ASSESSMENT OF LEAF BIOMASS PRODUCTION OF SELECTED DECIDUOUS INDIGENOUS BROWSE SHRUB IN SEMI-ARID ECOLOGICAL ZONE OF MWANGA DISTRICT, TANZANIA

GEORGE FERDINAND FUPI

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ABSTRACT

The major problem facing ruminant livestock production in semi-arid ecological zone is lack of adequate feed and of good quality throughout the year. The problem is more critical in the dry season. In semi-arid ecological zone leaf litter of shrubs and bushes are an important feed resource during the dry season. *Grewia bicolor* is the main deciduous indigenous browse shrub dominating the western lowland areas of Mwanga district. This study aimed at investigating the influence of season and lopping on re-growth potential, leaf biomass production and nutritive value of *Grewia bicolor* in western semiarid area of Mwanga district. The treatments were: T_1 control (where the *G. bicolor* plant was not-lopped), T_2 where *G. bicolor* plants was lopped at the start of short rain season (November), T_3 where *G. bicolor* plants was lopped at the start of long rain season (March). A complete randomized design was used in this study, where four replications were laid across a general slope and three treatments were applied in each replication. The study revealed that the local feed resources for grazing ruminants in the study area during the dry season were mainly leaf litter of deciduous browse shrubs, leaf litter of annual and perennial grasses, and some edible forbs. The leaf litter of *G. bicolor* deciduous browse shrub had high CP content ranging from 7 – 9 % while the understory grasses were low in CP (4 – 6 %). Lopping of *G. bicolor* increased leaf litter production from 94 to 217 kgDM/ha. It can be concluded that *G. bicolor* can be utilized to increase livestock production while undertaking some lopping techniques to increase leaf litter production and to maintain the balance between its canopy size and desirable understory grass species.

DECLARATION

I, George Ferdinand Fupi, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

George Ferdinand Fupi Date
(MSc. Candidate)

The above declaration is confirmed by

Prof. E.J. Mtengeti Date
(1st Supervisor)

Prof. C.P.I Mahonge Date

(2nd Supervisor)

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DEDICATION

This work is dedicated to my beloved parents Dr. Ferdinand Fupi and Dr. Agnes Fupi for their guidance, prayers and playing a cornerstone role in my education development.

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ABBREVIATIONS AND SYMBOLS

AOAC	Association of Official Analytical Chemist
^{o}C	Degree Celsius
CP	Crude Protein
DASP	Department of Animal Science and Production
DM	Dry Matter
Ha	hectare
IVDMD	*Invitro* Dry Matter Digestibility
IVOMD	*Invitro* Organic Matter Digestibility
Kg	Kilogram (s)
MM	Millimeter
NDF	Neutral Detergent Fiber
MRT	Duncan's new Multiple Range Tests
MSE	Mean Standard Error
Spp	species
SAS	Statistical Analysis System
SUA	Sokoine University of Agriculture
PCQ	Point Centered Quarter

CHAPTER ONE

1.0 INTRODUCTION

Livestock production in semi-arid areas is characterized by low productivity due to low quantity and quality of feed. Leaf litters of shrubs and bushes are important feed sources during the dry seasons, otherwise ruminant animals rely on thorny plant and may consume plants that may contain toxic compounds. In semi-arid ecological zone of Mwanga District, ruminant animals survive on leaf litter of deciduous indigenous shrubs during the dry season (Msangi, 2014). Leaves of deciduous indigenous browse shrubs are characterized by high crude protein and minerals (Devendra, 1990; Coppock, 1994). The level of nutrients of deciduous browse shrubs leaves varies due to various factors such as plant species, harvesting regime, season and location (Solomon, 2001). Research evidence indicates that when lopped, the indigenous browse shrubs increase amount of feed to ruminant animals in terms of increased sprouting of twigs (Kimse *et al.,* 1987).

Grewia bicolor is the main deciduous indigenous browse shrub dominating the western lowland areas of Mwanga District (Msangi, 2014), and it is identified as the main feed for ruminants in this semi-arid land with frequent droughts. It is usually a many stemmed shrub, occasionally small tree up to 5 to 10 m in height. Deeply fissured and peeling away in strip when it is at older stage and its stem bark is normally grey to reddish grey in color and smooth when young. Flowering and fruiting occur during the rainy season and deciduous leaves fall during the dry seasons (Mbuya *et al.*, 1994) and can build lots of leaf litter unless it is continuously consumed by ruminants. Ruminant livestock browse on the fresh or dead leaves (litter) and young stems. It is favored more by sheep and goats than other ruminants such as cattle.

More research on the nutritional value, productivity (biomass production) and management of deciduous indigenous browse shrubs of this ecological zone is therefore required so as to improve an understanding on how to reduce livestock feed shortage during the critical dry months. This study aimed at investigating the influence of season and lopping on re-growth potential, leaf biomass production and nutritive value of *Grewia bicolor* in semiarid areas of Mwanga District.

1.1 Problem Statement

The major problem facing ruminant livestock production in semi-arid ecological zone is lack of adequate feed and of good quality throughout the year. The problem is more critical in the dry season where grazing animals walk long distance without getting enough forage to graze. In this semi-arid ecological zone leaf litter of shrubs and bushes are an important feed resource during the dry season and drought conditions. Rigorous literature search reveals that in semi-arid ecological zone rangelands, scanty detailed study has been conducted on the influence of season and lopping on re-growth potential and leaf biomass production of deciduous indigenous browse shrubs but many studies have been done on estimating the above ground biomass in forest ecosystems. Browse biomass estimation for rangelands are very rare and many studies in rangelands have focused more on the livestock despite the fact that the browse biomass indeed forms the basis for livestock exploitation in these areas (Foroughbakhch *et al.*, 2009). Moreover, most of studies on rangeland productivity (e.g. Cho *et al.*, 2007; George *et al.*, 2009; Mengistu *et al.*, 2005; Nafus *et al.*, 2009; Yayneshet *et al.*, 2009) have focused on measuring biomass production of herbaceous vegetation ignoring the browse species, which are an important component of the ruminant livestock feed. Furthermore, for some few browse biomass production studies, more focus has been put on exotic than indigenous species (Sanon *et al*., 2007). Lack of quantitative information on leaf biomass production, available leaf litter biomass during the dry season and management regime for increased productivity is a hindrance to estimating the local shrubs support to the ruminants depending entirely on natural forages throughout the year. There is therefore a need to carry out a study to quantify leaf biomass production in situ with and without lopping. Quantitative information about the amount of leaf litter produced by indigenous browse shrubs in different season in semi-arid ecological zone of Mwanga District is also worth to investigate.

1.2 Justification of the Study

The semi-arid lowland rangelands of Mwanga District receive low annual rainfall (< 500 mm), which is not enough to sustain grasses and evergreen shrubs for grazing throughout the year. During the dry season, ruminant animals in this area survive on grazing leaf litter of deciduous indigenous shrubs (Msangi, 2014). The finding of this study will help to understand leaf litter production potential of *G. bicolor*, a deciduous indigenous shrub abundantly found in semi-arid western lowlands of Mwanga District and hence its importance in terms of providing animal feed in the dry season. The finding will also be useful to livestock stakeholders and policy makers as input in strategies for mitigating the problem of shortage of livestock feed in semi-arid areas, especially during the dry season.

1.3 Objective of the Study

1.3.1 Overall objective

To investigate the influence of season and lopping on re-growth potential, leaf biomass production and nutritive value of *Grewia bicolor* in semiarid areas of Mwanga District.

1.3.2 Specific objectives

1. To determine the effect of season and lopping on leaf litter production of *G. bicolor*
2. To assess the effect of season and lopping on re-growth rate of lopped G. *bicolor*
3. To determine the effect of season on chemical composition of *G. bicolor* leaves
4. To determine the effect of season and lopping *G. bicolor* shrubs on the understory herbaceous plants species composition and biomass production.

1.4 Hypotheses

1. There is no significant effect of season and lopping on litter biomass production of *G. bicolor*
2. There is no significant effect of season and lopping on re-growth performance of *G. bicolor* after lopping.
3. There is no significant difference between short and long rain seasons in terms of chemical composition of *G. bicolor* leaves
4. There is no significant effect of season and lopping on understory herbaceous plants species composition and biomass production of *G. bicolor.*

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Litter Production from Indigenous Browse Shrubs

Shrubs are defined as woody plant species of less than 6m and usually having multiple basal stems. Shrubs are classified as fodder if they are browsed by animals. In the dry season grazing ruminants require substantial amount of feed with crude protein content of about or above 7 % (Crowder and Chheda, 1982) so as to improve the intake of the dry highly lignified forages. Shrub leaves can be a viable alternative of oil seed cakes to improve the ruminant animals' diet because they contain higher levels of crude protein than most traditional feeds (especially grasses) used in animal feeding (Devendra, 1990; Coppock, 1994). Shrubs have high capacity to produce large quantity of leaves in range sites with prolonged dry periods because have massive and deep root system and thus have good access to water that infiltrated into the subsoil (30-150 cm) (Knoop and Walker, 1985). Leaf litter of these shrubs normally fall during the whole year and may reach peak during the mid of the second half of the dry season (Wieder and Wright, 1995). This leaf litter is an important feed resource for grazing ruminants during the dry seasons when herbaceous vegetation are rather scarce in semi-arid ecological zones.

2.2 Re-growth Characteristics of Lopped Indigenous Browse Shrubs

The removal of shoot growth from shrubs species either by grazing, lopping or by clipping stimulates the plant to produce new twigs (Kirmse *et al.*, 1987). They produce green foliage (leaves and twigs) of high nutritive value (Papachristou and Papanastasis, 1994) during the dry season, when forage from herbaceous plants is of low availability and quality (Papachristou *et al.,* 1999). If deciduous shrubs species are to be used as fodder resources for providing green feed to the animals, it is better to be cut once during the growing period. Such treatments will ensure not only higher amounts of total biomass but also richer in nutritionally grazeable material (Platis *et al*., 1999). The response of shrubs to lopping depends on the intensity, frequency, and season of lopping (McKell, 1980; Buwai and Trlica, 1977).

2.3 Chemical Composition and Contribution of Indigenous Browse Shrubs in the Quality of Ruminant Feeds

Shrubs are important sources of fodder for livestock in the semi-arid ecological zone and withstand harsh climatic conditions better than herbaceous species (Silanikore *et al.*, 1996). Shrub or browse species maintain their green leaves longer into dry season (Coppock, 1994). The ability of most browse species to remain green for a longer period is attributed to their deep root systems, which enable them to extract water and plant nutrient (Le Houérou, 1980) and are known to supply fodder with high crude protein (CP) content and minerals (Devendra, 1990; Coppock, 1994).

The nutritional value of deciduous browse shrub can be influenced by various factors; such as plant part, harvesting regime, season and location. These factors appear to influence chemical composition, palatability, rumen degradability, voluntary intake and nutrient utilization by ruminant animals (Solomon, 2001). The differences in nutrient content within shrub genera could be associated with the inherent nature of the species. Therefore, there could be morphological differences within the same species and differences in lignin, cellulose and hemicelluloses (Buyene, 2009). Browse species also provide vitamin and mineral elements, which are often lacking in mature natural grass pastures, especially during the dry season (Skerman *et al.*, 1988). Normally, the crude protein (CP) content of range herbaceous forages is between 8% to 12% of dry matter (DM) at the beginning of rainy season but drops to 2.2% to 4% during the dry season (Amaning-kwarteng, 1991) but most browse plant leaves have crude protein content of about or above 10% even in the dry season.

2.4 Changes of Herbaceous Vegetation Composition under Lopped Shrubs

Lopping the shrubs canopy improves the light underneath and thus increases herbaceous biomass, cover and diversity (Bates *et al.,* 2000). Changes in herbaceous vegetation species composition under lopped shrubs over time may be a good indicator of species' responses to cutting compared to un-cut shrubs. Herbaceous growth increases with cutting intensity increases (Angasa, 2002), due to increased light availability to the understory.

Herbaceous biomass, cover and diversity understory can increase by nearly 50% in lopped as compared to the un-lopped shrub canopy (Tolera *et al.,* 2012). Studies elsewhere have shown that tree cutting method influences richness of herbaceous species and the relative abundance of a few of the species among the initial population that were intolerant of shrub canopy cover (Dougil and Trodd, 1999). Generally, several findings suggest that reduced shrubs canopy cover could restore herbaceous plant productivity and biodiversity (Tolera *et al*., 2012; Bates *et al*., 2000; Smit, 2004; Ansley and Catellano, 2006). The sensitivity of some herbaceous species shown in various studies reflects the fact that, tree clearing/cutting/lopping could not be applied to the wider rangelands where bush encroachment is a problem. It is rather suggested that lopping should be done very strategically, where the local community could apply it to their range sites with enclosures (Angassa and Oba, 2008) as opposed to conducting large scale land clearing which may lead to environmental hazard due to overgrazing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area description

This study was carried out at Kiruru village reserved grazing area. The village is located in Lembeni Ward in Mwanga District. The District is located at 3° 46’ to 3°47’ south and 37°35’ to 37°50’ east. Kiruru village is located in the western lowland semi-arid part of the District. Western lowlands are on the leeward side and receive annual rainfall range between 300-500mm with frequent occurrences of severe drought usually in February and September as the driest months with an average amount of rainfall of less than 10mm. The minimum and maximum temperature varies from 16 °C to 32 °C.

Kiruru village is one of the villages where ruminant livestock production is among the major production system. In this village livestock graze in natural shrub lands with sparse grass vegetation and shrubs provide leaf litter during the dry season to the grazing animals.

3.2 Materials

Material and tools that were used include: a portable weigh balance for measuring fresh weight of vegetation samples and leaf litter, A 0.5 x 0.5 metallic quadrant frame to demarcate leaf litter sampling unit, tape measure for plot size and shrub crown diameter measurement, secateurs, bush knife for lopping the shrubs and sickle for understory vegetation clipping, plastic and paper bags for vegetation sample collection, pegs to demarcate the plots, ranging poles for aligning a straight line and masking tape for labeling the sample bags. The study was conducted in a reserved grazing area of the village where *G. bicolor* is the dominant vegetation.

3.3 Experimental Design

A complete randomized design was used in this study, where four replications were laid across a general slope and three treatments were allocated randomly in each replication. The treatment was T_1 control (where the *G. bicolor* plant was not lopped), T_2 where *G. bicolor* plants was lopped at the start of short rain season (November), T_3 where *G. bicolor* plants was lopped at the start of long rain season (March) (Appendix 1).

3.4 Sampling Procedures and Field Data Collection

Before laying down an experiment in the village reserved grazing area, a baseline study was done to estimate *G. bicolor* shrub density and its canopy cover by using Point Centered Quarter (PCQ) method as described by Herlocker (1999). Two transect lines of 100m each and 100m apart were used in this baseline study and distance from one sampling station to another was 20 m. The experimental area was demarcated in place where the baseline study had been conducted. Experimental area was demarcated into a total of twelve plots (i.e. three plots per replication). The size of each plot was 12m (Long) x 5m (Wide) = 60 m^2 with an inter-plot spacing of 2m. Four sampling frames were fitted in each plot and make a total of forty eight sampling frames. In each sampling frame three *G. bicolor* plants were tagged and used for all measurements of vegetative and leaf biomass production. The *G. bicolor* in T_2 in each replication was lopped at 20 cm above the ground in the beginning of short rain season in November and those in T_3 was lopped at the beginning of long rain season in March. Sprouting rate was assessed by counting the sprouts from five identified lopped branches of four *G. bicolor* plants in T_2 and T_3 plots. A 150 g sample of *G. bicolor* browse twigs of less than 5mm stem diameter was harvested once every month from wet and dry seasons in both lopped and unlopped treatments using secateurs and packed in paper carrier bags and thereafter transported to Sokoine University of Agriculture Animal Nutrition laboratory for oven drying, to determine dry matter content and chemical composition.

Line interception method was used to get herbaceous plant species composition understory lopped and unlopped *G. bicolor* canopy and percentage ground cover in each experimental plot in March and July. In this method, a 30 m tape measure was stretched out along the two diagonals of the experimental plots. The distance intercepted by forage, litter, bare ground and forbs were recorded. The forbs and forage species were identified so as to get herbaceous compositional cover.

A quadrant of 0.5m x 0.5m was thrown once in each of the four sampling frame of each experimental plot and all herbaceous plants in the quadrant harvested and weighed by using an electronic and portable weighing scale and packed in paper carrier bags and thereafter transported to Sokoine University of Agriculture Animal Nutrition laboratory for oven drying, to determine dry matter content, yield and chemical composition.

Leaf litter biomass samples were collected in four *G. bicolor* browse plants after determining their canopy area. The leaf litter of every individual plant was weighed separately by using an electronic portable weighing scale and thereafter transported to Sokoine University of Agriculture Animal Nutrition laboratory for oven drying, to determine dry matter content, yield and chemical composition.

3.5 Laboratory Sample Analysis

Chemical composition analysis was carried out for twigs, leaf litter and herbaceous plants understory the *G. bicolor* canopy. Samples were analyzed for dry matter content (DM) and crude protein (CP) according to AOAC (1990). The two stages technique of

Tilley and Terry (1963) were used to determine in vitro dry matter and organic matter digestibility (IVDMD and IVOMD). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) of the samples were analyzed according to the forage fibre analysis methods of Van Soest *et al.,* (1991).

3.6 Data Analysis

The data collected were analyzed using general linear model of SAS (2002). The following statistical model was used to analyse the collected data for leaf litter biomass and chemical composition, herbaceous plant species and chemical composition, sprout rate and ground cover:

$Yij = \mu + ti + eij$

Where: - Y_{ij}= Observation on the i^{th} lopping treatment on the j^{th} season, μ = the general mean, t_i = the effect of the i^{th} lopping treatment and E_{ij} = the random error.

Duncan's new Multiple Range Test (MRT) was used to test if there are significant differences between the treatment means.

CHAPTER FOUR

4.0 RESULTS

4.1 Weather condition during the experimental period

Records of rainfall during the experimental period are shown in Table 1. Total rainfall during the short rain season (October-December 2014) was 237mm and was lower than the amount of rainfall during the long rain season (March-May 2014), that is, 315mm. The total rainfall during the experimental period was 565mm received in 53 days.

Table 1: Monthly rainfall from October 2014 to July 2015

Mouth	Amount (mm)	Number of rainfall days
October, 2014	15	4
November, 2014	106	13
December, 2014	116	7
January, 2015	9	2
February, 2015	4	1
March, 2015	130	8
April, 2015	163	11
May, 2015	22	7
June, 2015	0	0
July, 2015	0	0

Source: Natural Resource Office Mwanga District

4.2 Shrub Species Density and their Canopy Cover

Baseline study was conducted to estimate *G. bicolor* shrubs density and its canopy cover by using Point Centered Quarter (PCQ) method (Table 2, Appendix 2). *G. bicolor* shrub tree density and canopy cover were higher than all other species in the study area. *G. bicolor* shrub had high relative frequency which indicated that the species was well distributed in the area. The total percentage canopy cover of the area was 73.79%. The grazing site vegetation type could be classified as shrub grassland.

Table 2: Shrub and tree species density and canopy cover of the study area

Species name	Tree Density (No. tree/ha)	Tree canopy area (m^2)/ha	% Canopy cover
G. bicolor	680.21	4516.59	45.17
Balanite	40.01	2676.67	26.77
Acacia	80.02	184.85	1.85

4.3 Effect of Season and Lopping on Leaf Litter Production of *G. bicolor*

The results of leaf litter production as affected by lopping *G. bicolor* during the short and long rains are shown in Table 3. Leaf litter production was significantly (P< 0.05) higher in long than in short rain seasons. In both short and long rain seasons lopping leaf litter production was relatively higher in lopped than un- lopped *G. bicolor* shrubs. Leaf litter production from lopped *G. bicolor* during short and long rain seasons were 94.45 kgDM/ha and 217.08 kgDM/ha, respectively and were higher than that of the un-lopped *G. bicolor* in both short and long rain.

Table 3: Mean Leaf litter production of lopped *G. bicolor* during short and long rain seasons

Season	Un-lopped (kgDM/ha)	Lopped (kgDM/ha)
Short rain	57.15 ± 25.98^{A}	94.45 ± 25.98^{A}
Long rain	179.78 ± 31.82^{B}	217.08 ± 25.98^{B}
Mean	118.47	155.77

Values in the same column followed by different letters are significantly different at P<0.05

4.4 Effect of Season and Lopping on Sprouting Performance of *G. bicolor*

The results of sprouting performance as affected by lopping *G. bicolor* during short and long rain seasons are shown in Table 4. Sprouting performance from lopped *G. bicolor* during the long rain seasons had the highest number of sprouts per plant (117 sprouts per plant) as compared to *G. bicolor* lopped during the short rain season (72 sprouts per plant).

Table 4: Number of sprouts of lopped *G. bicolor* at short and long rain seasons. (Lopped in Nov 2014 and March 2015 and sprouting data recorded in March 2015 and July 2015, respectively)

Season	**Number of sprouts (No/plant)**
Short rain	72^{B}
Long rain	117.25^{A}
Mean	94.62500
SEM	5.1164
P-value	0.0006

Means with same superscript letter are not significantly different at P>0.05
SEM=Standard Error of Means.

4.5 Effect of Season on Chemical Composition of *G. bicolor* leaf litter

Mean effect of season on chemical composition and digestibility of *G. bicolor* leaf litter is shown in Table 5. There was no significant difference (P>0.05) between the seasons with regard to DM, IVDMD and IVOMD. However, the short rain season leaf litter had significantly (P<0.05) higher Ash, CP and NDF than that of the long rain season.

Table 5: Mean effect of season on Chemical Composition and digestibility of leaf litters of *G. bicolor*

	Chemical composition (g/kg DM				IVDMD	IVOMD
Season	**DM**	**Ash**	**CP**	**NDF**	**g/kg DM**	**g/kg DM**
Short rain	91.42^A	19.84^A	8.95^A	61.74^A	35.38^A	32.16^A
Long rain	91.12^A	13.49^B	7.85^B	47.87^B	37.56^A	34.50^A
Mean	91.24	16.03	8.29	53.42	36.69	33.57
SEM	0.7809	0.6506	0.2259	0.5270	0.6252	0.6750
P-value	0.0856	0.0002	0.0278	0.0001	0.1671	0.1638

Means with same superscript letter are not significantly different at (p>0.05). level.
SEM=Standard Error of Means

4.6 Monthly Change of Chemical Composition of *G. bicolor* leaves

Monthly change of chemical composition of *G. bicolor* leaves from November, 2014 to July, 2015 is shown in Figure 1. Crude Protein, ASH and NDF content of *G. bicolor* during the short rain season were relatively higher than those of long rain season. The CP content was below 10% in June and July. The NDF on the other hand ranged from 40 - 50% throughout the seasons.

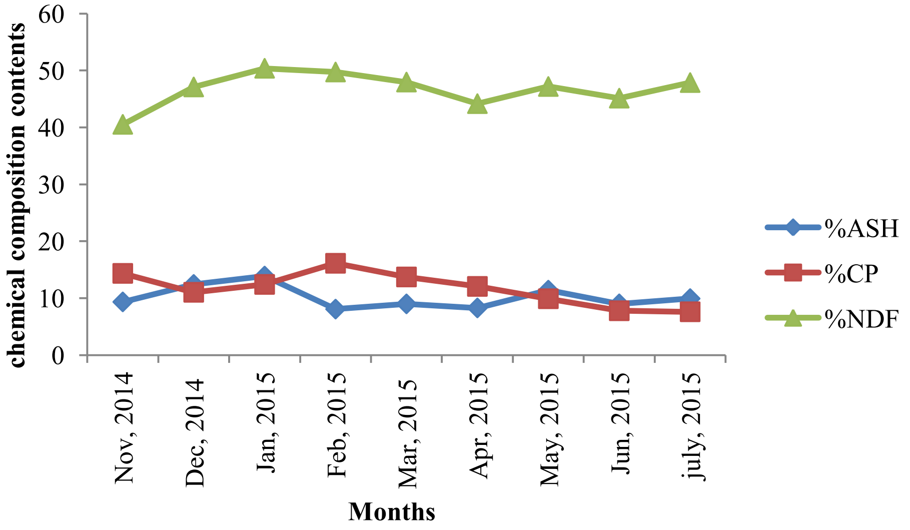

Figure 1: Monthly change of chemical composition contents of *G. bicolor* leaves

4.7 Vegetation Cover under Lopped *G. bicolor* During the Short and Long Rain Seasons

There was relatively higher understory forage and forbs cover in March as compared to July (Table 6). Litter cover and bare ground were relatively higher in July than in March.

Table 6: Percentage ground cover for understory lopped *G. bicolor* shrubs

Ground cover (%)	**Lopped Short rain (March)**	**Lopped Long rain (July)**
Forage	46.12	34.29
Litter	24.26	29.85
Bare	19.75	30.68
Forbs	9.87	5.18

4.8 Herbaceous Species Composition under Lopped *G. bicolor* Shrub during the Short and Long Rain

Annual grasses (*Setaria* spp, *Rhynchelytrum repens*) had higher coverage than perennial grasses (*Enteropogon macrostachyus, Panicum* spp) (Table 7). There was more forbs cover in March than in July while the land that was covered by litter and bare ground were higher in July than in March.

Table 7: Effect of lopping on understory herbaceous species composition

Understory herbaceous species	**Coverage percentage (%) of each species**	
	Lopped short rain (March)	**Lopped long rain (July)**
Grasses		
Setaria spp	4.39	2.46
Rhynchelytrum repens	37.35	27.87
Enteropogon macrostachyus	0.99	1.28
Panicum spp	3.39	2.68
Forbs		
Osimum spp	0.18	3.58
Sida glomerata	0.60	1.60
Tephrosia spp	1.74	0
Sida spp	5.23	0
Commelina bangalensis	2.12	0
Litter cover and bare ground	44.01	60.53

4.9 Effect of Season and Lopping *G. bicolor* shrubs on the Understory Herbaceous Plant Biomass Production

The results of understory herbaceous biomass production as affected by lopping *G. bicolor* during short and long rain seasons are shown in Table 8. A slight variation of understory herbaceous biomass production between treatments was observed. Understory herbaceous biomass production for the lopped *G. bicolor* during short rain and long rain seasons were 2475.14 kgDM/ha and 3369.80 kgDM/ha respectively. For the un-lopped *G. bicolor* understory biomass production during the short rain and long rains were 2503.79 kgDM/ha and 3398.44 kgDM/ha respectively.

Table 8: Mean effect of season and lopping *G. bicolor* on understory herbaceous biomass production during the short and long rain seasons

Season	Un-lopped (kgDM/ha)	Lopped (kgDM/ha)
Short rain	2503.79±146.15^{A}	2475.14±113.56^{A}
Long rain	3398.44±175.01^{B}	3369.80±146.15^{B}
Mean	2951.12	2922.47

Values in the same column followed by different letters are significantly different at $P<0.05$

4.10 Effect of Season on Chemical Composition and Digestibility of Understory Herbaceous Vegetation in *G. bicolor* Shrubs

Mean effect of season on chemical composition and digestibility of understory herbaceous vegetation from *G. bicolor* shrubs are shown in Table 9. There were no significant ($P>0.05$) difference between the season with regard to DM and NDF. However, the short rain season herbaceous vegetation had significantly ($P<0.05$) higher Ash, CP, IVDMD and IVOMD than long rain season.

Table 9: Mean effect of season on chemical composition and digestibility of understory herbaceous vegetation in *G. bicolor* shrub bushes

	Chemical composition (g/kg DM)				IVDMD	IVOMD
Season	**DM**	**Ash**	**CP**	**NDF**	**g/kg DM**	**g/kg DM**
Short rain	91.12^{A}	9.78^{A}	5.89^{A}	71.96^{A}	29.28^{A}	25.83^{A}
Long rain	91.63^{A}	8.19^{B}	4.02^{B}	68.29^{A}	25.45^{B}	23.42^{B}
Mean	91.37	8.98	4.95	70.12	27.37	24.62
SEM	0.2254	0.2945	0.1852	0.8392	0.3918	0.4609
P-value	0.2542	0.0311	0.0001	0.0859	0.0002	0.0231

Means with same superscript letter are not significantly different at $P >0.05$;
SEM=Standard Error of Means

CHAPTER FIVE

5.0 DISCUSSION

5.1 Weather Condition and Vegetation Characteristics during the Study Period

The rainfall distribution was rather poor in both short and long rains. Out of 92 days of each season only 24 to 26 days were raining. The rainiest month was April of which 163mm of rain were received within 11 days. This rainfall indicates typical arid and semi-arid rangeland condition where the rainfall distribution is always poor but with high rainfall intensity (i.e. most of the rainfall falls in very short time) and followed by high runoff and low infiltration and therefore, it leads to low land productivity (Tivy, 1990).

The total rainfall of 565mm received during the experimental period seems to be relatively high given the fact that in this study area it has been observed that only five years out of thirty years may record ≥ 500mm of rainfall per year (Mtengeti *et al*., 2012). The most dominant deciduous browse shrubs in the study area was *G. bicolor* followed by *Acacia* spp indicating that *G. bicolor* can significantly contribute to the ruminant feed in this semi-arid ecological zone with low and erratic rainfall and insignificant presence of perennial grasses. However, in term of canopy cover *G. bicolor* covered greater than forty percent of study area followed by *Balanite aegypticum.*

The total shrub canopy cover of nearly 74% leaves very little open area for herbaceous vegetation cover (i.e. grasses and legume). This leads to less grazing vegetation and thus gives way to the browses to dominant the area. In this area however, it has been reported that ruminant animal survive on leaf litter of deciduous indigenous shrubs during the dry season (Msangi, 2014).

5.2 Effect of Lopping on Leaf Litter Production and Sprouting Performance of *G. bicolor*

Lopping of *G. bicolor* increased leaf litter production through increased number of sprouting. This was more pronounced in the long rain season as compared to short rain season. This result agrees with those of Kirmse *et al.* (1987) and shows that the removal of shoot growth from shrubs species either by grazing, lopping or by clipping stimulates the plant to produce new twigs and hence increases the amount of leaves. Short rain season produced higher leaf litter biomass per sprout (762g per sprout) than long rain season (540g per sprout). This could be due to the high number of sprout per plant 117 (23 sprout per branch) in the long rain season as compared to 72 sprout per plant (14 sprout per branch) in short rain season. It shows that there is a limit of the number of sprout per branch in improving leaf biomass production.

5.3 Effect of Season on Chemical Composition and Digestibility of *G. bicolor* leaves

Grewia bicolor leaf litter produced in the short rain season had high ASH, CP and NDF as compared to those produced in long rain season. The decrease of ASH and NDF content of *G. bicolor* leaves with onset of dry season was also noted by Heuzẽ *et al.* (2013). The NDF range of 40 – 60% from this study was within those reported by Heuzẽ *et al.* (2013). These researchers reported average CP content ranging from 9.6 to 21.5% which is slightly higher than the one obtained in this study that ranges from 7.6 to 16.1%; this could be due to difference in location and time of collection and age of the plant (Aganga *et al.*, 2000). The short rain litter was collected in early March during the beginning of long rain season while the long rain season litter was collected in early July after nearly fifty days of dryness. The decrease of CP content of *G. bicolor* leaves with onset of dry season was also noted in Botswana by Aganga *et al.* (2000). However the digestibility varied slightly due to season.

5.4 Vegetation Cover and Herbaceous Species Composition under Lopped *G. bicolor* Shrub

Lopping in the short rain season improved understory vegetation cover as compared to lopping in the long rain season. Understory vegetation cover was recorded in early March for short rain season and July for long rain season fifty days after the onset of drought. The highest forage cover was dominated by annuals grasses (*Setaria spp, Rhynchelytrum repens*) in the study area which indicated poor range condition (Herlocker, 1999). In July most of the annual grasses have dried out and left large parts of land bare. The study area had low content of perennial grass (*Enteropogon macrostachyus* and *Panicum* spp).

The forbs cover was relatively higher in short rain season than in long rain season, some of this forbs can improve stocking capacity in beginning of the rain season (i.e. *Commelina bangalensis* and *Sida* spp). However, most of these forbs were not found in July, thus, they cannot be used in estimating stocking capacity of this study area.

The litter cover ranged from 24 to 30% signifying the advantage of deciduous browse species in terms of providing feed and protecting the soil from being dislodged by rainfall and thus reducing soil erosion, and conserving soil moisture that could be lost through evapotranspiration.

5.5 Effect of Season on Biomass Production, Chemical Composition and Digestibility of Understory Herbaceous Vegetation in *G. bicolor* Shrub

The understory herbaceous biomass was rather lower in short rain season than in long rain although the difference between lopped and un-lopped within the season was rather low. The ASH, CP and digestibility of understory herbaceous species was rather low in both seasons ranging from 8.2 to 9.8% for ASH, 4.0 to 5.8% for CP and 25.5 to 29.3% for IVDMD. However, the NDF was rather high ranging from 68.3 to 72%. The results from this study were in agreement with those reported by Mtengeti and Mwakasendo (2012) who reported higher amount of NDF under low light intensity.

Although the yield of understory herbaceous vegetation was about 2.5 to 3.4 tDM/ha it was rather poor in terms of CP content and digestibility as compared to a leaf litter of *G. bicolor* whose biomass reached about 0.2 tDM/ha and had 1 – 2 CP unit above the ruminant maintenance CP of 7% for ruminant production (Crowder and Chheda, 1982). It means that the leaf litter of *G. bicolor* has a great importance in subsisting the ruminant animal population of most of the western semi-arid low land of Mwanga District.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

On the basis of the findings of this study the following conclusions are made:

1. *G. bicolor* in the grazing lands of semi-arid areas available would be potentially utilized for livestock feeding, as leaf litter during the dry seasons. However, some improvement strategies are required to increase its leaf litter biomass production and understory species to efficiently use these feed resource during the dry season.
2. Lopping of *G. bicolor* increased leaf litter production by increasing leaf litter production through increased number of sprouting hence increased the amount of leaves per plant and biomass production.
3. The study revealed that the resources used to feed livestock during the dry season were leaf litter of deciduous browse shrubs, litter of annual and dry perennial grasses, and some forbs. The leaf litter of *G. bicolor* deciduous browse shrubs had high CP content ranging from 7 and 9 % while the grasses were low in CP. High nutritive value of the *G. bicolor* leaf litter implies that it can be used as supplement feed especially during the dry season.
4. Lopping *G. bicolor* in short rain improves understory vegetation cover as compared to lopping in the long rain. The forbs cover was relatively higher in short rain than in long rain, some of these forbs can improve stocking capacity at the beginning of rain season.

6.2 Recommendations

On the basis of the findings of this study the following recommendations are made:

i. *G. bicolor* can be introduced as a source of fodder in animal production farms and silvopastoral system

ii. The *G. bicolor* available in the study area should be utilized to increase livestock production while undertaking some lopping techniques to increase leaf litter production and to maintain the balance between the deciduous indigenous shrubs and the herbaceous species

iii. Apart from season, lopping and nutritive value, *G. bicolor* needs to be investigated further in terms of palatability, digestibility, feed intake, animal response trial and anti-nutritional factors in order to be able to enhance its utilization in the future

iv. The study was conducted for one year (in short and long rain season) and on one type of soil. Therefore, it is recommended that the experiment should be done for longer period of at least two years and on different soil types

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APPENDICES

Appendix 1: Experimental layout plan showing number of plots and replication.

Rep 1	Rep 2	Rep 3	Rep 4
T_1	T_3	T_2	T_1
T_2	T_1	T_3	T_2
T_3	T_2	T_1	T_3

KEY

T_1 = control (uncut),

T_2 = plants were coppiced at 20 cm above the ground at the start of short rain season (November),

T_3= plants were coppiced at 20 cm above the ground at the start of long rain season (March)

Appendix 2: Baseline study on species density and canopy cover of the area

Sampling point within a transect line		Species name (Trees/Shrubs)	Distance/Quarter (m)	Canopy area (meter square)
1	1	G. bicolor	3.9	14.82
	2	Balanite	3.3	11.52
	3	Balanite	3.3	60
	4	G. bicolor	3.6	5
				0
2	1	Acacia	2.7	4.62
	2	G.bicolor	4.6	3.74
	3	G.bicolor	5.5	5
	4	G.bicolor	7.3	2.88
				0
3	1	G. bicolor	2.8	3.06
	2	G. bicolor	2.9	11.52
	3	G. bicolor	3.5	11.47
	4	G. bicolor	2.1	5.98
				0
4	1	G. bicolor	2.8	11.88
	2	G. bicolor	4.2	9.6
	3	G. bicolor	2.8	6.6
	4	G. bicolor	3.5	6.5
				0
5	1	G. bicolor	2.7	7.02
	2	G. bicolor	2.1	2.1
	3	G. bicolor	2.5	2.72
	4	G. bicolor	4.6	3
		Total	70.7	189.03

Density of tree (No. tree/Unit area which is 10,000 m^2 in this case) is

- ✓ Mean distance (D) = 70.7m/20 tree in 5 sample = 3.535m
- ✓ Absolute density= Area/D^2 = $10,000m^2/3.535^2$ = 800.24 trees/ 10,000 m^2

Tree density by species

Species	Frequency / Quarter	Density (Tree/ha)
G. bicolor	17/20= 0.85	0.85*800.2417 =680.2054
Acacia	1/20 = 0.05	0.05*800.2417 =40.0121
Balanite	2/20 = 0.10	0.1*800.2417 = 80.0242

Total	800.2417

Absolute frequency = (No. points with species / total points)

Species	Absolute Frequency
G. bicolor	(5/5)*100 =100
Acacia	(1/5)* 100 = 20
Balanite	(1/5)*100 = 20

Mean crown cover of G. bicolor =189.03 – 76.14/ 17 = 6.64 m^2 /tree

Mean crown cover of Balanite = 71.52 – 4.62/2 = 33.45 m^2 /tree

Mean crown cover of Acacia = 4.62/1 = 4.62 m^2 /tree

Tree canopy area coverage in the whole area (10,000m^2)

For G. bicolor = 6.64m^2 /tree X 680.21 tree/ 10,000m^2 = 4516.59m^2 /10,000m^2

For Balanite species 33.45m^2 /tree X 80.02 tree /10,000m^2 = 2676.67m^2 /10,000m^2

For Acacia species = 4.62m^2 /tree X 40.01 tree/ 10,000m^2 = 184.85 m^2 / 10,000m^2

Percentages cover by the species

G. bicolor 4516.59/10,000 X 100 = 45.17%

Balanite 2676.67/10,000 X 100 = 26.77%

Acacia species 184.85/10,000 = 1.85%

Open area = 100% – (45.17% + 26.77% + 1.85%) = 26.21%

The relative frequency of each species

Species	Relative Frequency
G. bicolor	71.4286
Acacia	14.2857
Balanite	14.2857

Appendix 3: Anova model for leaf litter production

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	57.1471191	B	25.98275305	2.2	0.0412
Lopped 1	37.2988612	B	31.82224354	1.17	0.2564
Lopped 0	0	B	.	.	.
season 1	122.6297907	B	31.82224354	3.85	0.0012
season 0	0	B	.	.	.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lopped	1	6498.99548	6498.99548	1.21	0.2862
season	1	72775.7307	72775.73066	13.58	0.0018
Lopped*season	1	30.32502	30.32502	0.01	0.9409

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	56.1417167	B	29.88681943	1.88	0.0776
Lopped 1	39.309666	B	42.26634538	0.93	0.3654
season 1	125.6459978	B	51.76548973	2.43	0.0266
Lopped*season 1 1	-5.0270119	B	66.82895988	-0.08	0.9409

Parameter	Estimate	Standard Error	t Value	Pr > |t|
lopped long	217.075771	25.98275	8.35	<.0001
lopped short	94.44598	25.98275	3.63	0.0019
Ulopped long	179.77691	31.82224	5.65	<0.0001
Ulopped Short	57.147119	25.98275	2.2	0.0412

Appendix 4: Anova model shown number of sprouts per plant at lopped G. bicolor at the short and long rain seasons.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	1	8190.250000	8190.250000	19.53	0.0006

Level of treat	N	sprouts	
		Mean	**Std Dev**
2	**8**	72.000000	19.7267042
3	**8**	117.250000	21.2047838

Appendix 5: Anova model shown effect of season on chemical composition of *G. bicolor* leaves.

G. bicolor litter production

The GLM Procedure

Dependent Variable: DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	5.17296917	1.29324229	2.65	0.0572
Error	25	12.21861750	0.48874470		
Corrected Total	29	17.39158667			

R-Square	CoeffVar	Root MSE	DM Mean
0.297441	0.766230	0.699103	91.23933

Source	DF	Type I SS	Mean Square	F Value	Pr > F
sesn	1	0.65280889	0.65280889	1.34	0.2587
rep	1	0.59925333	0.59925333	1.23	0.2787
trt	2	3.92090694	1.96045347	4.01	0.0308

Source	DF	Type III SS	Mean Square	F Value	Pr > F
sesn	1	1.56570417	1.56570417	3.20	0.0856
rep	1	0.59925333	0.59925333	1.23	0.2787
trt	2	3.92090694	1.96045347	4.01	0.0308

```
                              The SAS System

                            The GLM Procedure

Dependent Variable: ASH
        Source            DF  Sum of Squares  Mean Square  F Value  Pr > F

        Model              4     301.5102167   75.3775542     5.72  0.0021

        Error             25     329.4196533   13.1767861

        Corrected Total   29     630.9298700


                R-Square  CoeffVar  Root MSE  ASH Mean

                0.477882  22.64353  3.629984  16.03100


            Source  DF    Type I SS  Mean Square  F Value  Pr > F

            sesn     1  289.9157422  289.9157422    22.00  <.0001

            rep      1    3.6540300    3.6540300     0.28  0.6031

            trt      2    7.9404444    3.9702222     0.30  0.7425


            Source  DF  Type III SS  Mean Square  F Value  Pr > F

            sesn     1  244.4816667  244.4816667    18.55  0.0002

            rep      1    3.6540300    3.6540300     0.28  0.6031

            trt      2    7.9404444    3.9702222     0.30  0.7425
```

```
                                  The SAS System

                                The GLM Procedure

Dependent Variable: CP

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

        Model             4      12.96896333    3.24224083      2.19   0.0990

        Error            25      36.97590333    1.47903613

        Corrected Total  29      49.94486667


                    R-Square   CoeffVar   Root MSE   CP Mean

                    0.259666   14.67606   1.216156   8.286667


              Source   DF    Type I SS   Mean Square   F Value   Pr > F

              sesn      1   8.75605556    8.75605556      5.92   0.0225

              rep       1   4.09221333    4.09221333      2.77   0.1087

              trt       2   0.12069444    0.06034722      0.04   0.9601


              Source   DF  Type III SS   Mean Square   F Value   Pr > F

              sesn      1   8.07360000    8.07360000      5.46   0.0278

              rep       1   4.09221333    4.09221333      2.77   0.1087

              trt       2   0.12069444    0.06034722      0.04   0.9601
```

```
                                   The SAS System

                                 The GLM Procedure

Dependent Variable: NDF
          Source           DF  Sum of Squares  Mean Square  F Value   Pr > F
          Model             4     1474.071056   368.517764    52.62  <.0001
          Error            25      175.068824     7.002753
          Corrected Total  29     1649.139880

                       R-Square  CoeffVar  Root MSE  NDF Mean
                       0.893842  4.953895  2.646272  53.41800

                Source  DF    Type I SS  Mean Square  F Value  Pr > F
                sesn     1  1385.946005  1385.946005   197.91  <.0001
                rep      1    27.494613    27.494613     3.93  0.0586
                trt      2    60.630437    30.315219     4.33  0.0243

                Source  DF  Type III SS  Mean Square  F Value  Pr > F
                sesn     1  1367.305104  1367.305104   195.25  <.0001
                rep      1    27.494613    27.494613     3.93  0.0586
                trt      2    60.630437    30.315219     4.33  0.0243
```

```
                                The SAS System

                              The GLM Procedure

Dependent Variable: IVDMD
     Source            DF  Sum of Squares  Mean Square  F Value  Pr > F
     Model              4      35.1095400    8.7773850     0.69  0.6041
     Error             25     316.8325800   12.6733032
     Corrected Total   29     351.9421200

             R-Square  CoeffVar  Root MSE  IVDMD Mean
             0.099759  9.703861  3.559958    36.68600

          Source  DF    Type I SS  Mean Square  F Value  Pr > F
          sesn     1  34.37442000  34.37442000     2.71  0.1121
          rep      1   0.21845333   0.21845333     0.02  0.8966
          trt      2   0.51666667   0.25833333     0.02  0.9798

          Source  DF  Type III SS  Mean Square  F Value  Pr > F
          sesn     1  25.66801667  25.66801667     2.03  0.1671
          rep      1   0.21845333   0.21845333     0.02  0.8966
          trt      2   0.51666667   0.25833333     0.02  0.9798
```

G.bicolor understory herbaceous vegetation.

```
Dependent Variable: DM
     Source            DF  Sum of Squares  Mean Square  F Value  Pr > F
     Model              5     12.93751767   2.58750353     2.98  0.0393
     Error             18     15.62306566   0.86794809
     Corrected Total   23     28.56058333

               R-Square  CoeffVar  Root MSE  DM Mean
               0.452985  1.019585  0.931637  91.37417


          Source  DF   Type I SS  Mean Square  F Value  Pr > F
          sesn     1  1.53015000   1.53015000     1.76  0.2009
          rep      1  1.76041667   1.76041667     2.03  0.1715
```

Source	**DF**	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
trt	2	5.14142291	2.57071145	2.96	0.0773
line	1	4.50552810	4.50552810	5.19	0.0351

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
sesn	1	1.20393332	1.20393332	1.39	0.2542
rep	1	2.11023350	2.11023350	2.43	0.1363
trt	2	5.64528434	2.82264217	3.25	0.0623
line	1	4.50552810	4.50552810	5.19	0.0351

```
                                The SAS System

                             The GLM Procedure

Dependent Variable: ASH
     Source           DF  Sum of Squares  Mean Square  F Value  Pr > F

     Model             5     16.94053399   3.38810680     1.28  0.3148

     Error            18     47.59482851   2.64415714

     Corrected Total  23     64.53536250

              R-Square  CoeffVar  Root MSE  ASH Mean

              0.262500  18.10031  1.626086  8.983750

          Source  DF   Type I SS   Mean Square  F Value  Pr > F

          sesn     1 15.12093750   15.12093750     5.72  0.0279

          rep      1  0.92433750    0.92433750     0.35  0.5617

          trt      2  0.40604959    0.20302480     0.08  0.9264

          line     1  0.48920940    0.48920940     0.19  0.6722

          Source  DF Type III SS   Mean Square  F Value  Pr > F

          sesn     1 14.46660580   14.46660580     5.47  0.0311

          rep      1  0.79606417    0.79606417     0.30  0.5900

          trt      2  0.48705483    0.24352741     0.09  0.9124

          line     1  0.48920940    0.48920940     0.19  0.6722
```

```
                                The SAS System

                              The GLM Procedure

Dependent Variable: CP
       Source           DF  Sum of Squares  Mean Square  F Value  Pr > F

       Model             5     24.29324929   4.85864986     5.35  0.0035

       Error            18     16.34644654   0.90813592

       Corrected Total  23     40.63969583


                  R-Square  CoeffVar  Root MSE  CP Mean

                  0.597771  19.25013  0.952962  4.950417


            Source  DF   Type I SS  Mean Square  F Value  Pr > F

            sesn     1 20.85070417  20.85070417    22.96  0.0001

            rep      1  1.02920417   1.02920417     1.13  0.3011

            trt      2  0.27704905   0.13852453     0.15  0.8596

            line     1  2.13629191   2.13629191     2.35  0.1425


            Source  DF Type III SS  Mean Square  F Value  Pr > F

            sesn     1 21.16239857  21.16239857    23.30  0.0001

            rep      1  1.14009317   1.14009317     1.26  0.2772

            trt      2  0.42383679   0.21191840     0.23  0.7942

            line     1  2.13629191   2.13629191     2.35  0.1425
```

```
                              The SAS System

                            The GLM Procedure

Dependent Variable: NDF
      Source           DF  Sum of Squares  Mean Square  F Value  Pr > F
      Model             5      95.6820850   19.1364170     0.79  0.5713
      Error            18     436.6848484   24.2602694
      Corrected Total  23     532.3669333

               R-Square  CoeffVar  Root MSE  NDF Mean
               0.179730  7.024012  4.925471  70.12333

          Source  DF   Type I SS  Mean Square  F Value  Pr > F
          sesn     1 80.88681667  80.88681667     3.33  0.0845
          rep      1  0.34081667   0.34081667     0.01  0.9070
          trt      2  4.83218135   2.41609068     0.10  0.9057
          line     1  9.62227029   9.62227029     0.40  0.5367

          Source  DF Type III SS  Mean Square  F Value  Pr > F
          sesn     1 80.08263786  80.08263786     3.30  0.0859
          rep      1  0.33258704   0.33258704     0.01  0.9081
          trt      2  4.75163497   2.37581749     0.10  0.9072
          line     1  9.62227029   9.62227029     0.40  0.5367
```

```
                              The SAS System

                            The GLM Procedure

Dependent Variable: IVDMD

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

       Model              5     102.2646111   20.4529222     5.14  0.0042

       Error             18      71.6231722    3.9790651

       Corrected Total   23     173.8877833


             R-Square  CoeffVar  Root MSE  IVDMD Mean

             0.588107  7.289233  1.994759    27.36583


          Source  DF   Type I SS    Mean Square  F Value  Pr > F

          sesn     1  87.93681667  87.93681667    22.10  0.0002

          rep      1   0.01815000   0.01815000     0.00  0.9469

          trt      2   1.13796345   0.56898172     0.14  0.8677

          line     1  13.17168100  13.17168100     3.31  0.0855


          Source  DF  Type III SS   Mean Square  F Value  Pr > F

          sesn     1  86.97352568  86.97352568    21.86  0.0002

          rep      1   0.01813559   0.01813559     0.00  0.9469

          trt      2   0.98904444   0.49452222     0.12  0.8839

          line     1  13.17168100  13.17168100     3.31  0.0855
```

```
                                 The SAS System

                               The GLM Procedure

Dependent Variable: IVOMD
        Source            DF  Sum of Squares  Mean Square  F Value  Pr > F

        Model              5      58.1882250   11.6376450     2.16  0.1051

        Error             18      97.1915083    5.3995282

        Corrected Total   23     155.3797333


                    R-Square  CoeffVar  Root MSE  IVOMD Mean

                    0.374490  9.437576  2.323688    24.62167


                 Source  DF    Type I SS  Mean Square  F Value  Pr > F

                 sesn     1  34.75226667  34.75226667     6.44  0.0207

                 rep      1   2.00681667   2.00681667     0.37  0.5497

                 trt      2   7.17492236   3.58746118     0.66  0.5268

                 line     1  14.25421935  14.25421935     2.64  0.1216


                 Source  DF  Type III SS  Mean Square  F Value  Pr > F

                 sesn     1  33.28263682  33.28263682     6.16  0.0231

                 rep      1   2.25896710   2.25896710     0.42  0.5259

                 trt      2   6.29232505   3.14616252     0.58  0.5686

                 line     1  14.25421935  14.25421935     2.64  0.1216
```

```
                                The SAS System

                               The GLM Procedure

Dependent Variable: IVOMD
        Source           DF  Sum of Squares  Mean Square  F Value  Pr > F
        Model             4      42.1600292   10.5400073     0.71  0.5951
        Error            25     373.0413175   14.9216527
        Corrected Total  29     415.2013467

                R-Square  CoeffVar  Root MSE  IVOMD Mean
                0.101541  11.50847  3.862856    33.56533

            Source  DF   Type I SS  Mean Square  F Value  Pr > F
            sesn     1 39.49923556  39.49923556     2.65  0.1163
            rep      1  2.43105333   2.43105333     0.16  0.6899
            trt      2  0.22974028   0.11487014     0.01  0.9923

            Source  DF Type III SS  Mean Square  F Value  Pr > F
            sesn     1 30.71343750  30.71343750     2.06  0.1638
            rep      1  2.43105333   2.43105333     0.16  0.6899
            trt      2  0.22974028   0.11487014     0.01  0.9923
```

Appendix 6: Anova model shown effect of lopping *G. bicolor* shrubs on the understory herbaceous plant species composition

Source	DF	Type III SS	Mean Square	F Value	Pr > F
lopped	1	6470.772	6470.772	0.03	0.8647
season	1	6310501.56	6310501.555	28.78	<0.0001

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	2503.786436	B	146.1468	17.13	<.0001
lopped 1	-28.648582	B	166.7539	-0.17	0.8647
lopped 0	0	B	.	.	.
season 1	894.657969	B	166.7539	5.37	q
season 0	0	B	.	.	.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
lopped long	3369.79582	146.14679	23.06	<.0001
lopped short	2475.13785	113.560248	21.8	<.0001
Ulopped long	3398.4444	175.008096	19.42	<.0001
Ulopped Short	2503.78644	146.14679	17.13	<.0001

Appendix 7: Chemical composition of leaves of *G. bicolor* from semi-arid ecological zone of Mwanga District

	Chemical composition (g/kgDM)			
	DM	**Ash**	**CP**	**NDF**
November,2014	89.89	9.33	14.34	40.53
December,2014	92.17	12.40	11.01	47.10
January,2015	92.39	13.87	12.40	50.38
February,2015	89.59	8.06	16.11	49.73
March,2015	90.69	8.98	13.71	47.96
April,2015	92.68	8.27	12.05	44.17
May,2015	91.22	11.39	9.88	47.18
June,2015	91.34	8.99	7.77	45.13
July,2015	92.44	9.91	7.59	47.87