzoia), the current commercial cultivars are relatively resistant to fungal diseases, which generally infect either leaves or grain and seed heads. Seed and head diseases tend to have more restricted distributions, but can cause substantial losses of grain particularly in wet years (Bogdan, 1969). Leaf diseases occur more widely throughout the world wherever Rhodes grass is grown (Robinson, 1960; Sonoda, 1974 ; Alcorn, 1976; Kishi, 1998). The main virus disease of Rhodes grass is Chloris Striate Mosaic Virus (CSMV) (Greber, 1989). The causal agent of CSMV is a geminvirus reported only from Australia where Rhodes grass is also infected by the less easily transmitted Paspalum Striate Mosaic Virus . Symptoms of maize streak virus , the major African geminivirus, have also been observed on Rhodes grass in Zimbabwe (Wickens, 1937).

2.6.3 Weeds

According to Abebe *et al.,* (2015) 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 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 sickle when there is vigorous growth is another alternative to control weeds. Using a herbicide like 2-4-D is also effective to remove young broad leaved weeds.

2.7 Establishment

Rhodes grass can be established vegetatively (root splits) or from seed. Seed rate varies depending on seed quality (germination and purity), sowing method , environmental conditions and land preparation. Generally, the seed rate should be from 3 - 15 kg per ha considering the previous factors. High seed rate is usually important in cooler and high altitude areas. Seed should be sown on the surface no deeper than 2 cm (Cook *et al.,* 2005). Rhodes grass can be row sown or broadcasted. For broadcasting seed can be mixed with soil or sand . After sowing it should be covered with light soil by using tree branches. Alternatively, sowing the seed and light packing by driving animals before and after sowing is also another option. However, if the labour is available, it can be planted in rows . In this case, the spacing between rows should be 20 cm (Abebe *et al* (2015). Planting should be conducted when the soil gets moist . Care has to be taken to uniformly apply/drill the seeds over the prepared land.

2.8 Fertilizer Management

In its native habitat , Rhodes grass favors the more fertile soils , and among the C4 grasses is generally regarded as a high fertility species. Rhodes grass responds well to nitrogen fertilizer after a basic pre-plant phosphorus application. For example, Andrew and Robins (1971) showed that the critical percentage of phosphorous in pre-flowering top growth of pioneer Rhodes grass (2.2g kg-1) was towards the top end of the nine C4 grasses studied , including a number of other fertility- demanding species. Typically Rhodes grass becomes less persistent as soil fertility declines, and this trend can be exacerbated by overgrazing (Russell, 1985a). Katambora, however, appears better adapted to , and is more persistent on, low fertility soils than other cultivars (Cook, 1978; Skerman and Riveros, 1990).

2.8.1 Nitrogen

The nitrogen requirement of Rhodes grass are met by transfer from the legume component in a mixed pasture or by fertilizer nitrogen in the case of pure grass pasture or hay crop. In some cases Rhodes grass has been established on naturally fertile soils, and may require little or no nitrogen fertilizer for some years until available soil nitrogen is depleted.

Nitrogen is the nutrient that most frequently limits yield. It is almost deficient in soils of Africa and most of tropics. Burhan and Hago (2000) pointed that nitrogen is an important element to produce protein in plants cells. Therefore, it enters in all enzymes composition. Thus, nitrogen plays an important role in plant growth and physiological processes. This element enhances vegetative growth ; therefore , decrease in nitrogen content of the soil reduces plants growth and yield.

Valenzuela and Smith (2002) found that Rhodes grass responds well to nitrogen fertilizer after a basic pre-plant phosphorus application. Addition of 50-60 Ib/acre nitrogen when seedlings are 4-8 inches tall gives vigorous stand

. Khair (1999) pointed that Rhodes grass responds well to N fertilization when applied in separate dose after harvest . Similar result is reported by Abusuwar (2005). Wilkinson and Langdale (1976) showed that a spilt application of nitrogen is superior to large single application in producing yield of warm season grasses. Skerman (1990) gave similar statement describing that Rhodes grass had a spectacular linear response to nitrogen in presence of adequate phosphorus and potassium. Henzell (1971) reported that nitrogen fertilization caused a significant increase in the nitrogen content of soil , roots and dry matter of Rhodes grass. Kaftasa (1990) reported that dry matter yield of Rhodes grass increased steadily up to 72-83 days of regrowth period and then decreased slightly or remained high. Nitrogen fertilization increase the crude protein content of Rhodes grass by about 15% at the early stage of growth but fertilized Rhodes grass contained less crude protein at advanced growth stage.

In most situations, nitrogen is the major element limiting growth. Under rain fed conditions on moderate to low fertility soils in southern Queensland, Henzell (1963) reported increases of greater than sevenfold in DM production of Rhodes grass receiving split dressings of N fertilizer totaling 448 kg/ha annually (a linear response to about 300 kg/ha annually on a more fertile cracking clay soil in the same region, (Cowan *et al*., 1995a).

2.8.2 Compound fertilizers

According to Abebe *et al* (2015) Rhodes grass is productive in moderate to high fertile soils. If the soil is infertile, applying nutrients to the soil is essential. Applying nitrogen and phosphorus fertilizers is recommended . Applying DAP fertilizer at the rate of 100 kg/ha at planting and urea at the rate of 50 kg/ha after establishment and at every cut is essential. Some literature recommend applying 100 kg/ ha nitrogen after each cut. If available , applying manure is another option . Manure can be applied at the rate of 5 - 10 ton ha-1 (ESGPIP, 2008). In general , grasses have a high requirement for N, P and K. These nutrients should be applied after each cut or grazing. Generally, it is recommended that annual maintenance nutrient requirements for N, P and K is 50 - 300, 10 - 20 and 25 - 50 kg/ ha, respectively (ESGPIP, 2008). In addition to biomass improvement, fertilizer application enhances both nutritive value and yield. Rhodes grass gives an increased response to phosphorus, in some areas. Usually, split applications after each cut or after grazing cycles are better than one basic application with the usual rate of 275 to 400 kg/ha. Generally, cut and carry system requires more maintenance inputs than the grazing system. If sown pastures are well-utilized and maintained with fertilizers, they will continue to provide high herbage yield for up to five years and start to decline thereafter (Loch *et al.,* 2004).

2.9 Dry matter production

As with other forage grasses, the productive potential of Rhodes grass is strongly influenced by the soil and climatic conditions at the particular site. Dry matter production is restricted by low soil fertility, low rainfall , and by a shorter season for growth. Rhodes grass DM production also decreases as frequency of cutting increases , giving shorter cycles of regrowth. For these reasons, DM yields of Rhodes grass reported in the literature vary widely (Loch *et al.*, 2004).

Rhodes grass DM production ceases under very low winter temperatures , but where there are no frosts or minimal frost damage, Rhodes grass continues to grow slowly during winter provided there is sufficient moisture. Extending the re growth period by cutting less frequently will increase DM production, but at the expense of CP concentration (Aii and Stobbs, 1980; Mbwile and Udén, 1997). In the occupied Palestine, for example, Dovrat and Cohen (1970) showed that irrigated plots cut at 28 day intervals gave 50% higher DM yield than comparable plots cut at a shorter 14 day regrowth cycle . Different cultivars of Rhodes grass can also have different patterns of DM production through the growing season. In southern Queensland , for example, Cook and Mulder (1984a) found that Katambora produced more dry matter than Callide during the spring, but that this pattern was reversed during the autumn such that the total annual yield was similar for both cultivars

Abebe *et al.,* (2015) reported that on average, the productivity of Rhodes grass on farmer's fields was from 8.74 to 9.1 tons dry matter ha-1 per year on rain-fed conditions . The mean productivity of native pasture is 4.2 ton dry matter ha-1 based on a study conducted in the central highlands of Ethiopia. Based on several studies, the dry matter yields of Rhodes grass generally ranges from 7 - 25 ton ha-1 per year, depending on variety, soil fertility environmental conditions and cutting frequency (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-1 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.

2.10 Nutritive value

According to Abebe *et al.,* (2015) as the nutritive value declines after flowering, 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 stemmy. 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 (Abebe *et al.*, 2015).

2.10.1 Crude protein (CP)

Rhodes grass CP concentration varies from about 3% to 19.5% in whole plant tops (Rhodel and Boultwood, 1971; Thomas, 1975b) and depends on a number of factors. Under range land condition where the plants are allowed to grow unchecked throughout the year, CP typically decline to quite low levels as the herbage mature (Dzowela *et al*., 1990). Soil fertility affect herbage CP, and can be amended by applying N fertilizer , which increase CP levels (Brockington , 1964; Cook and Mulder,1984b) .There are also seasonal differences in Rhodes grass CP , with concentration generally lower during winter or the dry season (Macken-zie *et al*., 1982; Russell,1994) . Plant –part differences follow the typical pattern with leaf CP greater than that in stem (Cowan *et al*., 1995a).

2.10.2 NDF, ADF and Crude Fiber

Crude fiber generally varies from 300 to 400 g kg^{-1} (Bogdan,1969), but the actual value depends on the age of regrowth and seasonal condition. Crude fiber , acid detergent fiber (ADF), and neutral detergent fiber (NDF) increase with age of regrowth (Addy and Thomas, 1977; Dzowela *et al*., 1990; Mbwile and Uden , 1997; Mero and Uden, 1997). Concentration of NDF for Katambora Rhodes grass selected by sheep during summer (63.6%) were comparable to, or a little higher than other grasses, and during winter (77.8%) were about 12%-18% higher than the comparator species (Van Niekerk,1997). Katambora ADF (29% in summer, 38.7%in winter) was omparable to the other species. Acid detergent lignin values for Katambora, however, were comparable in summer (4,3%), but higher than some comparators during winter (7.3%).

2.10.3 Minerals and other chemical constituents

Bogdan (1969) states that P and Ca concentration in Rhodes grass are about the same or slightly lower than in other C_4 grasses. Herbage Mg and K concentrations are usually lower, but Na concentration is three to five times higher. Rhodes grass also tends to be low in copper (Cu) (Jones *et al*., 1995; Jumba *et al*., 1995) and zinc (Zn) (Jumba *et al.*, 1995), and Cu deficiency has been observed in sheep grazing Rhodes grass in Saudi Arabia (Chamberlain and Clarke, 1981). Again , there is seasonal variation in mineral levels , with concentration generally lower during winter or dry season (Russell, 1994). Blaney *et al*. (1981) recorded 0.44% total oxalate in Rhodes grass , which was the only one of seven sown C_4 grass species classed as (non-hazardous) to horses with respect to its effect on dietary Ca . Further work by Mc Kenzie and Schultz (1983) showed that oxalate crystals are rarely found in leaves of Rhodes grass , unlike Buffel grass and Setaria which were the most hazardous species in the earlier study.

2.10.4 Digestibility

Key factors determining digestibility are the concentration and composition of cell walls and their breakdown in the rumen. The DM digestibility of Rhodes grass in early Australian (Milford,1960a,1960b ;Minson and Milford ,1967; Milford and Minson ,1968; Minson ,1972) and African trails (Reid *et al*.,1973) ranged from 34% to 67.2% and 26.2% to 79.3%, respectively. In both cases , digestibility decline with age of regrowth .Variation in digestibility among accessions in these studies was confirmed by Sleper (1974) across a larger collection of 88 Rhodes grass lines. In Minsons (1972) work , in vivo DM digestibility in regrowth of Rhodes grass was comparable to that of other similarly adapted C4 grasses, and in older regrowth declined at approximately 1.9 % / day. Similarly, although van Niekerk *et al*., (1989) found large seasonal differences in vitro digestibility of esophageal samples of Katambora Rhodes grass (46% for stand over forage in winter compared with 61% in summer), comparable to other pasture grasses growing in the same area. In some situation digestibility can also be improved by applying fertilizer N (Minson , 1973), which is of strategic value in improving cool - season feed quality provided soil moisture is adequate (Kretschmer and Wilson, 1995). Aii and Stobbs (1980) reported higher protein solubility for Rhodes grass (39%) than for setaria (26.3% - 30.2%), Pangoladigigrass (27.9%), guineagrass (28.9%), and Kikuyu grass (*Pennisetum clandestinum* Hochst. *ex* Chiov. ; 35.1%).They also found that solubility of Rhodes grass protein almost double from the first to fourth leaf , and was higher again in the stems and inflorescences . Soluble protein is easily broken down in the rumen, and high levels can affect the flow of non – ammonia N from the rumen. Microbial grown in the rumen (which is the source of much of protein reaching the small intestine) is dependent primarily on supply of energy and rumen degradable N. In a digestibility study with sheep, van Niekerk (1997) reported low rumen – ammonia – N and volatile fatty acid concentration (suggestive of rumen energy shortage) for Katambora Rhodes grass grazed during winter, and also recorded lower intake and in vitro digestibility compared to other grasses. During summer, however, these rumen parameters were much higher in Rhodes grass and comparable to the other species with no indication of any shortage of energy in the rumen.

2.10.5 Intake

Wide variation in intake has been reported for Rhodes grass, reflecting a number of external factors. In studies by Milford and Mison (1968), daily DM intake ranged from 45.2% to 59.4% in monthly regrowth of six cultivars/accessions, and from 39.4% to 44.9% in older regrowth (42-140 day) . Some cultivars (e.g. Callide) are more palatable than others (e.g. Pioneer), particularly in older regrowth (Camerron , 1967; Cameron and Mullaly,1970). Minson and Milford (1967) found that the DM intake of Callide and Samford began to decline after 50 day regrowth. Van Niekerk (1997) recorded seasonal differences in digestibility organic matter intake of katambora Rhodes grass , from 25 g kg $W^{-0.75}$ (summer) to 19.5 g kg $W^{-0.75}$ (winter), and these data were appreciably lower than comparable intake data from bottle Brush grass and Gatton panic in both seasons.

2.11 Rhodes grass as forage crop

Rhodes grass is grown as forage in rangeland, as a pure stand in irrigated pastures or as a mixture with legumes in irrigated agriculture. It can be used as fresh forage or in the form of silage , but utilization as hay and green forage is the major use. According to FAO, (2003) the crop makes quite good hay if cut just as it begins to flowering or a little earlier. Old stand gives low quality hay. Silage has been made successfully in Nigeria, Zambia and Northern Australia, but generally it does not give satisfactory silage . In Zambia , Rhodes grass alone yielded annually 58 DM ton/ha. Under irrigation in Texas, yield of dry matter of 15.8 ton/ha was recorded. In South-West Australia a yield of 23.6 ton/ha was annually obtained from an irrigated Rhodes grass pasture treated with three dressings of fertilizer at eight weeks during summer. Each dressing provided 56, 22 and 45 kg/ha of Nitrogen, Phosphorus and Potassium , respectively (FAO, 2003). Duke (1983) , found that the dry matter yield was 15.5–17.2 MT/ha annually in Florida, U.S.A, and higher yields reported when planted in 25cm rows and fertilized with 150kgN/ha. Gherbin *et al*. (2007), showed that *Chloris gayana* yielded high dry matter in warm-season areas when grown with other species (grasses) and showed values ranging from 16.4 to 21.1ton/ha. Abudiek (1980) found that Rhodes grass resulted in the highest yield from mixture of grasses with butterfly pea and phillipesara in Sudan. Ehrlich *et al*. (2003) pointed that reducing the frequency and total volume of irrigation resulted in a reduced level of pasture yields of Rhodes grass.

According to Abebe *et al* (2015) 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 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. Highest production is attained in the second year. Rhodes grass is tolerant to heavy grazing and cutting, but production is reduced by very frequent defoliation. After the first year it should be harvested anytime of the year when it reaches the optimum harvesting stage . In areas where frost occurs it should be harvested before the onset of frost. Studies show that cutting in every 28- day is better than cutting in every14- days interval in irrigated conditions . It is better if cuttings are taken at monthly intervals. This depends on establishment year. It takes several months to harvest Rhodes grass pasture in the establishment year . After that year it can be harvested every month based on availability of rain (irrigation) and fertilizer (manure).

If Rhodes grass is used for grazing there should be care . Rhodes grass is very palatable to livestock. So , the pasture can be damaged by overgrazing. So, it is better to adopted cut and carry system when using Rhodes grass pasture. Digestibility and Crude Protein (CP) content declines as the plant mature . So, for better utilization regular cutting and fertilization of the crop is necessary . Over mature Rhodes grass should be cut or burned . Burning is applicable in Rhodes grass as the grass is fire tolerant.

2.12 Rhodes grass research in the Sudan

The earliest attempt to introduce Rhodes to Sudan was made in 1970s by the Range and Forage Administration. Another attempt was done by the Arab Authority for Investment and Agricultural Development during 1980s . The results achieved were said to be encouraging , however, both attempts were undocumented.

Mohammed (2014) stated that introducing forage cultivars with attributes better than that of Abu Sab'in and in the same time suitable to mechanized hay-making system will help greatly in boosting fodder production in the Sudan. Of these crops, Rhodes Grass appears to be the best candidate, capable of playing a key-role in revolutionizing fodder production in the Sudan. Moreover, being a perennial Crop with high yielding capacity, good storability and transportability, Rhodes grass is expected to help in bridging the accidental gaps in forage production. Such gaps are part of the negative features characterizing the traditional green chopping system.

Abdelrahman (2007) studied the effect of seed rate and NPK fertilization on growth ,yield and forage quality of Rhodes grass. He reported that, Rhodes grass fresh and dry yields significantly influenced by increasing fertilization. Abuswar (2005) reported that Rhodes grass responded well to nitrogen fertilization applied in separate dose after harvest . Saad (2009) studied the effect of nitrogen fertilization on quality of Rhodes grass cultivars katambora, Callide, Boma and Fine cut , the results showed that nitrogen levels significantly increased all agronomic parameters measured in all cultivars, nitrogen application led to slight increase in crude protein with no significant effect in all cultivars other than Katambora . Elnazier (2010) , studied the effect of irrigation interval and seed rate on growth yield and quality of Rhodes grass. The results showed that irrigation interval had no significant effect on agronomic and quality traits. However, reducing seed rate and irrigation interval gave high values for all traits other than fiber content which tended to increase when seed rate and irrigation intervals were increased .Yossif, (2009) studied the effect of organic and inorganic fertilization on proximate analysis of Rhodes grass, using urea (100kgN/ha), farm yard manure (FYM – 5 ton/ha), chicken manure (CHM-3ton/ha), the results revealed that all proximate analysis parameter were not significantly affected by fertilization. In two experiment conducted in Sudan (Shambat) during 2006 and 2007 Maarouf (2008) studied the agronomic quality performance of five Rhodes Grass cultivars (Fine Cut, Top Cut, Hay Maker, Katambora Australia and Katambora Zimbabwe) in comparison with four local cultivars comprising two perennial forage legumes: Alfalfa 'Berseem Hijazi', Clitoria and two annual forage sorghum varieties (Abu Sab'in and Sudangrass). The Rhodes and forage legumes cultivars were evaluated across 19 and 9 cuts in the first and the second experiment , respectively. The forage sorghum cultivars were evaluated for 4 cuts in both experiments. The contrast analysis indicated that Rhodes group significantly out yielded forage sorghum in all cuts other than the first one. The Rhodes Grass also significantly out yielded Alfalfa and Clitoria throughout all cuts. Quality wise, the results obtained indicated the inferiority of Rhodes compared to Alfalfa (cv Berseem Hijazi). However, compared to sorghums, percentages of protein shown by Rhodes Grass in this study (11% - 13%) were quite comparable, if not better than those reported for sorghum in the Sudan. The results obtained in this study, suggested the validity of introducing Rhodes Grass as a new forage crop in the Sudan as it lends itself to modernized systems of forage production (mechanized hay-making system) that help greatly in boosting fodder production. Being a perennial crop with high yielding capacity, good storability and transportability, Rhodes Grass is expected to help in bridging the accidental gaps in forage production.

CHAPTER THREE

MATERIALS AND METHODS

Two studies were conducted during 2016-2018. The first one dealt with empirical assessment of Rhodes grass performance as affected by nitrogen and variety. In the second study, farmer's fields were surveyed to investigate cultural practices and yield in different production systems of Rhodes grass as compared to Alfalfa. Materials and methods used in both studies are:

3.1The field experiment

3.1.1The experimental site

The experiment was conducted at Shambat during 2016-2017 in the demonstration farm of the College of Agricultural Studies , Sudan University of Science and Technology , latitude 15˚39' N; Longitude32˚31'E,280 meter above sea level . The location is in the semi-arid tropical region with very hot summer and a short rainy season between July and September. Temperature, rain fall and relative humidity of the growing season are presented in Appendix II. The soil of the site is moderately clay, non saline, non sodic with pH of 7.8 (Appendices III and IV).

3.1.2Management and Cultural practices

The seeds of Rhodes grass were sown in 28- August, 2016. The individual plot size was two ridge 7m long spaced at 0.75m. The seeds were drilled manually in furrows opened in one side of the ridge using seed rate of 20 kg/ha. Phosphate fertilizer was added before sowing at a rate of 50 Kg P_2O_5/ha .The first irrigation was given immediately after sowing; irrigation water was applied after that at intervals of 7-10 days. However, the experiment was sporadically subjected to shortage of irrigation water leading to partial infestation with termite. Weeds were kept at minimum using hand tools .The zero cut (cut of the seed-crop) commenced after 65 days from sowing, a time at which all entries in each plot were in 25% to 50% bloom. Thereafter , succeeding cuttings throughout the age of the experiment were approximately maintained at intervals of 35 to 40 days or when 10%-25% of plants in each plot have flowered . Forage yield continued to be taken up to the ninth cut after which the experiment was terminated. However , the data of cut 8 and cut 9 will not be reported due to sever termite infestation.

3.1.3Treatments and experimental design

Two Rhodes grass (*Chloris gayana* Kunth) cultivars were used in this study, namely : Fine cut and Reclaimer. The seeds we received from Selected Seed Co. of Australia via their local agent in the Sudan.Three levels of nitrogen fertilizer in a form of urea were studied viz.: 60kgN/ha, 120kgN/ha and 0.0kgN/ha (Control). The treatments were arranged in split plot experiment with fertilizer treatments assigned to the main plots and the varieties to the sub-plots. The treatments were applied after each cut and replicated four times, however, due to termite damage , the data of one of the replicates was deemed unreliable

3.1.4 Data collection

Green matter yield (GMY) (t/ha): Estimated from the center of the plot excluding one meter from each side of the two ridges. Plants were cut at a height of 6 cm and the green matter yield (GMY) was immediately recorded using spring balance.

Dry matter yield (DMY) (t/ha): Estimated from a sample of one kg randomly taken from each harvested plot and oven dried at 80^{o}C for 48 hours

Plant height (cm): Five Plants from the whole plot were randomly taken and the height was measured from the soil surface to the tip of the plant.

Proximate analysis for forage quality traits: Three forage quality traits were studied across the two Rhodes grass varieties and the three fertilizer levels using material from two replicates and three cuts spread over the seven cuts, namely: cut 2, cut 5 and cut 7. The samples taken to estimate the dry matter yield were used for the analysis. The percentages of the following quality traits were determined on dry matter basis following the standard procedure of A.O.A.C.1984:

- Neutral detergent fiber (NDF).
- Acid detergent fiber (NDF).
- Crude protein (CP).

The chemical analysis was carried out in the laboratory of the Faculty of Animal Production, University of Khartoum, Shambat.

3.2 Field survey study

Fifteen agricultural projects were surveyed representing a random sample of 10, 4 and 1 projects in Khartoum, River Nile and Northern States, respectively. The survey covered the period August/2017 through August/2018. Of the 15 projects surveyed, 9 are Rhodes grass producing projects. The other 6 are Alfalfa projects included for comparison . Names of the projects and their locations are shown Table 1.

3.2.1 Production systems

Two distinct production systems were studied based on method of irrigation:

Pivot irrigation system: This is represented by the areas of West Omdurman, Shendi, ElDamer and south Dongla . This production system is characterized by light sandy soils with high permeability and elevated capital costs of the pivot system.

Surface (Border) irrigation system: This is mainly confined to Sundus Scheme in Khartoum State. The soils are clayey sodic with low permeability allowing surface irrigation but limited yield potential. Costs of production are low compared to pivot system mainly because of the inexpensive surface irrigation system.

3.2.2 The Questionnaire

The questionnaire was designed to comprehend the major features of Rhodes grass production as a newly introduced crop to Sudan. The field managers were directly interviewed. Telephone contacts were used for follow-ups. The major topics covered are listed below:

A. General information:

- Project name
- Location
- Soil type
- System of irrigation
- Water source
- Crops grown
- Area cultivated

B. Cultural practices

- Variety
- Sowing date
- Planting method
- Seeding rate
- Fertilization
- Watering interval

C. Pests

- Weeds, insects and diseases
- Pest control

D. Harvest

- Method of harvest and machinery used
- Days to zero cut (cut of the seed crop)
- Interval of succeeding cuts
- Age at cutting
- Number and timing of cuttings
- Plant height at cutting

- Hay making and machinery used

E. Yield

- Green matter yield
- Dry matter yield

Table 1. Names of the projects surveyed by State and location (2017-18)

S.N.	Project Name	Location/Scheme	State	Contact Name
1	Talabia Agricultural Project	Sundus	Khartoum	Abdelbagi
2	Talabia Agricultural Project	Sundus	Khartoum	Abdelbagi
3	Abu Abdelaziz Agricultural Project	Sundus	Khartoum	Khalied
4	Algmeabi Agricultural Project	Sundus	Khartoum	Hossam
5	Alertiga Project	West Omdurman	Khartoum	Khalied
6	Khodarna Agricultural Project	West Omdurman	Khartoum	Abdelelha
7	Alaarck Agricultural Project	West Omdurman	Khartoum	Alhamem
8	Sedonex Agricultural Project	West Omdurman	Khartoum	Alhares
9	Nadec Agricultural Project	West Omdurman	Khartoum	Hamed
10	Kawleen Agricultural Project	West Omdurman	Khartoum	Maliek
11	Abalhakhames Agricultural Project	Shendi	River Nile	Khalied
12	Abalhakhames Agricultural Project	Shendi	River Nile	Khalied
13	Mokabrab Agricultural Project 1	EldDamer	River Nile	Abdelbagi
14	Mnaseer Agricultural Project	EldDamer	River Nile	Abdelbagi
15	AlbanAlsafi Agricultural Project	South Dongola	Northern	Saeeed

3.3 Statistical analysis

The data collected for forage yield and plant height were subjected to analysis of variance (ANOVA) following the standard procedure of analyzing split plot in RCB design (Cochran and Cox, 1957). The data of the forage quality study were analyzed as factorial in Completely Randomized Design (Cochran and Cox, 1957). Source of variation and partitioning of degrees of freedom used in both analyses are shown in Tables 2 and 3, respectively. The Least Significant Difference (LSD) procedure was used to separate the means. In addition to descriptive statistics, the data of the questionnaire were subjected regression analysis (Payne *et al.*, 2007).The statistical package GenStat (2009) was used to run the analysis.

Table 2. Source of variation and partitioning of degrees of freedom used in the split plot analysis

Source of variation	d.f	
Block (R)	r-1	2
Dose (A)	a-1	2
Error (a)	(a-1).(r-1)	4
Variety (B)	b-1	1
A.B	(a-1).(b-1)	2
Error (b)	a(r-1).(b-1)	6
Cut No (C)	c-1	6
A.C	(a-1).(c-1)	12
B.C	(b-1).(c-1)	6
A.B.C.	(a-1).(b-1).(c-1)	12
Residual	(n-1)-53	282

Table 3. Source of variation and partitioning of degrees of freedom used in the factorial analysis

Source of variation	d.f	
Var (V)	v-1	1
Dose (D)	d-1	2
Cut (C)	c-1	2
Dose.Cut	(d-1).(c-1)	4
Dose.Var	(d-1).(v-1)	2
Cut.Var	(c-1).(v-1)	2
Dose.Cut.Var	(d-1).(c-1).(v-1)	4
Residual	(n-1)-17	237

CHAPTER FOUR

RESULTS

4.1 Agronomic performance

4.1.1 Variation among treatments

Table 4 shows mean squares for forage yields of 2 Rhodes grass cultivars evaluated for 7 cuts. Differences between varieties were not significant for forage yield. Interaction of varieties with cuts was also insignificant. Differences between fertilizer doses for dry yield and their interaction with variety were highly significant. Variation among cuts and their interaction with doses were also highly significant for forage yield. The greatest magnitude of mean squares for forage yield was obtained by the dose, cut and their interaction.

Table 4. Mean squares for green (GMY) and dry (DMY) matter yields of 2 Rhodes grass cultivars evaluated for 7 cuts (2016-2017).

Source of variation	d.f	GMY (t/h)	DMY (t/h)
Block	2	266.40	7.705
Dose(D)	2	5282.85 *	298.361 **
Residual	4	359	12.188
Variety(V)	1	0.40ns	0.034 ns
D x V	2	63.47 n.s	5.817 **
Residual	6	26.79	1.351
Cut	6	2021.13 **	200.126 **
D x C	12	251.47 **	14.314 **
V x C	6	13.64 n.s	0.198 ns
D x V x C	12	5.32 n.s	0.605 ns
Residual	282	24.54	1.730

***: Significant at 5% probability level.**

****: Significant at 1% probability level.**

Ns: Not significant at 5% probability level.

Table 5 shows mean squares for days to flowering and plant height of 2 Rhodes grass cultivars evaluated for 7 cuts. Significant difference among dose, cut and their interaction were encountered for both traits. Differences between varieties and the interaction of dose with variety were significant for days to flowering but not for plant height.

Table 5. Mean squares for days to flowering and plant height of 2 Rhodes grass cultivars evaluated for 7 cuts (2016-2017).

Source of Variation	d.f	Days to flowering	Plant height
Block	2	30.77	1351.1
Dose(D)	2	99.59 ns	1683.9 *
Residual	4	129.70	323.6
Variety(V)	1	25.19 **	94.3 n.s
D x V	2	2.04ns	14.2 n.s
Residual	6	0.82	35.7
Cut	6	214.40 **	5433.8 **
D x C	12	109.62 **	311.6 **
V x C	6	4.37 n.s	30.8 n.s
D x V x C	12	0.85 n.s	29.2 n.s
Residual	282	13.84	104.7

***: Significant at 5% probability level.**

****: Significant at 1% probability level.**

Ns: Not significant at 5% probability level.

4.1.2 Forage yield and related traits

4.1.2.1 Main effects

Effect of nitrogen dose on forage yield and some related traits are presented in Table 6. The nitrogen dose 120kgN/ha significantly increased the dry (DMY) and green (GMY) matter yields over 60kgN/ha and the control. The dose 60kgN/ha gave higher DMY and GMY than the control but the difference in yield was not statistically significant.

The plant height obtained by the nitrogen dose 120kg N/ha (92 cm) was significantly higher than that of 60kg N/ha (83 cm). It was also higher than that of the control (88 cm) but the difference was not statistically significant. Table 7 shows that the nitrogen dose 120kg/ha has increased DMY and GMY by 118.5% and 96.7% , respectively whereas the respective increases for the dose 60kg/ha were 16.3% and 15.1%.

Table 6. Effect of nitrogen dose on Rhodes grass yield (t/h) and some related traits

Dose	60kgN/ha	120kgN/ha	N0 (control)	Mean	SE±	LSD(5%)	CV(%)
Dry matter yield	3.14	5.90	2.70	3.61	0.269	1.295	36.4
Green matter yield	12.2	24	10.6	14.3	1.46	7.03	34.6
Plant height (cm)	83	92	88	88	1.4	6.7	11.7
Days to flowering	30.9	31.9	32.8	32.1	0.879	4.225	11.6

Table 7. Percent increase in Rhodes grass yield (t/ha) obtained by nitrogen dose over the control

Dose	Dry matter yield (DMY)	Green matter yield (GMY)	Increase over control (%)	
			DMY	GMY
120kgN/ha	5.90	24.0	118.5	96.7
60kgN/ha	3.14	12.2	16.3	15.1
Control	2.70	10.6	-	-

The effect of variety on forage yield and related traits was depicted in Table 8. Reclaimer and Fine cut gave comparable yields of 3.62 and 3.60 t/ha, respectively. Comparable GMYs have been also obtained with respective yields of 14.4 and 14.3 t/ha. Both varieties showed comparable performance for plant height and days to flower averaging 88 cm and 32.1 day.

Table 8. Effect of variety on Rhodes grass yield and related traits

Variety	Reclaimer	Fine cut	Mean	SE±	CV%
Dry matter yield (t/h)	3.62	3.60	3.61	0.090	36.4
Green matter yield (t/h)	14.4	14.3	14.3	0.40	34.6
Plant height (cm)	87	88	88	0.5	11.7
Days to flowering	32.4	31.8	32.1	0.070	11.6

4.1.2.2 Interaction effects

Table 9 shows the effect of dose x variety interaction on forage yield. The highest yields were obtained when using the dose 120kgN/ha with Reclaimer (DMY = 6.23, GMY =25.1t/ha) whereas the lowest ones were obtained by the control with Reclaimer (DMY = 2.62, GMY =10.3/ha). Fine cut gave the highest yields under the dose 60kgN/ha (DMY = 3.26, GMY =12.7 t/ha)

Table 9. Effect of dose x variety interaction on dry (DMY) and green (GMY) matter yields of Rhodes grass

Variety Dose	DMY(t/h)		GMY (t/h)	
	Reclaimer	**Fine cut**	**Reclaimer**	**Fine cut**
60kgN/ha	3.01	3.26	11.7	12.7
120kgN/ha	6.23	5.57	25.1	22.9
N0(Control)	2.62	2.78	10.3	10.8
Grand Mean	3.61		14.3	
SE±	0.284		1.52	
LSD (5%)	1.272		5.66	
CV%	36.4		34.6	

The effect of dose x cut interaction on dry forage yield was shown by Table 10. For all doses, forage yield was the highest in the first cut then started to decrease. The dry matter yield obtained by 60kgN/ha decreased from 6.59 to

0.81 t/ha in the first and the 7th cut, respectively. Similar trend was observed for the control treatment . However, the dose 120kgN/ha, that gave 9.27 t/ha in the first cut, maintained comparatively high DMY in the sub sequent cuts (i.e. cut6 = 7.15, cut5 =6.18 t/ha) before decreasing sharply to 0.81 t/ha in cut7 . The total DMY from 7 cuts was 38.3, 22.0 and 18.9 for 120kgNha , 60kgNha and the control , respectively. The results obtained for GMY kept generally the same trend as in DMY.

Table 10. Effect of dose x cut interaction on dry (DMY) and green (GMY) matter yields of Rhodes grass

Dose Cut	DMY (t/ha)			GMY(t/ha)		
	60kgN/ha	**120kgN/ha**	**N0(Control)**	**60kgN/ha**	**120kgN/ha**	**N0(Control)**
Cut1	6.59	9.27	7.23	20.3	32	22.7
Cut2	3.75	5.81	2.97	19.9	29	16.2
Cut3	3.80	6.81	2.15	16.3	30.8	9.8
Cut4	2.34	2.25	1.46	10	26.6	5.9
Cut5	2.44	6.18	1.66	7.2	21.7	4.9
Cut6	2.23	7.15	2.62	6.7	22.2	5.5
Cut7	0.81	0.81	0.81	5	5.5	6.3
Total	22.0	38.3	18.9	85.4	167.8	71.3
Grand Mean	3.61			14.3		
SE±	0.36			1.74		
LSD(0.05)	1.36			6.94		
CV%	36.3			34.6		

Table 11shows the effect of variety x cut interaction on forage yield. In most cases, both varieties performed similarly in forage yield across cuts. Reclaimer gave the highest yield in cut1 (DMY = 7.72, GMY = 25.4 /t/ha) whereas the DMY and GMY of Fine cut were 7.44 and 23.5 t/ha, respectively. In the 7th cut the DMY of both varieties was 0.81 t/ha, however, Fine cut gave higher GMY (6.7 t/ha) than Reclaimer (4.9t/ha) but the difference in yield was not statistically significant . The total DMY from 7 cuts was similar in both varieties amounting to 25.2 t/ha.

Table 11. Effect of variety x cut interaction on dry (DMY) and green (GMY) matter yields of Rhodes grass

Variety Cut	DMY (t/ha)		GMY(t/ha)	
	Reclaimer	**Fine cut**	**Reclaimer**	**Fine cut**
Cut1	7.72	7.44	25.4	23.5
Cut2	3.81	3.94	20.2	20.4
Cut3	3.72	3.73	16.8	16.6
Cut4	2.62	2.63	12	12.2
Cut5	3.01	2.97	9.9	9.4
Cut6	3.63	3.68	11.3	11.3
Cut7	0.81	0.81	4.9	6.7
Total	25.3	25.2	100.5	100.1
Grand Mean	3.61		14.3	
SE±	2.64		1.02	
LSD(0.05)	0.737		2.84	
CV%	36.4		34.6	

Tables 12 and 13 show the effect of dose x variety x cut interaction on dry (DMY) and green (GMY) matter yields, respectively. For DMY, the highest yield (10.14 t/ha) was obtained by the interaction of cut1, variety Reclaimer and the dose 120kgN/ha , whereas the lowest DMY (0.80 t/ha) was shown by the interaction of cut7 with both varieties and doses. Similar trend was kept by GMY where the highest yield (35.4 t/ha) was shown by the interaction of cut 1, variety Reclaimerand the dose 120kgN/ha. The lowest GMY (4.0 t/ha) was shown bythe interaction of cut7, variety Reclaimerand the dose 60kgN/ha. The total DMY from 7 cuts across variety and nitrogen dose ranged from 18.4 t/h (Reclaimer-control) to 43.6 t/ha (Reclaimer-120kgNha)

Table 12. Effect of dose x variety x cut interaction on dry (DMY) matter yields of Rhodes grass

	Reclaimer			Fine cut		
	60kgN/ha	**120kgN/ha**	**N0(Control)**	**60kgN/ha**	**120kgN/ha**	**N0(Control)**
Cut1	6.37	10.14	7.20	6.81	8.41	7.27
Cut2	3.65	6.05	2.77	3.85	5.57	3.17
Cut3	3.55	7.33	1.99	4.04	6.29	2.30
Cut4	2.34	5.35	1.41	2.34	5.15	1.52
Cut5	2.34	6.32	1.69	2.55	6.05	1.36
Cut6	2.02	7.60	2.45	2.44	6.70	2.79
Cut7	0.80	0.80	0.84	0.88	0.80	0.81
Total	21.1	43.6	18.4	22.9	39.0	19.2
Grand Mean	3.61					
SE±	0.452					
LSD(0.05)	1.598					
CV%	36.4					

Table 13. Effect of dose x variety x cut interaction on green (GMY) matter yields of Rhodes grass

	Reclaimer			Fine cut		
	60kgN/ha	**120kgN/ha**	**N0(Control)**	**60kgN/ha**	**120kgN/ha**	**N0(Control)**
Cut1	19.8	35.4	23.1	20.8	28.6	22.3
Cut2	19.8	28.9	16.1	20	29.1	16.3
Cut3	16	31.8	9.7	16.6	29.8	10
Cut4	9.6	27.6	5.4	10.4	25.7	6.3
Cut5	6.9	22.7	5.1	7.6	20.7	8.6
Cut6	7.8	23.8	7.8	8.6	20.7	7.8
Cut7	4.0	5.4	5.2	6	5.7	7.5
Grand Mean	14.3					
SE±	2.01					
LSD(0.05)	7.47					
CV%	34.6					

The effects of dose x variety, cut x dose, cut x variety and dose x cut x variety interactions on plant height are presented in Tables 14, 15, 16 and 17, respectively. Significant interactions will only be highlighted . The tallest plant stature (104 cm) was obtained by cut1 with 120kg N/ha whereas the shortest one (52 cm) was shown by cut7 with 60kgN/ha, generally plant heights obtained by 120kgN/ha are taller across different cuts than those shown by 60kg N/ha and the control.

Table 14. Effect of dose x variety interaction on plant height (cm) of Rhodes grass

Variety Dose	Reclaimer	Fine cut
60kgN/ha	82	84
120kgN/ha	92	92
N0 (control)	87	89
Grand Mean	**88**	
SE±	**2.1**	
LSD(5%)	**7.6**	
CV%	**11.7**	

Table 15.Effect of cut x dose interaction on plant height (cm) of Rhodes grass

Dose Cut	60kgN/ha	120kgN/ha	N0(Control)
Cut 1	100	104	100
Cut 2	96	96	96
Cut 3	90	93	90
Cut 4	92	94	92
Cut 5	86	92	86
Cut 6	80	83	80
Cut 7	52	80	72
Grand Mean	88		
SE±	2.4		
LSD (5%)	8.4		
CV%	11.7		

Table 16. Effect of Cut x variety interaction on plant height (cm) of Rhodes grass

Variety Cut	Reclaimer	Fine cut
Cut 1	101	101
Cut 2	95	96
Cut 3	90	96
Cut 4	91	94
Cut 5	87	86
Cut 6	79	80
Cut 7	68	70
Grand Mean	88	
SE±	2.0	
LSD (5%)	5.5	
CV%	11.7	

Table 17. Effect of cut x dose x variety interaction on plant height (cm) of Rhodes grass

	Reclaimer			Fine cut		
	60 KgN/ha	**120 kgN/ha**	**N0 (Control)**	**60 kgN/ha**	**120 kgN/ha**	**N0 (Control)**
Cut 1	98	104	100	101	104	99
Cut 2	94	95	96	95	96	96
Cut 3	91	94	87	91	92	92
Cut 4	88	93	91	90	95	94
Cut 5	82	93	86	81	92	85
Cut 6	70	84	81	76	85	79
Cut 7	51	80	69	52	80	75
Grand Mean	88					
SE±	4.4					
LSD (5%)	12.3					
CV%	11.7					

The effects of cut x dose, cut x variety and cut x dose x variety interactions on days to flowering are presented in Tables 18, 19, and 20, respectively .Significant interactions will only be highlighted. Table 18 shows that the earliest flowering (23.1 day) was achieved by cut7 with dose 60kgN/ha whereas the latest flowering was shown by the same cut for the doses 120kgN/ha (37.2 day) and 60kgN/ha (37.6 day).

Table 18. Effect of cut x dose interaction on 50% flowering (day) of Rhodes grass

Dose Cut	60 kgN/ha	120 kgN/ha	N0(Control)
Cut 1	27.92	28.58	28.33
Cut 2	31.67	32.50	31.96
Cut 3	30.92	28.92	31.12
Cut 4	32.92	31.25	32.21
Cut 5	32.75	31.58	34.17
Cut 6	34.00	32.92	34.00
Cut 7	23.08	37.17	37.62
Grand Mean	32.08		
SE±	2.4		
LSD (5%)	8.4		
CV%	11.6		

Table 19. Effect of cut x variety interaction on 50% flowering (day) of Rhodes grass

Variety Cut	Reclaimer	Fine cut
Cut 1	28.50	28.08
Cut 2	32.58	31.46
Cut 3	31.00	30.04
Cut 4	32.79	31.42
Cut 5	33.50	33.46
Cut 6	33.79	33.71
Cut 7	34.29	34.46
Grand Mean	32.08	
SE±	0.706	
LSD (5%)	1.966	
CV%	11.6	

Table 20. Effect of cut x dose x variety interaction on 50% flowering (day) of Rhodes grass

	Reclaimer			Fine cut		
	60 kgN/ha	**120 kgN/ha**	**N0 (Control)**	**60 kgN/ha**	**120 kgN/ha**	**N0 (Control)**
Cut 1	28.58	28.67	28.58	28.08	28.50	28.08
Cut 2	32.75	32.17	32.75	31.17	32	31.17
Cut 3	31.50	28.67	31.50	30.75	31.83	30.75
Cut 4	33	31.83	34.33	31.42	34	34
Cut 5	34.33	31.83	34.33	34	34	34
Cut 6	34	33	34.08	34.17	34	33.92
Cut 7	25	37.17	37.50	27.17	25	37.75
Grand Mean	32.08					
SE±	1.329					
LSD (5%)	4.794					
CV%	11.7					

4.2 Quality performance

4.2.1 Variation among treatments

Table 21 shows mean squares for neutral (NDF), acid (ADF) detergent fibers and crude protein (CP) of the two Rhodes grass cultivars evaluated across 7 cuts. The effects of nitrogen dose and cutting age were significant for NDF and ADF whereas the effect of variety for both traits was not significant. For crude protein, significant effect was only detected among cutting ages. The effect of dose x cut was significant for NDF and ADF whereas the effect of dose x variety was significant only for ADF. The interaction of dose x cut x variety was significant for NDF and CP.

Table 21. Mean squares from ANOVA for neutral (NDF), acid (ADF) detergent fibers and crude protein (CP) of 2 Rhodes grass cultivars evaluated across 7 cuts (2016-2017).

Source of Variation	Mean Squares			
	d.f	Shambat 2016/2017		
		NDF (%)	ADF (%)	CP (%)
Dose(D)	2	543.76 **	252.51**	3.946 ns
Cutting age (C)	2	2180.52**	1160.35**	234.739 **
Variety (V).	1	239.70ns	30.91ns	21.048 ns
D x C	4	270.28*	460.43**	14.363 ns
D x V	2	135.51ns	222.12**	4.142 ns
C x V	2	33.82ns	15.47ns	1.121ns
D x C x V	4	250.11 *	55..89ns	26.210 *
Residual	237	76.49	46.50	9.129

***:Significant at 5% probability level.**

****:Significant at 1% probability level.**

Ns: Not significant at 5% probability level

4.2.2 Main effects

The effect of nitrogen dose on nutritive value of Rhodes grass is shown in Table 22. The ADF value (42.7%) shown by the dose 60kgN/ha was the lowest (desirable) and that obtained by 120kgN/ha (46.6%) was the highest. In contrast, the NDF value (63.3%) shown by 120kgN/ha was lower (desirable) than 60kgN/ha (66.8%) and the control (68.4%) . Crude protein obtained by 120kgN/ha was 8.5% and that of the other doses was 8.1%.

Table 22. Effect of nitrogen dose on nutritive value of Rhodes grass

Dose	ADF (%)	NDF(%)	CP(%)
60kgN/ha	42.7	66.8	8.1
120kgN/ha	46.6	63.3	8.5
N0(Control)	44.3	68.4	8.1
Grand Mean	44.5	66.7	8.2
SE±	0.85	1.09	0.38
LSD (5%)	2.06	2.65	0.91
CV%	15.3	13.1	36.8

Table 23 shows the effect of variety on nutritive value of Rhodes grass which reflects no significant differences between cultivars. The ADF, NDF and CP averaged 44.5%, 66.7% and 8.2%, respectively.

Table 23. Effect of variety on nutritive value of Rhodes grass

	ADF(%)	NDF(%)	CP(%)
Reclimaier	44.9	65.7	7.9
Fine cut	44.2	67.6	8.5
Grand Mean	44.5	66.7	8.2
SE±	0.6	0.78	0.27
CV%	15.3	13.1	36.8

Table 24 shows the effect of cutting age on nutritive value of Rhodes grass. Cutting after 182 and 268 day resulted in lower ADF percentage than cutting after 75 day with respective values of 41.7% , 42.9% and 48.5%. For NDF, cutting after 268 day gave the lowest value (60.8%) compared to 75 day (70.3%) and 182 day (68.7%). Crude protein was the best (9.9%) when cutting after 75 day compared to 182 day (6.6%).

Table 24. Effect of cutting age on nutritive value of Rhodes grass

Cutting age*	ADF (%)	NDF (%)	CP (%)
75 day	48.5	70.3	9.9
182day	41.7	68.7	6.6
268 day	42.9	60.8	8
Grand Mean	44.5	66.7	8.2
SE±	0.75	0.97	0.33
LSD (5%)	2.05	2.63	0.93
CV%	15.3	13.1	36.8

***: Number of days from zero cut**

4.2.3 Interaction effects

Table 25 shows the effect of nitrogen dose x cutting age interaction on nutritive value of Rhodes grass. Only significant interaction will be highlighted.

Nitrogen dose x cutting age: The nitrogen dose 60kgN/ha x cutting age 182 day gave the lowest ADF value (37%) whereas the same dose with cutting age 75 day gave the highest ADF value (50%). Similar trend was noticed when using the same cutting ages with control. Cutting at 268 day with nitrogen dose 120kgN/ha gave higher ADF value (49.3%) than with other cutting ages. For NDF, the nitrogen dose 120kgN/ha x cutting age 268 day gave the lowest value (54%) compared to other cutting ages (> 65%). Similar trend was noticed for the same cutting age with other nitrogen doses. For crude protein , the nitrogen dose 120kgN/ha x cutting age 75 day gave the highest value (11.1%) compared to other interactions . Similar trend was noticed for the same cutting age x other doses in contrast to respective interactions.

Variety x nitrogen dose interaction: Table 26 shows the effect of nitrogen x variety interaction on nutritive value of Rhodes grass. The nitrogen dose 60kgN/ha with Fine cut gave the lowest ADF value (41.5%) followed by

Control with Reclaimer (43.4%). The highest ADF value (48.6%) was noticed for the dose 120KgN/ha with variety Reclaimer.

Table 25. Effect of nitrogen dosex cutting age interaction on nutritive value of Rhodes grass

Cutting age* Dose	ADF(%)			NDF(%)			CP(%)		
	75 day	**182 day**	**268 day**	**75 day**	**182 day**	**268 day**	**75 day**	**182 day**	**268 day**
60kg N/ha	50	37	40.7	69.5	66.1	64.6	9.4	6.8	8.1
120kg N/ha	45.1	45.4	49.3	66.8	69.3	54	11.1	6.7	7.5
N0(Control)	49.6	42.2	40.6	72.5	69.6	62.4	9.4	6.3	8.3
Grand Mean	44.5			66.7			8.2		
SE±	1.49			1.91			0.66		
LSD (5%)	3.55			4.55			1.57		
CV%	15.3			13.1			36.8		

***: Number of days from zero cut**

Table 26.Effect of nitrogen x variety interaction on nutritive value of Rhodes grass

Variety Dose	ADF(%)		NDF(%)		CP(%)	
	Reclaimer	**Fine cut**	**Reclaimer**	**Fine cut**	**Reclaimer**	**Fine cut**
60kg N/ha	43.9	41.5	67.7	66.1	7.6	8.6
120kg N/ha	48.6	44.6	61.4	65.2	8.1	8.9
N0(Control)	43.4	45.3	67	69.7	8	8.2
Grand Mean	44.5		66.7		8.2	
SE±	1.22		1.57		0.54	
LSD (5%)	2.92		3.78		1.31	
CV%	15.3		13.1		36.8	

Variety x cutting age interaction: The effect of cutting age x variety interaction on nutritive value of Rhodes grass was not significant. The data are presented in Table 27.

Table 27. Effect of cutting age x variety interaction on nutritive value of Rhodes grass

Variety Cutting age*	ADF(%)		NDF(%)		CP(%)	
	Reclaimer	**Fine cut**	**Reclaimer**	**Fine cut**	**Reclaimer**	**Fine cut**
75 days	48.4	48.6	68.6	71.9	9.5	10.3
182 days	42.3	41.2	67.9	69.4	6.4	6.7
268 days	43.6	42.3	60.4	61.2	7.8	8.3
Grand Mean	44.5		66.7		8.2	
SE±	1.08		1.38		0.48	
LSD (5%)	2.92		3.74		1.29	
CV%	15.3		13.1		36.8	

***: Number of days from zero cut**

Nitrogen x cutting age x variety interaction: The effect of nitrogen dose x cutting age x variety interaction on CP and NDF of Rhodes grass are presented in Tables 28 and 29, respectively. For crude protein, the nitrogen dose 120KgN/ha at cutting age 75 day in both varieties gave the higher CP (10.9%-11.3%) than other respective interactions.

For NDF (Table 29), the nitrogen dose 120KgN/ha at cutting age 268 day gave the lowest NDF in both varieties (48.7 % for Reclaimer , 59.3% for Fine cut) in contrast to control dose at cutting age 75 day that gave the highest NDF with respective values of 71% and 74%.

Table 28. Effect of nitrogen dose x cutting age x variety interaction on crude protein (CP %) of Rhodes grass

Variety	Reclaimer			Fine cut		
Cutting age	75 day	182 day	268 day	75 day	182 day	268 day
60kg N/ha	7.4	7.8	7.8	11.4	6.0	8.4
120kg N/ha	10.9	6.2	6.9	11.3	7.2	8.0
N0(Control)	9.7	5.8	8.3	9.2	6.9	8.4
Grand Mean	8.2					
SE±	0.96					
LSD(5%)	2.25					
CV%	36.8					

Table 29. Effect of nitrogen dose x cutting age x variety interaction on neutral detergent fiber (NDF%) of Rhodes grass

Variety	Reclaimer			Fine cut		
Cutting age	75 day	182 day	268 day	75 day	182 day	268 day
60kg N/ha	68.4	66.9	67.6	70.6	65.5	62
120kg N/ha	64.5	71.7	48.7	69.3	67.2	59.3
N0(Control)	71	66.5	63	74	72.7	61.8
Grand Mean	66.7					
SE±	2.77					
LSD (5%)	6.53					
CV%	13.1					

4.3 Field survey study

4.3.1 Descriptive analysis

Yield and cutting management: Tables 30 and 31 show agronomic performance, cutting and farm size of Rhodes grass and Alfalfa, respectively. Dry yield of Rhodes grass in the farmers' field averaged 2.87t/ha /cut with a range of 0.96 to 5.95t/ha . The number of cuts/year averaged 7.23 (5-9 cuts) with cutting interval of 40 days (30-50 day). The zero cut commenced 70 days (60-90 day) after sowing. Plant height averaged 104 cm (100-120 cm) . The average farm size of Rhodes grass was 202 ha (50.4-336 ha) whereas that of Alfalfa was 688 (46.2-2521 ha). The dry yield of Alfalfa averaged 2.34t/ha /cut , ranging 0.95-3.53 t/ha. Cutting number per year averaged 8.7 cuts (8-10 cut) with interval of 27.3 day (21-35 day). The zero cut of Alfalfa commenced 78.5 day (61-90 day) after sowing. The plant height of Alfalfa averaged 53.3 cm (35-80 cm).

Table 30. Agronomic performance, cutting management and farm size of Rhodes grass in the farmer's fields

Parameter	Mean	Min	Max	Range	SD
Dry yield per cut (t/ha)	2.869	0.959	5.95	5.355	1.468
Cutting number /year	7.25	5	9	4	1.282
Cutting interval (day)	40	30	50	20	7.071
Zero Cut (day)	70	60	90	30	12.25
Plant height (cm)	103.8	100	120	20	7.44
Farm Size (ha)	202	50.42	336.1	285.7	112.3

Table 31. Performance, cutting management and farm size of Alfalfa in the farmer's fields

Parameter	Mean	Min	Max	Range	SD
Dry yield per cut (t/ha)	2.34	0.952	3.53	2.618	0.830
Cutting number /year	8.667	8	10	2	1.033
Cutting interval (day)	27.33	21	35	14	5.203
Zero Cut (day)	78.5	61	90	29	10.93
Plant height (cm)	53.33	35	80	45	16
Farm Size (ha)	688.2	46.22	2521	2475	970.7

Seed rate: Table 32 shows seeding rate of Rhodes grass at different sowing methods as compared to Alfalfa. The seed rate of Rhodes grass using seed drill method of sowing was 23.2 kg/ha whereas that for broadcasting method was 19 kg/ha. The respective seed rates for Alfalfa were 33.8 and 38.1 kg/ha. The average seed rate of Rhodes grass for both sowing methods was 22.7 kg/ha whereas that of Alfalfa was 34.5 kg/ha.

Table 32. Seeding rate (kg/ha) of Rhodes grass at different sowing methods as compared to Alfalfa

Crop Sowing method	Rhodes grass	Alfalfa
Seed drill	23.21	33.80
Broadcast	19.04	38.08
Mean	22.74	34.51
Min	19.04	28.56
Max	28.56	38.08
SD	2.942	3.609

Fertilization (kg/ha): Tables 33 and 34 show fertilization of Rhodes grass and Alfalfa, respectively, as practiced in the farmers' fields. For Rhodes grass the average dose of DAP fertilizer used by farmers was 135 ranging 119-190 kg/ha , urea 113 (71.4-119 kg/ha) and phosphorous (TSP) 8.92 (0.0-71.4 kg/ha) . The potassium sulfate (K_2SO_4) and ammonium sulfate $(NH_4)_2SO_4)$ were used at average rate of 3.57 (0.0-28.6kg/ha) and 7.43(0.0-59.5kg/ha), respectively. Micro elements and humic acid were used at average rate of 0.6 (0.0-1.91 kg/ha) and 10.1(0.0-71.4 kg/ha) respectively.

Table 33. Fertilization of Rhodes grass in the farmer's fields

Parameter	Mean	Min	Max	Range	SD
DAP (kg/ha)	135.4	119	190.4	71.4	30.46
Urea (kg/ha)	113	71.4	119	47.6	16.83
Phosphorus _(TSP) kg/ha	8.92	0.0	71.4	71.4	25.24
K_2SO_4(kg/ha)	3.57	0.0	28.6	28.6	10.10
Amino sulphate (Kg/ha)	7.43	0.0	59.5	59.5	21.04
Micro-Elements (kg/ha)	0.595	0.0	1.91	1.91	0.636
Humic acid (L/ha)	10.12	0.0	71.4	71.4	28.86

For Alfalfa, DAP fertilizer was applied at average rate of 159 (119-238 kg/ha), phosphorous (TSP) 4.76 (0.0-28.6 kg/ha) and urea 41.7 (0.0-71.4 kg/ha). The potassium and ammonium sulfate were used at average rate of 7.93 (0.0 - 28.6kg/ha) and 2.78(0.0 -16.7 kg/ha), respectively. Micro elements and humic acid were used at average rate of 0.238 (0.0-1.91 kg/ha) and 0.793 (0.0-4.76 kg/ha), respectively.

Table 34. Fertilization of Alfalfa the farmer's fields

Parameter	Mean	Min	Max	Range	SD
DAP (kg/ha)	158.7	119	238	119	61.45
Urea (kg/ha)	41.65	0.0	71.4	71.4	25.80
Phosphorus (TSP) kg/ha	4.76	0.0	28.56	28.56	11.66
K_2SO_4(kg/ha)	7.933	0.0	28.56	28.56	12.65
Amino sulphate (Kg/ha)	2.777	0.0	16.66	16.66	6.801
Micro-Elements (kg/ha)	0.238	0.0	1.19	1.19	0.532
Humic acid (L/ha)	0.793	0.0	4.76	4.76	1.943

Effect of soil type on forge yield: Table 35 shows the effect of soil type on forage yield. Rhodes grass yield produced under the poor permeable soils of Sundos Scheme (2.18 t/ha) was lower than that produced under the light permeable soils of West Omdurman and River Nile State (3.21t/ha) with reduction in yield amounting to 32.1%. The respective Alfalfa yields were 0.95 and 2.62 t/ha with yield reduction amounting to 63.6 %.

Table 35.Effect of soil type on dry forge yield (t/ha)

Crop	Dry forge yield (t/ha)		Effect on yield	
	Poor permeable soil (Sundos)	Permeable soil (West Omdurman + River Nile State)	Reduction (t/ha)	Reduction (%)
Rhodes	2.182	3.213	1.031	32.088
Alfalfa	0.952	2.618	1.666	63.636
Mean	1.874	2.943	1.069	36.323
SD	1.368	1.128	0.24	21.276

4.3.2 Regression analysis

Table 36 shows the F values and regression estimates of yield on different practices and growth parameters. The probability of the F values indicates that the relationship between Rhodes grass yield and different parameters studied were not significant. The t-statistic of the estimates of the parameters indicates that the response of yield to the studied parameters is insignificant in most cases.

Table 36. Regression of Rhodes grass yield on different practices and growth parameters

Parameter	F value	a (intercept)			b (slope)		
		estimate	s.e.	T value	estimate	s.e.	T value
Nitrogen	0.52^{ns}	2.57	1.16	2.22*	-0.0155	0.0395	-0.39^{ns} (10)†
Phosphorus	1.34^{ns}	2.094	0.595	3.52**	-0.0376	0.0548	-0.69^{ns} (10)
Micro elements	0.15^{ns}	2.380	0.640	3.72**	-1.83	1.42	-1.28^{ns} (9)
No of cuts/year	1.01^{ns}	6.72	5.20	1.29^{ns}	0.441	0.722	0.61^{ns} (10)
Seed rate	1.44^{ns}	5.79	5.66	1.02^{ns}	-0.017	0.227	-0.07^{ns} (11)
Days to zero cut	0.36^{ns}	-0.40	4.36	-0.09^{ns}	-0.0358	0.0674	-0.53^{ns} (11)
Plant height	2.75^{ns}	3.76	1.79	2.10^{ns}	0.1660	0.0628	2.64* (10)

† : figure between bracket denotes degrees of freedom

Response to fertilizer application: The Figures 1, 2 and 3 shows the response of Rhodes grass yield to nitrogen , phosphorus and micro-elements, respectively, as compared to Alfalfa. Rhodes grass yield showed positive response to nitrogen (Urea) fertilization whereas Alfalfa yield depicted no response (Fig.1). In contrast, Alfalfa yield responded positively to increased fertilizations with phosphorous (TSP) more than Rhodes grass yield (Fig.2). The yield of both crops showed no or little response to fertilization with micro-elements. However, a weak trend towards positive and negative response could be noticed for Alfalfa and Rhodes grass, respectively.

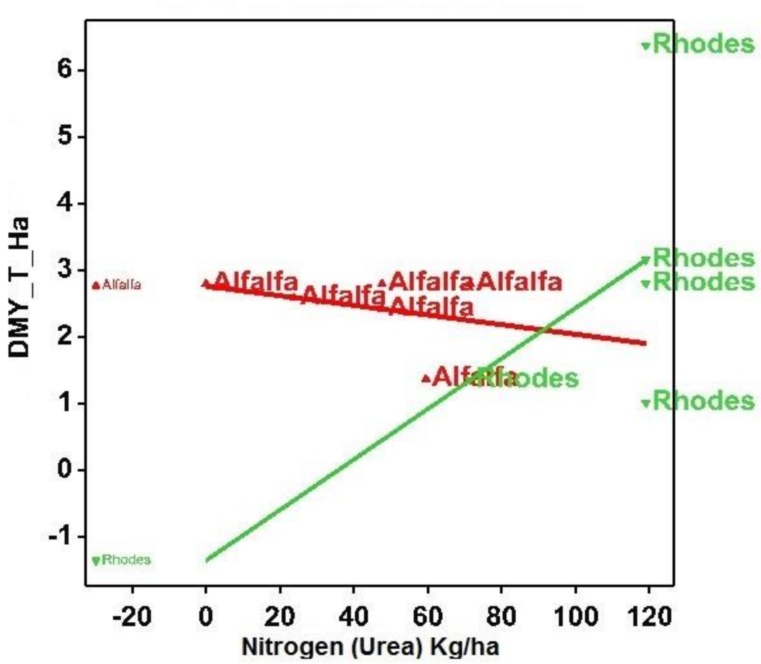

Fig. 1. Response of Rhodes grass yield to nitrogen as compared to Alfalfa

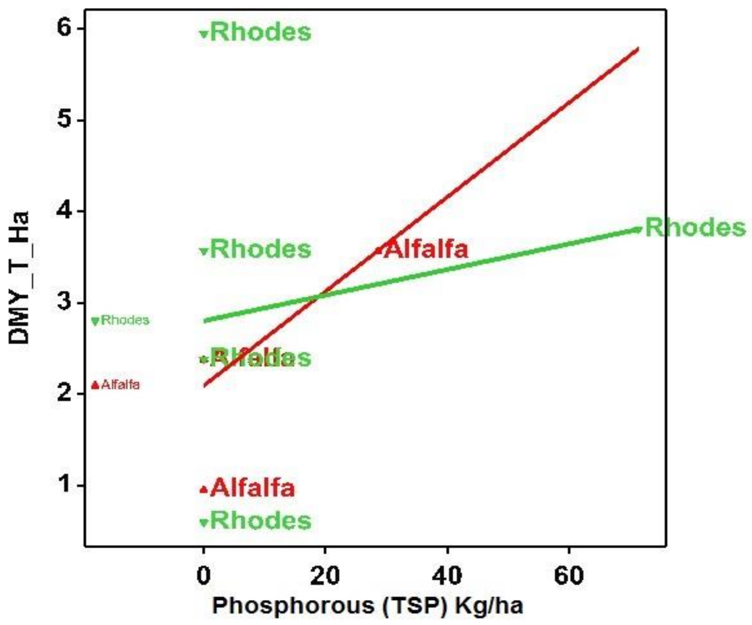

Fig. 2. Response of Rhodes grass yield to phosphorus as compared to Alfalfa

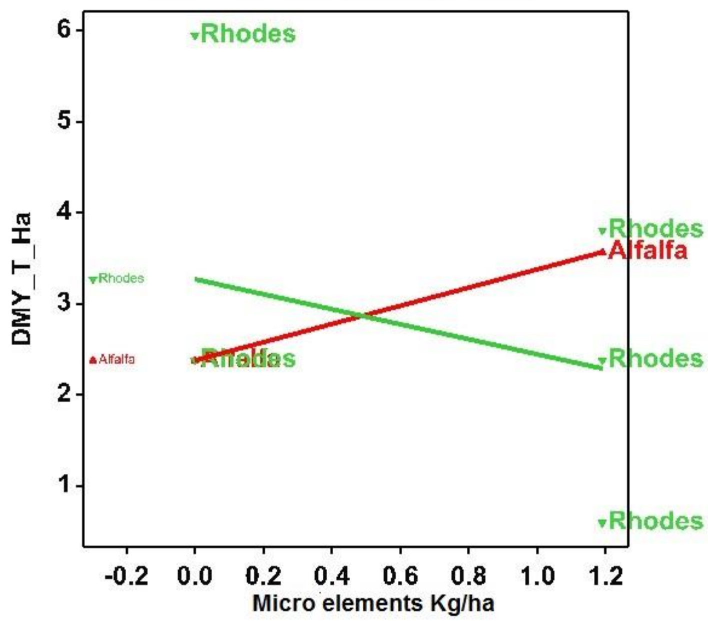

Fig. 3. Response of Rhodes grass yield to micro-elements as compared to Alfalfa

Response to seed rate and cutting management: The Figures 4, 5 and 6 show the response of Rhodes grass yield to seed rate, number of cuts/year and days to zero cut, respectively, as compared to Alfalfa. The yield of both crops showed negative response towards increased seed rate (Fig. 4). The yield of Rhodes grass showed no response towards increased number of cuts/year unlike that of Alfalfa which showed negative response (Fig.5). The yield of Rhodes grass depicted no response to number of days taken to zero cut (Fig.6) whereas that of Alfalfa responded positively to increase days to zero cut.

Response to plant height: Fig. 7 shows the response of Rhodes grass and Alfalfa yields to plant height. Rhodes grass yield showed clear positive response to increased plant height, in contrast, Alfalfa yield showed no or week negative response.

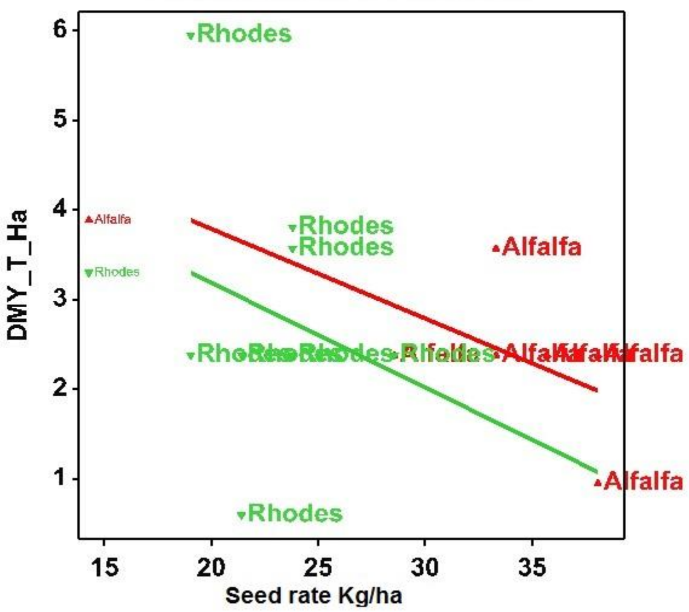

Fig. 4. Response of Rhodes grass yield to seed rate as compared to Alfalfa

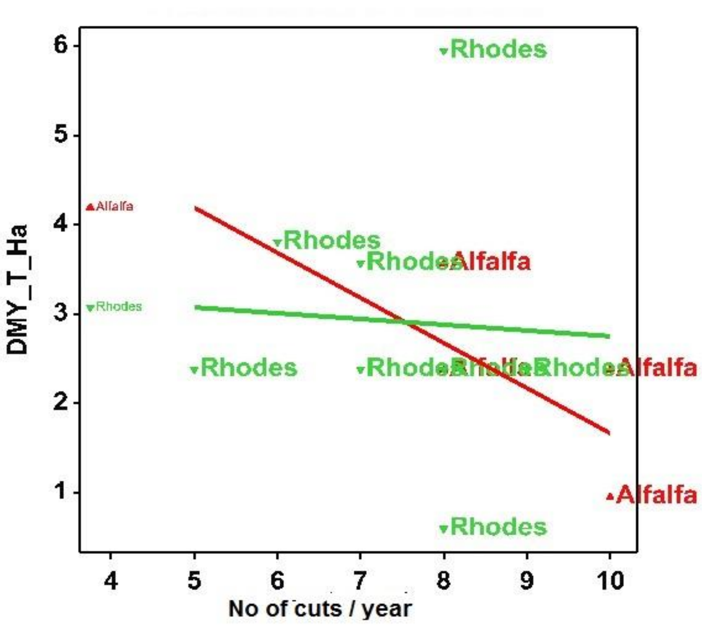

Fig. 5. Response of Rhodes grass yield to No of cuts/year as compared to Alfalfa

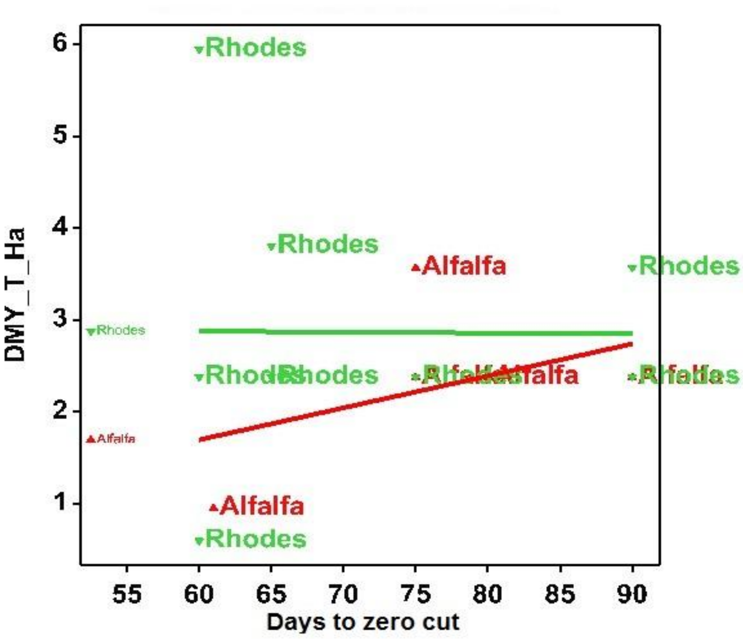

Fig. 6. Response of Rhodes grass yield to days to zero cut as compared to Alfalfa

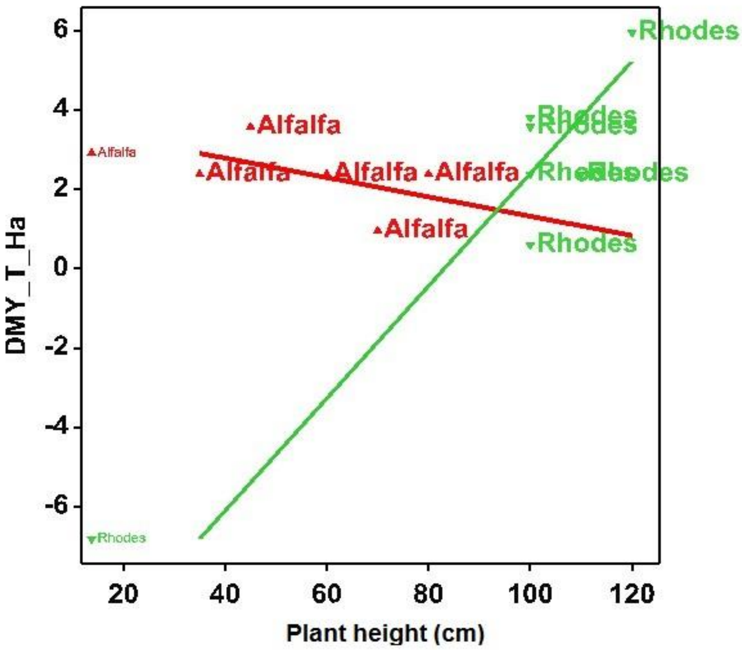

Fig. 7. Response of Rhodes grass yield to plant height as compared to Alfalfa

CHAPTER FIVE

DISCUSSION

5.1 Agronomic performance

5.1.1Variation among treatments

Most of the variability observed for agronomic performance in this study could be attributed to the effect of fertilizer doses, cuts and their interaction. The effect of variety seems to have little or no contribution to the variability observed specially for forage yield. The genotypic differences between varieties for forage yield might have been curtailed by the uncontrolled variations as evident by the high error mean square (residual) which is more than 50 times greater than the variety mean squares (Table 4). This might also explain the high coefficient of variations noticed for forage yield. The difficulties encountered in irrigation water coupled with termite infestation were some of the main reasons behind the uncontrolled variations . However, lack of differences between Rhodes grass varieties due to narrow genetic base must also be considered. The two Rhodes grass varieties used in this study belong to the diploid types and both of them are selected from Katambora population (Loch *et al*,2004). Insignificant differences among Katamboratypes in forage yield have been reported (Maarouf, 2008).

5.1.2 Forage yield and related traits

The study revealed that nitrogen fertilization increased Rhodes grass yield irrespective of the variety and cut effect. Yield increment amounting to 118% was obtained when a dose of 120kgN/ha was used . This result substantiates the previous findings reported by many workers (Skerman, 1990; Valenzuela and Smith 2002; Loch, *et al*, 2004; ESGPIP, 2008; Abebe *et al*, 2015). Loch, *et al*, (2004) reported that in most situations, nitrogen is the major element limiting growth. Increment in Rhodes grass yield up to sevenfold due to nitrogen application has been reported (Henzell, 1963). Research works conducted in Sudan also pointed to the significant effect of nitrogen on Rhodes grass yield (Abuswar, 2005; Abdelrahman, 2007). However, in the present study, the lower dose of nitrogen (60kgN/ha) failed to show significant increase in yield over the control. The leaching effect might obscure the difference between lower treatment level and the control.

The present study as well as many other studies (Koul,1997; Gasim, 2001; Adam, 2004) showed that plant height is significantly increased by nitrogen fertilizer. Increased plant height could be one of the factors contributing to high forage yield. Other yield component contributing to forage yield may include population density resulting from plant coverage via stolons. However, this feature was not monitored in the present study since high level of seed rate (20 kg/ha) had been used.

The interaction of variety and the dose of nitrogen for dry matter yield is highly significant pointing to the differential performance of variety across different fertilization levels. Similarly, a differential performance of dose across cuts exists indicating that the response of Rhodes grass yield to nitrogen dose was influenced by cutting age. The potential of dry matter yield of Rhodes grass depicted in this experiment (Table 12) ranged from 18.4 to 43.6 t/ha per year (7 cuts). This is within the range reported in the literature which is extremely variable ranging from 8.7-9.1 (Abebe *et al*, 2015) up to 35-60 t/ha/year (Cook *et al.*, 2005). However, the yield levels showed by this experiment were lower than those reported in Sudan by Maarouf (2008) who presented data showing that dry yield amounting to 53.9 t/ha could be obtained for 7 cuts in the year. The relatively low yield might be attributed to the termite attack and shortage of irrigation water.

5.2 Quality performance

Variability among treatments for quality traits showed the same trend as for agronomic traits . Again, lack of differences between Rhodes grass varieties for quality traits could be attributed to the narrow genetic base since both varieties have been developed from Katambora population. Therefore , most of the variability observed for quality traits in this study could be attributed to the effect of cutting age and nitrogen fertilization . The effect of cutting age on NDF, ADF and protein content has been reported by Keftasa (1990).The ADF measures digestibility. The lower the ADF value the better the digestibility and energy value of the fodder. NDF predicts intake potential ; the higher the NDF, the lower the intake (Steve and Marble, 1997). There was a general trend that nitrogen application improved digestibly, however, this was not evident at the low nitrogen dose (60KgN/ha) possibly due the leaching effect as pointed earlier. The intake potential was found to be improved by nitrogen in this study. These findings agree with those reported by Keftasa (1990) who found that both NDF and ADF were lower in nitrogen fertilizer Rhodes grass if cut early, however, he noted that higher NDF and ADF values have been obtained if cut late (advanced maturity).

The present study showed that the crude protein (CP) was not significantly increased by nitrogen fertilizer where only slight increase in CP was obtained by applying the highest dose of nitrogen (120kgN/ha). This is in conformity with the results obtained by Saad (2009) . Disagreeing results were reported by Keftasa (1990) and Loch, et al, 2004 . However, the former stated that nitrogen fertilization at the later stages of growth decreased CP content.

The study showed that cutting age has significant effect on quality traits. CP was significantly higher at earlier growth stage than the later ones. Similar results were obtained by Mbwile and Uden (1997). The NDF and ADF value were decreased at increased age of cutting indicating improved digestibility and potential intake . These results disagree with those reported by Mbwile and Uden (1997).

Based on the most significant factors affecting quality traits in this study (nitrogen dose x cutting age interaction) the results obtained for crude protein (6.3%-11.1%) and ADF (37.0%-50.0%) were within the range reported in the literature for Rhodes grass (CP = 4.4%-16.6%, ADF = 37.0%-50.1%) (Heuze *et al*, 2016). The range obtained for NDF (48.7%-74%) was however , lower than that reported in the literature (70.5-80.8%) (Heuze *et al*, 2016). Babiker (2010) studied quality traits of Rhodes grass in the Sudan . He reported NDF values ranging 68.5%-70.3%, ADF ranging 42.4%-45% and CP ranging 10.6%-11.4%.

5.3 Field survey study

The Rhodes grass yield in the farmer's fields (0.96 to 5.95 t/ha/cut) is well expected when compared to that obtained under the experiment based on nitrogen dose x cut interaction (0.81- 9.27 t/ha/cut) indicating that a room exists for further yield improvement in farmer's field. The survey study revealed that Rhodes grass is higher yielding than Alfalfa (0.95-3.53 t/ha/cut). The performance of both crops reported to be negatively affected by water logging under poor permeable soils (Loch, 1980; Heuzéetal, 2016). The survey results revealed that Rhodes grass withstood poor permeable soils better than Alfalfa. Yield reduction of Alfalfa grown under poor permeable soils of Sundos Project (63.6%) was twice greater than that of Rhodes grass (32%).The farm size of Alfalfa (688 ha) is more than 3 folds of that of Rhodes grass (202 ha). However, area of Rhodes grass is expected to increase at the expense of Alfalfa in the near future considering its higher yielding capacity and tolerance to biotic and a bioticstresses.

The average seed rates used by farmers is high (22.7 kg/ha) than that reported in the literature. According to Cook *et al*., (2005) the seeding rate of Rhodes grass should be 3 - 15 kg/ha depending on seed quality (germination and purity), sowing method , environmental conditions and land preparation . However, higher levels of seed rate might be necessary to ensure quick crop establishment in soils with low permeability. The seed rate used by broadcasting method of sowing (19 kg/ha) was unexpectedly lower than that used by seed drill (23.2 kg/ha). This might be attributed to the dilution effect of mixing the seed with inert materials.

The statistics obtained for regression analysis of Rhodes grass yield were not significant , hence, have no predictive value. However, the graphs were used to illustrate the general trend of relationship between yield and different practices and growth parameters.

The response of Rhodes grass yield to nitrogen fertilization in the farmer’s field was positive, substantiating the results obtained by field experimentation. Linear response of Rhodes grass yield to nitrogen fertilization has been reported (Loch, et al, 2004). The lack of response noticed for Alfalfa yield to nitrogen fertilization could be explained by the ability of the crop to fix nitrogen . In contrast, Alfalfa yield showed better response to phosphorous than Rhodes grass. Arshad, (2016) reported that Rhodes grass yield is reduced by too low or high levels of phosphorous and nitrogen. Moreover, nitrogen fixation is suppressed when phosphorous supplies are limited (Mikkelsen, 2004) indicating the direct as well as indirect importance of phosphorous fertilization in Alfalfa crop. The field survey study revealed little or no response of both crops to fertilization with micro-elements, however, the weak positive response shown by Alfalfa may be in conformity with Maryam *et al* (2016) . The lack of apparent response to micro elements in the farmer’s field is not unexpected since the lands are mostly newly cultivated.

The survey results revealed negative response for Rhodes grass and Alfalfa yields to seed rate.Supportive results for Rhodes grass were reported by Elnazier (2010) who stated that reducing seed rate and irrigation interval improved Rhodes grass performance in all traits other than fiber content. For Alfalfa, Rankin, (2008) reported little benefit to seeding over 10 pounds per acre arguing that Alfalfa forage yield is not just a function of the number of plants per unit area, but also the number of stems per plant and weight per stem.

The lack of response to number of cuts per year may indicate that Rhodes grass yield is less affected by intensive cutting as compared to Alfalfa which showed negative response . Abebe *et al* (2015) reported that Rhodes grass is tolerant to heavy grazing and cutting but he noted that production is reduced by very frequent cuttings (i.e. biweekly). The strong positive response of Rhodes grass yield to plant height in contrast to Alfalfa may indicate that the yield of the latter is more dependent on number of stems per plant.

5.4 Outlook

Rhodes grass is a crop of a great future to elevate fodder bottlenecks in Sudan. The present study confirmed the importance of nitrogen fertilizer in increasing forage production of Rhodes grass. However, the soils of the Sudan are inherently low in nitrogen suggesting the need for more research to optimize nitrogen requirement across cuts i.e. to what extent we can skip applying nitrogen across cuts. There is a need also for fine-tuning the seeding rate as evident from the survey results.

Most if not all of Rhodes grass varieties grown in the Sudan belong to the diploid group with little or no variation among cultivars as showed by this study. Diploid varieties suit mainly hay production largely used for export in the Sudan. New variety research efforts must include varieties of the Tetraploid group i.e. Samford ,Callide ,Masaba ,Boma etc. Such varieties are characterized by high productivity and palatability and suitable for grazing and green chopping systems especially in dairy farm.

Apart from Sundos Project , most of the Rhodes grass grown in the Sudan isproduced under the expensive pivot irrigation system. Surface (Border) irrigation system assisted by laser leveling will greatly reduce costs of production and allow for fully mechanized production. More studies are needed to investigate strengths and weaknesses of Rhodes grass production under Border irrigation system especially in soils of low permeability e.g. soils of Sundos Project

5.5 Conclusion

No differences between varieties had been detected for forage yield and quality traits possibly due to the narrow genetic base since both varieties are developed from the diploid Katambora population. More attention should be given to Tetraploid varieties (Callide, Samford) to enhance dairy farms production around cities and densely populated areas.

Nitrogen application has significant positive impact on productivity of Rhodes grass. Yield increment of 118% has been obtained whena dose of 120kgN/ha was applied after each cut. It is essential that management of nitrogen dose across cuts should be optimized. The success of Rhodes grass cultivation using border irrigation suggests its expansion in the near future in the problematic saline sodic soils south of Khartoum – north of Gezira. The low-cost forage produced by this system will contribute in reducing prices of animal products.

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APPENDICES

Appendix1.Quantities imported of Rhodes grass seed (ton)

Varieties	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Total**
Fin cut	10.000	51.600	145.000	178.000	290.000	90.110	764.110
Reclaimer	1.550	-	15.000	8.400	70.000	20.000	114.950
Katambora	2.500	-	-	-	26.500	15.000	44000
Fast cut	-	-	-	-	3.200	32.000	35.200
Commander	-	-	-	-	30.000	20.000	50.000
Callide	-	-	-	-	25.000	-	25.000

Appendix II. Monthly average temperature of meteorological data for the experimental period at Shambat

	2016				2017			
Month	Max Temp. (°C)	MinTemp. (°C)	Rain Fall (mm)	Relative Humidity (%)	Max Temp. (°C)	MinTemp. (°C)	Rain Fall (mm)	Relative Humidity (%)
Jan	-	-	-	-	16.8	34.2	-	30
Feb	-	-	-	-	14.9	31.6	-	23
Mar	-	-	-	-	17.8	36.3	-	19
Apr	-	-	-	-	24	40.9	-	17
May	-	-	-	-	26.3	41.6	5.3	29
Jun	-	-	-	-	26.4	42.4	1.5	30
Jul	-	-	-	-	26.7	39.9	40.4	42
Aug	25.2	36.1	69.5	55	24.8	36.6	15	52
Sep	25.4	39.2	23	63	26.5	39.3	2.5	43
Oct	24.6	40.2	-	32	24.3	39.4	-	27
Nov	21.4	37	-	31	20.8	34.8	-	30
Dec	17.5	33.4	-	34	18.3	33.6	-	38

Appendix III. Chemical and physical soil properties of the experimental site

Depth (cm)	pH	SP	ECe (dm/m)	Ca+Mg (mmol+L)	Na (m mol+I)	SAR	CaCO3	Clay (%)	Silt (%)	Sand (%)
0-15	7.79	53.6	1.4	9	5.1	2.4	5.1	42.1	15.9	42
15-35	7.88	50	1	6	4.3	2.5	4.88	39.6	15.8	44.6
35-51	7.87	56	1.2	5	7.1	4.5	4.99	44.1	16.4	39.5
51-75	7.91	66.4	2	8	12.5	6.3	4.88	51.4	16.6	32
75-90	7.71	64	2.2	6	16	9.2	5.2	50	16.6	33.4

Appendix IV. Soil analysis for Nitrogen (N), Phosphorus (P) and potassium (K)

Depth (cm)	N%	P (meg/kg)	K (meq/l)
0-20	0.084	0.53	0.195
0-20	0.140	0.79	0.096
0-20	0.140	0.46	0.070
Mean	**0.121**	**0.59**	**0.120**
20-40	0.112	0.54	0.079
20-40	0.098	0.54	0.066
20-40	0.098	0.51	0.084
Mean	**0.103**	**0.53**	**0.076**