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HARAMAYA UNIVERSITY

As *Thesis* Research advisor, I here by certify that I have read and evaluated this thesis Prepared, under my guidance, by **ASHAGRE ABATE**, entitled: **EFFECT OF NITROGEN FERTILIZER AND HARVESTING STAGE ON YIELD AND QUALITY OF NATURAL PASTURE IN FOGERA DISTRICT, NORTH WESTERN ETHIOPIA.** I recommend that it be submitted as fulfilling the Thesis Requirement.

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As member of the *Board of examiners of the Msc Thesis Open Defense Examination*. We certify that we have read evaluated the Thesis prepared by ASHAGRE ABATE and examined the candidate. We recommended that the Thesis be accepted as fulfilling the *thesis requirement for the Degree of Master of Science* in Agriculture (Range Ecology and Management).

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Chair-person	Signature	Date
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Internal examiner	Signature	Date
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External examiner	Signature	Date

DEDICATION

This thesis is heartily dedicated to my wife, **Abeba Wubetu** and my daughter **Beteliham Ashagre** for their moral support and encouragement during my work at Haramaya University.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my bonafide work and that all sources of materials used for this thesis has been duly acknowledge. This thesis has been submitted in partial fulfillment of the requirement for M.Sc. degree at the Haramaya University and is deposited at the University library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution any where for the award of any other academic degree, diploma or certificate.

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LIST OF ACRONYMS AND SYMBOLS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
BoRD	Bureau of Agriculture and Rural Development
C	Carbon
C^{o}	Degree Centigrade
CE	Cellulose
CEC	Cation Exchange Capacity
CF	Crude Fiber
cm	Centimeter
CP	Crude Protein
CV	Coefficient of Variation
DAP	Diammonium Phosphate
DM	Dry Matter
DWR	Dry Weight Rank
Ece	Electrical Conductivity of extracts
ETB	Ethiopian Birr
FC	Frequency of Cutting
FR	Fertilizer
GR	Grass
GTDW	Grand Total Dry Weight
ha	Hectare
HMC	Hemi cellulose
HR	Forbs
i.e.	That is
ILCA	International Livestock Center for Africa

ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success of Ethiopian Farmers
IVDMD	*In Vitro* Dry Matter Digestibility
Kg	Kilogram
LSD	Least Significant Difference
LG	Legume
m	Meter
mS	MilliSiemen
N	Nitrogen
NDF	Neutral Detergent Fiber
NI	Net Income
NPN	Non-Protein Nitrogen
NWZMS	North Western Zone Meteorological Service
OC	Organic Carbon
OM	Organic Matter
P	Phosphorus
PDMY	Pasture Dry Matter Yield
ppm	Parts per million
SAS	Statistical Analysis Software
SDW	Sub-sample Dry Weight
SE	Standard Error
SFW	Sub-sample Fresh Weight
SH	Stage of Harvesting
SPSS	Statistical Package for the Social Sciences
t	Tone
TA	Total Ash
TC	Total production Cost
TDW	Total Dry Weight
TFW	Total Fresh Weight
TR	Total Revenue
TVC	Total Variable Cost

BIOGRAPHICAL SKETCH

The author was born in December 1977 in South Gondar Zone of the Amhara Regional State, Estie Mekaneyesus. He attended his elementary education at Mekaneyesus elementary and secondary school. After successfully passing the Ethiopian School Leaving Certificate Examination, he joined Alemaya University of Agriculture and Graduated with a B.Sc. degree in Animal Science in July 2000.

Soon after graduation he was employed by the Ministry of Agriculture as Livestock Production and Forage Development Expert in the *woreda* level of South Gondar Zone where he served from August 2000 to 2006.

Finally, the author joined the post graduate studies of Haramaya University in October 2006 in the Department of Animal Sciences to study for his Master of Science degree in Range Ecology and Management.

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Lastly, my heartfelt gratitude goes to my wife, Abeba Wubetu and my daughter Beteliham for their understanding, encouragement and love during my stay away from home.

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ABSTRACT

This experiment was carried out to assess botanical composition, DMY and chemical composition of Fogera upland natural pastureland under different application rates of N fertilizer and harvesting stages of natural pasture at smallholder farmers condition. The *experiment was conducted using 3 x 4 factorial experiment arranged in a randomized complete block design with three replications and the treatment consisted three stages of harvesting (60, 90 and 120 days) and four levels of N fertilizer application (0, 23, 46 and 69 kg N/ha) on the natural pasture land.*

The botanical composition of the natural pasture land that have been identified at the experimental site included thirteen grasses, seven annual legumes and seven other herbaceous species belonging to different families. The influence of stages of harvesting was significant ($P<0.05$) but application of N fertilizer was not significant on total DMY of the pasture. Natural pasture harvested at 120-days of harvesting and at a fertilizer application of 69 kg/ha results the highest DMY (9.97 t/ha) while the lowest level was (5.38 t/ha) from unfertilized plots at 120-days of harvesting. The effect of stage of harvesting and fertilizer level on DMY of legume components was highly significant ($P<0.001$) but for the grass components stage of harvesting had non- significant effect, where as fertilizer had a highly significant effect ($P<0.001$). The relative proportion of legumes in the pastureland reached highest at 90-days of harvesting at all levels of fertilizer application. The proportion of legumes varied from the highest mean of 56.18% to the lowest of 37.66% at 90 and 120-days of harvesting, respectively while that of grasses ranged from 58.09% to 40.24% at 120 and 90-days of harvesting, respectively. The relative proportion of grasses increased with increasing levels of N fertilizer and stage of harvesting up to 120-days. Significant effect of stage of harvesting ($P<0.001$) on CP, NDF, ADF, hemi-cellulose, cellulose, P and IVDMD were obtained at all levels of fertilizer application. At 60-days of harvesting, highest values of

15.53%, 0.41% and 54.86% were obtained for CP, P and IVDMD, respectively. However, the lowest values 55.63%, 37.32%, 17.55% and 32.02% were obtained for NDF, ADF, hemi-cellulose and cellulose, respectively at the same stage of harvesting. The CP content was significantly ($P<0.001$) lower (6.76%) at 120-days of harvesting compared with other stages of harvesting. At all levels of N- fertilizer, the mean CP content obtained were above the reported critical level for ruminant's microorganism's functioning (7%). The IVDMD at 90 and 120-day harvesting was 50.09% and 38.76%, respectively. The values at all harvesting stages were below the reported threshold value that ranged between 55 and 70% for medium quality forages from natural pastures. The results obtained in the present study revealed that fertilizer application increased the yield of natural pasturelands by 36.07%. Fertilizer applications at the level of 46 kg/ha resulted in higher mean dry matter yield of 9.58 t/ha and higher nutritional quality (11.89% CP, 1.08 t/ha CPY, 49.91% IVDMD and 4.65 t/ha IVDMDY) of the natural pasture. This level of fertilizer application combined with 90 days of (October) harvesting should be practiced for higher Pasture yield and quality parameters

1. INTRODUCTION

Livestock production is an integral part of the subsistence crop-livestock systems of the Ethiopian highlands. It is a source of draught power, manure and transport to support the crop sector. It is also a source of cash, nutrition and asset for the rural communities. Livestock is considered as a mobile bank that could be hired, shared, inherited and contracted by rural households. Although the contribution of livestock to facilitate the crop sector has been recognized all along, its productivity in Ethiopia is declining to a level that may affect the sustainability of synergism between the crop and livestock sectors. One of the major constraints to livestock productivity is lack of feed, both in quality and quantity (Tilahun, et al., 2005). Livestock feed in the country is based on natural pastures, fallow grazing, and stubble grazing and crop residues. Alemu and Lemma (1991) reported that more than 90 percent of the livestock feed in Ethiopia come from crop residues and natural pasture. This resource consists of a wide range of grasses, legumes and other herbaceous species.

Natural pasture and crop residues are poor in quality and provide inadequate protein, energy, vitamins and minerals (Daniel, 1990). Thus, the existing feed resources do not meet the nutrient requirements for growth and reproduction of animals. Adane and Berhan (2005) reported that the herbage yield and nutritional quality of natural pasture is generally low. The herbage makes rapid growth of fair quality early in the rainy season but during the dry season only over-matured herbage of poor quality is available. This results in slow growth rates, poor fertility and high mortality rates, especially in young stock. In certain areas where improved forage crops have been introduced, farmers failed to utilize them at the optimum developmental stages, which would ensure an appropriate balance between quality and quantity to satisfy livestock requirements and support reasonable animal production (Taye, 2004). Forage resource improvement with emphasis on management practices that promote yield and nutritive value are, therefore, one of the important measures that have to be taken to reverse the prevailing scenario of poor animal productivity.

In the Ethiopian highlands most pasturelands have suffered encroachment of crop production as a consequence of the growing human population. The increase in human population and the decline in land productivity demanded an expansion in arable land that led to a reduction in the amount of land available for natural pasture and browse (Alemayehu, 1997). Thus, the pastures are practically those available only on steep slopes, field margins and roadsides (Ali, 2004). Consequently, the livestock are forced to concentrate on very limited pastureland. This results in overgrazing, which in turn leads to invasion by unpalatable plant species and finally a decline in the quality and quantity of pasture. The latter become worse as the dry season advances. The overgrazing affects the botanical composition of the natural pasture which is the major factor affecting the potential of the pasture to sustain livestock productivity. The changes in botanical composition primarily brought about by animal activities that usually affect the nutritive value of natural pastures and in turn influence the productivity of animals. Appropriate grazing management must be practiced in order to maintain a favorable balance in the botanical composition of the available natural pasture.

Although the natural grasslands constitute the major feed source of livestock in most developing countries, these resources have several limitations. They have a sub-optimal nutritive value for only a short period of the year and decline quickly on maturity (Zinash *et al.,* 1995). Furthermore, prolonged harvesting time results in poor quality of the native hay (Gashaw *et al*., 1991; Teshome *et al*., 1994). Forage yield and nutritional qualities of pasture are influenced by numerous factors representing ecological conditions and management activities. Those factors include frequency of cutting, species composition, stage of maturity of plants, climatic conditions, soil fertility status and season of harvesting. As pasture gets mature it is characterized by high content of fiber with a higher grade of lignifications and low protein content. Changes of quality during the growing period of grasses are particularly high under tropical climatic conditions due to the physiological, biochemical and anatomical adaptation of the tropical grasses (Carbon 4 grasses) to utilize the high temperature and high solar radiation regime prevailing in the tropics (Nelson and Moser 1994).

Generally, in the high-lands of the country which contains high livestock and human population, there is a severe shortage of grazing resource together with marked decline in the quality of the natural pasture (Adane, 2003). Evidently there is paucity of information on improved management and utilization of this resource at the smallholder farm level, including optimum stage and frequency of harvesting of the herbage, levels of fertilizer application as strategies for increasing pasture productivity.

Within the Ethiopian highland system occurs the Fogera plain, on which this study is focused, is home to the well known Fogera cattle breed. The breed is large-framed and one of the best indigenous milk animals in the country. It is also known for its meat production and traction power. Unfortunately, cattle of this potential milk are suffering due to feed shortage both in quality and quantity. Even though the study area has high potential contribution to the smallholder’s livestock production in that area, poor productivity of the grazing lands both in quality and quantity of the grazing resource poses a great problem in livestock farming. This problem inevitably calls for improving the productivity of the grazing lands in that area.

One of the most viable and simple management interventions to avert the severe feed shortage is to improve the quality and quantity of the natural pasture through employing improved management and conservation practices. The management systems, particularly utilizing the pasture at early stages of growth with proper growing management might improve the productivity of pastures both quantitatively and qualitatively (Zinash *etal*., 1995). However, information on botanical composition and optimum stage of harvesting of forages of natural pasture as a strategy for increasing pasture productivity at smallholder farmers level in Fogera district with high livestock and human population density and declining land holding is very scanty. Thus, there is a need to determine botanical composition, DMY as well as optimum stage of harvesting as a strategy to intervene the prevailing traditional pasture management systems at smallholder farmers level.

The objective of this study was to achieve the following:-

- To determine the botanical composition, dry matter yield and chemical composition of the natural pasture under different nitrogen fertilizer application and stages of harvesting in Fogera district.

2. LITERATURE REVIEW

2.1. Major Species Components of Natural Pasture

Natural pastures are composed of grasses (Poaceae), legumes (Fabaceae), sedges (Cyperaceae), and other heterogenous plants in various families, which could be herbaceous or woody forms (McIllroy, 1972). The first two plant groups; grasses and legumes, make up the bulk of the herbage that are valuable as animal feed.

2.1.1. Grasses

Grass is a common word that generally describes a monocotyledonous green plant in the family Poaceae. It occupies a greater area of the world's surface than any other plant family, occurring in almost every terrestrial environment and provides a vital source of food for human and animals (Cheplick, 1998). Forage grasses can be either annuals or perennials with a wide spectrum of adaptation and diverse growth habits and thus they are distributed in all continents and climatic zones (Pamo and Piper, 2000). Both annual and perennial grasses are herbaceous (non-woody) plants, made up of a grouping of units called tillers. Perennial grasses often live for relatively a few or several seasons by succession of secondary tillers, which replace the original tillers. However, annual grasses flower and die without producing replacement tillers which will be the reason for the death of the whole plant (Wolfson and Tainton, 2000).

According to Pamo and Piper (2000), at maturity, the grasses range in height from a few centimeters to 20 meter or more. Despite having common morphological characteristics, some grass species may show many modifications from the typical structure. The modifications allow species to adapt to specific environmental conditions and provide a means for identification.

2.1.2. Legumes

Legumes are classified under the family Fabaceae (Leguminoseae). The legume family contains about 18,000 species, which are valued for their ability to grow in a symbiotic relationship with nitrogen fixing bacteria, and for their drought resistance (McDonald *et al*., 2002). It is composed of threee sub-families: Caesalpiniodeae, Mimosoideae and Papilionoideae. The latter constitutes the majority of cultivated pasture legumes. Legumes are widely spread in both temperate and tropical climates with numerous herbaceous species which are grown on pasture or as fodder crops and are of considerable importance for natural grazing (Bogdan, 1977). Leguminous plants in general can be annuals, biennials or perennials. They have a narrower range of adaptation which requires a higher management level than that for grasses (Pamo and Piper, 2000). Nutritionally, the legumes are superior to grasses in protein and mineral content such as calcium and phosphorus. The increase in animal production from use of legumes is therefore due to relatively high content of crude protein and the high digestibility of forage legumes and to the high intake by animals feeding on them (Whiteman, 1980).

2.2. Natural Pastures as Feed Resource for Livestock

In most areas of sub-Saharan Africa, the major even the sole feed source available for large parts of the year in smallholder production systems are natural pastures (Smith, 1992; Gylswyk, 1995). However, natural pastures mostly suffer from seasonally spells of dry periods during which they drop in quality, which is characterized by high fiber content, low digestibility and very low protein and energy content (Ndlovu, 1992; Topps, 1995).

In Ethiopia, it has been estimated that more than 90 percent of livestock feed requirement is provided by natural pastures, which consist of a wide range of grasses, legumes and other herbaceous species (Lulseged, 1985). The yield as well as quality of pasture is very low due to poor management and over stocking. Natural pastures would be adequate for live weight maintenance and weight gain during wet seasons, but would not support maintenance for the rest of the year (Zinash *et al*., 1995). The productivity from grazing land is insufficient in both quantity and quality for optimal livestock growth and production. Studies indicated that poor production of grazing lands and large herd size on small farmlands caused overgrazing of natural pasturelands resulting in serious land degradation. Consequently, soil fertility declines causing lowered dry matter yields from the natural pasturelands. Moreover, prolonged harvesting time impairs the quality of native hay (Varvikko, 1991; Gashaw, 1992).

2.3. Effect of Harvesting Stage on Yield and Quality of Natural Pasture

2.3.1. Botanical composition

Botanical composition refers to the proportion of grass, legume and other forage species biomass in a given area. Natural pasture in the highland areas has relatively high proportion of grass and legume species, but the proportion of legumes declines with decreasing altitude (Alemayehu, 1985). Most legumes are often grown in mixtures with pasture grasses. Some of the N that is fixed by legumes becomes available in the soil and increases the production and quality of herbage (Bogdan, 1977). However, when a pure grass pasture is grown without a legume component, it eventually suffers a reduction in yield through N defoliation. On the other hand, a pure stand of legume pasture fixes N in excess of its requirement that attracts invading non-legume weeds and grasses. Legumes contain more crude protein, calcium and phosphorus, and often lower crude fiber values. They can improve the feeding value of grasses (Webster and Wilson, 1980). Hence, the quality of a pasture can be improved by the inclusion of forage legumes, which are not so bulky and maintain their high quality throughout the year (Tarawali *et al.*, 1991).

Pasture composition (irrespective of plant species) can be affected by the harvest date of first cut and frequency of harvesting which consequently reduces the nutritive value (Rinne and Nykannen, 2000). Hence, the main problem of legumes management in mixed pastures is that of ensuring their persistence and maintaining their proportion with respect to stage of maturity (Miller, 1984). Frequently, grazing can reduce the vigor of forage plants. Frequent grazing particularly at early maturity reduces serious weed invasion in perennial rye grass pastures.

Furthermore, grazing reduces the ability of pastures to continue producing herbage while frequent cutting can lead to change in botanical composition (McKenziel, 1997).

2.3.2. Forage yield

Stage of frequency of cutting significantly influence the yield and quality of herbage produced. A significant linear increase in the dry matter yield (DM) has been reported in the natural pasture with increasing stages of growth of grasses up to 90 days (Teshome, 1987; Zinash *et al.*, 1995). The dry matter yield of both unfertilized and fertilized pastures increased with maturity. However, at the same stage of harvesting age, fertilizer application resulted in a significant increase in dry matter yield at 60 and 90 days of harvest, while no significant effect was observed at 30 days of harvesting (Adane, 2003; Teshome *et al.*, 1994). Similarly, Daniel (1996) reported that highest DM yield was attained on average at the 69th and 74th days of growth with N application, respectively at 50 percent to 100 percent heading and seed setting, respectively with and with out nitrogen application. The frequency and severity at which pasture plants are defoliated have pronounced effects on the quality of available forage. Harvesting early to get better nutritive value will reduce the DM yield, so the harvest time should balance quality and yield (Tessema, 2003). In order to maximize production, the pasture should retain sufficient leaf to allow for rapid growth for as much of the growing season as possible. The more severely a plant is defoliated, the more slowly it will recover and the less severely it is defoliated, the more rapid will be its re-growth. Hence, the more frequently the pasture is severely defoliated the lower will be the overall dry matter yield (Bartholomew, 2000).

2.3.3. Forage quality

Buxton (1996) reported that forage maturity stage at harvest is identified as the most important factor affecting the composition and nutritive value of pastures. Effects of stage of harvesting on forage digestibility are associated with increase in forage neutral detergent fiber content and its lignification’s (Smith *et al.*, 1972). Hence, increasing stage of maturity of forages results in an increase in the indigestible fraction of forage. Moreover, crude protein content and its rumen degradability decrease with increasing stage of maturity (Blade *et al.*, 1993). The crude protein content varies widely among forage plants, but in all species, it declines with increasing age of forage plants (Sarwar *et al*., 1999). The aging of forage is frequently associated with a decrease in leafiness and an increase in stem to leaf ratio (Vansoest, 1982). The low nutritive value of native pastures cut at late maturity is identified by its low crude protein and mineral, and high lignin contents (Teshome, 1987). Hence, the decrease in the crude protein as grasses get matured is due to an increase in the proportion of stem, which has lower crude protein content than the leaf fraction (Laredo and Minson, 1973). The decrease in the content of crude protein in matured native pastures is also attributed to the decline of the proportion of legumes in the pasture. Harvesting at advanced stage of maturity caused a decrease in proportion of legumes in native pasture from 11 to 4 percent in dry matter. Hence, to maintain the required percentage of crude protein, having high proportion of legumes in the pasture is of paramount importance along with harvesting at optimum stage of maturity (Kidane, 1993).

Tropical grasses are generally characterized by lower nutritive value even in their early stages of growth due to lower levels of easily digested materials in their cell wall due to rapid rate of achieving maturity (Minson, 1980). Harvesting stage of pasture forages is an important factor significantly affecting digestibility. The digestibility of all grasses decreases as they mature (Minson, 1977), with increasing age, the proportion of potentially digestible components comprising soluble carbohydrates, cellulose, hemi-cellulose and other indigestible fractions such as lignin, cuticle and silica increase, which result in lower digestibility leading to lower rates of disappearance from the gastro intestinal tract (Van Soest, 1982). According to Minson (1977), the dry matter digestibility in the plant parts also decreases with advancing plant growth. The declining dry matter digestibility of stems at advanced maturity is attributed to greater indigestible component, which increase with advancing stage of plant growth. The digestibility of tropical grasses is lower than that of temperate grasses. They have higher lingo-cellulose content and the digestibility of their cell wall material (fiber) is lower. This lower digestibility gets worse with increase in maturity and greater lignifications of plant species (Wilson, 1994).

The proportion of forage legume in the pasture is affected by stage of maturity (Kidane, 1993) and this can also affect the digestibility of the pasture. The digestibility would probably increase as the proportion of forage legume increases because the legumes often have higher digestibility than grasses (Topps, 1995). Moreover, tropical and subtropical species have a lower leaf to stem ratio than temperate species. The relevance of this is that stem material is less digestible than leaf material, and its digestibility declines more rapidly than that of leaf material (Mannetje, 1984).

2.4. Effect of Fertilizer Application on Yield and Quality of Natural Pasture

Both quantity and quality of natural pasturelands can be improved by application of fertilizer. Hence, sufficient response to fertilizer application is one of the desirable characteristics expected of natural pasturelands. The high nitrogen requirement of pastures, coupled with their pervasive root system results in efficient absorption of nitrogen from the soil. Thus, in grass dominated pastures about 50 to 70 percent of applied fertilizer nitrogen is normally taken up, although this decreases at very high nitrogen levels (Miles and Minson, 2000) due to deficiencies of some micronutrients in the soil and displacement of phosphate concentrations at higher levels of nitrogen (Falade, 1975). Grasses can obtain their nitrogen in a number of ways, but the most important sources are from fertilizers and associated legumes. Legumes vary in their ability to produce nitrogen, and for the most responsive grasses no legumes can adequately supply the needs of grass. Hence, the simplest way to achieve maximum production from grass is to apply inorganic fertilizer with high nitrogen content (Skerman and Riveros, 1990).

Adane (2003) reported that, the yield of the natural grasslands increases with increasing levels of fertilizer application up to 125 kg/ha regardless of decline in overall production due to frequent grazing and cuttings in one growing season. Moreover, fertilizers not only increase yield but also influence species composition of natural pastures. Therefore, according to Daniel (1987) application of phosphorus alone increases percentage of legumes while heavy nitrogen application encourages grasses by suppressing legumes.

2.4.1. Botanical composition

The effect of fertilization on the botanical composition is very marked where legumes make up a considerable part of the vegetation. In such areas, the amount of legumes and their phosphorus content increases sharply with phosphorus fertilization (Gilbert *et al.,* 1992). On the other hand, nitrogen especially at higher level decreases the legumes even though phosphorus was applied (Crowder and Chheda, 1982; Daniel, 1987). Hence, strategically applying nitrogen to boost the grass component or phosphorus to boost the legume component can achieve a balance between grass and clover (Bartholomew, 2000).

Application of nitrogen fertilizers to grass-legume pastures has dramatic effects on the legume component by altering botanical composition. Presence of high levels of nitrate or ammonium will inhibit nodulation and reduces rate of nitrogen fixation that leads to reduction in legume content (Whiteman, 1980). When legumes are growing with grasses, the grasses are stronger competitors for available nitrogen, and take up most of that applied. This will lead to an increased rate of growth, leaf expansion and tillering in the grasses, often leading to suppression of the legume owing to shading (Miles and Manson, 2000). In grass-legume pastures, when legumes supply insufficient nitrogen, additional nitrogen generally needs to be provided by strategic application of nitrogen fertilizer. This however, creates certain management difficulties, since additional nitrogen reduces fixation by the legumes while it improves the relative competitive ability of the associated grass. Hence, phosphorus fertilizer must be applied to deficient soils for establishment and long-term maintenance of legumes in the pasture (Miles and Manson, 2000).

2.4.2 Forage yield

The application of fertilizers on natural pasture has been clearly shown to improve the herbage yields (Adane, 2003). When nitrogen is applied, there is usually an initial linear response. But, there is a phase of diminishing response and a point beyond which nitrogen has little or no effect on yield. The dry matter yield of fertilized plots of natural pasture has been shown to be 9.47 ton/ha as compared to unfertilized plots 5.67 ton/ ha at 90 days of harvest (Adane, 2003).Therefore, the amount of dry matter produced for each kilogram of nitrogen applied depends largely on the species under consideration, frequency of defoliation and growth condition (Miles and Manson, 2000). The importance of phosphorus for the survival and nitrogen fixation by legumes in a natural pasture has also been widely recognized. Phosphorus plays role in nodule development and in the activity of the associated *Rhizobia* (Crowder and Chheda, 1982). However, in the tropics, the soils are generally deficient in phosphorus. Hence, on well-managed legume enriched natural pastures, the application of phosphate fertilizer often provides an effective factor in increasing productivity (Pagot, 1992).

2.4.3. Forage quality

Application of nitrogen to pasture usually results in marked increase in the level of crude protein content. However, the great variability in crude protein content due to nitrogen applied exists in early stages of growth. The crude protein content of most grass species is adequate to meet minimum nutritional requirements for livestock in early stages of harvesting but reaches levels below this requirement in later stages of harvesting. Hence, addition of nitrogen and phosphorus results in considerably higher crude protein content (Goetz, 1975).

The increase in the crude protein content of grasses through fertilization depends on the availability of soil nitrogen. Nitrogen fertilizer application and growing legumes in association with grasses also increases the level of soil nitrogen. This has increased the crude protein percentage of the grass but has no consistent effect on dry matter digestibility (Minson, 1973). Fertilization at early stages of growth greatly influences the accumulation of non-structural and insoluble carbohydrate levels. Insoluble carbohydrate decreased with increasing nitrogen supply and soluble carbohydrate levels increase with increase in phosphorus supply (Miles and Manson, 2000). Nitrogen fertilizer also improves the concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF) in early cut *pennisetum purpureum*. However, according to studies of the same author, nitrogen fertilizer could not reverse the adverse effects of maturity on the quality. Similarly, the lignin content of the grass of fertilizer application was higher at late cutting. Thus, the digestibility value is lower too (Sarwar *et al*., 1999).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location and choice of the study area

The study was conducted on a smallholder natural pastureland at Fogera district, South Gondar Zone of the Amhara National Regional State. Geographically, the study site is situated at $13^{0}19'$N latitude and $37^{0}36'$E longitudes (Figure 1).

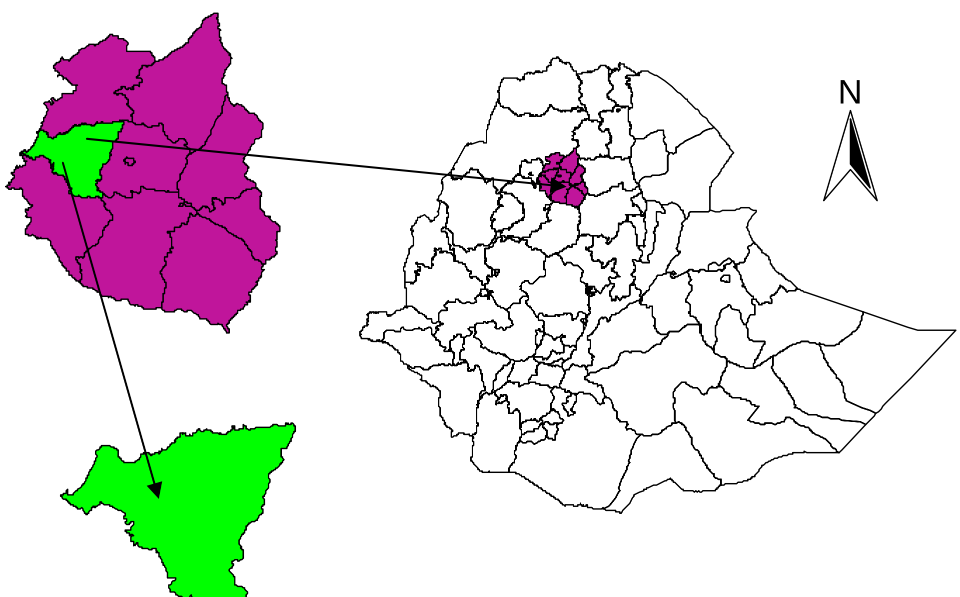

Figure 3.Location Map of the study Area (Fogera district)

Woreta is the capital of the district and is found 625 Km from Addis Ababa and 55 Km from the Regional capital, Bahirdar. The district was selected as the study area because it is the home to the well known Fogera breed of cattle, which is localized to the Fogera Plains. Livestock farming is an integral part of the agricultural activity in the district, which determines the well being of smallholder farmers in the area.

3.1.2. Topography, climate, soil and land form

The topography of the district comprises 76% flat land, 11% mountain and hills and 13% valley bottom. The study site is located on the hill side with an elevation of 1858 m.a.s.l. and falls in the *Woinadega (mid-altitude)* traditional agroecological classification. According to the North Western Zonal Meteorological Station (NWZMS, 2004) report, Woreta receives an average annual rainfall of 1225.8 mm (Figure 2). The major portion of the total annual rainfall is received between June and October. The average yearly minimum and maximum temperatures (Figure 3) are 12.60 ^{o}C and 27.90 ^{o}C, respectively (NWZMS, 2004).

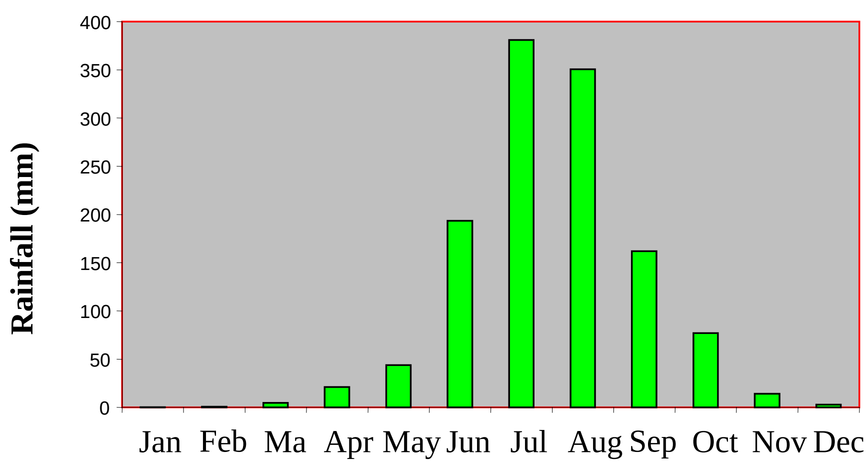

Figure 4. Monthly rainfall distribution at Woreta Station (data compiled for 10 years)

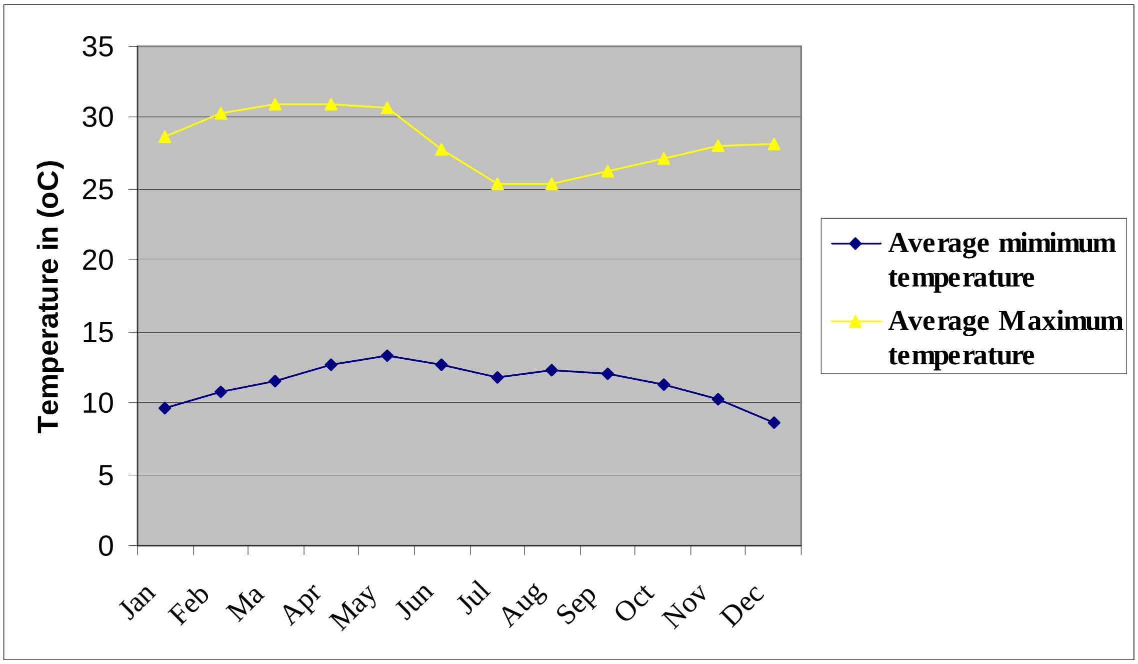

Figure 5. Monthly Average minimum and maximum temperature (^{o}C) at woreta station (data compiled for 10 years)

According to the Woreda Office of Agriculture, the dominant (65%) soil type in the Fogera plains is black clay soil (*Pellic Vertisol*). However, the soil of the study site is *Orthic luvisol*.

Table 1. Land use pattern of the research district

Description	Hectare	Percentage
Cultivated land	51472	43.8
Grazing land	26999	23.0
Forest, bush and shrub land	2190	1.8
Fruit crops	251	0.2
Water bodies	23354	19.9
Swampy area	1689	1.5
Settlement and road	7075	6.0
Waste land	4375	3.8
Total land	117404	100

Source: Fogera district IPMS (2005)

3.1.3. On-farm feed resources

Natural pasture could be utilized as a grazing or green feed in the form of cut and carry system. It is the major feed resources in Fogera district. The resource occupies about 23% of the total land coverage. In the district, livestock production entirely depends on the use of natural pasturelands, fallow croplands and crop residues (Table 2). In the area, the annual DM yield of privately owned natural pasturelands was estimated to be 3.92-5.52 t/ha. However, due to seasonality of rainfall distribution and the high stocking rate, DM yields from communally owned natural pasturelands are highly reduced and cannot provide the nutritional requirements for more than half of the year Continuous grazing and stall-feeding of mostly oxen with crop residues are the common feeding systems in the highlands of Ethiopia. Free grazing, sometimes under the control of herders, is also practiced with natural pasturelands, fallows and stubble grazing. Zinash et al. (1995), Lemma (2002), and Alemayehu (2004) reported that livestock in the central highlands graze on communal, fallow and permanent pasturelands during cropping season and on croplands after harvest.

The contribution of crop residues to the feed resource base is significant (Getachew, 2002; Solomon, 2004). Daniel (1988), Lemma (2002) reported that under the Ethiopian condition, crop residues provide 40 to 50% of the annual livestock feed requirement. In most central highlands of Ethiopia, crop residues account for 27% of the total annual feed supply during the dry periods (Gashaw, 1992). The quantities of different crop residues produced depend on the total area cultivated, the access of the season’s rainfall, crop species as well as other inputs such as fertilizers (Daniel, 1988). Oxen are given priority for feeding crop residues mainly during the peak period of ploughing and followed by weak animals and lactating cows (Mohamed and Abate, 1995). Trees and shrubs play a significant role in livestock production in very limited places. The importance and availability of trees and shrubs in tropical Africa are influenced by the distribution, type and importance of livestock, their integration and role within the farming systems and availability of alternative sources of feed (Getachew, 2002).

Table 2.Major on farm feed resources, availability and their utilization in the research district (in percentage)

Types of Feed	Time of Availability	Feeding System	Percentage Proportion	Rank of Proportion
Straw			68	1st
a. Rice	December-June	Stall feeding		
b. Maize Stover	January-May	“ “		
c. Finger millet	February-June	” ”		
d. Teff	December-June	” ”		
e. Barley	March-June	“ “		
f .Wheat	March-June	“ “		
Native Pasture			25	2nd
a. Green grass	June-November	Free grazing		
b. Hay	March-May	Stall feeding		
Aftermath	October-February	Free grazing	5	3rd
Browsing Fodder Tree Legumes			2	4th
a. *Pileostigma thonningii* (Yekola wanza)	April-May	Stall feeding		
b. *Combretom globiferus* (Avalo)	“ “	Stall feeding		
c. *Cordia africana* (Wanza)	“ “	“ “		
d. *Ficus gnaphalocarpa* (Bamba)	“ “	“ “		
e. *Sesbania sesban*	“ “	“ “		

Source: Fogera district Agricultural and Rural Development Office unpublished document, Woreta, Ethiopia.

In the research district, the extent of improved forage crop cultivation by majority of smallholder farmers is very limited due to their limited knowledge on improved forages, scarcity of land for forage cultivation and traditional feeding practices.

3.1.4. Farming system

Like most parts of South Gondar Zone, the predominant form of farming practice in Fogera district is smallholder mixed crop livestock farming. Mixed farming systems are characterized by interdependency between crop and livestock activities (Ostergaard, 1995). It is the main system of production for smallholder farmers in many developing countries (Ostergaard, 1995; Blackburn, 1998). The largest share of the total milk and meat available in the country is produced by mixed farming systems (Ostergaard, 1995). The principal objective of farmers engaged in mixed farming is to gain complementary benefit from an optimum mixture of crop and livestock farming and spreading income and risks over both crop and livestock production (Lemma, 2002; Solomon, 2004). In the mixed crop livestock farming systems, livestock provide important inputs to crop cultivation, especially manure and traction. Livestock are often the major source of cash that farmers can use to buy agricultural inputs. In turn, crops provide livestock with feed in the form of residues and by-products from crop production, which are converted into valuable products like meat, milk, and traction (ILCA, 1992; BoRD, 2003).

Livestock rearing for milk, draught power and meat is a major part of the overall agricultural activities in the research district. All types of livestock graze on the communal grazing land with a high stocking rate that characterize the traditional system of grazing management (Table 3). However, in recent years the natural pastureland is invaded by unwanted weed such as *Hygrophila auriculata* (*Amekala)*, which is estimated to be 10,000 hectares of the Woreda grazing land is invaded by this weed species.

Table 3. Livestock population and herd composition in the Fogera district

Types	Local	Crossbred	Total
Cattle (TLU)	116461.8	276	116737.8
a. Cow (TLU)	47139	114	47253
b. Heifers (TLU)	12059.5	13.2	12072.7
c. Oxen (TLU)	46689	-	46689
d. Young bulls (TLU)	19441	12	19453
e. Calves (TLU)	5794.6	15.2	5809.8
Sheep (TLU)	789.1	-	789.1
Goats (TLU)	1662.1	-	1662.1
Horses (TLU)	4.8	-	4.8
Mules (TLU)	557.6	-	557.6
Donkeys (TLU)	4464.4	-	4464.4

Source: Fogera district IPMS (2005)

3.2. Experimental Design

The study was conducted using a 3 x 4 factorial experiment arranged in a randomized complete block design with three replications. The treatments for the study were three stages of harvesting (60, 90 and 120 days) (Adane and Berhan, 2005), and four levels of nitrogen fertilizer application (0, 23, 46 and 69 kg N/ha) ILCA (1983). The net plot size consisted of an area of 12 m^2 (4 m x 3 m) and the block had an area of 209 m^2 (19 m x11 m). Each experimental plot and its replication had 1 m and 2 m border on each side to avoid the border effect of treatments and blocks, increasing the gross plot size to 671 m^2 (61 m x 11 m).

3.3. Sampling Procedures

The vegetation from each treatment was sampled using a quadrat of 0.25 m^2 (0.5 m x 0.5 m) size during a predetermined sampling period. The material was harvested with a sickle at a height of 10 cm above ground. The quadrat was randomly thrown three times per plot and the average weight of the three harvests per plot was used for determination of pasture yield and quality. Following harvesting the forage samples from each plot were weighed, labeled and air dried under shade and kept in separate perforated bags for chemical analysis.

A total of thirty-six representative oven-dried forage sub-samples were taken to ILRI nutrition laboratory for chemical analysis. The samples were dried in an oven at 65 -70^oC for 72 hours and ground using Willey mill to pass through 1 mm sieve. Ground samples were allowed to equilibrate at room temperature for 24 hr and stored until required for chemical analysis.

For determination of species composition, forage samples were harvested at harvesting stages of 60, 90 and 120 days and samples were weighed immediately and hand-sorted into botanical components of grasses, legumes and others (weeds) and then each of these were weighed separately.

3.4. Measurements

3.4.1. Botanical composition

The botanical composition with regard to relative proportion of the grasses, legumes and other herbages in the treatment plots on weight basis was determined by relating the weights of each group to the weight of the whole samples. The dry weight rank (DWR) procedure (Tothill *et al*., 1978) that involves cutting and sorting by hand was used to measure percentage proportion of each forage type.

$$\text{TDW of species} = \frac{\text{TFW of a species}}{\text{SFW of a species}} \times \text{SDW of a species} \qquad (1)$$

$$\text{\% proportion of species} = \frac{\text{TDW of a species}}{\text{GTDW}} \times 100 \qquad (2)$$

Where, TFW = Total fresh weight of individual species, SFW = sub-sample fresh weight, TDW = Total dry weight, SDW = sub- sample dry weight and GTDW = Grand total dry weight.

Identification of species was undertaken in situ by using an illustrated field guide of Froman and Persson (1974) for grasses and Thulin (1972) for legumes.

3.4.2. Pasture yield

The pasture yield was determined on dry matter basis by harvesting forage samples from an area of 0.25 m^2 (0.5 m x 0.5 m) quadrat which was randomly thrown three times per plot. The average weight of the forage in the quadrat was used and extrapolated into dry matter yield per hectare (t/ha).

Forage samples within the quadrat area were harvested by hand and weighed immediately. Sub-samples representing 10% of the whole forage samples harvested from the treatments were taken for DM determination. The effect of cutting frequency was investigated on plots which already harvested at 60 days stage of harvesting. Cutting was made three times, each at 30 days interval, and the sum of the yields of the 1st and 2nd cutting was compared with the yields of plots harvested once at 90 day. Similarly, the sum of the yields of the first, second and third harvests was compared with the yield of the single harvest at 120 days interval.

3.4.3. Chemical analyses

The chemical analyses for determination of nutritional composition were carried out by the proximate analyses method. Nitrogen content was determined by taking sub-samples from an oven-dried forage sample employing the Kjeldhal method (AOAC, 1990). The protein content was calculated by multiplying the nitrogen content by 6.25. The total ash content was determined by igniting the forage samples in a muffle furnace at 550 ^{o}C for 5 hours (AOAC, 1990). The Van Soest method of forage analysis was applied to determine Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). The amount of hemi-cellulose was determined as the difference between NDF and ADF, where as cellulose content was determined by subtracting Acid Detergent Lignin (ADL) and Acid Detergent Fiber ash (ADF ash) from Acid detergent fiber (ADF). Phosphorus content was determined by auto-analyzer (Chemlab, 1978). The modified Tiller and Terry method was used for the determination of *in-vitro* dry matter digestibility of forage samples (Van Soest and Robertson, 1985).

The forage samples were dried to a constant dry weight in an oven at 100 ± 5 ^{o}c for 24 hrs to determine percent dry weight before any analytical procedure. All the chemical analysis of the samples was performed in duplicate. Finally, all results were calculated on a dry matter basis.

3.4.4. Soil analysis

Soil samples were collected randomly from12 spots within the experimental site at a depth of 0-10 cm before broadcasting of nitrogen fertilizer. The collected soil samples were dried and thoroughly mixed (composited) and prepared for determination of pH, organic matter (OM), electrical conductivity of extracts (ECe),available phosphorus (P), total nitrogen (N) and texture. Total N and available P were estimated by the Kjeldahl procedure (Bremner and Mulvaney, 1982) and Olsen method (Olsen, *et al*., 1954), respectively. The Walkley and Black (1954) method as described by Anderson and Ingram (1993) was used to determine OM. Organic matter percentage was obtained by multiplying organic carbon percentage with 1.724. The pH of the soil was measured potentiometrically using a digital pH meter in the supernatant suspension of 1: 2.5 liquid ratios where the liquid was water. Soil texture was determined by using the hydrometer method (Black et al., 1965). Determination of ECe of soil water was made by an indirect measurement of soil salinity. The soil analyses were undertaken at Haramaya University Soil Laboratory.

3.6. Statistical Analyses

Analysis of variance (ANOVA) was carried out using the General Linear Model Procedure of SAS (SAS, 1998). Cutting frequency was analyzed by MSTATC (1989) Mean separations were made using the Least Significant Difference (LSD). The association between (60, 90, 120), (0, 23, 46, 69), DMY and quality parameters of natural pasturelands was determined by correlation analysis (SPSS, 1996).

1. The model for the design is as follows:

$Y_{ijk} = \mu + F_i + H_j + FH_{ij} + R_k + E_{ijkR}$

Where, Y_{ijk}= Observation in the j^{th} harvesting stage and i^{th} fertilizer application (the response variable)

μ = Overall mean

F_i = the i^{th} fertilizer effect

H_j = the effect of j^{th} harvesting stage

R_k= the effect of k^{th} replication

FH_{ij} = the effect of ij^{th} interaction between fertilizer and harvesting stage

E_{ijkR}= Random error (residuals)

2. The model of cutting frequency is as follows:

$Y_{ijk} = \mu + F_i + C_j + FC_{ij} + R_k + E_{ijkR}$

Where, Y_{ijk}= Observation in the j^{th} cutting frequency and i^{th} fertilizer application (the response variable)

μ = Overall mean

F_i = the i^{th} fertilizer effect

Cj = the effect of j^{th} cutiing frequency

R_k= the effect of k^{th} replication

FC_{ij} = the effect of ij^{th} interaction between fertilizer and cutting frequency

E_{ijkl}= Random error (residuals)

4. RESULTS AND DISCUSSION

4.1. Physical and Chemical Characteristics of Soil of the Experimental Field

Analytical results of the composite surface soil indicated that the soil was clay loam in texture (34.52% clay), brown (when dry) and dark reddish brown (when moist) in color (Table 4). It was slightly acidic (pH 6.81), low in total N and organic carbon where as the available P was medium (Table 5). The C: N ratio (11.43:1).

Table 4. Physical properties of soil at the study site

Particle size distribution (%)				Soil color	
Sand	Silt	Clay	Textural class	Dry	Moist
57.48	8	34.52	Clay loam	Brown	Dark reddish brown

Murphy (1968) classified soil total N of less than 0.10% as low, 0.10-0.15% as medium, 0.15-0.25% as high and greater than 0.25% as very high. The Netherlands Commissioned by Ministry of Agriculture and Fisheries (1985) also reported soil total N (%) of > 0.300, 0.226-0.300, 0.126-0.225, 0.050-0.125 and < 0.050 as very high, high, medium, low and very low, respectively, and total C (%) of greater than 3.50, 2.51-3.5, 1.26-2.50, 0.60-1.25 and < 0.60 as very high, high, medium, low and very low, respectively. The report included C/N ratios of > 25, 16-25, 11-15, 8-10 and < 8 as very high, high, medium, low and very low respectively. Moreover, Tekalign *et al*. (1991) classified soil N availability of < 0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and > 0.25% as high. The actual rating of available P level is based on a relative range of extractable P in (ppm) of 0-5 ppm, 6-10 ppm, 11-15 ppm, 16-20 ppm and 21-25 ppm as very low, low, medium, high and very high, respectively. The electrical conductivity (EC) of a soil indicates the amount of salt in the soil sample. Soils with EC extract grater than 4 ms/cm (4 mmohs/cm) generally indicate the occurrence of excess salts and need for reclamation (Netherlands commissioned by the Ministry of Agriculture 1985) and Tekalign *et al*. (1991). In this study area soil sample result indicates that total salt content was < 0.15%, it is salt free soil and ECE value of 0.054 ms/cm (Table 5).

The total N, available P, organic carbon and C: N ratio of the soil in the study area low, medium, low and medium, respectively.

Table 5.Major chemical properties of soil at the study site

PH (1:2.5 H_20)	Total N (%)	P (ppm)	OC (%)	C:N Ratio	OM (%)	EC mS/cm
6.81	0.098	15.73	1.12	11.43:1	1.93	0.054

4.2. Botanical Composition

Forage species of natural pasture that have been identified at the experimental site is presented in Table 6.Thirteen grasses, seven annual legumes and seven other herbaceous species belonging to different families were identified in situ to species level. The majority of grass species identified were *Echnochloa, Cynodon, Digitaria, Pennisetum, Setaria,Chloris, Panicum, Andropogon and Sporobolus* and the legumes that were identified include *Trifolium, Smithia, Vicia and Aeschynomene* species. Most forage species identified in this study had similarities with previous reports on forage species composition in the highlands of Ethiopia, indicating that the high lands are rich in pasture composition, particularly indigenous grasses and legumes (Kidane, 1993; Adane, 2003; Tessema, 2003; Yihalem, 2004).

The diversified species composition of the natural pastureland is a desirable attribute in terms of pasture quality, quantity and persistence. Hence, the presence of desirable perennial and annual grasses like *Echnochloa, Cynodon, Digitaria, Pennisetum, Setaria, Chloris, Panicum, Andropogon and Sporobolus* species in the study area would indicate the degree of persistenceof these species against the regours of drought, frost and high grazing pressure consistent with the harshness of the prevailing climatic biotic factors.

Table 6.Grass, legumes and other herbaceous species in the research area

Family Poaceae (Gramineae) species	Life form	Local name (Amharic)
Echnochloa colona (L.) Link	Annual	Yeberie sar
Cynodon dactylon (L.) Pers	Perennial	Serdo
Digitaria velutina (Forssk.) P.Beauv.	Annual	NA
Pennisetum macrourum Trin.	Annual	Tucha
Setaria pallidefusca (Schumach.) Stapf and C.E Hubb.	Annual	Dimamo
Chloris pycnothrix Trin	Annual	NA
Panicum coloratum L.	Perennial	NA
Andropogon abyssinicus Fresen	Annual	Gaja
Sporobolus africanus (Poir)	Perennial	Murie
Setaria verticillata (L.) P. Beauv	Annual	Chemgegit sar (koskusit)
Snowdenia polystachya (Fresen.) Pilg.	Annual	Muja
Hyparrhenia rufa (Nees) Stapf	Annual	Sembeliet
Sorghum arundinaceum (Desv.) Stapf	Annual	Malito
Family Fabaceae (Leguminoseae)		
Trifolium decorum Chiov.	Annual	Wajima
Trifolium steuddneri Schuding	Annual	Maget
Trifolium mattirolianum Fiori	“ “	NA
Trifolium multinerve A. Rich	“ “	NA

Table 6. (Continued)

Smithia abyssinica (A. Rich) Verde	“ “	Kuakuya
Vicia sativa L.	“ “	Yeamora guaya
Aeschynomene schimperi Hoetist.ex A. Rich	“ “	Kuakuya
Family Asteraceae (Compositeae)		
Bideus macrantha	Annual	Adei abeba
Tagetus minufa	“ “	Yederg arem
Family Amaranthaceae		
Amaranthus sp.	“ “	NA
Family Acanthaceae		
Hygrophila auriculata	“ “	Amekala
Tribulus sp.	“ “	Akakima
Lanceolata minor	“ “	Wonbert (Gorteb)
Lamiaceae (Labiateae)		
Plecranthus sp.	“ “	Gimagimie

NA= Not available (native name)

The results showed that the legume botanical composition of natural pasture was highly influenced by stages of harvesting and fertilizer application (Table 7). The effect of nitrogen fertilizer and stages of harvesting was significant for legumes ($P<0.001$) and ($P<0.01$), respectively (Appendix Table 1). At 60 days of harvesting the overall mean percentage of legume and grass proportion was similar, which is 48.02% and 48.00% respectively (Table 7 and 8).

Table 7.Percentage composition of legume component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	72.83	79.23	50.68	67.58^{A}	5.95
23	50.94	63.03	38.95	50.97^{B}	4.96
46	36.19	50.17	42.52	42.96^{B}	4.50
69	32.12	32.29	18.48	27.63^{C}	4.82
Overall Mean	48.02^{yx}	56.18^{x}	37.66^{y}		
SE	5.63	6.44	4.92		

Overall mean superscripts A- C in columns and x, y in rows followed by the same letter are not significantly different at 5% significant level.

Legume proportion reached its maximum at 90 days of harvesting with mean of 56.18%. However, the proportion decreased to a mean of 37.66% at 120 days of harvest. This is logically due to the short life span of the majority of legume species as compared to the grass species, most of which are perennials (Table 6). Thus, as was observed physically, the annual legumes matured faster than grasses, aged and gave way to the dominance of the perennial grasses regardless of presence of grazing. This finding is in agreement with earlier reports of Adane (2003) and Yihalem (2004). On the other hand, the effect of nitrogen fertilizer and stages of harvesting was significant for grasses ($P<0.001$) and ($P<0.05$), respectively (Appendix Table 2). Unlike a decrease in the proportion of legumes, the proportion of grasses increased from 40.24% at day 90 to 58.09% at day 120 (Table 8). Such an increasing trend in the grass composition has also been reported on other highland natural pastures with an advancing stage of harvest (Kidane, 1993). The mean grass proportion at highest level of fertilizer used in the experiment was as high as 68.99% compared with unfertilized plots (32.05), the increment in the proportion of grass being 115.26%, and this reflects the role of nitrogen fertilizer in influencing the grass-legume botanical composition in favor of the grass (Teshome, 1987).

Table 8.Percentage composition of grass component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	27.17	20.77	48.21	32.05^{C}	5.66
23	47.59	36.97	57.29	47.28^{B}	4.42
46	51.29	39.44	49.74	46.82^{B}	5.21
69	65.97	63.77	77.14	68.99^{A}	4.52
Overall Mean	48.00^{yx}	40.24^{y}	58.09^{x}		
SE	5.39	5.91	4.78		

Overall mean superscripts A- C in columns and x, y in rows followed by the same letter are not significantly different at 5% significant level.

In case of legumes, the average legume proportion was higher in the unfertilized plots (67.58%) than that in the fertilized plots which ranged from 50.97% to27.63%.This would indicates that nitrogen fertilizer had an indirect suppressing effect on the proportion of legumes by inducing luxuriant growth and hence dominance of the grasses. Moreover, high proportion of legumes on the unfertilized plots would be a favorable opportunity to the poor farmer in that the higher legume proportion found in an unfertilized pasture could still maintain an optimum percentage of crude protein for higher animal performance. The proportion of other herbaceous components was not significantly affected by stages of harvest since mean composition varied very slightly from 3.98% to 4.25% at 60 and 120 days of harvest respectively, (Table 9).

Table 9.Percentage composition of forbs component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	0.00	0.00	1.11	0.37^{B}	0.37
23	1.47	0.00	3.76	1.74^{B}	0.78
46	12.52	10.39	7.75	10.22^{A}	3.43
69	1.91	3.95	3.41	3.41^{B}	0.61
Overall Mean	3.98	3.58	4.25		
SE	2.34	2.11	1.01		

Overall mean superscripts A and B in columns followed by the same letter are not significantly different at 5% significant level.

Fertilizer causes a significant difference (P<0.05) in the proportion of forbs. As observed in the study nitrogen tends to favor grass dominance and with that suppressing the legumes. Other fertilizers like phosphorous and molybdenum tend to enhance legume growth and dominance in the sward. An increase in proportion of legumes influences the proportion of related grasses and apparently their nutritive value as reported by Shehu and Akinola (1995) and Gebrehiwot *et al.* (1997). The authors indicated that the presence of legumes in association with grass-legume pasture produced forage of higher quality than the pure grass pastures. The proportion of legumes in non-fertilized plots was high when compared with fertilized plots at 60 and 90 days of harvesting. However, the dominance of grasses was observed in later days of harvesting at 120 days. At 60 days of harvesting, the legumes widely appeared in the field and maintained a highest proportion up to 90 days of harvest. The relative proportion of grasses in the pastureland reached the highest (77.14%) at 120 days of harvesting and the lowest (20.77%) at 90 days of harvesting. In fact, the higher relative proportion of grasses as compared with other species was due to reduction of legumes and forbs appeared and decrease at 60 and 90 days of harvesting due to the increase in the proportion of legumes and forbs (Fig 4).The relationship between stages of harvesting and dry matter yield (DMY) of legume component in the natural pasture was curvilinear.

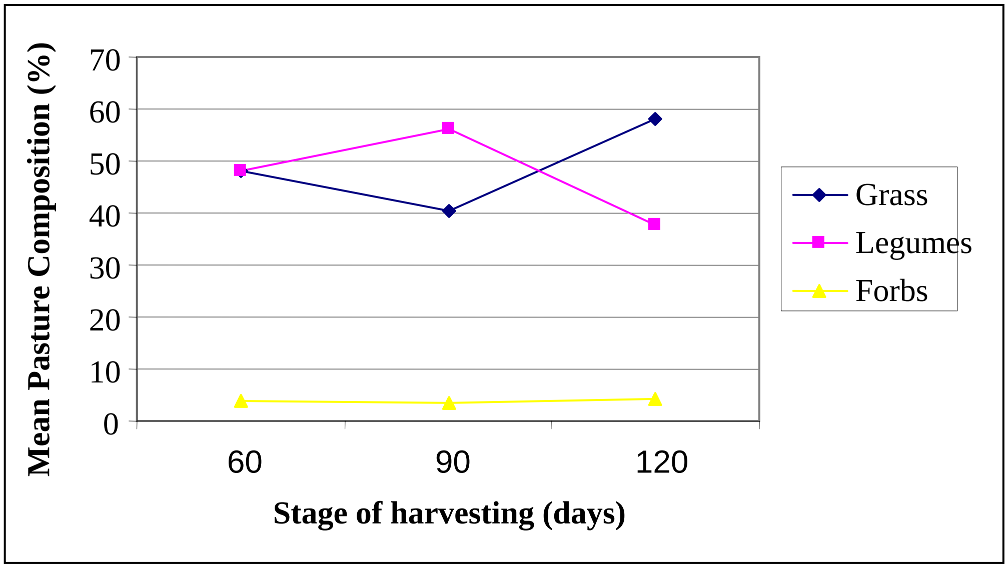

Figure 4. Percentage proportion of grasses, legumes and other forbs as influenced by different stages of harvesting

As the age of the pasture advanced the mean DMY of the legume in unfertilized plot increased until it reached its peak (6.57 t/ha) at 90 days of harvesting (Table 10).

Table 10.Dry matter yield (t/ha) of legume component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	3.94	6.57	2.61	4.37^{A}	0.64
23	3.19	5.52	2.86	3.86^{A}	0.50
46	2.96	4.58	3.05	3.53^{A}	0.40
69	2.17	2.76	1.68	2.21^{B}	0.30
Overall Mean	3.07^{y}	4.86^{x}	2.55^{y}		
SE	0.26	0.51	0.28		

Overall mean superscripts A and B in columns and x, y in rows followed by the same letter are not significantly different at 5% significant level.

However, there was a subsequent drop in mean dry matter yield of legumes at 120 days of harvesting and at the control (1.68 t/ha). In contrast, the mean DMY of grass increased from

2.06 to 6.26 t/ha as the level of fertilizer increased from 0 to 69 kg/ha (Table 11).Due to the effect of nitrogen fertilizer the DMY of the grass component was increased by 204% as compared to the control and the highest fertilizer level (69 kg/ha).Moreover, natural pasture harvested at 120 days and at 69 kg /ha nitrogen fertilizer results higher DMY (7.85 t/ha) of grass .As a result there was over 190% DMY increment of grass component of the natural pasture between the control and the highest fertilizer application (69 kg N/ha) at 120 day of harvest.

Table 11.Dry matter yield (t/ha) of grass component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	1.54	1.93	2.70	2.06^{C}	0.43
23	3.23	3.24	4.16	3.54^{CB}	0.40
46	3.88	3.85	3.72	3.82^{B}	0.45
69	5.26	5.67	7.85	6.26^{A}	0.82
Overall Mean	3.48	3.67	4.61		
SE	0.58	0.59	0.73		

Overall mean superscripts A- C in columns followed by the same letter are not significantly different at 5% significant level.

Table 12.Dry matter yield (t/ha) of forbs component at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	0.00	0.00	0.07	0.02^{B}	0.02
23	0.12	0.00	0.29	0.14^{B}	0.06
46	1.15	1.15	0.58	0.96^{A}	0.37
69	0.18	0.35	0.45	0.33^{B}	0.07
Overall Mean	0.36	0.38	0.35		
SE	0.23	0.24	0.09		

Overall mean superscripts A and B in columns followed by the same letter are not significantly different at 5% significant level.

The mean dry matter yield of other sward components (forbs) of the pasture declined from 0.38 t/ha at 90 day of harvesting to 0.35 t/ha at 120 days of harvesting. This result contradicts the reports on similar studies by Adane (2003) and Yihalem (2004) who stated that forbs proportion increased with increasing stages of harvesting of natural pasture. The increased forbs DMY that occurred at 90 days of harvesting might be due to the dominance of legumes invite to utilized excess nitrogen produced by rhizobium bacteria while at the later stage of the pasture, i.e. at 120 days of harvesting, it had suffered dominance by the grass species. The failure of the legume to support forbs is mainly due to aging and subsequent decline in the competitive ability of the legume at a later stage of mixed pasture development (Whiteman, 1980; Miller, 1984; Shehu and Akinola, 1995). On the other hand, nitrogen fertilizer did significantly ($P<0.05$) affect the forbs proportion of the pasture (Table 12).

4.3. Pasture Yield as Affected by Nitrogen Fertilizer and Harvesting Regime

4.3.1. Effect of nitrogen fertilizer application on herbage yield

There was a significant effect (P<0.05) of stage of harvest on pasture DMY (Table 13). The DMY ranged from 5.38 to 8.50 t/ha, 6.54 to 8.77 t/ha and 7.61 to 9.97 t/ha on non- fertilized, the lowest fertilizer level (23 kg/ha) and highest fertilizer level (69 kg/ha), respectively. The highest DMY (9.97 t/ha) was obtained at 120-days of harvesting at a nitrogen fertilizer application rate of 69 kg/ha while the lowest was (5.38 t/ha) from unfertilized plots at 120-days of harvesting

Table 13.Dry matter yield (t/ha) of natural pastureland at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	5.49	8.50	5.38	6.46	0.73
23	6.54	8.77	7.31	7.54	0.49
46	7.99	9.58	7.35	8.31	0.82
69	7.61	8.79	9.97	8.79	0.66
Overall Mean	6.91^{y}	8.91^{x}	7.51^{yx}		
SE	0.56	0.44	0.63		

Overall mean superscripts x and y in rows followed by the same letter are not significantly different at 5% significant level.

The comparison on mean yield attained from both unfertilized and fertilized plots at a certain stages of harvest showed that unfertilized plots had the lowest pasture yield of 5.38 t/ha at 120 days of harvesting due to the decline of legumes in the pasture whereas fertilized plots yield was as high as 8.77 t/ha. This trend was similar for yields obtained from plots with different fertilizer levels. On the other hand, comparison of stage of harvest under different fertilizer levels showed that the yield at 90 days of harvesting was consistently the highest because of at this stage of harvesting the proportion of legume was higher that contributes the of the overall DMY increment of the natural pasture.

The pasture yield was lower at 120 day of harvesting at all levels of fertilizer except the highest level (69 kg N/ha), which was in sharp contrast to that at 90 days of harvesting. This could be mainly due to the drying and loss of lower leaf parts of forage materials as forage gets matured, and as well, the decline in the proportion of legumes in the pasture with increasing days of harvesting. This result is in agreement with that reported by Akinola and Whiteman (1985), who described a decline in the dry matter yield of natural pasture as harvesting day progressed mainly due to drying and an increase in the loss of lower leaf parts from plant. In order to maximize yield from legumes with higher CP content, the pasture should be harvested at mid (90 days) early October (Kidane, 1993).

Natural pasture harvested at 120 days of harvesting and 69 kg N/ha fertilizer level results a DMY of 9.97 t/ha. This indicates a yield increment of 85.32% over the unfertilized plots, which are comparable with the results reported by Adane (2003) and Teshome (1987). At the unfertilized plots, there was an increased legume proportion, which contributed to a marked increase in DMY. On the other hand, application of nitrogen fertilizer resulted in increased grass proportion. As a consequence, it can be inferred that the increased productivity of natural pastures in terms of the amount of herbage obtained could be due to improved soil fertility from application of N-fertilizer since the analyzed soil sample of the site was low in total N. On the other hand, the decline in the proportion of legumes at 120 days of harvesting might have contributed to reduced total yield of the pastureland as it has been reported by Miller (1984), Adejumo (1992), Shehu and Akinola (1995) and Gebrehiwot *et al*. (1997), who attributed the reduction in vegetative growth of legumes as a factor for decreased dry matter yield of the pasture with advanced maturity.

4.3.2. Effect of harvesting time and cutting intervals on herbage yield

The frequency of cutting had a significant effect (P<0.01) on total yield. A comparison of mean total yield at different cutting intervals shows that the total yield of the first cut at 90 days of harvesting was the highest (10.92 t/ha) and the least was (3.86 t/ha) on the first cut at 60 days harvesting. However, frequent cutting of the same plot with 30 days interval indicated a consecutive decline of the yield from the first to the third cut for all levels of fertilizer application.

Table 14.Pasture yield performance (t/ha) at different frequencies of cutting after 60 days harvesting and levels of fertilizer application

Cutting frequency at 30 days interval					
Fertilizer level	**1st cutting**	**2nd cutting**	**3rd cutting**	**Over all Mean**	**SE**
0	3.86^{d}	0.91^{b}	0.37^{b}	1.70^{B}	1.25
23	5.80^{c}	1.52^{ab}	0.53^{b}	2.62^{B}	0.63
46	7.51^{b}	2.07^{a}	0.92^{a}	3.50^{A}	0.71
69	10.45^{a}	2.43^{a}	1.13^{a}	4.67^{A}	1.15
Overall Mean	6.91^{x}	1.73^{y}	0.74^{z}		
SE	0.75	0.72	0.20		

Overall mean superscripts A and B in columns and x-z in rows, mean superscripts a-d in rows followed by the same letter are not significantly different at 5% significant level.1st =plots harvested at 60 days, 2nd = plots harvested at 90 days and 3rd = plots harvested at 120 days

A significant effect (P<0.001) of fertilizer was observed on the total herbage yield obtained from repeated clipping and on the forage yield from plots harvested at different frequencies. When repeated cuttings were compared with harvesting once at 90 and 120 days of harvesting, there was a significant (P<0.01) increment on the dry matter yield of plots with frequent cuttings and increasing levels of fertilizer application. However, a total dry matter yield increment 10.50 and 14.01 t/ha was obtained in three cuttings at an interval of 30 days with N fertilized applications at the rate of 46 and 69 kg/ha, respectively (Table 15).

A significant interaction effect (P<0.001) of cutting frequency and fertilizer application was obtained for the DM yield. Low total yield was obtained on repeated harvesting at unfertilized and fertilized plots with the level of 23 kg/ha. The interaction effect of fertilizer and cutting frequency resulted in the highest DM yield of 14.01 t/ha at an application of 69 kg/ha nitrogen, when pasture was harvested three times at an interval of 30 days.

Table 15.Mean total yield (t/ha) of pastureland at different frequencies of cutting intervals (three cuttings at 30 days interval)

	Fertilizer level (kg/ha)			
Days of cuttings	**0**	**23**	**46**	**69**
30 days				
1st	3.86	5.80	7.51	10.45
2nd	0.91	1.52	2.07	2.43
1st-2nd	4.77	7.32	9.58	12.88
3rd	0.37	0.53	0.92	1.13
1st-3rd	5.14	7.85	10.50	14.01
90days	9.22	9.75	10.58	10.95
120 days	5.38	7.31	7.35	9.97

Findings of this study are in agreement with research results reported by Broatch (1970) and Hendy (1973), who suggested the maintenance of adequate intervals between consecutive cuttings in order to maximize yield from the natural pasturelands, so that the grasses can retain sufficient leaf material, which allow rapid growth for as much of the growing season as possible.

4.4. Pasture Nutritive Value as Affected by Nitrogen Fertilizer and Harvesting Regime

4.4.1. Crude protein

The crude protein content of forage samples from the natural pastureland decreased ($P<0.001$) from mean value 14.04% at 60 days to 6.76% at 120 days of harvesting (Table 16). The analysis of variance showed a highly significant ($P<0.001$) effect of stages of harvesting and interaction within treatment means on CP content. Fertilizer application had no- significant ($P>0.05$) effect on CP content (Table 16).

Table 16.Crude protein content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	15.53	12.64	7.11	11.76	1.26
23	15.49	10.87	6.11	10.82	1.36
46	11.25	11.89	7.49	10.21	1.31
69	13.91	11.83	6.34	10.69	1.24
Overall Mean	14.04^{x}	11.81^{y}	6.76^{z}		
SE	0.74	0.77	0.26		

Overall mean superscript x- z in rows followed by the same letter is not significantly different at 5% significant level

The results on nutritive value illustrated that the crude protein content of samples from the unfertilized as well as fertilized plots significantly decreased ($P<0.001$) as the age of the pasture advanced. The highest CP content of 15.53% was obtained at 60 days of harvesting (September) with unfertilized plots and the lowest crude protein content 6.11% was obtained from application of nitrogen fertilizer level at the rate of 23 kg/ha at 120 days of harvesting (November).The higher CP content from the unfertilized plots could be explained by the density of legume components in the pasture (Table 7) which was higher in the unfertilized plots than the fertilized plots. The reason for suppression of legumes in the fertilized plots is partly the indirect effect of nitrogen by inducing dominance of the grass component which tends to suppress the legume. Nitrogen may also influence legume growth through its inhibitory effect on Rhizobial nitrogen fixation. Therefore, the high CP content from unfertilized plots is most probably brought about by higher composition of legumes in the sward, and legumes generally have high content of CP. As has been observed in the study site and elsewhere in the northern part of Ethiopia, native clovers (*Trifolium*) tend to dominate the natural pasture in the fallows and crop borders. The higher CP content from pastures early-harvested than late-harvested herbage is expectable in that CP content of pastures generally declines with maturity. The results obtained in this study were in agreement with those reported by Zinash *et al*. (1995), Adane (2003), Adane and Berhan (2005) and Yihalem (2004), who indicated that the decline in CP content of the pasture along with increasing stage of harvesting. This might be due to the dilution of the crude protein content by an increasing amount of structural carbohydrates in the late harvested forage materials (Hassan *et al*., 1990).

The CP content of forage at 120 days of harvesting was significantly lower ($P<0.001$) than the other two stages of harvesting. On non- fertilized plots the CP content of forage decreased from the herbage harvested at 60 days to that harvesting at 120 days. Similarly, the differences in CP content among the rest of harvesting stages were all significant ($P<0.001$). Considering the CP content under different levels of nitrogen application, the means for the stages of harvesting on crude protein content indicated significant difference ($P<0.001$) among 60, 90 and 120 days of harvesting.

On the other hand, considering similar stages of harvesting the pasture had considerably higher CP content at zero fertilizer level and subsequently there was no significance increase in crude protein content as the levels of fertilizer application increased. As explained above, the increased CP content at unfertilized plots might be due to increased proportion of legumes in the pasture, which generally contain high accumulation of nitrogen in the plant tissue. This is in line with the report of Shehu and Akinola (1995), whose findings proved the high contribution of legumes in maintaining the CP content of grass-legume mixed pastures and associated depression in crude protein content with advancing stages of growth, consistent with the reduction in the proportion of legumes in the pasture due to defoliation.

In the late harvested herbages, the dominance of grasses over the legume species has been observed in natural pastures found elsewhere in the highlands (Kidane, 1993). Such a decrease in the legume composition associated with late harvesting is considered as one of the factors that reduce the crude protein content of pasturelands. In this study the mean CP content of the forage samples taken from the 120 days of harvesting was below 7%, which is minimum CP level required for rumen functioning.

4.4.2. Neutral detergent fiber

NDF content of the forage samples ranged between 55.63% at 60 days to 74.36% at 120 days of harvesting (Table 17). Stage of harvest had highly significant effect (P<0.001) on NDF content unlike levels of nitrogen fertilizer application (Appendix Table 10). Harvesting stage means averaged over the same level of fertilizer indicated a significant (P<0.001) difference among 60, 90 and 120 days of harvesting (Table 17).

Table 17.Neutral detergent fiber content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	55.63	65.33	74.36	65.11	2.80
23	56.12	63.19	75.41	64.91	2.85
46	64.18	62.48	71.91	66.19	2.09
69	56.57	60.90	72.22	63.23	2.66
Overall Mean	58.13^{z}	62.98^{y}	73.48^{x}		
SE	1.75	0.71	0.72		

Overall mean superscript x-z in rows followed by the same letter is not significantly different at 5% significant level

Increased NDF content with advanced age of pasture was also reported by (Kidane, 1993; Adane, 2003 and Yihalem, 2004). In this study, at the same fertilizer levels, including zero fertilizer level, NDF significantly increased (P<0.001) with the advanced age of the pasture.

However, at the same stage of harvest, the effect of fertilizer was non significant for NDF. The results of this study agree with that reported by Teshome (1987), Zinash et al. (1995), Adane (2003) and Adane and Berhan (2005), who reported an increase in the level of fertilizer application on natural pasture had no-significance role in maintaining the nutritive value of the pasture with regard to its effect on fiber fractions.

4.4.3. Acid detergent fiber

The ADF content of forage samples varied from 37.9% to 52.15% on unfertilized plots at the 60 and 120 days of harvesting, respectively (Table18). The analysis of variance (Appendix Table 11) showed that the difference in ADF content of samples at different stages of harvesting was significant (P<0.001).

Table 18.Acid detergent fiber content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	37.90^{gef}	41.83^{de}	52.15^{a}	43.96	2.16
23	37.32^{g}	43.24^{dc}	51.49^{a}	44.02	2.20
46	46.63^{bc}	41.49^{def}	50.71^{ba}	46.28	1.69
69	37.56^{gf}	42.24^{d}	50.19^{ba}	43.33	2.04
Overall Mean	39.85^{z}	42.20^{y}	51.14^{x}		
SE	1.39	0.73	0.41		

Mean superscript a-e with in rows and overall mean superscript x, y in rows followed by the same letter are not significantly different at 5% significant level

The results obtained also showed a linear increase in ADF content with a corresponding increase in days of harvesting (Fig 5). However, no significant difference was observed among the forage samples taken from different fertilizer level treatments but with the same stages of harvesting. In this study, at the same fertilizer levels, including zero fertilizer level, ADF significantly increased (P<0.001) with an increase in the number of days harvest and interaction of treatment means, i.e., approaching maturity over-maturity of the pasture. Consequently, at the same stage of harvesting, the effect of fertilizer was non- significant for ADF. The lack of significance in the effect of N levels could be that the effect of harvesting stage is superior to the effect of N fertilizer in the amount of structural carbohydrates (fiber) accumulation, hence, logically; the effect of fertilizer has been confounded by stage of harvest, which is more decisive factor in the concentration of fibrous material. The results of the present study are agreement with that reported by Teshome (1987), Zinash *et al*. (1995) and Adane (2003). The authors described that the increase in the level of fertilizer application on the pasture at different stages of growth had no significant role in maintaining the nutritive value of the pasture forage regarding fiber fractions including ADF Gebrehiwot *et al*. (1996) based on their finding, indicated an increase in ADF concentration to have close association with a decrease in a leaf-to-stem ratio and an increase in cell wall lignifications with advanced stages of growth.

4.4.4. Hemi-cellulose

The effect of stage of harvesting on the hemi-cellulose concentration was significant (P<0.001). The content of hemi-cellulose increased linearly with stage of harvesting and the mean comparison on stage of harvesting (Table 19) showed a significant effect (P<0.001) in the hemi-cellulose composition. The hemi-cellulose content of forage samples increased from 17.73% to 23.50% at 60 and 90 days of harvesting, at zero fertilizer level.

Table 19.Hemi-cellulose content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	17.73	23.50	22.21	21.15	0.97
23	18.81	19.96	23.91	20.89	0.87
46	17.55	20.99	21.20	19.91	0.91
69	19.01	18.66	22.04	19.90	1.17
Overall Mean	18.28^{y}	20.78^{x}	22.34^{x}		
SE	0.75	0.72	0.61		

Overall mean superscript x, y in rows followed by the same letter is not significantly different at 5% significant level

On the other hand, at the same stage of harvest different levels of N fertilizer had no significant effect on the hemicellulose content. The increase in hemicellulose content with advancing age of the pasture was in agreement with the report of Teshome (1987), Adane (2003), Yihalem (2004) and Kidunda *et al.* (1990).

4.4.5. Cellulose

The cellulose content of the analysed forage samples varied significantly ($P<0.001$) consistent with the different stage of harvesting and interaction within level of fertilizer. Analysis of variance (Appendix Table13) showed a significant increase ($P<0.001$) in cellulose content of the pasture due to advances in stage of harvesting, ranges from 32.99% to 42.25% from 60 to 120 days of harvesting from unfertilized plots. The levels of fertilizer application on natural pasture had no- significant effect on cellulose content of the pasture (Table 20). The correlation observed was positive ($r= 0.72$) as well as significant ($P<0.01$), in which cellulose content of forage increased along with increasing stage of harvesting. The results of this study are in line with those reports of Van Soest (1982) and Adane (2003) who noted an increase in cellulose content of forages with advances in stage of harvesting (Fig 5).

Table 20.Cellulose content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	32.99^{dc}	34.25^{dc}	42.25^{a}	36.49	1.48
23	32.08^{d}	36.32^{bc}	41.89^{a}	36.76	1.46
46	39.42^{ba}	33.94^{dc}	41.23^{a}	38.19	1.41
69	32.02^{d}	35.14^{dc}	41.18^{a}	36.11	1.54
Overall Mean	34.13^{y}	34.91^{y}	41.64^{x}		
SE	1.09	0.70	0.39		

Mean superscript a-e with in rows and columns and overall mean superscript A-C in columns and x, y in rows followed by the same letter are not significantly different at 5% significant level

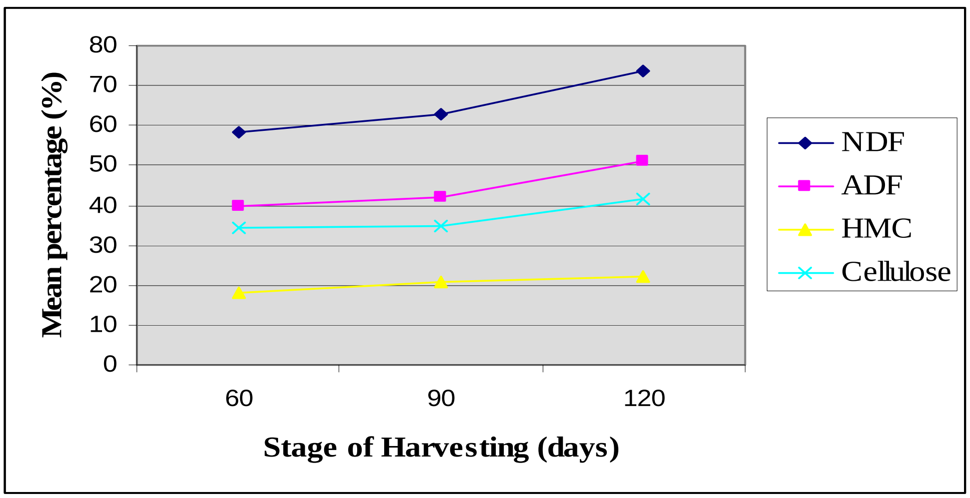

Figure 5.The NDF, ADF, Hemi-cellulose and Cellulose contents as influenced by stages of harvesting

4.4.6. Total ash

The total ash content of the natural pasture increased ranged from 9.79% on unfertilized plot to 11.01% at 69 kg/ha fertilizer level at 60 days of harvesting. Analysis of variance (Appendix Table14) showed day of harvesting as having a highly significant ($P<0.001$) effect, and similarly, fertilizer application had significant (P<0.05) effect on total ash content of forage. On unfertilized plots, total ash content decreased as stage of harvesting increased up to 90 days. Similarly, on fertilized plots the effect of stage of harvesting on total ash content of forage samples revealed a significant effect (P<0.05) from 60 to 120 days of harvesting (Table 21).

In this study, the effect of fertilizer at the same stage of harvesting on total ash content was significant (P<0.05). However, the result was not consistent at different levels of fertilizer application. On the other hand, the mean effect of stage of harvesting showed significantly decrease (P<0.001) in the total ash content from 60 to 120 days of harvesting.

Table 21.Total ash content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	9.79	8.15	9.09	9.01^{B}	0.28
23	10.47	8.03	8.32	8.94^{B}	0.42
46	12.77	9.59	9.87	10.74^{A}	0.82
69	11.01	9.28	9.69	9.99^{BA}	0.33
Overall Mean	11.01^{x}	8.76^{y}	9.24^{y}		
SE	0.55	0.31	0.23		

Overall mean superscript A and B in columns and x, y in rows followed by the same letter are not significantly different at 5% significant level

The trend observed in the present study indicated the ash content of the natural pasture declined with advancing stage of harvesting. These results are in line with those reported by (Teshome, 1987; McDonald *et al*., 1995; Zinash *et al*., 1995 and Adane, 2003). The authors indicated the decline in total ash content of forages from fertilized pasture which brings about earlier dilution and translocation of different minerals associated with vegetative portion of the plant (leaf portion) to roots at late stage of maturity as described by Maynard et al. (1981).

4.4.7. Phosphorous

Phosphorus content of forage samples declined from 0.41% to 0.24% and from 0.38% to 0.15% of DM in unfertilized and fertilized plots at 60 and 120 days of harvesting, respectively. The P content of forage samples from non fertilized plots was significantly higher ($P<0.001$) than that of fertilized plots and decreased with increasing fertilizer levels (Table 22). The results were appreciably comparable with the published P requirements for growing cattle which ranged between 0.11 to 0.34%t of pasture DM (ARC, 1980). However, the analysis of variance revealed significance difference ($P<0.001$) on P content of forages harvested at different stages of harvesting. Lower P content was observed with advancing days of harvesting and at higher levels of fertilizer reflecting the importance of early harvesting management for higher P content in the forage. The results of this study are in line with those reported by Teshome (1987), Kidane and Varvikko (1991) and Adane (2003).

Table 22.Phosphorus content (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	0.41	0.27	0.24	0.31	0.03
23	0.38	0.27	0.15	0.27	0.04
46	0.34	0.28	0.20	0.27	0.04
69	0.38	0.21	0.16	0.25	0.04
Overall Mean	0.38^{x}	0.25^{y}	0.19^{z}		
SE	0.02	0.02	0.02		

Overall mean superscript x-z in rows followed by the same letter is not significantly different at 5% significant level

The decrease in phosphorus content as the age of the pasture advanced might be due to the translocation of P to seeds and root parts of herbage as described by different researchers (Minson, 1980 and Crowder and Chheda, 1982). Moreover, Coates (1994) pointed out that the depression of P concentration with progressing plant maturity is due to rapid fluctuations in soil moisture and other factors affecting plant growth.

4.4.8. *In vitro* dry matter digestibility

Stage of harvesting and its interaction in the level of fertilizer caused a significant effect ($P<0.001$-$P<0.01$) on the *in vitro* dry matter digestibility, respectively (Table 23). The IVDMD decreased as the age of the forage advanced. The analysis of variance (Appendix Table 16) showed significant ($P<0.001$) difference among mean IVDMD values of different stages of harvesting and levels of fertilizer application.

Table 23.In vitro dry matter digestibility (percentage) at different stages of harvesting and levels of fertilizer application

	Days of Harvesting				
Fertilizer level	**60**	**90**	**120**	**Overall Mean**	**SE**
0	54.86	50.38	36.59	47.28	3.46
23	54.62	49.59	36.52	46.91	2.84
46	47.23	49.91	40.23	45.79	3.29
69	53.63	50.51	41.71	48.62	2.31
Overall Mean	52.59^{x}	50.09^{x}	38.76^{y}		
SE	2.51	1.70	0.97		

Overall mean superscript x, y in rows followed by the same letter is not significantly different at 5% significant level

Samples from fertilized and unfertilized plots at 60 days of harvesting had IVDMD value of 54.86% and 53.63% at zero and 69 kg/ha of nitrogen fertilizer levels, respectively. The comparison among the fertilizer levels also revealed that the IVDMD decreased with increasing levels of fertilizer application and advancing days of harvesting of the natural pasture. The results of this study showed that IVDMD was higher on harvesting at early stage of growth. This was in agreement with the findings of Zinash et al. (1995), Tessema (2003), Adane (2003) and Yihalem (2004) who reported depressed IVDMD of the grass species harvested at relatively advanced stages of maturity. This might be due to presence of certain substances notably lignin, which might have been deposited in the cell wall with increasing maturity (Vansoest, 1982) and the increasing proportion of stem at advanced maturity, which is less digestible than the leaf portion (McDonald et al., 1995).

Table 24.Effect of harvesting stage and fertilizer levels on the crude protein yield and digestible dry matter yield

Combination of harvesting stage and fertilizer levels	DMY (t/ha)	CP (%)	CPY(t/ha)	IVDMD (%)	IVDMDY (t/ha)
(0, 60)	5.49	15.53	0.85	54.86	2.93
(23, 60)	6.54	15.49	1.01	54.62	3.57
(46, 60)	7.99	11.25	0.87	47.23	3.67
(69, 60)	7.61	13.91	1.04	53.63	4.05
(0, 90)	8.50	12.64	1.07	50.38	4.39
(23, 90)	8.77	10.87	0.95	49.59	4.33
(46, 90)	9.58	11.89	1.08	49.91	4.65
(69, 90)	8.79	11.83	1.04	50.51	4.40
(0, 120)	5.38	7.11	0.38	36.59	1.99
(23, 120)	7.31	6.11	0.45	36.52	2.65
(46, 120)	7.35	7.49	0.56	40.23	2.95
(69, 120)	9.97	6.34	0.62	41.71	4.14

DMY= Dry Matter Yield, CP (%) = Crude Protein percentage, CPY= Crude Protein Yield, IVDMD (%) = *In Vitro* Dry Matter Digestibility, IVDMD= In Vitro Dry Matter Digestibility Yield

Different levels of nitrogen fertilizer applications had no significant effect on the CP and IVDMD and their means within the treatment declines as the stage of harvesting progresses. However, the interaction of stage of harvesting and different fertilizer levels resulting significant ($P<0.01$) effect as shown (Table 16 and 23) for CP and IVDMD, respectively. Moreover, natural pasture harvested at 90 days and 46 kg N/ha fertilizer levels results higher chemical composition of natural pasture (9.58 t/ha DMY, 11.89% CP, 1.08 t/ha CP yield, 49.91% IVDMD and 4.65 t/ha digestible DMY) (Table 24) .Steady decline in chemical composition with increasing growth for tropical grasses as generally been attributed an increase in structural components (cell walls) in the leaf to stem ratio (Kabuga and Darko, 1993).

4.5. Correlation Coefficient between Dry Matter Yield and Nutritive Value of Natural Pasture

4.5.1. Correlation analysis

The correlation coefficient between the CP and cell wall contents such as NDF, ADF, hemi-cellulose and cellulose indicated negative values of -0.89, -0.91, -0.51 and -0.89, respectively. While other quality parameters such as IVDMD and P contents, the CP was correlated with correlation coefficient values of 0.82 and 0.79, respectively. The correlation coefficient obtained between CP and IVDMD in the present study was comparable with the reports of Barton *et al*. (1976) who reported high correlation coefficient value of r= 0.90 for tropical grasses. Similarly, the IVDMD was negatively correlated with correlation coefficient value of r= -0.81, -0.81,-0.47 and -0.79 for NDF, ADF, hemi-cellulose and cellulose, respectively. This indicated that with increasing maturity of forage the IVDMD declined due to an increase in structural carbohydrate fractions and their high degree of reinforcement with indigestible material specifically lignin as described by Van Soest, (1982) and McDonald *et al*. (1995).

Table 25.Correlation coefficients between stage of maturity, cutting frequency and fertilizer application with DMY and quality parameters of natural pasturelands

	PDMY	CP	NDF	ADF	HMC	CE	P
PDMY	1						
CP	-0.25	1					
NDF	0.11	-0.89**	1				
ADF	0.04	-0.91**	0.94**	1			
HMC	0.20	-0.51**	0.72**	0.44**	1		
CE	-0.003	-0.89**	0.90**	0.99**	0.37*	1	
P	-0.42*	0.79**	-0.73**	-0.71**	-0.49**	-0.67**	1
IVDMD	-.116	0.82**	-0.81**	-0.81**	-0.47**	-0.79**	0.74**

** = P<0.01, *= P<0.05, PDMY= Pasture Dry Matter Yield; CP= crude Protein; NDF= Neutral Detergent Fiber; ADF= Acid Detergent Fiber; HMC= Hemi-cellulose; CE= Cellulose; P= Phosphorus; IVDMD= In Vitro Dry Matter Digestibility

5. SUMMARY AND CONCLUSIONS

The study was conducted in *Fogera* district of South Gondar Zone of Amhara Regional Sate. In the area, insufficient supply and poor quality of feeds constitute the major technical constraint to livestock production. The objectives of this study were to determine the botanical composition, dry matter yield and chemical composition of the *Fogera* upland natural pasture under different application rates of nitrogen fertilizer and harvesting stages of natural pasture at smallholder farmer condition.

A native pastureland reserved as a source of hay production and managed by a smallholder farmer was selected for the field experiment. Nitrogen fertilizer with varying rates was applied on the research plots as recommended by ILCA (1983) for the fertilization of pasturelands in central highlands of Ethiopia. Three stages of harvesting (60, 90 and 120 days) as practiced by smallholder farmers in other central highlands were chosen as harvesting time. The forage samples were harvested at the fixed stages of harvest, weighed in the field and dried in an oven to make it ready for chemical analysis at ILRI nutrition laboratory.

The data recorded from weighing of the forage samples for the different stages of harvesting indicated that overall mean DMY of 7.54 and 8.79 t/ha were attained at 23 and 69 kg/ha of nitrogen fertilizer levels, respectively. The DMY attained from unfertilized plots was only 6.46 t/ha. On the other hand, natural pasture harvested at high fertilizer level (69 kg/ha) and stage of harvesting at 60 and 120 days resulted in a dry matter yield of 7.61 t/ha and 9.97 t/ha, respectively, with an overall mean DMY of 8.79 t/ha for fertilized plots.

Fertilization of the pasture plots up to the level of 69 kg/ha improved the DMY to 36.07% over the non fertilized plot. The results of this study indicated reduced nutritive values of forages with advancing stage of harvesting of plants. Harvesting pasture forages at 60 days provided the highest feeding values as measured by feed quality parameters. The CP content of forages harvested from unfertilized plots was higher than fertilized plots, but decreased from 15.53% at 60 days of harvesting to 7.11% at 120 days. As the application of fertilizer increased from the lowest (23 kg/ha) to the highest (69 kg/ha), even if, the over all CP percentage decreased from 11.76% to 6.34% statistically there was no significant difference with in the control and fertilized plots. Generally, the crude protein content of natural pasture of the study area is higher as compared to the previous reports in the central highlands of the country which is a mean of 5.6% (Adane, 2003). This indicates that natural pasture in the north western highlands is richer in legume proportions. The crude protein content declined as the stage of harvesting exceeded 60 days.

Stage of harvesting and levels of fertilizer application affected species composition in terms of grass-legume proportion. At 60 days of harvesting the proportion of grasses and legumes is equivalent, increasing legume proportion at 90 days of harvesting. The legume contributed 56.18% of the biomass. Even though the relative proportion of legume was the highest at 90 days of harvesting, the period under flowering stage was very short that it started declining at 120 days of harvesting till the percentage of legume proportion reached 37.66%.

The slight reduction in DMY recorded at 120 days of harvesting might not be only due to the defoliation of some forage parts alone, but also due to the reduction of legume proportion which affected the contribution of the legumes by weight to the total forage DMY of the pastureland. Application of nitrogen fertilizer did not promote the proportion of legumes in the natural pastureland; rather it promoted the proportion of grasses as the result of fertilization with increasing stage of harvesting. The correlation among the quality parameters CP and IVDMD was positive, whereas the correlation coefficient values of both CP and IVDMD with NDF, ADF, hemi-cellulose and cellulose indicated negative relationship.

6. RECOMMENDATIONS

- Relatively high crude protein content (15.53%) and moderate DMY of (7.99 t/ha) were achieved when forages from natural pasture were harvested at 60 days (September). Therefore, harvesting of forages on the pastureland for feeding and preserving in the form of hay should be practiced at this stage of harvesting, instead of harvesting at prolonged stage

- Natural pasture harvested at 90 days of harvesting (October) and fertilizer applications at the level of 46 kg/ha at resulted in higher mean dry matter yield of 9.58 t/ha and higher nutritional quality (11.89% CP, 49.91% IVDMD) and 1.08 t/ha crude protein yield and 4.65 t/ha *in vitro* dry matter digestibility of the natural pasture. This level of fertilizer application should be practiced for higher pasture yield and feed quality parameters.

- Frequent harvesting of forages from plots with fertilizer application levels above 46 kg/ha produced higher total DM yield as compared to yields from single harvest. Therefore, frequent harvesting of forages should be practiced from plots with higher levels of fertilizer application for higher pasture yield and forage quality parameters.

- Evaluation of indigenous species from natural pastureland may prove to be useful for future forage development schemes and pasture improvement programs because they are well adapted to the local environment.

- Provision of strong extension services about pasture improvement strategies and training farmers on in harvesting and storage of hay is very important

7. SCOPE FOR FUTURE WORK

- Hay obtained from grazing lands is a major feed resource on which livestock production of the area relies. Most grazing lands in the area consist of forages of grass-legume mixtures. Therefore, detailed studies on nutritive values of the identified grass and legume species will be of paramount importance for their promotion and optimizing stages of harvesting and levels of fertilizer for high DM yield and nutritional quality of the pastureland should be studied in different years and in different seasons.

- The magnitude of improving of the quality of natural pasture by stages of harvesting and fertilizer application should be assessed along with the effects on feed intake and animal productivity in terms of milk yield and body weight gain. Therefore, feeding trials need to be undertaken to substantiate the results of the present study

- The degree of invasion of *Hygrophila auriculata* weed (*Amekalla*) and its relation to the natural pastureland degradation should be given due attention.

- Since this study was carried out only at one location representing the research district, it is important to conduct similar studies on different locations with varying climatic conditions and soil types, different feed resource types and grazing management practices in the north-western highlands which have higher livestock population but a declining land size per household.

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9. APPENDIX

Appendix Table 1.Analysis of the effect of different stages of harvesting and levels of fertilizer application on the percentage proportion of legume component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	598.65	299.33	1.66^{NS}	0.2133
Treatment	11	10363.32	942.12	5.22***	0.0005
Stage of harvesting (A)	(2)	2068.2	1034.1	5.73**	0.0099
Fertilizer (B)	(3)	7476.02	2492.01	13.81***	0.0001
AB	(6)	819.09	136.52	0.76^{NS}	0.6113
Error	22	3970.39	180.47		
Total	35	25295.67			

NS= not-significant, **= P<0.01, ***= P<0.001

Appendix Table 2.Analysis of the effect of different stages of harvesting and levels of fertilizer application on the percentage proportion of grass component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	975.72	487.86	2.86^{NS}	0.0785
Treatment	11	8652.58	786.59	4.62**	0.0011
Stage of harvesting (A)	(2)	1924.11	962.06	5.65*	0.0105
Fertilizer (B)	(3)	6238.64	2079.55	12.21***	0.0001
AB	(6)	489.83	81.64	0.48^{NS}	0.8165
Error	22	3747.79	170.35		
Total	35	22028.67			

NS= Not-Significant, *= P<0.05, **= P<0.01, ***= P<0.001

Appendix Table 3.Analysis of the effect of different stages of harvesting and levels of fertilizer application on the percentage proportion of other forbs component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	65.68	32.84	0.91^{NS}	0.4171
Treatment	11	584.14	53.10	1.47^{NS}	0.2117
Stage of harvesting (A)	(2)	2.68	1.34	0.04^{NS}	0.9636
Fertilizer (B)	(3)	515.4	171.8	4.76*	0.0105
AB	(6)	66.05	11.01	0.31^{NS}	0.9275
Error	22	793.78	36.08		
Total	35	2027.73			

NS= Not-Significant, *= P<0.05

Appendix Table 4.Analysis of the effect of different stages of harvesting and levels of fertilizer application on dry matter yield of legume component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	2.54	1.27	1.47^{NS}	0.2526
Treatment	11	66.85	6.08	7.03***	0.0001
Stage of harvesting (A)	(2)	35.28	17.64	20.40***	0.0001
Fertilizer (B)	(3)	23.07	7.69	8.89***	0.0005
AB	(6)	8.50	1.42	1.64^{NS}	0.1837
Error	22	19.02	0.86		
Total	35	155.26			

NS= Not-Significant, ***= P<0.001

Appendix Table 5.Analysis of the effect of different stages of harvesting and levels of fertilizer application on dry matter yield of grass component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	14.78	7.39	2.84^{NS}	0.0799
Treatment	11	97.17	8.83	3.40**	0.0071
Stage of harvesting (A)	(2)	8.76	4.38	1.68^{NS}	0.2087
Fertilizer (B)	(3)	81.69	27.23	10.47***	0.0002
AB	(6)	6.72	1.12	0.43^{NS}	0.8507
Error	22	57.23	2.60		
Total	35	266.35			

NS= Not-Significant, **= P<0.01, ***= P<0.001

Appendix Table 6.Analysis of the effect of different stages of harvesting and levels of fertilizer application on dry matter yield of forbs component

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	0.87	0.43	1.08^{NS}	0.3579
Treatment	11	5.59	0.51	1.26^{NS}	0.3071
Stage of harvesting (A)	(2)	0.004	0.002	0.01^{NS}	0.9947
Fertilizer (B)	(3)	4.69	1.56	3.89*	0.0227
AB	(6)	0.89	0.15	0.37^{NS}	0.8902
Error	22	8.85	0.40		
Total	35	20.89			

NS= Not-Significant, *= P<0.05

Appendix Table 7.Analysis of the effect of different stages of harvesting and levels of fertilizer application on dry matter yield of natural pastureland

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	4.86	2.43	0.78^{NS}	0.4715
Treatment	11	70.77	6.43	2.06*	0.0119
Stage of harvesting (A)	(2)	25.39	12.69	4.06*	0.0315
Fertilizer (B)	(3)	27.96	9.32	2.98^{NS}	0.0533
AB	(6)	17.42	2.9	0.93^{NS}	0.4935
Error	22	68.72	3.12		
Total	35	215.12			

NS= Not-Significant, *= P<0.05

Appendix Table 8.Analysis of the effect of frequent cutting on the pasture yield

Source of variation	Degree of freedom	Sum of square	Mean square	F value	Pro.
Replication	2	7.15	3.57	15.86***	0.0001
Harvesting (A)	2	262.03	131.01	581.43***	0.0000
Fertilizer (B)	3	42.32	14.11	62.59***	0.0000
AB	6	32.79	5.47	24.26***	0.0000
Error	22	4.96	0.23		
Total	35	349.25			

***= P<0.001

Appendix Table 9.Analysis of the effect of different stages of harvesting and levels of fertilizer application on crude protein content of natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	11.83	5.92	1.27^{NS}	0.3000
Treatment	11	379.07	34.46	7.41***	0.0001
Stage of harvesting (A)	(2)	334.07	167.04	35.92***	0.0001
Fertilizer (B)	(3)	11.37	3.79	0.82^{NS}	0.4993
AB	(6)	33.62	5.60	1.21^{NS}	0.3406
Error	22	102.30	4.65		
Total	35	872.27			

NS= Not-Significant, ***= P<0.001

Appendix Table 10.Analysis of the effect of different stages of harvesting and levels of fertilizer application on neutral detergent fiber of natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	2.28	1.14	0.08^{NS}	0.9277
Treatment	11	1681.69	152.88	10.09***	0.0001
Stage of harvesting (A)	(2)	1477.85	738.92	48.77***	0.0001
Fertilizer (B)	(3)	40.36	13.45	0.89^{NS}	0.4628
AB	(6)	163.48	27.25	1.80^{NS}	0.1460
Error	22	333.35	15.15		
Total	35	3699.00			

NS= Not-Significant, ***= P<0.001

Appendix Table 11.Analysis of the effect of different stages of harvesting and levels of fertilizer application on acid detergent fiber on natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	19.53	9.77	1.62^{NS}	0.2204
Treatment	11	1047.01	95.18	15.80***	0.0001
Stage of harvesting (A)	(2)	850.88	425.44	70.62***	0.0001
Fertilizer (B)	(3)	45.19	15.07	2.50^{NS}	0.0860
AB	(6)	150.94	25.16	4.18***	0.0060
Error	22	132.54	6.02		
Total	35	2246.10			

NS= Not-Significant, ***= P<0.001

Appendix Table 12.Analysis of the effect of stages of harvesting and levels of fertilizer application on hemi-cellulose of natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	8.63	4.32	0.74^{NS}	0.4904
Treatment	11	155.42	14.13	2.41^{NS}	0.0381
Stage of harvesting (A)	(2)	100.99	50.49	8.61***	0.0017
Fertilizer (B)	(3)	11.42	3.81	0.65^{NS}	0.592
AB	(6)	43.02	7.17	1.22^{NS}	0.3324
Error	22	129.02	5.86		
Total	35	448.49			

NS= Not-Significant, ***= P<0.001,

Appendix Table 13.Analysis of the effect of stages of harvesting and levels of fertilizer application on cellulose of natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	17.61	8.8	2.02^{NS}	0.1568
Treatment	11	535.21	48.66	11.15***	0.0001
Stage of harvesting (A)	(2)	408.73	204.37	46.83***	0.0001
Fertilizer (B)	(3)	22.32	7.44	1.71^{NS}	0.1951
AB	(6)	104.16	17.36	3.98***	0.0076
Error	22	96.00	4.36		
Total	35	1184.03			

NS= Not-Significant, ***= P<0.001

Appendix Table 14.Analysis of the effect of different stages of harvesting and levels of fertilizer application on the total ash content of natural pasture

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	0.21	0.10	0.06^{NS}	0.9373
Treatment	11	58.19	5.29	3.30**	0.0083
Stage of harvesting (A)	(2)	33.56	16.78	10.46***	0.0006
Fertilizer (B)	(3)	19.99	6.67	4.16*	0.0178
AB	(6)	4.64	0.77	0.48^{NS}	0.8148
Error	22	35.29	0.22		
Total	35	151.88			

NS= Not-Significant, *= P<0.05, **= P<0.01, ***= P<0.001

Appendix Table 15.Analysis of the effect of different stages of harvesting and levels of fertilizer application on the phosphorus content

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Prob.
Replication	2	0.08	0.04	20.82***	0.0001
Treatment	11	0.26	0.02	4.51**	0.0010
Stage of harvesting (A)	(2)	0.22	0.11	57.76***	0.0001
Fertilizer (B)	(3)	0.02	0.005	2.68^{NS}	0.0718
AB	(6)	0.02	0.003	1.31^{NS}	0.2954
Error	22	0.04	0.002		
Total	35	0.64			

NS= Not-Significant, **= P<0.01, ***= P<0.001

Appendix Table 16.Analysis of the effect of stages of harvesting and levels of fertilizer application on in vitro dry matter digestibility

Source of variation	Degrees of freedom	sum of square	Mean square	F value	Pro.
Replication	2	479.09	239.55	7.76***	0.0028
Treatment	11	1483.57	134.87	4.37**	0.0016
Stage of harvesting (A)	(2)	1302.95	651.48	21.11***	0.0001
Fertilizer (B)	(3)	36.69	12.23	0.40^{NS}	0.7568
AB	(6)	143.92	23.99	0.78^{NS}	0.5963
Error	22	678.79	30.85		
Total	35	4125.02			

NS= Not-Significant, **= P<0.01, ***= P<0.001

Appendix Table 17.The mean annual rainfall (mm), average minimum and maximum temperature (^{0}c) at Woreta Station

Year	**Mean Rainfall (mm)**	**Average Minimum temperature (0c)**	**Average Maximum temperature (0c)**
1995	1063.30	12.04	27.05
1996	1380.40	12.64	29.58
1997	929.70	11.80	27.29
1998	1341.60	10.13	28.65
1999	1519.30	9.08	28.71
2000	1467.00	11.08	28.07
2001	1152.90	9.45	28.73
2002	1142.90	12.88	29.06
2003	1273.50	10.67	28.56
2004	1225.80	12.60	27.85

NB: XX= Data not available
Source: North Western Zone Meteorological Service (2004), Bahir Dar.