Rangeland Improvement by Interseeding and Water Conservation in Semi-arid Zone of the Sudan

"South Darfur, Nyala Province"

By

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Dedication

To my wife, children, brothers and sisters.

To the souls of my father, mother Khadiga and sister Aarafa.

I dedicate this work with my love

Abdelrahman

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ABSTRACT

Research was conducted over a 2-year period at Agleri (40km North East of Nyala)-Western Sudan in a semi-arid zone under rainfed conditions. The objectives were to evaluate the adaptability of introduced perennial pasture legumes and grasses to semi-arid conditions, and to assess the current status of rangelands vegetation and the effect of improved pasture on livestock performance. Four introduced perennial pasture species, namely *Stylosanthes hamata, Macroptilium atropurpureum, Clitoria ternatea* (legumes) and *Cenchrus ciliaris* (grass) were studied.

Two ploughing methods viz. spring toothed cultivator and spike toothed harrow were used, grazed and ungrazed plots were evaluated.

Nested in management design was used. Grazing management and ploughing methods form the main plots and pasture species formed the sub-plots, with three replicates. The plot size was 15 × 30m. Data were randomly collected on a number of attributes, for each treatment in each replicates, were used for statistical analysis. Measurements of plant density, composition, ground cover, frequency, forage yield and forage quality determination were carried out along with livestock performance.

Generally, all treatments had no significant differences on soil moisture content, but there were significant differences encountered among pasture species for most characters studied; namely, plant density, % vegetative cover and survival rate, and forage yield. *Stylosanthes hamata* as a pure stand and as a mixture with *Cenchrus*

ciliaris was almost outstanding in growth attributes and forage yield compared to others introduced pasture species.

Vegetation measurements indicated that the plant composition and frequency were almost the same in grazed and ungrazed exclosures, the dominant annual grasses were *Aristida spp., Chloris virgata* and *Eragrostis termula.* The fewer plant species were *Brachiraria xantholeuca* and *Brachiaria deflexa.* The dominant forbs were *Zornia glochidiata, Old landia senegalensis* and the fewer plant species were *Alysicarpus ovalifolus* and *Commelina spp.* The dominant trees and shrubs were *Boscia senegalensis, Acacia tortlis* and *Acacia senegal,* whereas the fewer species were *Combretum glutinosum* and *Adenium obesum.*

Among the introduced pasture species *Stylosanthes hamata* and *Cenchrus ciliaris* were able to compete with local plant species. The study indicated that there was no significant effect of ploughing and grazing management methods on pasture species attributes and forage yield, but spring toothed cultivator showed better results in plant growth attributes and forage yield.

It was found that plant density, vegetation ground cover, survival rate ands forage yield were better in plots that plough by spring toothed cultivator than spike toothed harrow. The forage of introduced pasture species was of high quality compared to the indigenous local species. Grazing trial for both seasons showed that the improved pasture increased rams body weight in the first and the second periods and started to decline in the third period, while under traditional pastures, the ram body weight started to decline in the second and the third periods

بسم الله الرحمن الرحيم

ملخص الدراسة

تم إجراء هذا البحث بالمنطقة شبه الجافة تحت ظروف الري المطري في غرب السودان، لفترة عامين بموقع أفلليري التي تقع شمال شرق مدينة نيالا علـي بعـد ٤٠ كيلومتر. الهدف من الدراسة هو تقييم مدي أقلمة النباتات الرعوية المستوردة البقولية (إسـ ـتايلوهماتا Stylosanthes hamata، سـ ـراترو Macroptilium atropurpureum وكلايتوريا Clitoria ternatea) ونباتات نجيلي (الحسـكنيت الناعم Cenchrus ciliaris) للمنطقة شبة الجافة بغرب السودان وتقيـيم الوضـع الراهن للنباتات بأرض المرعي التي أجريت فيها عملية الإستزراع، بالإضافة إلي معرفة حالة الحيوان الذي يتغذي علي المراعي المحسنة.

إستخدم نوعان من المحاريث الزراعية في تجهيز الأرض وهما محـراث ثقيـل spring toothed cultivar ومحراث خفيف spike toothed harrow وتم تقييم المسورين المرعي وغير المرعي.

أستخدم في البحث التصميم العشي، بثلاثة مكرارات مساحة الحـوض ١٥×٢٠ متر. طرق الحراثة وإداة الرعي يكونان الحوض الرئيسي، والنباتات الرعويـة يكـون الحوض الفرعي. جمعت عشوائياً عدة بيانات متعلقة بخصائص النبات من كل مكرر وتم تحليلها إحصائياً. ومن ثم تم قياس الغطاء النباتي، الكثافة النباتية، التركيـب النـوعي للنباتات، التكرار النباتي وكمية ونوعية العلف بالإضافة إلي تقييم حالة الحيوان.

أوضحت النتائج عدم وجود فروقات معنوية في المحتوي الرطوبي للتربة بجميع المعاملات، لكن وجدت فروقات معنوية بين أنواع النباتات في معظم الخصائص النباتية

التي درست وشملت الكثافة النباتية، نسبة الغطاء النباتي، معدل النباتات الحية وإنتـاج العلف. كما وجد أن نبات الإستايلو هماتا Stylosanthes hamata عندما يكـون منفرداً أو مخلوطاً مع حسكنيت ناعم Cenchrus ciliaris أعطت أعلي النتائج فـي خصائص نمو النبات وإنتاج العلف مقارنة مع أنـواع النباتـات الرعويـة المسـتوردة الأخري.

وأظهرت نتائج القياسات النباتية عدم وجود إختلافات واضـحة فـي التركيـب النوعي للنباتات والتكرار النباتي بين المسور المعرض لرعي الحيوانات والمسور الغير معرض للرعي. وأوضحت النتائج أن الحشائش السائدة بموقع الدراسة هي القو، عفـن الخديم والبنو والموجودة بأعداد قليلة هي أم فراو وأبو جفرة أما الأعشاب السائدة هـي شليني والفرجوب والقليلة منها هي أم نفيفيرة والبيض. أمـا الأشـجار والشـجيرات السائدة فهي المخّيط والسّيال والهشاب أما القليلة منها هي أشجار الهبيـل وشـجيرات السم.

أظهرت النتائج أن من بين النباتات المستوردة إن كل من نبات الحسكنيت الناعم وإستايلو هماتا لهما قدرة تنافسية عالية بين النباتات المحلية. أوضحت النتـائج عـدم وجود أثر معنوي لكل من إدارة المراعي ونوع الحراثة علي خصائص النمو والإنتاج.

لوحظ أن الكثافة النباتية ونسبة الغطاء النباتي ومعدل النباتات الحيـة وإنتـاج العلف أفضل في الأحواض التي تمت حراثتها بـالمحراث الثقيـل مقارنـة بـالمحراث الخفيف. كما دلت النتائج علي أن نوعية علف النباتات المستوردة أفضل مـن نوعيـة علف النباتات المحلية.

أظهرت نتائج تجربة الرعي لموسمين وجود فروقات معنوية بين وزن الخـراف التي إستغلت المرعي المحسن مقارنة بالمراعي الطبيعية التقليدية، حيث وجـد أن وزن

الخراف المستغلة للمرعي المحسن بدأ في الزيادة في الفترة الأولي والثانية للرعي وبدأ يتناقص في الفترة الثالثة للرعي بينما بدأ وزن الخراف المستغلة للمراعـي الطبيعيـة التقليدية الزيادة في الوزن في الفترة الأولي للرعي وبدأ يتناقص فـي الفتـرة الثانيـة والفترة الثالثة للرعي وهي الأخيرة.

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CHAPTER ONE

INTRODUCTION

The Sudan is the largest country in Africa, covering about 2.5 million km². The human population was estimated to be 30 millions and is growing at rate of 2.5% per annum. The estimated livestock number was 37.093 million cattle, 46.095 million sheep, 38.548 million goats and 3.108 million camels (AOAD, 2001).

The country consists of desert (28.9%) semi-desert (19.6%), low rainfall savanna (27.6%), high rainfall savanna (13.8%) flood region (9.8%) and mountain vegetation (0.3%) (Harrison and Jackson, 1958). Sudan has a great potential for agricultural development, conservative estimates showed that about 84 million ha is suitable for arable crop production, 24 million ha for rangeland and 64.36 million ha for forests (Ministry of Agriculture and Forestry, 2001).

In the Sudan, livestock is raised mainly by pastoral and agro-pastoral groups, with the former dependent on livestock and the latter on both livestock and cultivation. The herd size may vary from below fifty head to a few thousands per household. Pastoral herders are mainly semi-nomadic, as in case of Western Sudan and Southern Blue Nile where traditional movements occur between wet and dry season grazing areas. The wet season rangeland is an alternative grazing area for migratory livestock owners due to the availability of both pastures and water, and also because of the unsuitable conditions (mud and biting insects) in the dry season grazing areas.

In Sudan, the total dry matter available to livestock was estimated to be 104.8 million tons. Natural rangeland produce 77.6 million tons of dry matter and crop residues and factories by-products contributed by about 22 million tons, green forage 4 million tons and concentrated feed by about 1.2 million tons. The total number of animal units in the country was estimated to be 64.618 million. One tropical animal unit requires 3.3 tons dry matter per year. Thus, the total dry matter required to support 64.618 million animal units is equal to 213.2 million tons, hence the feed gap was estimated to be 108.4 million tons (Abu Suwar and Darag, 2002). In order to bridge this feed gap an increasing of rangeland productivity and better range management is required.

Seeding may be the only feasible way to rehabilitate semi-arid rangelands where 25-50 years are needed for a good cover to develop naturally under protection. Seeding could be attempted in areas receiving less than 300 mm of rainfall. Special considerations such as terraces, soil pits accumulate runoff water and conservation of soil should be met. However, seedlings are not likely to survive unless the soil is wet to a depth of at least 30cm at the time of germination (Heady and Heady, 1982).

Many natural rangelands have been improved by a simple introduction of controlled grazing management system. This often leads to a change in botanical composition without the deliberate introduction of new species. A further stage of improvement is reached when new grass species are introduced deliberately, often with accompanying legume, with or without the destruction of the indigenous grasses. The improvement of natural rangeland is strongly needed. This is because sustainable livestock production substantially contributes to the national economy of the Sudan.

Range improvement through fencing was carried out at different locations of the Sudan (Kordofan, Butana and Darfur). This practice has shown promising results in different parts due to good management and facilities. Reseeding of introduced pasture species was practiced since 1980's, 1990's up to now at different locations in the country. These reseeded areas had little success due to the lack of information about the adaptability of these species to the environment and lack of water conservation measures (Range and Pastures Administration, Khartoum, 2000).

South Darfur in Western Sudan is considered as one of the main potential livestock production areas in the country as well as rangelands. The livestock production systems are nomadic, transhumance and sedentary. Nomads and transhumance usually move with their animals from south to north parts of the state at the beginning of rains avoiding biting flies and mud in the south. These animals normally spent about two months grazing at the basement areas around Nyala town. These areas are traditionally known as wet season grazing area (*Makharif*), in addition to these migratory groups, sedentary livestock and camel owners are also using the same (*Makharif*) during wet season. However, the concentration of the huge number of migratory livestock in a confined (*Makharif*) leads to over utilization. In addition to this, shifting cultivation, uncontrolled cutting of trees and drought effects are likely to be the causes of rangeland deterioration in these areas. Therefore, there is an urgent need for better applicable and sustainable range management and improvement techniques in the (*Makharif*) areas. Thus, the main objective of the present investigation is to test the possibility of range improvement by inter-seeding on basement land system in semi-arid zone.

The Specific Objectives are:

1- To test the adaptability of introduced perennial pasture species namely, *clitoria ternatea*, *stylosanthus hamata* c.v verano *Marcoptilium atropurpureum* and *Cenchrus ciliaris*.

2- To determine the quantity and quality of both sown and native pasture species.

3- To measure the effect of ploughing in relation to soil moisture conservation and consequently plant growth attributes and forage yield.

4- To measure the plant composition and occurrence of the plant communities of the reseeded rangeland.

5- To examine the effect of improved pastures on livestock body weight performance during dry season.

6- To test the effect of protected and unprotected rangeland with regard to range improvement.

CHAPTER TWO
LITERATURE REVIEW

Range land covers nearly half the earth's land surface, 47% in all. Nearly half of this total area lies in the tropic and subtropics. The tropical rangelands support vast herds of domestic animals. About one-third of the world's people live on the same rangelands both in cities and as producers on the land. Many tropical people could not live without meat, milk and skins produced by range animals. People continue to increase in numbers, but no more land can be created. Range resources have great potential for production of food and other resources, if they are carefully managed (Heady and Heady, 1982).

2.1. Range improvements:

In developing countries, range livestock in the next 25 years are expected to increase at even faster rates than for the last 8 years due to the improvement in disease control measures. This in addition to the conversion of rangeland to cropping land will place tremendous pressure on rangeland in these countries and this will necessitate major change in grazing practices to prevent wide spread rangeland degradation (Holechek, 1989). In order to limit further rangeland degradation, range improvement could be one of the effective tools to be used. However, Vallentine (1980) stated that range improvements are special treatments, developments, and structures used to improved range forage resources or to facilitate their use by grazing animals.

Range seeding, control of undesirable range plants, applying fertilizer to range and pasture, and pitting, furrowing, and water spreading are direct means for developing and improving range forage resources. Range improvements such as stock water developments, fences, and trial provide the means for more effective management of grazing and thus indirect improvement of the forage resources. They also enable more efficient utilization of the forage resource and thus increase animal production (Vallentine, 1980).

2.2 Range Seeding:

The determination of restoring rangelands by natural means or by artificial seeding is a matter of judgment. Therefore, the decision should be based on the kinds and amounts of plants remaining, the expected rate of recovery and the cost of the alternative approaches. The climate and the supplementary treatments that may be used in speeding-up natural restoration, soil conditions including erosion, and whether the site is adapted to present artificial seeding techniques. Reducing stocking rates, changing season of use, initiation of special grazing systems or improving distribution of grazing by fencing, additional water development, or other practices may be sufficient for range recovery. Natural restoration may need to be accelerated by weed and bush control or land treatment such as pitting and water spreading (Vallentine, 1980). Lehouerou (1981) found that the regeneration is, in many cases, possible whenever the pressure on the land is decreased. The regeneration can be speeded up artificially by sound land use practices and proper use of the natural resources so as to provoke a biological recovery.

Any arable land receiving more than 625mm is mostly utilized for cropping so reseeding of pastures will only be an option in difficult areas where special seeding techniques will be needed (Skerman and Riveros, 1989). Barron, (1997) concluded that successful revegetation efforts under arid conditions, demand long term planning and monitoring efforts to insure success. Heady and Heady (1982) stated that, rangelands are seeded to provide a cover of plants and to improve the vegetation that already exist. Seeding may be done for a variety of reasons some of which are:

1. tropical legumes are sown partly to amend protein deficiencies in the forage
2. plants with high palatability are sown to improve forage
3. Removing bush by fire will increase under story forage production as already tested at Gazala Gawazat range and livestock research station during 1960 or mechanical and chemical means
4. Abandoned or marginal cropland returns to range production faster if it is seeded compared to natural succession under protection.
5. Seeding can protect embankments, damps road cuts and disturbed lands from soil erosion

2.2.1 Natural reseeding:

Natural revegetation is based on checking the current cause or causes of depletion and allowing secondary succession to raise range condition to satisfactory level. Improved management, particularly of grazing, must be provided to restore vigour and accelerate the spread of the remaining desirable forage plants. Adequate seed production and seedling establishment of the desirable species is important, but revegetation spread through tillers, rhizomes or stolons is equally important for many forage plants. However, when insufficient desirable forage plants remain, consideration must then be given to artificial seeding (Vallentine, 1980).

2.2.2 Artificial seeding

Heady and Heady (1982) and Peter, (1982), concluded that grassland renovation is a system of conservation tillage which seeks to improve existing cultivated or native grass sods with minimum or no tillage. The improvement may be achieved by sowing legumes into an existing grass so that the two plants will grow together. Seeding may result in an excellent forage crop in a year or two, but natural recovery usually takes longer time.

Reseeding is generally successful on the sites where soil moisture and nutrients for plant growth are adequate. C*enchrus* *ciliaris* and *Lasiurus sindicus* have been reseeded successfully over thousands of hectares in Thal and Dhabeji rangelands, primarily due to timely monsoon rainfall immediately after seeding although average annual rainfall in these areas is less than 300 mm (Mohammed and Nielsl, 1990). Seed pelleting using clay and manure for seed coating was found to increase percentage seeds germination particularly in sand soils (CBRRP, 1997)

Interseeding provides an alternative to complete seedbed preparation where erosion hazard is high, the preparation of complete seedbed is impractical, and the purpose is to modify rather than to replace the present plant stand. Hence interseeding is a compromise between slow natural reseeding and relatively quick establishment expected from complete seedbed preparation. The primary purpose of interseeding is to establish in rows native grasses of higher successional rank than the residual plants between rows and raise range condition to fair or good in three to five years. The interseeding of introduced species into native range has met with variable success. Experience revealed that satisfactory establishment and maintenance of introduced grasses on semi-arid range sites generally require greater suppression of the native plant community than that provided by interseeding. Interseeding can be considered successful only if the seeded species permanently established and begin to replace the resident cover between rows (Vallentine, 1980).

2.2.2.1. Site selection:

The suitable site for seeding is characterized by deep soil of medium or loamy texture. Slopes should be gentle and unlikely to be eroded or to have the soil blown away during the interval between the seeding operation and establishment of dense plant cover. Equipment for seeding operates more easily on flat land than on hills. Plants seeded on the best sites often scatter to other locations through the actions of animals and water (Heady and Heady, 1982)

Mohammed and Maktin (1990) reported that some researchers indicated that flat lands with medium-textured soil were very suitable for seeding *Cenchrus ciliaris* in Thal.

2.2.2.2. Pasture species for seeding:

Crowder (1982) stated that in selecting a new grass or legume, or replacing an old one with an improved cultivar of the same species, the following points should be considered:-

1- Adaptation to the general region and local conditions.
2- Intended use–continuous or rotational grazing, hay, silage, green chop, ration grazing and soiling.
3- Species or cultivar characteristics (ease to establishment, palatability, length of vegetative stage of growth, response to applied fertilizer, persistency, tolerance to drought,

grazing, cutting and burning, herbage yield and regrowth potential, seeding habit, ease of eradication).

4- Availability of seed or planting material.

5- Value of land – especially if the new grazing land is to be intensively used.

6- Type and quality of animals to be grazed or fed.

7- Topography of land – mechanizable or steep.

8- Managerial skill of the cattle man.

The grasses commonly used in improved grasslands are due to their ability to withstand repeated depletion, their potential to supply large quantities of nutritious forage for ruminant feed and their adaptability to a wide range of growing conditions (Lazenbly, 1988).

Whiteman (1980) reviewed that in developing plant introduction and evaluation programme, the first stage should be to define the characteristics required in pasture plants for the particular region. This requires an analysis of the climate and edaphic limitations. The limitation of the existing species and current land use, and definition of the characters sought in introduced pasture species are:

High yield of good quality forage, persistence, ability to associate with other species and ease of propagation. Established plant community should provide green fodder over a longer period of a year particularly during feed shortage seasons.

Selection of plant species to construct artificial plant communities in different ecological regions should emphasize on the following guidelines established.

1. Plant should be capable of surviving under harsh climatic condition and improve the land escape
2. Established plant community should provide green fodder for a longer period of a year, particularly during feed shortage season.
3. Plant community must withstand high and frequent grazing pressure.
4. Plant should produce an adequate amount of viable seeds which can be easily harvested and should be easy to be established (Skerman *et al.*, 1989; Jasra, 1995).

Perennial grasses are needed for seeding annual grasslands. Selection of plants for reseeding purposes would be facilitated by identification of perennial grasses that, once established are able to suppress resident annual plants production. Perennial grasses were allowed to establish in the absence of competition for the first growing season (Borman, *et al.,* 1991).

2.2.2.3. Mixed culture:

For the development of long-term improved pastures, it is advisable to include at least two compatible grasses and legumes. This allows for differences in sowing conditions, variation in germination and seedling growth due to localized soil and moisture situation. These provide for a more dense sod and sward, which help and prevent the ingress of weeds and gives a greater opportunity for diverse pasture and grazing management. To avoid delay in the stand establishment and to provide for more rapid ground cover and earlier grazing, mixture should contain a grass and legume, which germinate rapidly and produce early, even if those species die out after the first or second season (Crowder, 1982). He also added that legumes are desirable component of pastures and grazing lands where:

a- Nitrogen is a limiting factor for optimal growth of associated grasses;

b- A need exists for increased crude protein in herbage available for grazing;

c- Extended grazing into the dry season is desired and

d- Stability of the pasture system is given high priority.

Leguminous crops may play major roles in farming systems. They may be used as sources of food for human and livestock and also for soil conservation and fertility maintenance. For any legume species to play these roles, it must be adapted to the climatic, edaphic, and biotic environment in which it is intended to be used. Screening in different ecological zones before being put to any particular use is therefore very important (Cameron 1984; Iwuafor, 1998).

Walton (1983) stated that, one of the reasons for using a mixture arise from the vast variation that exist in the macro and micro environments provided by both climate and soil. Fertility level, pH, and soil moisture will vary over a field. Temperature, light intensity, and moisture will vary within and between years. The performance of the different forage species will not rank in the same order for all these diverse environmental circumstances. Thus, seeding and cropping hazards will not be the same for all species.

Vallentine (1980) reported that seeding a simple mixture of not more than two to five species with similar palatability, season of growth, grazing and drought resistance and regrowth rate greatly reduces management problems.

Middleton (1973) reported that dry-matter yield of *Brachiaria ruzizensis* was significantly ($P < 0.05$) higher in associations with legume species than in sole planting. Legumes in plots with *Brachiaria ruzizensis* boosted total dry-matter production by up to 52.4%. Also they found that total crude-protein yields from grass-legume mixture were significantly ($P < 0.01$) higher than from sole grass plots.

Peter (1982) indicated that growing a legume with a grass increases total herbage yield beyond that of legume grown alone so that animal intake and weight gains are increased.

Pyke (1991) reported that a diversity of species and growth forms may provide a more stable cover and productivity than a monoculture on sites characterized by environmental variability while potentially enhancing nutrient status of the site. Dobson (1977) found that white clover /perennial grass mixtures were superior to grass fertilized with nitrogen, and it was found that average clover / grass yields were consistently higher over the four years than grass/nitrogen yields. He recommended that white clover should be included in the grass mixtures in pasture lands to reduce the need for nitrogen fertilization.

2.2.3. Mechanical treatments:

Contour furrowing and seeding is a widely used method of range manipulation. These procedures have improved rangelands by increasing availability of moisture, decreasing soil erosion from wind and water, increasing forage production for livestock and wild life (Fisser, 1974). He also found that in the rangelands of semi-arid Western Wyoming with an average annual precipitation values as low as 100 to 150mm treated with contour furrowing and seeded, the total herbage production on the treated areas was 972 Ib/acre compared to 412 Ib/acre for untreated range. After 10 years from the treatment the total herbage production of the treated area declined to 590 Ib/acre but was still 54% greater than the control. Gannon (1977) stated that the purpose of renovation is to break up root-bound pastures, loosen hard soils and destroyed weeds. It is advisable to carry out tillage operations when moisture is present. However, pitting is also considered one of the mechanical treatments, which practices in order to speed-up range improvement process. Pitting can be done on flat land using a disc harrow or a harrow with tines that makes intermittent grooves in the soil. Rainwater collects in the pits, which break the soil crust, encourage infiltration and decrease water run-off then seeds collect in the pits, which provide a good habitat for plant growth (Heady and Heady 1982).

Contour furrowing effectively increased forage production on site where water loss due to run-off was the major growth limiting parameter (Wight, 1978). He also concluded that the major benefit of contour furrowing is improvement of the soil water regime by trapping rainfall runoff, and providing an environment favorable for establishing and producing seeded species that are often more palatable and productive than indigenous species. Fairbairn (1977) reported that pastures furrows provide more moisture for use by growing plant. This is of special importance during the establishment of new improved pastures in areas where moisture stress may be relieved by high intensity rainfall, which induces run-off. Further more, an earlier, healthier sward means quicker leaf-cover and added protection from erosion. Silcock (1980) indicated that if the resident vegetation has not been destroyed before sowing, there is little biological space to be exploited and no amount of seed will ensure a successful establishment.

Piano *et al.* (1987) found in plot trial in *Sordinia*, a mixture of *Phalaris aquatica* and *Trifolium subterraneum* was sown following, rotavation, harrowing in two directions or harrowing in one direction or was sod sown. In general, establishment and yield improved with increased tillage. Minimum tillage methods gave a lower incidence of sown species and higher weed populations than conventional tillage or rotavation. Harrowing in two directions gave relatively good establishment of *Trifolium subterraneum*. Sod sowing had little effect on the composition of the original sward. The effectiveness of minimum tillage appeared to depend largely on weed control. Bishop (1983) reported that the renovation treatments were cultivation with tines, deep ripper, disc harrow, disc plough and rotary hoe, with a control treatment no cultivation. Three of the experiments included on over sowing treatment of 2kg seed/ha of *Macroptilium atropurpureum*. Associated grasses were *Setaria sphacelata* at six sites and *Paspalum plicatulum* at one site. The main effect at all sites was for cultivation to increase the number of siratro seedlings over the control from 3 to 10 seedlings/m^2 and yield from 263 to 1289/kg/ha than tine ripping which disturbed approximately 50% of the pasture surface. An advantage of disc ploughing was a reduced associated grass yield. Over sowing with 2kg seed/ha siratro failed to increase populations or yield. An adequate seed reserve in the soil was essential.

Abusuwar (1986) showed that imprinted surface increased soil moisture over the untreated surface by 33% at oracle, and by 54% at the campus centre in Arizona, USA. He also reported that substantial increase in germination, seedling establishment and survival was a reflection of the increase in soil moisture in the imprinted treatments.

In Rajasthan contour furrowing on grasslands with shallow gravel soils increased forage production by 638.7% compared with untreated (Panjab-Singh, 1988). Griffith *et al.,* (1984) reported that ripening enabled the strongly rhizomatous western wheatgrass to reinvade the disturbed area, which increased yield and potential carrying capacity of the site.

2.2.4. Factors affecting pasture establishment.

Rainfall:

Gwynne (1966) concluded that annual rainfall figures in the tropics can be misleading, for the usual tropical rainfall pattern is a monsoonal type with marked seasonal concentrations of falls separated by dry periods. Thus, large quantities of rain may fall over a relatively short period. In addition, many of the individual falls are also very heavy and of short duration, so that water is often delivered to the land surface faster than the soil can absorb it and run-off after such storms can be very high. This is particularly true of the arid grasslands which may have an indicated annual rainfall of 125-375mm, but which may receive it all in a few afternoons. Thus, it can be seen that although the total annual rainfall may be good, the distribution of that rain throughout the year is frequently poor.

Lehouerou, (1981) stated that direct effect of rainfall fluctuations may be considered at least in three ways:

a- On botanical composition of plant communities.

b- On the number of individuals of each species and on plant cover.

c- On species development: biomass and production.

Crowder (1982) stated that rainfall is the greatest single factor affecting plant growth and herbage dry matter production in most of the tropics and sub-tropics. It's seasonal nature, variability and erratic, incidence, and high evaporation potential in many areas result in periods of short water stress and prolonged droughts.

Ridder (1982) reviewed that the growth of pasture species is determined by rainfall parameters such as distribution, number, amount, and intensity of individual rains and not by the average. Suliman (1980) reported that precipitation is regarded as the most important single factor influencing emergence, growth and productivity of pasture plants in arid environment.

Bunderson (1983) stated that the amount and distribution of rainfall is often highly variable from year to year with subsequent effects on forage yields, primary production assessments should always be related to rainfall for any given year. This will avoid making inferences regarding changes which do not take rainfall into consideration. Marietta and Britton (1989) reported that 950 kg/ha. biomass of raneland at Lubbock in 1981 and 11 kg/ha. at post in 1982. this variation in biomass was found to be due to variation in annual precipitation.

Leach (1976) reported that viable seed is essential for successful sown pasture establishment, so that the first step in studying establishment is to determine seed purity and viability, and secondly to assure seed germination especially in the arid areas, where rainfall is unreliable. It may be better to retain a proportion of hard seed if one germination event is followed by adverse conditions.

Climatic conditions are supremely important in the successful establishment of seedlings. The soil surface can dry out rapidly, restricting germination and emergence, unless a heavy cloud cover follows the rains. Also any resident vegetation grows very rapidly and usually overwhelms young seedlings. Thus, a rapid rate of germination and growth would be invaluable to most species, provided seeds did not geminate after unrealistically small falls of rains (Silcock, 1980).

Vallentine (1980) stated that an increase in soil moisture stress delays germination, rate of germination and total germination. However, in semi-arid areas, high seedbed temperature combined with low moisture levels is a major factor in the failure of range seedlings.

The seeding rates are a balance between a high density for good forage quality and long stand life and thin enough that there is not excessive competition between, individual forage plants (Iwuafor and Odunze, 1997). Vallentine (1980) showed that seeding rates for many species should be adjusted where research and experience have shown this to be desirable. Higher rates may be desirable for species or strains found to have low seedling vigour, high seedling mortality, and low spreading rates associated with seed production. Seed rates as low as six pure live seeds per square foot may be adequate for some species which spread rapidly.

The major purpose of seedbed preparation is to reduce or eliminate the existing vegetation and reduce the seed supply of undesirable competitive species (Vallentine, 1980). However, Heady and Heady (1982) stated that to prepare seedbed some kind of cultivation is required. A variety of machines has been used such as disc plough or harrow pulled by a heavy tractor, is the most widely used tool for seedbed preparation. Harrows that drop their teeth periodically to make pits at intervals in the soil are satisfactory where a complete cover of grass or legume is not necessary. Hodge (1979) mentioned that the introduction of a legume such as siratro into native pasture area. One chiseling or discing can give good results.

Sowing time is affected by species, sowing techniques, soil type, rainfall reliability, evaporation, temperature requirements for germination, soil erosion hazard, pest activity, accessibility of site in wet weather, frost hazard in colder areas and weed flora (Leach, 1976). Vallentine (1980) concluded that range seeding should generally be made immediately prior to the period of longest favorable growing conditions.

Iwuafor and Odunze (1997) stated that studies have found that only 30-40% of the seed will result in viable seedlings. Not all emerging seedlings survive. There are several reasons for the high mortality of the establishing seedlings: Slow growth due to low food supplies from small seeds; poor seed to soil contact due to the small seed; seeds on surface or deep seeded seeds; seedling damaged by weeds, insects or disease; and little seedlings are very susceptible to even short periods of drought and other severe weather conditions.

Slicock (1980) stated that no single seedlings characteristics consistently enhances seedling establishment in all tropical pasture situations. Soil fertility, soil moisture availability, surface soil structure and climate are so varied that each small region has its own special problems.

A detailed analysis of climatic data is an essential first step in any regional pasture development study, as it indicates the seasonal patterns of pasture growth, the potential pasture productivity, and the species likely to be successful in the region (Whiteman, 1980). Vallentine (1980) reviewed that favorable growing conditions in semi-arid areas may be limited to thirty days or less. Penning (1983) indicated that many seedlings and germinating seed dies shortly after germination because of too long dry periods between rains. Cook (1982) reported that germination and emergence of tropical pasture species were primarily dependent on micro environmental factors affecting seed water balance and on the length of time the soil surface remains wet relative to the germination rates of the species being sown. Competition between the resident vegetation and the established seedlings for nutrient and moisture was seen as the major factor limiting seedling growth and survival. Legumes were better suited to over sowing than grasses because of their independent nitrogen supply. Establishment and improvement using different management systems appeared to be limited to selection of species and environmental stress. The development of better sod seeding technology aimed at improving the growth and competitive ability seedlings capable of withstanding competition and surviving the establishing seedlings is also considered.

2.2.5. Range re-seeding in Sudan:

Rangeland rehabilitation by reseeding with or without fencing is routinely carried out by Range and Pasture Administration using locally collected seed of desirable native forage species. Also, FAO and IDA assisted with several rehabilitation trials over the last twenty years. The FAO assisted trial was conducted in the eighties at several locations in the semi-desert and Low Rainfall Savanna Zones following the 1984 drought. (Introduced pasture species include

Cenchrus ciliaris, Cenchrus setigerus, Chloris gayana, Panicum spp, and *Stylosanthes spp*.) However, results were not sufficiently well recorded and the performance of the reseeded pasture species was not monitored over a long period to generate enough reliable result. The limited observations available indicated that:-

1- In Sodari area of Northern Kordofan emergence of the reseeded introduced species was 30–45% and native species that grew simultaneously included *Cenchrus biflorus, Echinocloa colonum*, and *Dactyloctenium aegyptium*;

2- In the Butana area *Cenchrus. ciliaris* established had reached seed setting stage, *Stylosanthes spp.* reached flowering stage while *Chloris gayana* grew only vegetatively. Native species that grew simultaneously, such as *Aristida mutabilis, Cenchrus biflorus, Dactyloctenium aegyptium* and *Phynchosia memnonia*, were in very good conditions.

3- Constraint that hindered the implementation of the trial included late seed delivery towards the end of the wet season and no clear role for the beneficiary communities in protection and management of the site. (Zaroug 2000). He also reported that some improved pasture establishment efforts, for grazing improvement by local herds, were made in association with water spreading and runoff harvesting trials in Kassala State (Mukram) and in Khartoum State (Abu Delage and Wadi El-Hurba). In Khartoum State, *Cenchrus ciliaris*, *Cenchrus* *setigerus* and *Vigna trilobata* and *Phaseolus trilobus* were successfully established using mechanical seeding (wide level disc harrow) and low contour dykes (45cm) and he stated that without the necessary socio-economic studies to identify managerial and user responsibilities the established pasture did not persist. Furthermore, Zaroug (2000) reported that much effort has been made by Animal Production Research Stations and Projects to establish irrigated pasture for direct grazing, species such as *Cenchrus ciliaris, Chloris gayana, Panicum coloratum* and *Clitoria ternatea* were used in pure stands and grass/legume mixtures for direct grazing by sheep or cattle. Surplus forage was harvested and stored as baled hay.

Osman (1998) stated that the problems of range reseeding process in Sudan can be summarized as follows:

1. Poor planning.
2. Poor selection of pasture species (not adapted to environment mainly water stress).
3. Poor management.
4. Lack of experimental sites to determine techniques of reseeding of pasture species and their adaptability together with clear information about soil moisture conservation techniques.
5. Lack of people’s participation in developing such techniques.

2.2.5.1. Range reseeding in Kordofan:

- **Elodaya project at North Kordofan (UNSO/SUD/81/XO3) (1982-1993):**

This project was funded through special contribution by the Swedish Government to the United Nation Trust Fund for Sudano-Sahelian activities. This project was implemented within six fenced grazing paddocks to facilitate the application of the rest–rotation grazing system after the range rehabilitation activities were completed.

The reseeding of grass seeds and the transportation of brows tree seedlings cover a total area of 50399 ha. Figure indicates the design of the project (Appendix 15). In this project different exotic and indigenous forage seeds were reseeded. Examples of these seeds include *Blapharis linariifolia*, *Cenchrus ciliaris, Chloris gayana, Clitoria ternatea, Stylosanthes guianensis, Stylosanthes fruticosa* and *Dactyloctenium aegyptium.*

- **The Community Based Rangeland Rehabilitation for Carbon Sequestration and Biodiversity:**

This project was implemented over a total area of 23477 ha. In the dry savannah within Gireigikh rural council during the period extending as from 1995 up to year 2000. This project was financed jointly by the GEF/UNDP and the Government of Sudan. Reseeding for rangeland rehabilitation was conducted within the gazing allotment which cover almost 448.5 ha. Pelleted seeds were used to improve rangeland.

Vegetation cover and production increases the level of organic carbon above and under the soil. This project was implemented to test that carbon sequestration is possible under the condition of the dry savannah. Carbon sequestration is mainly to reduce global warning.

2.2.5.2. Range reseeding in South Darfur

South Darfur in Western Sudan lies within the semi-desert and savanna zones and is defined by the co-ordinates 24º 30' and 27º E longitude and 9º 30' and 13N latitude. Annual rainfall ranges between 300-1000mm, increasing from north to south. The landscape has been classified into four major land systems, Basement, Qoz, Alluvial and Bahr Land systems.

The animal units were estimated to be 4.768 millions and owned by nomads, transhumant and sedentary. The human population was estimated to be 2.8 million; they are mainly traditional farmers and livestock owners. Both farmers and livestock owner are communally using the land for cultivation and grazing (Ministry of Agriculture, South Darfur, 2001).

Range improvement was carried out at Gazala Gawazat during 1958. Dams or dikes were constructed across water ways (Wadies) to spread water over depleted rangeland for improvement using direct seeding of forage seeds.

The basement is a zone of advanced erosion close to Nyala caused by cutting of trees for fire wood, browse, over grazing, infertility and erosion on Qoz soils which are heavily cultivated. The options for range management and development were suggested as follow:

1- General range improvement projects, which means establishment of exclosures and this can be combined with general range management.

2- Support for irrigated gardens along wadis to produce green forage (HTS, 1986).

Since 1982-1997 Western Savanna Development Project, tried some range management and improvement practices, such as allocation of grazing rights to both sedentary and transhumant communities. Livestock community was involved in all range management and improvement steps. However, three rangeland exclosures on the basement were established for sedentary livestock community (total area of the exclosure ranged between 1500-3000ha). Within these exclosures range management and improvement were practiced such as estimation of dry-matter production, plant species composition, reseeding of depleted areas and the adoption of suitable grazing systems. The depleted areas of the exclosures were ploughed, spring toothed cultivator and spike toothed harrow were used, and reseeded into pasture species both introduced and native. The introduced pastures include, *Cenchrus ciliaris, Cenchrus setigerus, Stylosanthes hamata, Stylosanthes scabra,* and *Stylosanthes* *guyanensis*. whereas the native pasture species such as *Dactyloctenum aegyptium, chloris virgata* were used.

After two years from exclosures establishment the following results were reported by Western Savannah Development project (1982 - 1993):

1- Forage production was increased 5-10 times compared to the first year of establishment.

2- Herbage vegetative cover was increased from 35 to 65%.

3- Palatable pasture species composition was increased.

4- *Cenchrus ciliaris* and *C. setigerus* were well established, the native pastures species were well established, but *Stylosanthes scabra* and *Guyanensis* were poorly established.

5- Calving rate was increased (4.4%) and mortality rate was decreased (4.5%), and livestock price was increased by about (40%).

6- It was observed that the number of wildlife species inside the exclosures was increased.

Fodder banks as demonstration sites were established at six settlements and extension villages where annual rainfall was adequate (low rainfall savanna). The pastures species sown include - *Stylosanthes hamata, Stylosanthes scabra, Stylosanthes guganensis, Lablab purpureus, Cajanus cajan and Macroptilium atropurpureum*.

As reported by Western Savanna Development preoject (1992-1993) about 562kgs of introduced pasture seeds were produced during 1991/1992 at Muraya site where average rainfall is about 800mm. The pasture seeds produced were, *Macroptilium atropurpureum*, *Clitoria ternatea Stylosanthes hamata*, *Cajanus cajan* and *Cenchrus ciliaris*.

2.2.5.3. Selected pasture species for reseeding in the study area:

Clitoria ternatea (Kordofan pea, butterfly bean) is a perennial pasture legume belonging to the family *Fabaceae*. It is grown in the tropics and native to tropical America. It is a summer growing plant, low frost tolerance, can climb tall grasses and crops. Under rainfed the plant grows well from 400mm, with best performance in the areas of 1500mm. fairly drought tolerant and will not tolerate flooding. In Sudan Kordofan pea grows under rainfed in the drier areas of Kordofan.

The plant is well adapted to a wide range of soil conditions from sandy to deep alluvial loams and heavy black cracking clays. The seed is sown in spring to mid summer at 1 to 3kg/ha. The plant grows rapidly in warm moist weather, producing a dense cover four to six months after seeding, suppresses weeds very well. It grows well with tall grasses such as *Pennisetum purpureum*, *Cenchrus ciliaris, Panicum maximum*, *Chloris gayana* and with crops of Sudangrass and sorghum in the Sudan. The plant usually grazed lightly and in rotation to preserve the pasture. The plant produces about 3.3t/ha green forage under irrigation. The plant content of crude protein ranged from 10.5 to 25.5% of the dry matter.

For the commercial use the seeds are required to have a minimum germination of 50 percent and purity at least 93.5 percent with a maximum of 10 percent hard seed (Skerman *et al.*, 1988 and Khair, 1999).

Macroptilium atropurpureum **(**Siratro):

About 200 species of beans comprise this genus. They are mostly erect or twining herbs, native of China, India, Central and South America. Numerous cultivated beans provide human food and are all grazed by livestock. Siratro a perennial bred by Hutton of CSIRO from two Mexican forms of *M. atropurpureum* in the early 1960's. It is the outstanding achievement for breeders of pasture plant in Australia. It spreads by creeping stems. It has three loped leaves, it does well in hot tropical summer, but like all tropical pasture legumes will not tolerate frost.

Siratro is adapted to a wide range of soils with respect to texture and pH. It does particularly well on many sandy soils and can succeed on quite shallow soils. It grows in areas with annual rainfall ranged between 600-1800mm. Siratro recover quickly from drought by seed germination and new growth of an old stems. Planting seed rate: ranging from 2-4kg/ha. It nodulates freely and effectively with wild strains of cow pea rhizobium. Seed production may attain 100-

160kg/ha. Average crude protein content about 23% and crude fiber about 30.4% (Whiteman, 1980. Heady and Heady, 1982, Skerman *et al.*, 1988, Tothill and Jones, 1977 and Cook, 1977).

Stylosanthes hamata **C.V. Verano:**

It is a herbaceous annual to short-lived perennial, native to West Indies and then distributed to other part of the tropics. It is a summer growing plant; it flowers in 65-75 days after planting. It grows well under rainfed ranged between 600-900mm. It is drought and flood tolerant. It grows well in infertile, acid, sandy-surfaced and with some tolerance of slightly more alkaline soils. Under dry area half of the seed is treated and the half left hard to avoid failure of germination. A good seedbed preparation is needed for better plant establishment. The plant nodulates freely with a wide range of native cowpea rhizobia. Sowing of the plant is usually by broadcasting. The seeds are sown at the beginning of the rainy season and after adequate showers of rains, with the seed rate ranges from 1 to 4kg/ha. The plant is characterized by vigorous growth and it can keep up above the grass for longer period, so it combines well with *Urochloa mosambicensis*. The plant competes well with weeds and has no tolerance of dry-season fire.

The plant continuous vegetative growth after flowering begins and will continue to grow while seasonal conditions remain suitable.

The Queensland standard for *Stylosanthes hamata***,** verano seeds to be used in reseeding is 40 percent minimum germination and a maximum of 20 percent hard seed deemed to be germinable and minimum pure seed content is 90 percent.

The plant spread readily and widely, the hooked upper seed pods being spread readily by stock. *Stylosanthes hamata***,** verano produces a large amount of dry matter range from 2.5 to 10 ton/ha and seeds range between (75-700kg/ha.). The plant tolerate intensive grazing during the dry season. It contributes to soil by increasing its nitrogen (Skerman *et al.,* 1988, Humphreys, 1978, Mott *et al.,* 1976 and Gardener, 1978).

***Cenchrus ciliaris* (Buffel grass):**

This genus is native to the dry areas of East Africa. It is widely valued for its drought tolerance and high nutritive value. The members of this genus are stuffed, often rhizomatous, perennials or annuals. Twenty-five species are distributed in the warm predominantly tropical and sub-tropical areas, mostly in arid or semi-arid areas. This genus include many cultivars such as Biloela, Gayndah, American, West Australian, molopo, Boorara, Lawes, Nunbank and Tarewinnaba (Bogdan, 1977).

Buffel grass requires light textured soils of high phosphorus level and pH of 7 to 8. It grows well in arid areas under rainfed condition with an annual rainfall ranges between 300-750mm. A good seedbed is required for good seedling establishment and plant development. It requires seed rate about 5kg/ha and usually sown by broadcasting method. The seeds must be treated with ants anti dust before sowing. In the semi-arid area, the plant usually dominates weeds. The dry matter yield range from 4-9 ton/ha and the seed production may attain about 150 kg/ha. and the seed remain viable for two to three years. The dry matter crude protein content ranged from 3-16% and the crude fiber content range from 29-40%. It is a valuable stand over feed for summer grazing, it is very palatable when young, and remain fairly palatable at maturity.

It is valuable in erosion control and one of the best adapted grasses to semi-arid conditions. The main plant attributes is hardiness, deep-rooting ability to grow in arid areas, and generally free-seeding habit. It is persistence and resistance to trampling and drought tolerance (Skerman and Riveros, 1989, Humphreys, 1967).

Martha (1995) reported that in the Sornran desert of north west Mexico, where average annual precipitation is 320mm, the peak live biomass production of *Cenchrus ciliaris* varied from 465kg/ha in a summer of below average precipitation to 3045kg/ha in a summer of above average precipitation. However, buffel grass annually produces about three times more green forage than native grasses.

2.2.6. Range exclosures:

The pastoralists in Western Asia have developed management techniques to ensure sustainable and long-term exploitation of the natural resources. One such mechanism is a system of grazing reserves (hema) managed for various purposes, e.g. controlled grazing, water shed and forest protection or as food reserves in period of drought (Jungius, 1984).Taghi Farvar (1997) reported that system of hema and it is variants (such as Mahjar in Yemen, the Mahmiyya in Sudan and the Qoroq in Iran) are exclosures that have elaborate rules for grazing under community control.

Western Savannah Development project has undertaken innovative range management programmes. Several villages have been allowed to fence pastures, and they have exclusive grazing rights, in exchange for agreeing to keep livestock out of the exclosures during the wet season, until seed sets (Bret, 1989).

Mohammed (1990) reported that in Pakistan the rehabilitation of deteriorated range sites has involved protecting the areas from livestock grazing. In most of the rangelands, barbed wire fencing is common. He indicated that a researcher found a significant increase in forage yield, species composition and plant cover in the protected areas. Also another researcher recommended a minimum period of five years of complete protection before initiating proper grazing management, and he concluded that partial protection of the area from livestock grazing increased the vegetative cover by 30 percent over a period of ten years. However, Brad (1989) showed that total vegetation cover was not significantly different on the grazed and ungrazed areas.

Whiteman (1980) stated that a major FAO study in Kordofan province in transhumant grazing areas receiving rainfall of 280 to 570mm per annum demonstrated that exclosure of animals by fencing from degraded areas leads to quite rapid (2-3 years) improvement in perennial and annual grasses and legumes, and a marked increase in carrying capacity when compared with the open range. The increase in carrying capacity depended on the state of previous degradation. Suliman (1980) mentioned that when drought was severe and long duration, basal area was reduced to 40% and 50% in the unprotected and moderately grazed areas respectively.

All experiments showed that after a few years of total protection, the gentle slopes are dominated by palatable perennial grasses such as *Hyparrhenia hirta*, *cenchrus ciliaris*, *Dactylis hispanica*, which together may cover up to 80% of soil surface (Lehouerou, 1981).

Behnke (1985) reported that in South Darfur in the basement land system in the semi-arid zone, the protected grass communities inside the enclosures are of better palatability and nutritional quality, than those outside the fence and improved species composition on enclosed range site.

2.2.7. Evaluation of seeded rangeland:

2.2.7.1. Forage Quantity:

The precipitation is more than any other factor determines plant growth in semi-arid regions, and there is an almost linear relation between annual rainfall and annual productivity of rangelands. An average productivity of aboveground dry matter of 400–500kg/ha is found in the Northern Sahel (Penning 1983, Marietta and Britton, 1989)

Pasture production depends on various factors such as climate, nature of soil, botanical composition and vegetation structure, and type and intensity of management e.g. grazing patterns and stocking rates, fire and wildlife (Lehouerou *et al.* 1977). Batello, (2003) stated that vegetation production could vary tremendously ranging from 2000 kg dry matter per hectare in good rainfall years to almost zero to 100 kg dry matter per hectare in drought years.

Leach (1976) mentioned that the productivity of a pasture depends primarily on the capacity of the constituent species to convert incident radiant energy into animal feed. This capacity may be limited by low temperature, inadequate moisture, and insufficient nutrients or by previous pasture management. Knowledge of the response of the processes of growth and development to change in the physical and biotic environment form is an essential part of our understanding of pasture productivity. Gwynne (1966) reported that dry-matter production from arid and semi-arid grasslands is directly related to rainfall. In South-West Africa, for example, the dry weight of the aboveground grass parts increased by 1000kg/ha or 100gm/m² for every 100mm of rainfall. In view of this, and because of the erratic rains on much of the tropical grazing lands, it is essential that the grasses should be able to use as much of the available rainfall as possible, and the growth form of the aerial parts can be of very great importance. White man (1980) reported that the yield of a pasture is affected by a range of factors influencing the growth of the individual plants in the pasture swards, but any measure of overall pasture productivity must include the output of animal products derived from the pasture.

2.2.7.2. Forage Quality:

Ridder (1982) showed that forage quality is expressed as forage value, and depends on time essential elements, energy content and nitrogen content. The energy content depends on the digestibility of the organic matter, which in turn is determined by its crude fiber content. The higher the crude fiber content, the lower the digestibility and consequently the forage value. The nitrogen content of the forage is characterized by the digestible crude protein (DCP) content. The (DCP) is always proportional to the crude protein (CP) content. The (CP) of a forage is the percentage of nitrogen (N %), multiplied by 6.25.

Crowder (1982) reported that crude protein yield per unit area of land is often a proportional with the yield of dry matter. This is simply a function of dry matter yield and crude protein percentage. Crude protein yield increase as dry matter yield increase.

Heady and Heady (1982) stated that the characteristics of the plants which contribute to palatability and to the nutritional needs of grazing animals, include chemical composition, growth stage, proportion of leaves and external plant morphology or structure. However, palatability and nutritive value change with the stage of plant maturity. Young grass, three or four weeks old, usually has a protein content 10 - 15 percent, at seed maturity about 5 - 8 percent, and the protein content was lower to 1 - 3 percent when the plant dry and matured. They also added that cattle require feed of 5 to 6 percent protein content in order to maintain their body weight. Loss in nutritive value as grass matures results in weight losses of as much as 100kg in mature animals during the dry season. Slow maturing of young animals because of poor nutrition is one of the major management problems of tropical rangelands.

Heitschmidt (1995) mentioned that the age of tissue was the major factor altering seasonal forage quality values. Results of the experiment showed that crude protein concentrations were greater, and acid and neutral detergent fiber concentrations were less in live (Young) than dead (Old) tissue. Moreover, analysis of live tissue showed crude protein concentrations decline and fiber concentrations increased within a tissue class as age increased. For example, crude protein content of live Western wheat grass declined from 17.9 to 9.5 percent.

Under drier conditions, competition for moisture can reduce grass yields slightly. When this happens, the nitrogen concentration of the grass is found to be higher, frequently up to one percent higher. This combined with the legume yield and its high nitrogen content usually means that total yield of forage when offer to the animals is the same as it would be in a pure grass stand, but quality is substantially higher (Cameron, 1984).

The striking feature of native tropical pasture is the absence of a significant proportion of legumes. The crude protein content of mature grass is often extremely low, being between one and three percent for considerable periods of the year. At a young stage of growth, tropical grasses usually contain sufficient protein to meet the requirements of most classes of stock. However, the (CP) content falls rapidly as the plant matures and, after growing for two months, marked differences between (CP) levels of grasses are apparent (Milford and Minson 1966).

Holechek (1989) showed that many studies are consistent in showing that cattle and sheep diets generally have crude protein level of 10 to 12 percent and 12 to 16 percent, respectively, when forage is actively growing. During forage dormancy, crude protein levels drop to 4 - 7 percent for cattle and 6 - 12 percent for sheep. The higher values for sheep are explained by greater selectivity by sheep and the fact that sheep are generally grazed on ranges with a much higher forbs and shrubs component than on cattle range.

Unfortunately higher dry matter production in the tropics and sub-tropics is accompanied by a lower protein zones. The nitrogen content of tropical and sub-tropical pastures is usually in the order of 1-1.5 percent of dry matter. Developing on the stage of growth, cool temperate pastures will give 3 - 3.5 percent of nitrogen.

Heitschmidt *et al.,* (1995) stated that quantity and quality of forage produced are the principal factors affecting livestock production from grazing lands. The major factors affecting quantity and quality of herbage produced on range lands are

1. The inherent characteristics of a site as it relates to slope, aspect, and soil fertility
2. Climatic conditions
3. The kinds, size and density of plant present

2.2.7.3. Animal performance:

Carrying Capacity and Stocking-rate:

Mckell (1981) defined that carrying capacity is the numbers of animals that can safely be grazed in a given area without causing deterioration in the plant cover or soil. Therefore, the duration or a mount of grazing use should not exceed the tolerance of plants to sustain defoliation and should be designed to allow key plant species to maintain vigour and reproduction.

Simple scientific management may increase the productivity of resource from 2-10 times. The execution of management plans must be based on the following, to avoid failure:

1- Estimation of seasonal production levels of a given resources.

2- Seasonal fluctuations in the nutritive values of major plant species on the site.

3- Nutritional calendar for grazing livestock based on their physical conditions.

4- Developing grazing management plans in terms of appropriate stocking rate and appropriate kind of livestock (Jarba, 1995). He also added that for the rangeland resources to be sustainable the following four basic principles should be considered:-

i. Proper stocking-rate i.e. balancing animal numbers with the available forage resources.

ii. Use the kinds of livestock best suited the prevailing vegetal structure.

iii. Restricting range use to proper seasons of the year for the optimum benefit of both plants and animals.

iv. Well uniformed distribution of grazing animals over the range area. At present these basic principles are coupled with modern grazing strategies.

Whiteman (1980) indicated that critical determinant of animal production is the stocking-rate and method of grazing has only a minor influence. The most important role of grazing management must determine the optimum stocking-rate for sustained production. The aim of pasture management is to increase the optimum stocking-rate through better pasture management. Introduction of improved and better adapted pasture species, use of fertilizers, weed control, and efficient utilization of forage produced. Comparing native pastures with improved pastures, the stocking-rate increased from 1 to 1.3/ha and from 1 to 1.5/ha for both pastures, respectively. In improved pasture of green panic and snail clover in Australia with the stocking-rate of 1 to 2 A.U./ha, beef production weight gains are one kg per day from August to April from improved pastures. Animal growth rate are seasonal and follow a stop and grow pattern in a cycle corresponding with the available herbage as influenced by rainfall (Crowder, 1982).

Gannon (1977) reported that the main economic advantage in improved pastures lies on their higher carrying capacity. A high production per acre is obtained without loss in individual animal performance and without increasing drought risk. Maximum utilization is probably unwise in this variable environment, and a compromise has to be reached between animal production per acre and provision of fodder to provide insurance against drought. He also added that areas of native pastures dominated by inferior species should be used when they are immature and growing vigorously in the growing period. Area of improved pastures can then be used in the dry season when they are superior in quality to such native pasture.

Crowder (1982) reported that in carrying out grazing management studies the investigator, selects stocking rates based on knowledge or predictable herbage available for grazing, the intent is to balance the number of animals per unit area of land so as to utilize effectively and efficiently a major proportion of the forage at a grazing pressure to assure continued production of desirable species. He added that grazing pressures in years of high rainfall completely differ from those during prolonged drought periods. Since rainfall is so unreliable in the dry tropics, stocking at rough estimates of average herbage production is likely to lead to deterioration of range over a period of time. Crowder (1982) concluded that carrying capacity is too often based on the flush period, resulting in overstocking and overgazing in the dry period. A rapid decline in herbage nutritive value of predominately grass-based grazing lands impose additional constraints, so that animals loose a high proportion of the live weight gained in the rainy season. Holechek (1989) indicated that forage intake of grazing animals varies with body weight as well as with forage quantity and availability. Presently, intake for grazing animals is most commonly expressed as the weight of the forage consumed as a percentage of the animal's body weight. However, the dry-matter consumption by most range ruminants is about 2% of their body weight per day when values for different season are averaged across the year. Considerable seasonal variation occurs, with values as low as 1% during periods when forage is low in quality and availability are high. Many studies showed that great differences within and between range types occur with seasonal changes. Margon (1993) stated that there is no universal formula for determining stocking rates, and the carrying capacity of the pastures is usually imprecisely defined. The determination is more difficult in regions with high variability in rainfall from year to year so that over grazing is almost inevitable when several years of drought follow in succession.

Lehouerou (1981) reported that the average stocking rate in the arid zone of North Africa (between 100 and 400 mm isohyets) is 0.5 sheep equivalents per ha. This is about twice what it should be for long-term sustained productivity as shown by experiments over the last 40 years in the area and in comparison with more or less similar conditions of Northern America, South Asia, Southern Africa and Southern and Western Australia.

The carrying capacity is inadequate as the sole measure of production because it does not take into account individual differences in animal production between treatments, however the measurement of livestock change is the most common method for assessing the performance of animals on grazing experiments. Gain in live weight over time is a reflection of the quantity and quality of the feed ingested; it is also a good indication of the gain in carcass weight. Moreover, the initial and final weights of animals are necessary for an evaluation of production over a period, animals are usually weighed regularly, often every two or four weeks. These weighing are required in order to relate weight changes to pasture attributes and they are a guide to detecting animals that are not thriving (t'Mannetje, 1976).

Clark (1982) reviewed that cattle grazed on native pasture gained approximately 100kg/head/year compared with 140 - 200kg/head for those grazing buffel grass and siratro or buffel grass fertilized with nitrogen. When stocking rates were taken into account, live weight gain/ha/year were 30kg and 170kg at 0.9 ha/head, respectively. Live weight changes showed a similar pattern on native pasture or pasture oversown with *Stylosanthes spp*.

Dodd (1997) stated that management of grazing animals to create desired changes in rangeland vegetations is perhaps the best example of sustainable range improvements practiced in recent years. Prescription grazing has been successfully used to improve ecological condition of rangelands for natural biological diversity, wildlife, control of exotic plant species, increased livestock production, prevention of accumulation of fire fuels, and other management goals.

CHAPTER THREE

MATERIALS AND METHODS

Tow experiments were conducted at Agleri site, 40km North-East of Nyala town in South Darfur State (Latitude 12°-13' N and longitude 25°-8' E with an altitude of 642m above the sea level. The first experiment was conducted during the rainy seasons 2000/01, measurements of the parameters under study were made for first and the second seasons respectively. The second experiment was conducted during the rainy season 2001/02.

The main purpose of these experiments is to test the improvement of deteriorated natural rangeland by inter-seeding of three perennial pasture legumes and one perennial grass in addition to the ploughing operations as water conservation techniques.

3.1 Climate:

Ten years average of annual rainfall is about 300mm, at Nyala town with no regular seasonal pattern. Monthly rainfall during the tow seasons of the experiments as measured by rain gauge installed at the experimental site is shown in Fig 3.1 and Appendix 1.

3.1.1 Topography:

The area is characterized by undulating to rolling Pedi plain with difference in percentage of slopes. Gully, rill and sheet erosion are common. (Hunting Technical Services, 1986).

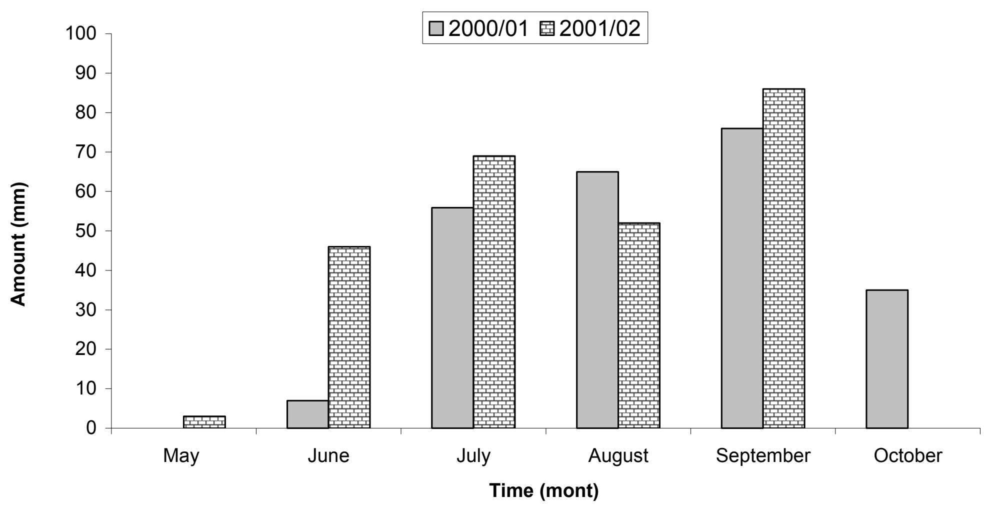

Fig. 3.1. Annual rainfall during two rainy season (2000/01-2001/02) at the study site

3.1.2 Soils:

The soils are shallow residual clay loams and sandy clay loams, with pH of 7.6. The soil surface is usually covered by gravels (Details of soil properties are shown in appendix 2).

3.1.3 Vegetation:

The native vegetation is a complex mixture of grasses, herbs and woody species. Dominant annual grasses are *Aristida spp.*, *Eragrostis tremula, Schoenefieldia gracilis* and *Chloris virgata.* The dominant forbs are *Zornia glochidiata*, *Oldlandia senegalensis* and *Tribulus terrestris*. The dominant trees and shrubs are *Boscia senegalensis, Acacia senegal*, *A. nubica*, and *A. tortilis*.

3.2 Experimental design and treatments:

The treatments consisted of grazing management, ploughing methods and pasture plant species. The treatments were arranged in a nested design with three replicates. Grazing management and ploughing methods formed the main plots and pasture plant species formed the sub-plots.

The grazing management consisted of two equal parts (grazed and ungrazed exclosures). Each exclosure was fenced by local materials (tree branches), and consisted of 36 plots and the plot size was $15 \times 20m^2$.

The ploughing methods consisted of spring toothed cultivator which removed native plant strips about 40-50cm wide and 15-20cm deep. The spike toothed harrow removed native plant strips 10-15cm and 5-8cm deep (plate 3.1 and 3.2). Rams of the same local breed and of similar age were allowed to graze one exclosure in dry season during the first and the second seasons of the experiments. The T-test was used to measure animal performance.

On the 23rd of July at the first season (2000/01) half the plots of the exclosure which allocated for grazing was randomly selected and ploughed by spring toothed cultivator and the other half was ploughed by spike toothed harrow. The same ploughing procedure was carried out in the other exclosure (ungrazed).

The pasture plants species which formed the sub-plots were three perennial pasture legumes namely *Stylosanthes hamata C.V verano* (Caribbean), *Macroptilium atropurpureum* (siratro) and *Clitoria ternatea* (Kordofan pea) and perennial grass *Cenchrus ciliaris* (buffel grass). The pasture species formed six treatments, of which three treatments as perennial pasture legumes as pure stand, and the three treatments as perennial pasture (grass – legume) as mixture.

Purity and germination tests were carried out to the four perennial pasture plants and the seed rate of each plant species was determined accordingly (Table 3.1).

Table 3.1: Purity %, germination % and seed rate of plants species

Plant species	Purity %	Germination %	Seed-rate kg/ha
Stylosanthes hamata	93	82	5
Macroptilium atropurpureum	95.8	55	5
Clitoria ternatea	98.8	72	6
Cenchrus ciliaris	72	16	10

Half the amount of pasture legume seeds, which needed for sowing, was treated with hot water in order to enhance seed germination. Both pasture legume and grass seeds were treated against ants and sown by broadcasting. Each of the three pasture legumes was sown on a separate plot as pure stand at one time and as a mixture with buffel grass. On the second rainy season 2001/02 a new experimental site adjacent to the experimental site of the first rainy season was conducted and all the treatments that carried out to experiment one in the first season were repeated to the experiment two on the second rainy season. Soil analysis at the experimental site, was done before the starting of the experiments (Appendix 3).

Plate 3.1 Ploughing by spring toothed cultivator

Plate 3.2 Ploughing by spike toothed harrow

3.2.1 Parameters measured:

- Percent soil moisture content: During the period 2000-2002, percent soil moisture content was determined at three depths, 25, 50 and 75cm for each treatment at the beginning, the mid and the end of rainy season in the two seasons. Gravimetric method was used for soil moisture determination.
- Plant population (density): A quadrat of 0.25 × 0.25m was randomly located within each plot and permanently fixed in each treatment. Within the fixed quadrat of 0.25 × 0.25m, the sown pasture plants were counted at seedling stage (21-30 days from sowing) and the counting of these pasture plants were continued on monthly intervals till maturity in November for the first and second seasons.
- Survival of Pasture Plants: On the same fixed quadrat of 0.25 × 0.25m within each plot, the counting of sown pasture plants continued from the seedling (mid of August till the end of January) to monitor plant survival during both seasons.
- Plant Composition: In each plot within the fixed quadrat of 0.25 × 0.25m indigenous and sown pasture plants were counted at 4 and 8 weeks in the first and second seasons. Also trees and shrubs were counted in the same plot of 15 × 30m for one season. Ranking of plant species composition and frequency was determined (Tables 9, 10, 11 and 12).
- Vegetation ground cover percentage: A quadrat of 1 × 1m was randomly located within each plot at seedling, flowering and

maturity stages. At each stage visual estimate of the vegetation ground cover percentage was carried out. In each time the visual estimate was done by the same person, during both seasons.

- Forage yield determination: A quadrat of 1 × 1m was randomly located within each plot, at flowering and maturity stages. Forage from sample plots of sown and local pasture plants were clipped at 5cm above the ground level. The clipped forage samples were separated into three pasture legumes as pure legume forage. Each one of these three pasture legume and buffel grass as a mixture and local pastures. Each sample of forage legume and a mixture (grass/legume) and local forage were put inside paper bags. All forage samples were put on an oven-dry at 72°C for 72 hours and the oven-dry weight was determined. Then forage yield in ton/ha was calculated for both seasons.
- Forage quality estimate: Four plant species samples from sown pasture and eight dominant indigenous pasture plants were randomly taken from different treatments on dry basis at maturity stage. Proximate analysis was done for Ash %, crude protein % (CP), crude fibre % (CF), DM% and OM% according to (AOAC, 1980).
- Grazing management: Based on carrying capacity and stocking rate, seven rams of the same local breed and of similar age (eight - ten months) were allowed to graze the exclosure for 45 days (treated). The rams were treated against internal and

external parasites, 4-6 ml of thiobendazole-oral and Ivermectine 1 ml/50kg body weight (injected) subcutaneously per each ram, respectively. Rams allowed to graze the assigned exclosure for 5 days before the starting of the first grazing period. The treated rams were watered once every two days, and body weight of rams were recorded at 15 days intervals and a weighing balance of 50kg was used. Other seven rams similar to the treated group were used as control; they were maintained under traditional grazing system. Body weight was also recorded at the same intervals of the treated group. In the second season, the same procedure was applied for the two experiments (one and two) with the difference in ram numbers due to the seasonal difference in forage production and consequently the carrying capacity (Cook, 1986, Darag and Suliman, 1988, Tarawalli *et al.,* 1995).

3.3 Statistical Analysis:

The collected data were analyzed according to statistical procedure (Gomez and Gomez, 1984) and computer package SAS (1991). Means were separated using the Duncan's multiple range tests. The analysis of variance was carried out using nested design (Appendix 3). Means separation was done for testing animal performance using student test.

CHAPTER FOUR

RESULTS

4.1 Effect of treatments on soil moisture content (%):

4.1.1 Experiment one:

Soil moisture data for the first experiment is presented in Table 4.1. In both seasons at all periods and depths, species had no significant effect on this parameter, except at depth 25 cm on the first and third periods. In the first season, the highest moisture content was recorded in treatments containing *Clitoria ternatea* + *Cenchrus ciliaris* (grass–legume mixture), followed by *Clitoria ternatea* (pure stand) in the first and the third periods, while *Stylosanthes hamata* + *Cenchrus ciliaris* (grass–legume mixture) recorded the lowest moisture percentage. In the second season, *Clitoria ternatea* + *Cenchrus ciliaris* recorded the highest moisture percentage followed by *Macroptilium atropurpurcum* + *Cenchrus ciliaris* in the second period, whereas *Stylosanthes hamata* recorded the highest percentage followed by *Macroptilium atropurpureum* + *Cenchrus ciliaris* in the third period.

Ploughing methods had no significant effect on soil moisture content at all periods and depths.

In the second season, it was observed that spring toothed cultivator ploughing in experiment one and two remained wetter than spike toothed harrow ploughing at all periods and depths (Plate 4.1).

The grazing management had significant effect in the first period at 25 cm depth (Table 4.1).

Figures 4.1 and 4.2 shows that as soil depths increased the soil moisture content decreased at all periods except the third period during both seasons.

The interaction between grazing management and ploughing methods were significant in the first season. (Appendix 4).

4.1.2 Experiment two:

Table 4.2 revealed that the sown pasture speccies had no significant effect on moisture content percentage at all depths and periods, except at 75cm in the first period during the second season. Likewise, ploughing methods had no significant effect on this parameter. Moreover, the grazing management had no significant effect on soil moisture content at all period and depths, except at 25cm and 50cm depths in the second period and 75 cm at the third period. The interaction between treatments was not significant on soil moisture content.

Table (4.1) Effects of treatments on soil moisture content (%) at different depths and periods for season 2000/01

Experiment I

Treatments	1st period (July)			2nd period (September)			3rd period (November)		
	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm
Stylosanthes hamata	7.58[ab]	6.2[a]	3.6[a]	5.17[a]	3.55[a]	3.39[a]	1.06[ab]	2.27[a]	2.59[a]
Macroptilium atropurpureum	7.62[ab]	7.11[a]	4.08[a]	5.02[a]	3.85[a]	3.62[a]	1.09[ab]	2.39[a]	2.80[a]
Clitoria ternatea	7.75[ab]	7.06[a]	4.57[a]	5.32[a]	3.29[a]	3.30[a]	1.23[a]	2.39[a]	2.87[a]
Stylosanthes hamata + cenchrus ciliaris	7.37[b]	6.74[a]	3.40[a]	5.09[a]	4.12[a]	4.09[a]	0.88[b]	2.11[a]	2.65[a]
Macroptilium atropurpureum + cenchrus ciliaris	7.52[ab]	7.21[a]	4.17[a]	5.18[a]	4.01[a]	3.85[a]	1.08[ab]	2.34[a]	2.73[a]
Clitoria ternatea + cenchrus ciliaris	8.15[a]	7.47[a]	4.06[a]	5.44[a]	3.99[a]	3.64[a]	1.00[ab]	2.28[a]	2.95[a]
SE ±	0.28	0.49	0.36	0.28	0.32	0.19	0.08	0.07	0.10
Spring toothed Cultivator (PL_1)	7.79[a]	6.75[a]	3.79[a]	5.16[a]	4.08[a]	3.64[a]	1.10[a]	2.31[a]	2.79[a]
Spike toothed harrow (PL_2)	7.55[a]	7.18[a]	4.20[a]	5.24[a]	3.52[a]	3.66[a]	1.05[a]	2.28[a]	2.74[a]
SE ±	0.28	0.51	0.47	0.17	0.15	0.44	0.11	0.18	0.29
Grazed (G_1)	8.53[a]	7.18[a]	3.9[a]	5.32[a]	3.82[a]	3.52[a]	1.10[a]	2.35[a]	2.77[a]
Ungrazed (G_2)	6.80[b]	6.76[a]	4.08[a]	5.08[a]	3.79[a]	3.78[a]	1.05[a]	2.24[a]	2.76[a]
SE ±	0.28	0.51	0.47	0.17	0.15	0.44	0.11	0.18	0.29
C.V	11.44	27.10	37.22	19.14	28.52	28.87	31.66	19.34	23.55

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level

Table (4.1cont.) Effects of treatments on soil moisture content (%) at different depths and periods for season 2001/02

Experiment I

Treatments	1st period (July)			2nd period (September)			3rd period (November)		
	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm
Stylosanthes hamata	3.66^{ab}	4.58^{a}	5.26^{a}	5.48^{a}	6.59^{a}	5.26^{a}	0.70^{ab}	1.62^{a}	2.48^{a}
Macroptilium atropurpureum	3.99^{ab}	4.50^{a}	4.44^{a}	5.07^{a}	6.35^{a}	4.56^{a}	0.52^{b}	1.12^{b}	1.64^{a}
Clitoria ternatea	4.46^{a}	5.46^{a}	5.49^{a}	5.55^{a}	6.26^{a}	4.50^{a}	0.61^{ab}	1.50^{ab}	1.94^{a}
Stylosanthes hamata + cenchrus ciliaris	3.96^{ab}	4.93^{a}	5.38^{a}	5.18^{a}	6.04^{a}	5.40^{a}	0.50^{b}	1.73^{a}	2.34^{a}
Macroptilium atropurpureum + cenchrus ciliaris	3.94^{ab}	4.46^{a}	5.56^{a}	5.15^{a}	6.72^{a}	4.29^{a}	0.63^{ab}	1.68^{a}	2.35^{a}
Clitoria ternatea + cenchrus ciliaris	3.40^{b}	5.35^{a}	5.35^{a}	5.62^{a}	6.89^{a}	4.62^{a}	0.75^{a}	1.51^{ab}	2.28^{a}
SE ±	0.30	0.51	0.59	0.23	0.32	0.47	0.07	0.16	0.20
Spring toothed Cultivator (PL$_1$)	3.96^{a}	5.15^{a}	5.54^{a}	5.39^{a}	6.69^{a}	4.87^{a}	0.63^{a}	1.54^{a}	2.23^{a}
Spike toothed harrow (PL$_2$)	3.85^{a}	4.62^{a}	4.96^{a}	5.30^{a}	6.26^{a}	4.67^{a}	0.61^{a}	1.52^{a}	2.11^{a}
SE ±	0.29	0.44	0.74	0.19	0.33	0.42	0.06	0.08	0.17
Grazed (G$_1$)	3.89^{a}	4.47^{a}	4.60^{a}	5.47^{a}	6.48^{a}	4.82^{a}	0.65^{a}	1.56^{a}	2.19^{a}
Ungrazed (G$_2$)	3.91^{a}	5.29^{a}	5.90^{a}	5.21^{a}	6.47^{a}	4.72^{a}	0.59^{a}	1.49^{a}	2.15^{a}
SE ±	0.29	0.44	0.74	0.19	0.33	0.42	0.06	0.08	0.17
C.V	28.78	38.45	46.01	15.96	19.16	36.87	43.33	36.60	35.08

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Table (4.2) Effects of treatments on soil moisture content (%) at different depths and periods for season 2000/02

Experiment II

Treatments	1st period (July)			2nd period (September)			3rd period (November)		
	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm	25 cm	50 cm	75 cm
Stylosanthes hamata	4.16[a]	4.09[a]	3.51[bc]	4.97[a]	5.86[a]	4.96[a]	0.77[a]	2.00[a]	2.38[a]
Macroptilium atropurpureum	4.15[a]	4.43[a]	4.03[abc]	4.96[a]	6.06[a]	5.03[a]	0.77[a]	1.88[a]	2.61[a]
Clitoria ternatea	6.04[a]	4.49[a]	3.99[abc]	4.83[a]	5.79[a]	4.71[a]	0.81[a]	1.76[a]	2.57[a]
Stylosanthes hamata + cenchrus ciliaris	3.37[b]	4.38[a]	4.46[ab]	4.90[a]	5.88[a]	4.98[a]	0.86[a]	2.09[a]	2.70[a]
Macroptilium atropurpureum + cenchrus ciliaris	4.41[a]	4.40[a]	4.72[a]	4.92[a]	5.58[a]	4.85[a]	0.76[a]	1.95[a]	2.40[a]
Clitoria ternatea + cenchrus ciliaris	4.45[a]	4.17[a]	3.36[c]	5.11[a]	6.05[a]	4.63[a]	0.90[a]	1.86[a]	2.20[a]
SE ±	0.32	0.27	0.35	0.18	0.23	0.31	0.08	0.17	0.17
Spring toothed Cultivator (PL_1)	4.32[a]	4.47[a]	4.16[a]	5.06[a]	5.93[a]	4.87[a]	0.85[a]	1.93[a]	2.47[a]
Spike toothed harrow (PL_2)	4.12[a]	4.18[a]	3.86[a]	4.83[a]	5.81[a]	4.85[a]	0.77[a]	1.91[a]	2.49[a]
SE ±	0.14	0.21	0.16	0.22	0.19	0.13	0.05	0.09	0.14
Grazed (G_1)	3.85[a]	3.26[a]	3.75[a]	5.08[a]	5.72[a]	4.23[a]	1.05[a]	2.16[a]	2.63[a]
Ungrazed (G_2)	4.59[b]	5.4[a]	5.28[a]	4.82[a]	6.01[a]	5.49[a]	0.58[a]	1.69[a]	2.32[a]
SE ±	0.14	0.21	0.16	0.22	0.19	0.13	0.05	0.09	0.14
C.V	26.20	22.86	29.81	15.09	14.58	21.99	40.03	32.27	25.90

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Plate 4.1 Effect of ploughing by spring toothed cultivator (the right site) and spike toothed harrow (The left site) on soil moisture content and drought

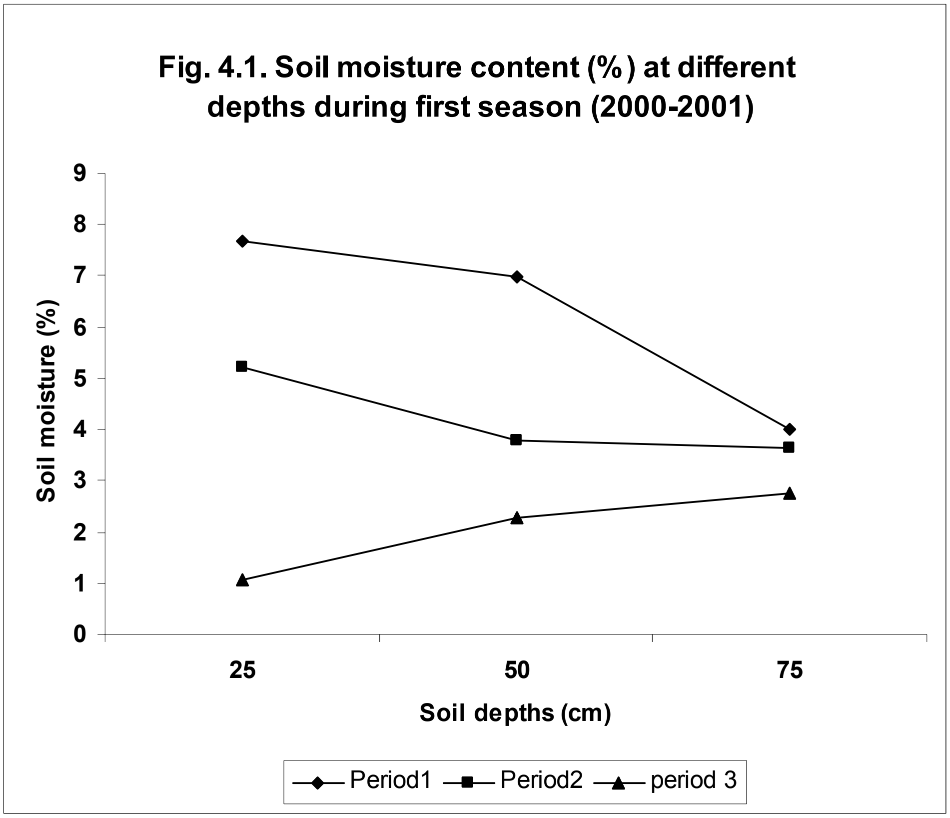
Fig. 4.1. Soil moisture content (%) at different depths during first season (2000-2001)
Soil moisture (%)
0
1
2
3
4
5
6
7
8
9
25
50
75
Soil depths (cm)
Period1
Period2
period 3

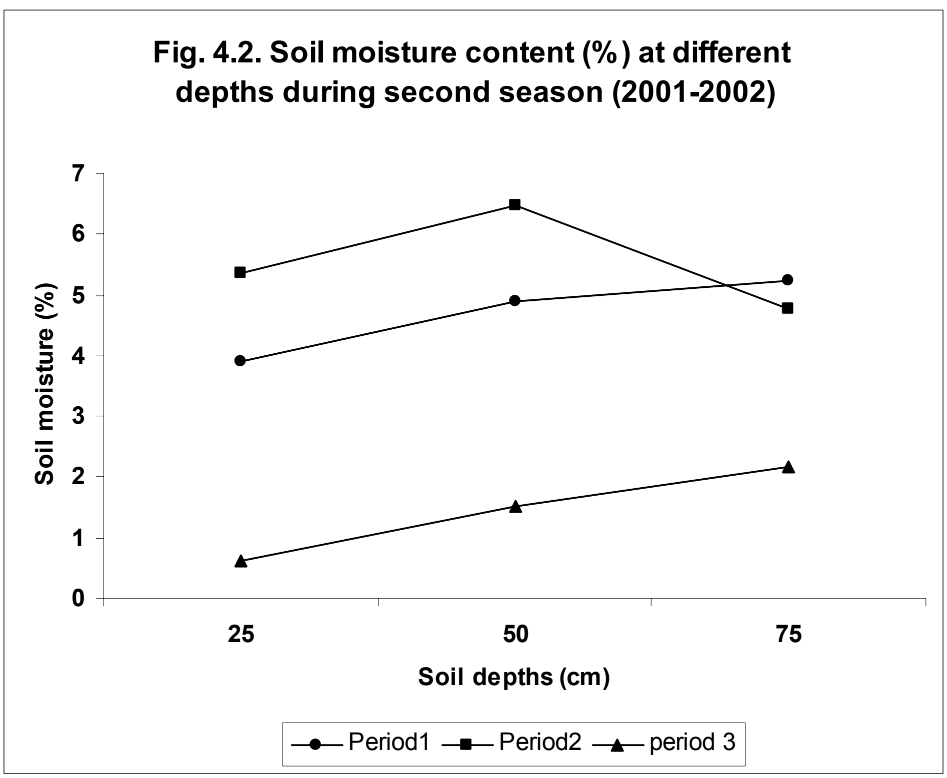
Fig. 4.2. Soil moisture content (%) at different depths during second season (2001-2002)
Soil moisture (%)
0
1
2
3
4
5
6
7
25
50
75
Soil depths (cm)
Period1
Period2
period 3

4.2 Effect of treatments on plant growth attributes

4.2.1 Pasture species density

The number of plants per unit area of 0.25 sq.m at each counting date during the two seasons is shown in Table 4.3.

In both seasons, in all counts, species had a significant effect on the plant density. In the two seasons, in both experiments, *Stylosanthes hamata* c.v *verano* + *Cenchrus ciliaris* (legume – grass mixture) scored the highest number of plants per unit area, followed by *Stylosanthes hamata* (pure stand), whereas *Clitoria ternatea* followed by *Macroptilium atropurpureum* (Siratro) scored the lowest number.

It was observed that during the first season of experiment one, the number of sown pasture species in all counts outnumbered the corresponding counts of experiment two in the second season.

Moreover, the number of sown pasture species decreased as counting time advanced in all treatments in both seasons. The ploughing methods and the grazing management had no significant effect on the number of sown pasture species in all counts in the two experiments, except at the first and the second counts in experiment two (Table 4.3).

Interaction between sown pasture species and ploughing methods, in all counts were significant in the first season in experiment one (Appendix 5), while interaction between all treatments were not significant in the second season in experiment two.

Table (4.3) Effects of treatments on plant density per 0.25 sqm for two experiments for season (2000/02)

Treatments	Experiment I				Experiment II			
	2000/01				2001/02			
	1st period (Augus.)	2nd period (Sept.)	3rd period (Octob)	4th period (Novemb)	1st period (Augus.)	2nd period (Sept.)	3rd period (Octob)	4th period (Novemb)
Stylosanthes hamata	14.58ab	15.50a	13.66a	13.2a	9.83a	8.91ab	8.50a	8.00a
Macroptilium atropurpureum	6.91cd	5.08bc	2.75cd	1.58cd	4.75b	3.50c	2.50c	1.50c
Clitoria ternatea	2.83d	2.41c	1.00d	0.67d	3.66b	3.00c	3.00c	2.58bc
Stylosanthes hamata + cenchrus ciliaris	18.08a	17.00a	14.00a	13.00a	11.33a	9.66a	8.75a	7.75a
Macroptilium atropurpureum + cenchrus ciliaris	10.75bc	8.75b	5.66bc	4.91bc	7.41ab	5.58bc	4.08bc	2.83bc
Clitoria ternatea + cenchrus ciliaris	10.66bc	9.50b	7.91b	6.66b	10.25a	8.08ab	6.58ab	5.25ab
SE ±	1.79	1.57	1.31	1.21	1.54	1.17	1.17	1.09
Spring toothed Cultivator (PL_1)	10.00a	10.38 a	6.47 a	5.64 a	8.55a	7.16 a	6.16 a	5.13 a
Spike toothed harrow (PL_2)	11.27 a	10.02 a	8.52 a	7.72 a	7.19b	5.75 a	4.97 a	4.16 a
SE ±	0.88	0.87	0.68	0.67	0.28	0.62	0.52	0.44
Grazed (G_1)	9.94 a	8.55 a	7.66 a	6.97 a	9.36a	4.97b	4.61 a	3.91 a
Ungrazed (G_2)	11.33 a	10.86 a	7.33 a	6.39 a	6.38b	7.94a	6.52 a	5.38 a
SE ±	0.88	0.78	0.68	0.67	0.28	0.62	0.52	0.44
C.V	57.66	56.15	60.19	62.94	64.81	62.85	71.53	79.23

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

4.2.2 Percent vegetation cover

Vegetation cover percent of the study site during the two seasons is shown in Table 4.4.

During the two seasons in both experiments, at all periods pasture species had a significant effect on vegetation cover percentage except period two in experiment two during the second season. During the first season, in experiment one, at the first period *Macroptilium atrpurpureum* (pure stand) recorded the highest vegetation cover percent followed by *Macropitilum atrpurpureum* + *Cenchrus ciliaris* while *Stylosanthes hamata* + *Cenchrus ciliaris* and *Clitoria ternatea* + *Cenchrus ciliaris* scored the lowest percent, while at the third period *Stylosanthes hamata* scored the highest percent and the lowest percent scored by *Macroptilium atropurpureum*. In the second season at the first period *Stylosanthes hamata* + *Cenchrus ciliaris* scored the highest percent. The lowest percent was scored by *Clitoria ternatea* while in the third period *Clitoria ternatea* + *Cenchrus ciliaris* scored the highest and *Clitoria ternatea* scored the lowest percent.

In experiment two in the second season *Clitoria ternatea* and *Macroptilium atropurpureum* + *Cenchrus ciliaris* and *Stylosanthes hamata* recorded the highest percent at the different three periods. The lowest cover percent was scored by *Macroptilium atropurpureum* + *Cenchrus ciliaris* followed by *Macroptilium atropurpureum* in the first and third period, respectively. In both seasons, in experiment one, Table (4.4): Effects of treatments on (%) vegetation cover at different periods of plant growth for two season 2000/02

Experiment I

Treatments	2000/01			2001/02		
	1st period (Augus.)	2nd period (Sept.)	3rd period (Novemb)	1st period (Augus.)	2nd period (Sept.)	3rd period (Novemb)
Stylosanthes hamata	23.33^{ab}	40.83^{ab}	55.83^{a}	40.83^{a}	37.91^{ab}	50.83^{a}
Macroptilium atropurpureum	35.83^{a}	53.33^{a}	50.00^{ab}	36.25^{ab}	30.41^{ab}	36.66^{b}
Clitoria ternatea	29.58^{ab}	36.25^{bc}	42.08^{b}	27.50^{b}	24.58^{b}	30.41^{b}
Stylosanthes hamata + cenchrus ciliaris	20.83^{b}	41.66^{ab}	44.58^{b}	46.25^{a}	39.58^{a}	42.50^{ab}
Macroptilium atropurpureum + cenchrus ciliaris	32.50^{ab}	29.16^{bc}	40.00^{b}	33.33^{ab}	34.58^{ab}	42.08^{ab}
Clitoria ternatea + cenchrus ciliaris	20.83^{b}	26.66^{c}	42.50^{b}	44.16^{a}	38.33^{a}	52.91^{a}
SE ±	4.66	3.47	3.78	4.44	4.38	4.20
Spring toothed Cultivator (PL_1)	20.83^{b}	30.00^{a}	42.36^{a}	40.69^{a}	40.27^{a}	52.63^{a}
Spike toothed harrow (PL_2)	33.83^{a}	45.97^{a}	49.36^{a}	35.41^{a}	28.19^{a}	32.50^{b}
SE ±	3.00	5.62	2.40	3.43	4.35	5.05
Grazed (G_1)	29.58^{a}	42.77^{a}	45.83^{a}	38.61^{a}	28.47^{a}	40.30^{a}
Ungrazed (G_2)	24.72^{a}	33.19^{a}	45.83^{a}	37.50^{a}	40.47^{a}	40.83^{a}
SE ±	3.00	5.62	2.40	3.43	4.35	5.05
C.V	60.21	41.15	28.91	42.05	48.56	39.49

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Table (4.4 con.) Effects of treatments on (%) vegetation cover at different periods of plant growth for one seasons 2001/02

Experiment II

Treatments	2000/01		
	1st period (Augus.)	2nd period (Sept.)	3rd period (Novemb)
Stylosanthes hamata	6.66[a]	7.50 [a]	7.91[a]
Macroptilium atropurpureum	7.08[ab]	6.25 [a]	5.41[b]
Clitoria ternatea	7.91[a]	7.91 [a]	6.66[ab]
Stylosanthes hamata + cenchrus ciliaris	6.25[ab]	6.66 [a]	6.66[ab]
Macroptilium atropurpureum + cenchrus ciliaris	5.00[b]	7.91 [a]	7.08[ab]
Clitoria ternatea + cenchrus ciliaris	5.83[ab]	7.50 [a]	5.83[ab]
SE ±	0.78	0.79	0.85
Spring toothed Cultivator (PL_1)	5.97[a]	7.77 [a]	6.25 [a]
Spike toothed harrow (PL_2)	6.94 [a]	6.80 [a]	6.94 [a]
SE ±	0.56	0.52	0.50
Grazed (G_1)	5.97 [a]	6.52 [a]	5.47 [a]
Ungrazed (G_2)	6.94 [a]	8.05 [a]	7.22 [a]
SE ±	0.56	0.52	0.50
C.V	43.56	38.24	45.01

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level it was observed that the highest vegetation cover percentage was recorded during period three, while the lowest percent was recorded during period one in the first season and during the second period in the second season. On the other hand, the vegetation cover percent in experiment two, in all periods, during the second season were almost the same.

Ploughing methods and grazing management had no significant effects on vegetation cover percent in both seasons in the two experiments, except for ploughing experiment one in the first season during the first period and in the second season during the third period (Table 4.4).

Interaction between grazing management and pasture species were significant during the first season in the second period in experiment one (Appendix 6). In experiment one, in both seasons, the interaction between the grazing management and ploughing methods were significant in the second and the third periods (Appendix 7). However, the interaction between the ploughing methods and pasture species were significant in experiment one during the second season (Appendix 8).

4.2.3. Survival rate

The percent survival rate of the sown pasture species during the two seasons is shown in Table 4.5. In both seasons, during all periods, the sown pasture species had a significant difference on the survival rate percentage. *Stylosanthes hamata* scored the highest survival rate percentage. It ranged between 68.42-97.91 followed by *Stylosanthes hamata* + *Cenchrus ciliaris* which ranged between 72-95.33 (Plates 4.2 and 4.3) throughout the experimental period in the two experiments. *Clitoria ternatea* recorded the lowest survival rate percentage. It ranged between 0.00-86.33 in the first season and from 66.42-100 in the experiment two in the second season in all periods (Plate 4.4), except, experiment one in the first season during the first period. In experiment two, in all periods except the first period, *Macroptilium atropurpureum* recorded the lowest percentage. It ranged between 29.82-66.83 (Plate 4.5).

The ploughing methods and the grazing management had no significant effect on the survival rate percentage of the sown pasture species during all periods in both seasons of two experiments except the grazing management in experiment one during the second period in the first season.

Table (4.5): Effects of treatments on sown pastures survival rate (%) at monthly interval for season 2000/01,

Experiment I

treatments	1st Agu/sep	2nd Sep/oct	3rd Oct/No	4th No/Dc	5th Dc/Jan
Stylosanthes hamata	92.91[a]	91.50[a]	97.91[a]	95.58[a]	94.25[a]
Macroptilium atropurpureum	70.00[b]	68.33[bc]	68.08[b]	29.83[b]	30.58[b]
Clitoria ternatea	86.33[a]	54.16[c]	38.91[c]	4.16[c]	0.00[c]
Stylosanthes hamata + cenchrus ciliaris	92.58[a]	80.91[ab]	93.66[a]	91.00[a]	95.33[a]
Macroptilium atropurpureum + cenchrus ciliaris	82.25[ab]	72.33[b]	88.58[a]	90.83[a]	92.75[a]
Clitoria ternatea + cenchrus ciliaris	87.25[a]	80.41[ab]	91.08[a]	85.58[a]	83.50[a]
SE ±	4.75	5.34	5.95	5.83	6.76
Spring toothed Cultivator (PL_1)	83.83[a]	75.72[a]	75.02[a]	64.22[a]	62.41[a]
Spike toothed harrow (PL_2)	86.61[a]	73.50[a]	84.38[a]	68.11[a]	69.72[a]
SE ±	2.11	4.24	2.96	2.70	2.80
Grazed (G_1)	83.97[a]	88.86[a]	83.88[a]	64.18[a]	61.30[a]
Ungrazed (G_2)	86.47[a]	60.36[b]	75.52[a]	68.19[a]	70.83[a]
SE ±	2.11	4.24	2.96	2.70	2.80
C.V	18.92	25.91	25.55	29.98	34.61

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Table (4.5cont): Effects of treatments on sown pastures survival rate (%) at monthly interval for season 2001/02,

Experiment II

treatments	1^{st} Agu/sep	2^{nd} Sep/oct	3^{rd} Oct/No	4^{th} No/Dc	5^{th} Dc/Jan
Stylosanthes hamata	92.00[a]	97.33[a]	95.41[a]	78.08[a]	68.42[a]
Macroptilium atropurpureum	77.75[ab]	66.83[c]	58.91[c]	29.83[b]	33.33[b]
Clitoria ternatea	78.41[ab]	100.00[a]	79.83[ab]	66.42[a]	72.92[a]
Stylosanthes hamata + cenchrus ciliaris	83.33[ab]	89.66[ab]	86.83[ab]	78.08[a]	72.25[a]
Macroptilium atropurpureum + cenchrus ciliaris	72.00[b]	81.83[b]	70.00[bc]	84.83[a]	88.92[a]
Clitoria ternatea + cenchrus ciliaris	73.83[b]	80.83[b]	84.33[ab]	81.42[a]	93.17[a]
SE ±	5.71	4.00	6.06	8.01	10.33
Spring toothed Cultivator (PL_1)	84.63[a]	86.86[a]	81.69[a]	75.02[a]	78.41[a]
Spike toothed harrow (PL_2)	74.47[a]	85.30[a]	76.75[a]	64.52[a]	64.58[a]
SE ±	3.29	1.76	3.56	4.17	5.70
Grazed (G_1)	77.27[a]	92.22[a]	81.88[a]	64.69[a]	62.91[a]
Ungrazed (G_2)	81.83[a]	79.94[a]	76.55[a]	74.86[a]	80.08[a]
SE ±	3.29	1.76	3.56	4.17	5.70
C.V	24.87	15.78	26.56	39.43	49.83

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Plate 4.2. Well established *Stylosanthes hamata*

Plate 4.3 Well established *Cenchrus ciliaris*

Plate 4.4. Poorly established *Clitoria ternatea*

Plate 4.5. Poorly established *Macroptilium atropurpurem*

Interaction between the sown pasture species and the ploughing methods had a significant effect on the survival rate percentage in the first season during the second and the third periods in experiment one, also during the second and fourth periods in experiment two in the second season (Appendix 9). The interaction between the sown pasture species and the grazing management had a significant effect on the survival rate percentage during the first, second and the fourth periods in the first season in the experiment one and the third period in the experiment two during the second season (Appendix 10).

4.3 Effect of treatments on forage yields (ton/ha):

4.3.1 Effect of treatments on sown and indigenous forage yield (ton/ha):

The estimated forage yield of the sown and indigenous pasture species during the two seasons is shown in Table 4.6.

In experiment one during the two seasons the analysis of variance showed that both sown and natural grown pasture species had a significant effect on forage yield at flowering and maturity stages, except indigenous pasture species at flowering and sown pasture at the maturity stages during the second season. In the first season at maturity the sown pasture, namely *Stylosanthes hamata* + *Cenchrus ciliaris* and *Clitoria ternatea*+ *Cenchrus ciliaris,* scored the highest dry matter yield of 0.288 tons/ha, and 0.245 tons/ha, respectively. On the other hand, *Stylosanthes hamata* produced the lowest record of 0.025 tons/ha at flowering and 0.102 ton/ha at maturity stages, while *Macroptilium atropurpureum* and *Clitoria ternatea* did not produce forage.

It was observed that in the first season in experiment one, the dry matter produced by the sown pasture species at flowering was lower than at the maturity stages, while the dry matter produced by natural pasture was reversed. The dry matter yield was higher at flowering than at maturity stages.

In the second season, at flowering, *Stylosanthes hamata* produced the highest dry matter (0.322 tons/ ha) followed by *Stylosanthes hamata* + *Cenchrus ciliaris* (0.311 tons/ha) compared to other sown pasture species in the treatment. At maturity, *Macroptilium atropurpureum* + *Cenchrus ciliaris,* followed by *Clitoria ternatea* + *Cenchrus ciliaris* produced the highest dry matter of 0.280 tons/ha and 0.266 tons/ha, respectively.

In the first season indigenous pasture species produced the highest yield of 0.875 ton/ha at flowering and 0.708 ton/ha at maturity.

It was noticed that the sown pasture species produced high dry matter at flowering and maturity in the second season compared to the dry matter that produced in the first season. Ploughing methods had no significant effect on the dry matter produced by sown and indigenous pasture species during both seasons, except indigenous pasture species at maturity stage.

During both seasons the sown and indigenous pasture species produced high dry matter under spring toothed cultivator ploughing (PL_1) compared to spike toothed harrow ploughing (PL_2). On the other hand, the grazing management had no significant effect on dry matter production in both seasons, with the exception of local pasture species at maturity in the second season (Table 4.6).

Table (4.6) Effects of treatments on forage yield (sown, indigenous and total) tons/hectare at different periods of plant growth for two seasons **Experiment I**

Treatments	2000/01					
	Forage yield at flowering (September)			Forage yield at maturity (November)		
	Sown	indigenous	total	Sown	indigenous	total
Stylosanthes hamata	0.025[b]	0.875[a]	0.900[a]	0.102[b]	0.708[a]	0.808[a]
Stylosanthes hamata + cenchrus ciliaris	0.108[ab]	0.515[b]	0.623[ab]	0.286[a]	0.264[b]	0.552[a]
Macroptilium atropurpureum + cenchrus ciliaris	0.148[a]	0.359[b]	0.507[b]	0.236[ab]	0.349[b]	0.585[a]
Clitoria ternatea + cenchrus ciliaris	0.172[a]	0.510[b]	0.682[ab]	0.245[ab]	0.365[b]	0.610[a]
SE ±	0.46	1.12	1.12	0.57	1.12	1.23
Spring toothed Cultivator (PL_1)	0.120[a]	0.598[a]	0.718[a]	0.258[a]	0.540[a]	0.798[a]
Spike toothed harrow (PL_2)	0.107[a]	0.532[a]	0.639[a]	0.178[a]	0.302[b]	0.480[b]
SE ±	0.40	0.78	1.11	0.42	0.48	0.62
Grazed (G_1)	0.137[a]	0.609[a]	0.746[a]	0.197[a]	0.431[a]	0.628[a]
Ungrazed (G_2)	0.09[a]	0.521[a]	0.611[a]	0.238[a]	0.411[a]	0.650[a]
SE ±	0.40	0.78	1.11	0.42	0.48	0.62
CV	86.94	63.08	56.44	83.91	73.74	58.15

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Table (4.6acont)

Treatments	2001/02					
	Forage yield at flowering (September)			Forage yield at maturity (November)		
	sown	Indigenous	total	sown	indigenous	total
Stylosanthes hamata	0.322[a]	0.598 [a]	0.920 [a]	0.150 [a]	0.935[a]	1.085 [a]
Stylosanthes hamata + cenchrus ciliaris	0.311[a]	0.354 [a]	0.666 [a]	0.253 [a]	0.548[b]	0.801 [a]
Macroptilium atropurpureum + cenchrus ciliaris	0.136[b]	0.468 [a]	0.604 [a]	0.280 [a]	0.639[b]	0.919 [a]
Clitoria ternatea + cenchrus ciliaris	0.256[ab]	0.393 [a]	0.649 [a]	0.266 [a]	0.744[ab]	1.010 [a]
SE ±	0.46	0.95	1.21	0.56	1.05	1.28
Spring toothed Cultivator (PL_1)	0.311[a]	0.493 [a]	0.804 [a]	0.310 [a]	0.844[a]	1.154[a]
Spike toothed harrow (PL_2)	0.202 [a]	0.379 [a]	0.581 [a]	0.164 [a]	0.589[b]	0.753[b]
SE ±	0.42	0.60	0.71	0.45	0.57	0.72
Grazed (G_1)	0.262 [a]	0.361 [a]	0.6230 [a]	0.203 [a]	0.576[b]	0.779[b]
Ungrazed (G_2)	0.251 [a]	0.510 [a]	0.761 [a]	0.272 [a]	0.858[a]	0.113[a]
SE ±	0.42	0.60	0.71	0.45	0.57	0.72
CV	57.61	63.12	49.82	71.92	41.40	38.02

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

Table (4.7) Effects of treatments on forage yield tons/ha at different period of plant Growth for season 2001/02

Experiment II

Treatments	Forage yield at flowering (September)			Forage yield at maturity (November)		
	sown	Indigenous	total	sown	indigenous	total
Stylosanthes hamata	0.075[a]	0.515[a]	0.610[a]	0.191[a]	0.517[a]	0.708[a]
Stylosanthes hamata + cenchrus ciliaris	0.165[a]	0.683[a]	0.848[a]	0.164[a]	0.595[a]	0.759[a]
Macroptilium atropurpureum + cenchrus ciliaris	0.108[a]	0.758[a]	0.866[a]	0.204[a]	0.417[a]	0.621[a]
Clitoria ternatea + cenchrus ciliaris	0.093[a]	0.668[a]	0.761[a]	0.159[a]	0.518[a]	0.677[a]
SE ±	0.32	1.09	1.03	0.44	0.70	0.91
Spring toothed Cultivator (PL_1)	0.128[a]	0.733[a]	0.861[a]	0.219[a]	0.597[a]	0.816[a]
Spike toothed harrow (PL_2)	0.102[a]	0.580[a]	0.682[a]	0.140[a]	0.426[a]	0.566[a]
SE ±	0.27	0.74	0.82	0.50	0.53	0.86
Grazed (G_1)	0.101[a]	0.554[a]	0.655[a]	0.154[a]	0.501[a]	0.655[a]
Ungrazed (G_2)	0.130[a]	0.758[a]	0.888[a]	0.205[a]	0.522[a]	0.727[a]
SE ±	0.27	0.74	0.82	0.50	0.53	0.86
C.V	87.40	45.62	40.82	84.98	41.28	42.54

Means followed by the same letter (s) in a given column for each factor are not significantly different at 0.05 level.

In the second season at the first harvest indigenous pasture species scored the highest dry matter yield of 0.528 tons/ha and 0.935 tons/ha at the second harvest, while the lowest dry matter produced at the first harvest of 0.354 tons/ha and 0548 tons/ha at the second harvest.

In experiment two in the second season, 0.758 tons/ha and 0.595 tons/ha were the highest dry matter produced at the first and the second harvesting dates, respectively, whereas the lowest dry matter produced were 0.515 tons/ha at the first and 0.417 tons/ha at the second harvest.

Ploughing methods and grazing management had no significant effect on the indigenous pasture species dry matter yield at the two harvesting dates.

Interaction between all treatments were not significant in both seasons.

4.4. Seed production of the sown pasture species during the two rainy seasons 2000/01 and 2001/02:

Cenchrus ciliaris and *Stylosanthes hamata* produced seeds, while *Macroptilium atropurpureum* and *Clitoria ternatea* did not produce seeds. The seeds were harvested by hand. During October 2000, *Cenchrus ciliaris* seeds were harvested, while *Stylosanthes hamata* seeds were harvested during December 2000. The average seed produced by *Cenchrus ciliaris* and *Stylosanthes hamata* were 0.075 and 0.005 tons/ha, respectively.

In the second season all sown pasture species produced seeds. *Cenchrus ciliaris* seeds were harvested during October while *Stylosanthes hamata*, *Macroptilium atropurpureum* and *Clitoria ternatea* were harvested during November and December 2001. The average pasture seeds produced by *Cenchrus ciliaris, Stylosanthes hamata, Macroptilium atropurpureum* and *Clitoria ternatea* were 0.041, 0.024, and 0.017 tons/ha, respectively.

4.5. Evaluation of some range plants quality in the study area:

As shown in Table 4.8 chemical analysis indicated that the leguminous species scored the highest crude protein percentage (CP) compared to the grasses. On the other hand, the grasses species recorded crude fiber percentage (CF) slightly higher than in legumes. Among the legumes *Macroptilium atropurpureum* scored the highest percentage of crude protein (17.2) and *Zornia glochidiata* scored the lowest percentage (5.20). On the other hand, *Oldlandia senegalensis* scored the highest percentage of crude fiber 34.9 (CF) while *Clitoria ternatea*, scored the lowest percentage (25.20).

Among grasses, *Dactyloctenium aegyptium* scored the highest percentage of crude protein (6.2), whereas *Aristida spp.* scored the lowest percentage (4.4). However, *Cenchrus biflorus* scored the highest percentage of crude fiber (37) while *Dactyloctenium aegyptium* recorded the lowest percentage (23.95).

Table 4.8. Proximate analysis of some indigenous and introduced range plants on dry matter basis during 2000/01.

Grasses						
Pasture species	Life form	DM%	Ash%	OM%	CP%	CF%
Aristida spp.	Annual	95.70	4.95	90.80	4.40	35.10
Dactyloctenium aegyptium	Annual	97.20	4.20	93.0	6.20	23.95
Cenchrus biflorus	Annual	95.40	8.95	84.45	4.80	37.0
Chloris virgata	Annual	93.70	7.40	86.30	5.50	31.70
Schoenefeldia gracilis	Annual	94.50	9.0	85.50	5.20	36.0
*Cenchrus ciliaris**	Perennial	94.10	11.30	82.90	6.10	29.60
Legumes						
Zorina glochidiata	Annual	95.90	6.10	89.80	5.20	32.50
Oldlandia sengalensis	Annual	91.50	9.20	82.30	8.20	34.9
Alysicarpus ovalifolius	Annual	94.80	8.80	86.0	16.4	27.0
*Macroptilium atropurpureum**	Perennial	95.95	12.50	83.45	17.2	33.10
*Clitoria ternatea**	Perennial	93.50	14.60	78.90	9.70	25.20
*Stylosanthes hamata**	Perennial	94.30	8.20	86.10	14.70	31.10

DM% : Dry matter percentage.

OM%: Organic matter percentage.

CP%: Crude protein percentage.

CF%: Crude fiber percentage.

*: Introduced pasture species

4.6. Evaluation of plant composition and frequency:

4.6.1. Grazed range site:

The vegetation measurements at the study area are shown in Table 4.9. During the first period (4 weeks) and the second period (8 weeks). *Zornia glochidiata* scored the highest plant composition percentage (50.36) and (48.23) respectively, followed by *Oldlandia senegalensis* and *Cenchrus clicaris*, in addition *Zornia glochidiata* scored the highest plant frequency percentage (69.44) and (94.44) respectively, followed by *Cenchrus ciliaris* and *Aristida spp.* On the other hand, the lowest plant composition and frequency percentages were recorded by *Alysicarpus ovalifolius, Vigna sun-hum* and *Alliums pp.* (0.05) and (2.78) respectively, followed by *Commelina spp.* and *Dactyloctenium aegyptium*.

It was observed that more palatable range plants species scored the lowest percentages of plant composition and frequency compared to unpalatable plant species.

In the second season, during the first period (4 weeks), *Aristida spp.* recorded the highest plant composition percentage (40.41) followed by *Zornia glochidiata* and *Oldlndia senegalensis*, while *Zornia glochidiata* scored the highest plant composition percentage (51.57) during the second period, followed by *Aristida spp.* and *Cenchrus biflorus.* On the other hand, *Alysicarpus ovalifolius* and *Sporobolus iocladus* showed the lowest plant composition percentage (0.01) followed by *Blepharis linariifolia* and *Alliums pp.* in both periods. With regard to plant frequency during the first and second periods, *Zornia glochidiata* scored the highest percentage of (100) and (97.22) respectively, followed by *Aristida spp.* and *Cenchrus biflorus.* The lowest % frequencies were scored by *Alysicarpus ovalifolius, Sporobolus iocladus* and *Allium spp.* (2.78) followed by *Blepharis linariirolia* (5.56).

Table 4.9. Plant composition and frequency of the study site experiments one. (The grazed site).

Botanical name	Period (week)	2000/01			2001/02		
		Plant number 0.25 m^2	Comp %	Frequ %	Plant number 0.25 m^2	Comp %	Frequ %
Zorina glochidiata	4	1112	50.36	69.44	4939	37.65	100.0
	8	900	48.23	94.44	2130	51.57	97.22
Oldlandia sengalensis	4	357	16.17	41.67	769	5.86	16.67
	8	340	18.22	41.66	26	0.62	8.33
Cenchrus ciliaris	4	149	6.75	50.00	46	0.35	36.11
	8	144	7.72	50.00	42	1.01	27.78
Aristida spp.	4	119	5.39	45.96	5300	40.41	100.00
	8	195	5.09	42.72	1327	32.13	94.44
Stylosanthes hamata	4	127	5.75	36.11	6	0.05	16.67
	8	120	6.43	36.11	5	0.12	13.89
Chloris virgata	4	68	3.08	22.22	314	2.39	44.44
	8	26	1.39	19.44	86	2.08	25.00
Macroptilium atropurpureum	4	39	1.77	33.33	-	-	-
	8	23	1.23	30.56	-	-	-
Geigeria alata	4	31	1.40	22.22	3.00	0.02	2.78
	8	34	1.82	33.33	-	-	-
Eragrostis tremula	4	29	1.31	25.00	147	1.12	38.89
	8	39	2.09	36.11	10	0.24	8.33
Clitoria ternatea	4	23	1.04	33.33	-	-	-
	8	22	1.18	33.33	-	-	-
Chlorophytum tuberosum	4	22	1.00	27.78	28	0.21	25.00
	8	8	0.43	13.89	6	0.15	13.89

Tephrosia uniflora	4	15	0.68	25.00	11	0.08	22.22
	8	17	0.91	27.78	1	0.02	2.78
Solanum dubium	4	12	0.54	22.22	20	0.15	16.67
	8	7	0.38	16.67	13	0.31	11.11
Cenchrus biflorus	4	10	0.45	13.89	384	2.92	61.11
	8	13	0.70	13.89	99	2.40	27.78
Digitaria ciliaris	4	-	-	-	28	0.21	11.11
	8	-	-	-	10	0.24	13.89
Fimbristylis dichotoma	4	9	0.40	16.67	7	0.05	11.11
	8	4	0.21	8.33	0	0	0
Ipomea spp.	4	7	0.32	13.89	25	0.19	22.22
	8	3	0.16	8.33	7	0.17	2.78
Commelina spp.	4	2	0.09	2.78	7	0.05	11.11
	8	2	0.11	5.56	7	0.17	5.56
Acanthus spp.	4	6	0.27	5.56	-	-	-
	8	36	1.93	33.33	-	-	-
Corchorus olitorius	4	5	0.23	13.89	32	0.24	44.44
	8	5	0.26	13.89	12	0.29	11.11
Vigna sun-hum	4	3	0.14	5.56	-	-	-
	8	1	0.05	2.78	-	-	-
Dactyloctenium aegyptium	4	3	0.14	5.56	406	3.08	83.33
	8	3	0.16	8.33	105	2.54	58.33
Allium spp.	4	3	0.14	8.33	1	0.01	2.78
	8	1	0.05	2.78	1	0.02	2.78
Tribulis terrstris	4	12	0.54	22.22	324	2.47	58.33
	8	5	0.26	11.11	126	3.05	50.00
Brachiaria xantholeuca	4	-	-	-	31	0.23	13.89
	8	-	-	-	3	0.07	2.78
Schoenefeldia gracilis	4	25	1.13	9.60	268	2.04	58.33
	8	10	0.53	4.50	104	2.52	36.11
Sporobolus iocladus	4	-	-	-	1	0.01	2.78
	8	-	-	-	0	0	0
Blepharis linariifolia	4	-	-	-	2	0.02	5.56
	8	-	-	-	2	0.05	5.56
Alysicarpus ovalifolius	4	1	0.05	2.78	1	0.01	2.78
	8	1	0.05	2.78	1	0.02	2.78
Hypoestes cancellata	4	-	-	-	12	0.09	5.56
	8	-	-	-	6	0.15	8.33
Others	4	19	0.89	30.58	3	0.03	8.33
	8	7	0.37	16.17	1	0.02	2.78

The percent of plant composition and frequency of experiment two is shown in Table 4.10. In experiment two, in the second season during the first period (4 weeks), *Cenchrus ciliaris* scored the highest plant composition (19.56), followed by *Stylosanthes hamata, Macroptilium atropurpureum* and *Zornia glochidiata.* While *Brachiaria deflexa, Eragrostis tremula* and *Cenchrus biflorus* scored the lowest percentage. On the other hand, *Zornia glochidiata* scored the highest % plant frequency (52.78), followed by (*Cenchrus ciliaris, Stylosanthes hamata* and *Macroptilium atropurpureum,* whereas *Digitaria ciliaris, Cenchrus biflorus* and *Brachiaria deflexa* scored the lowest % frequency (2.78). During the second period, *Stylosanthes hamata* recorded the highest percent plant composition (26.14), followed by *Cenchrus ciliaris* and *Macroptilium atropurpureum.* While *Eragrostis termula, Brachiaria xanthleuca* and *Brachiaria deflexa* scored the lowest percentage of both plant composition and frequency. On the other hand, *Cenchrus ciliaris* scored the highest % plant frequency (50), followed by *Zornia glochidiata, Stylosanthus hamata* and *Macroptilium atropurpureum*. It was observed that the highest percent plant composition and frequency were generally obtained by sown pasture (introduced) compared to the local pasture.

Table 4.10. Plant composition of the study site during the second season. (experiments two 2001/02).

Botanical name	Period (week)	Grazing site			Ungrazed site		
		Plant number 0.25 m^2	Comp %	Frequ %	Plant number 0.25 m^2	Comp %	Frequ %
Cenchrus ciliaris	4	80	19.56	50.00	152	27.33	50.0
	8	54	20.45	50.00	97	21.36	50.0
Stylosanthes hamata	4	73	17.85	33.33	114	20.5	33.33
	8	69	26.14	33.33	111	24.45	33.33
Macroptilium atropurpureum	4	52	12.71	33.33	46	8.27	33.33
	8	39	14.77	33.33	30	6.66	27.78
Zorina glochidiata	4	40	9.78	52.78	37	6.65	52.78
	8	24	9.10	41.67	31	6.83	41.67
Aristida spp.	4	36	8.80	25.0	21	3.78	36.11
	8	17	6.44	13.89	19	4.19	36.11
Schoenefeldia gracilis	4	25	6.11	27.78	3	0.54	5.56
	8	15	5.68	16.67	3	0.66	5.56
Clitoria ternatea	4	29	7.10	30.56	48	8.63	33.33
	8	17	6.44	27.78	40	8.81	33.33
Dactyloctenium aegyptium	4	14	3.42	22.22	7	1.26	13.89
	8	9	3.40	11.11	7	1.52	13.89
Tribulis terrstris	4	13	3.18	27.78	1	0.18	2.78
	8	9	3.40	19.44	1	0.22	2.78
Sporobolus iocladus	4	8	1.96	16.67	2	0.36	2.78
	8	5	1.89	13.89	2	0.44	2.78
Tephrosia uniflora	4	7	1.71	13.89	2	0.36	2.78
	8	2	0.76	5.56	0	0.0	0.0
Digitaria ciliaris	4	3	0.73	2.78	5	0.9	2.78
	8	0	0.0	0.0	5	1.10	2.78
Brachiaria xantholeuca	4	3	0.73	2.78	-	-	-
	8	1	0.38	2.78	-	-	-

Brachiaria deflexa	4	1	0.24	2.78	-	-	-
	8	1	0.38	2.78	-	-	-
Eragrostis tremula	4	1	0.24	2.78	40	7.19	52.78
	8	1	0.38	2.78	56	12.33	52.78
Cenchrus biflorus	4	1	0.24	2.78	1	0.18	2.78
	8	0	0.0	0.0	1	0.22	2.78
Chloris virgata	4	20	4.89	25.0	-	-	-
	8	10	3.79	16.67	-	-	-
Corchorus olitorius	4	5	1.22	11.11	14	2.52	25.0
	8	0	0	0	12	2.64	22.22
Hypoestes cancellata	4	1	0.24	2.78	5	0.9	8.33
	8	0	0	0	1	0.22	2.78
Ipomea spp.	4	-	-	-	9	1.62	11.11
	8	-	-	-	3	0.66	2.78
Chlorophytum tuberosum	4	-	-	-	3	0.54	8.33
	8	-	-	-	1	0.22	2.78
Alysicarpus ovalifolius	4	-	-	-	1	0.18	2.78
	8	-	-	-	0	0	0
Commelina spp.	4	-	-	-	4	0.72	8.33
	8	-	-	-	4	0.88	8.33
Solanum dubium	4	-	-	-	4	0.72	8.33
	8	-	-	-	4	0.88	8.33
Geigeria alata	4	-	-	-	1	0.18	2.78
	8	-	-	-	0	0	0
Oldlandia sengalensis	4	-	-	-	32	5.76	36.11
	8	-	-	-	21	4.63	30.56
Others	4				4	0.72	8.33
	8				4	0.88	8.33

4.5.2. Ungrazed range site:

Table 4.11 shows the percent plant composition and frequency during the first season in the first period (4 weeks). The vegetation measurement showed that the highest plant composition percentage was recorded by *Oldlandia senegalensis* (36.25) followed by *Zornia glochidiata, Stylosanthes hamata* and *Cenchrus ciliaris,* whereas *Cenchrus biflorus* and *Commelina spp.* scored the lowest percentage (0.13) followed by *Alysicarpus ovalifolius.* During the second period, *Zornia glochidiata* scored the highest percent plant composition (35.36) followed by *Oldlandia senegalensis, Stylosanthes hamata* and *Cenchrus ciliaris,* while *Tribulis terrestris* and *Commlenia spp* scored the lowest percentage (0.01) followed by *Chlorophytum tubarosum*. However, in the first period, *Zornia glochidiata* scored the highest percent plant frequency (91.67) followed by *Oldlandia senegalensis* and *Cenchrus ciliaris,* while *Cenchrus biflorus* and *Commlenia spp* scored the lowest percentage (3.33) followed by *Alysicarpus ovalifolius* (11.11). During the second period, *Zornia glochidiata* scored the highest percent frequency (88.89) followed by *Oldlandia senegalensis* and *Cenchrus ciliaris*, whereas *Tribulis terrestris* scored the lowest percentage (2.78) followed by *Commlenia spp* and *Chlorophytum tubarosum*.

Table 4.11. Plant composition in the study site during the two seasons. Experiments one (Ungrazed site).

Botanical name	Period (week)	2000/01			2001/02		
		Plant number 0.25 m^2	Comp %	Frequ %	Plant number 0.25 m^2	Comp %	Frequ %
Oldlandia sengalensis	4	861	36.25	63.89	1435	14.58	38.89
	8	635	32.45	66.67	120	2.99	11.11
Zorina glochidiata	4	768	32.0	91.67	4334	44.04	100.00
	8	692	35.36	88.89	2158	53.75	91.67
Cenchrus ciliaris	4	141	5.94	50.0	35	0.36	25.0
	8	128	6.54	50.0	23	0.57	25.0
Aristida spp.	4	60	2.53	50.36	1876	19.06	100.00
	8	45	2.31	57.70	1050	26.50	88.89
Stylosanthes hamata	4	164	6.90	33.33	20	0.20	16.67
	8	173	8.84	33.33	14	0.34	16.67
Chloris virgata	4	8	0.34	13.89	257	2.61	27.78
	8	17	0.87	13.89	14	0.35	16.68
Macroptilium atropurpureum	4	77	3.24	33.33	-	-	-
	8	59	3.01	33.33	-	-	-
Tephrosia uniflora	4	54	2.27	33.33	8	0.08	13.89
	8	13	0.66	19.44	1	0.02	2.78
Clitoria ternatea	4	36	1.52	33.33	-	-	-
	8	26	1.33	27.78	-	-	-
Eragrostis tremula	4	33	1.39	44.44	131	1.33	25.00
	8	40	2.04	52.78	11	0.27	11.11
Dactyloctenium aegyptium	4	5	0.21	5.56	635	6.45	94.44
	8	7	0.36	13.89	323	8.04	58.33
Digitaria ciliaris	4	12	0.51	11.11	112	1.14	16.67
	8	11	0.56	11.11	41	1.02	16.67
Geigeria alata	4	14	0.59	19.44	9	0.09	11.121
	8	41	2.09	47.22	2	0.5	2.27

Cenchrus biflorus	4	3	0.13	8.33	197	2.00	77.78
	8	4	0.20	11.11	55	1.37	38.89
Solanum dubium	4	19	0.8	25.0	10	0.10	16.67
	8	17	0.87	25.0	7	0.17	11.11
Chlorophytum tuberosum	4	5	0.21	8.33	14	0.14	8.33
	8	3	0.15	8.33	3	0.07	5.56
Ipomea spp.	4	7	0.29	13.89	47	0.48	55.56
	8	5	0.26	11.11	16	0.40	19.44
Fimbristylis dichotoma	4	18	0.76	10.56	25	0.25	11.11
	8	9	0.46	16.67	-	-	-
Commelina spp.	4	3	0.13	8.33	24	0.24	8.33
	8	2	0.10	5.56	15	0.37	8.33
Alysicarpus ovalifolius	4	4	0.17	11.11	2	0.02	5.56
	8	6	0.31	16.67	-	-	-
Ocimum spp.	4	37	1.56	13.89	-	-	-
	8	-	-	-	-	-	-
Corchorus olitorius	4	8	0.38	16.67	23	0.23	36.11
	8	6	0.31	13.89	2	0.05	8.33
Tribulis terrstris	4	6	0.25	8.33	105	1.07	66.67
	8	2	0.10	2.78	53	1.32	36.11
Schoenefeldia gracilis	4	11	0.46	10.31	525	5.33	55.56
	8	7	0.35	8.97	99	2.47	30.56
Brachiaria xantholeuca	4	-	-	-	2	0.02	2.78
	8	-	-	-	1	0.02	2.78
Brachiaria deflexa	4	-	-	-	2	0.02	2.78
	8	-	-	-	2	0.05	2.78
Other	4	20	0.83	29.47	14	0.14	25.01
	8	9	0.46	19.45	5	0.12	2.78

In the second season, during the first and second periods *Zornia glochidiata* recorded the highest percent plant composition and frequency of (44.04, 54.75) and (100 and 91.67), respectively. followed by *Aristids spp., Oldlandia senegalensis* and *Dactyloctenium aegyptium.* While *Brachiaria xantholeuca, Brachiaria deflexa*, and *Alysicarpus ovalifolius* scored the lowest percent plant composition and frequency of 0.02 and 2.78, respectively.

In experiment two, during the first period, *Cenchrus ciliaris* scored the highest percent plant composition (27.33) followed by *Stylosanthes hamata*, *Clitoria ternatea* and *Eragrostis tremula*. Whereas *Alysicarpus ovalifolius, Gerigeria alata* and *Cenchrus biflorus* scored the lowest percentage of (0.18). On the other hand, the higher percent plant frequency were recorded by *Zornia glochidiata* and *Eragrostis tremula* (52.78) followed by *Cenchrus ciliaris, Stylosanthes hamata* and *Clitoria ternatea.*

The lowest percent plant frequency was recorded by *Alysicarpus ovalifolius*, *Gerigeria alata* and *Cenchrus biflorus*. During the second period (8 weeks), *Stylosanthes hamata* scored the highest percent plant composition (24.45) followed by *Cenchrus ciliaris*, *Eragrostis tremula* and *Clitoria ternatea,* while *Hypoestes cancellata*, *Chlorophytum tuberosum* and *Cenchrus biflorus*, recorded the lowest percent plant composition and frequency of 0.22 and 2.78, respectively. The highest percent plant frequency was scored by

Eragrostis tremula (52.78) followed by *Cenchrus ciliaris, Zornia glochidiata* and *Aristida spp.*

4.5.3. Overstory vegetation:

The vegetation measurement of overstory (Table 4.12) indicated that *Boscia senegalensis* scored the highest percent plant composition and plant frequency of 45.10 and 84.7 respectively, followed by *Acacia tortilis* and *Acacia senegal.* Whereas, *Combretum glutinosum* recorded the lowest percentage of 0.25 and 1.4 of plant composition and frequency respectively, followed by *Acacia nilotica, Calotropis procera* and *Grewia tenax*.

Table 4.12. Tree and shrub composition and frequency in the study site (during two seasons) 1.08 ha.

Botanical name	Trees and shrubs number 300 m^2	Composition %	Frequency %
Boscia senegalensis	183	45.10	84.7
Acacia tortilis	107	26.40	52.8
Acacia Senegal	57	14.03	30.6
Acacia nubica	17	4.20	26.4
Combretum aculeatum	12	3.00	20.8
Balanites aegyptiaca	8	2.00	6.9
Cadaba farinosa	6	1.50	8.3
Grewia villosa	4	1.00	5.6
Cordia rothii	3	0.74	4.2
Capparis decidua	3	0.74	4.2
Grewia tenax	2	0.50	2.8
Calotropis procera	2	0.50	2.8
Acacia nilotica	2	0.50	2.8
Acacia mellifera	2	0.50	2.8
Adenium obesum	2	0.50	2.8
Combretum glutinosum	1	0.25	1.4

4.6. Grazing management and animal performance:

4.6.1. Carrying capacity and stocking rate:

According to the annual dry matter production of the improved grazing range site (exclosure), carrying capacity and stocking rate were calculated, following Suliman and Darag method (1988), which involves:

1. Daily animal unit requirement as 11.0 kg/day.
2. Dry forage yield/ha obtained from the samples.

Then the animal unit per hectare was calculated as per day, per month and per year on the basis of the following equations:

1. Animal unit/ha/day = $\frac{\text{D.M production}}{\text{daily animal requirement}}$

2. Animal unit/ha/month = $\frac{\text{A.U / ha / day}}{30}$

3. Animal unit/ha/year = $\frac{\text{A.U / ha / month}}{12}$

4. Carrying capacity = $\frac{1}{\text{Number of animal unit}}$

5. Stocking rate = $\frac{\text{Site total area}}{\text{ha, Au / yr}}$

A.U. = Animal Unit (1 cow, or 1.25 camel or 0.2 sheep or goat).

D.M. = Dry matter

M. = Month

yr = year.

In the first season the average dry matter produced per hectare was 576kg, hence the carrying capacity and stocking rate were calculated:

1. Animal unit/ha/day = $\frac{576\text{kgs}}{11\text{kgs}}$ = 52.4/ha/day.

2. Animal unit/ha/month = $\frac{52.4 / \text{ha} / \text{day}}{30}$ = 1.75/ha/m.

3. Animal unit/ha/1.5m = $\frac{1.75 / \text{ha} / \text{m}}{1.5}$ = 1.17/ha/1.5m

4. Carrying capacity = $\frac{1}{1.17}$ = 0.85/ha/Au/1.5m

5. Stocking rate = $\frac{1.08\text{ha}}{0.85\text{ha} / \text{Au} / 1.5\text{m}}$ = 1.3 A.u

Therefore the number of rams supposed to graze the range site (exclosure) = 1.3A.U × 5 sheep = 6.5 = 7 rams.

In the second season the average dry matter produced per hectare was 717.3 kgs, thus carrying capacity and stocking rate were calculated:

1. Animal unit/ha/day = $\frac{717.3\text{kgs}}{11\text{kgs}}$ = 65.2/ha/day.

2. Animal unit/ha/month = $\frac{65.2/\text{ha}/\text{day}}{30}$ = 2.2/ha/m.

3. Animal unit/ha/1.5m = $\frac{2.2/\text{ha}/\text{m}}{1.5}$ = 1.47/ha/1.5m

4. Carrying capacity = $\frac{1}{1.47}$ = 0.68 ha/Au/1.5m

5. Stocking rate = $\frac{1.62\text{ha}}{0.68\text{ha}/\text{Au}/1.5\text{m}}$ = 2.38 A.U

Thus, the number of rams supposed to graze the range site = 2.38 A.U × 5 sheep = 12 rams.

4.6.2. Rams body weight performance:

The result showed that (Table 4.13) in both seasons the rams body weights were significantly affected by grazing an improved pasture. In the first and second seasons, the heaviest body weights recorded after 15 days from grazing the exclosure were 3.3kg and 2.2kg, respectively. The lightest body weights recorded were 0.14 kg and – 0.81 kg after 15 days of grazing at the third period, respectively. On the other hand, the heaviest body weight scored after 15 days of grazing the traditional open range area were 0.93 kg and 0.92 kg at the first period in the first and second seasons, respectively. While the lightest body weights were – 1.4 kg and – 1.71 kg after 15 days of grazing of the third period of both seasons, respectively.

However, the body weight gained by rams utilizing the exclosure was higher than that of the traditional open grazing area in the two seasons. It was observed that as dry season advanced, the body weight decreased till it reached a negative value (Plates 4.6, 4.7 and Appendix 14).

Table 4.13. Animal performance as affected by grazing management of improved and traditional rangelands

Treatments	1st season (2000/01)			2nd season (2001/02)		
Body weight / Grazing	BWT_1 15 days	BWT_2 30 days	BWT_3 45 days	BWT_1 15 days	BWT_2 30 days	BWT_3 45 days
Exclosure	3.33[a]	1.24[a]	0.14[a]	2.2[a]	1.81[a]	-0.81[a]
Open grazing	0.93[b]	-0.50[b]	-1.46[b]	0.92[b]	-1.25[b]	-1.71[b]
SE ± (Exclosure)	0.18	0.27	0.35	0.55	0.53	0.27
SE ± (Open grazing)	0.20	0.29	0.33	0.40	0.38	0.19

Means followed by the same letter(s) in a given column are not significantly different at 0.05 level according to Duncan Multiple Range Test.

BWT: Body weight

Plate 4.6. Improved range exclosure before grazing

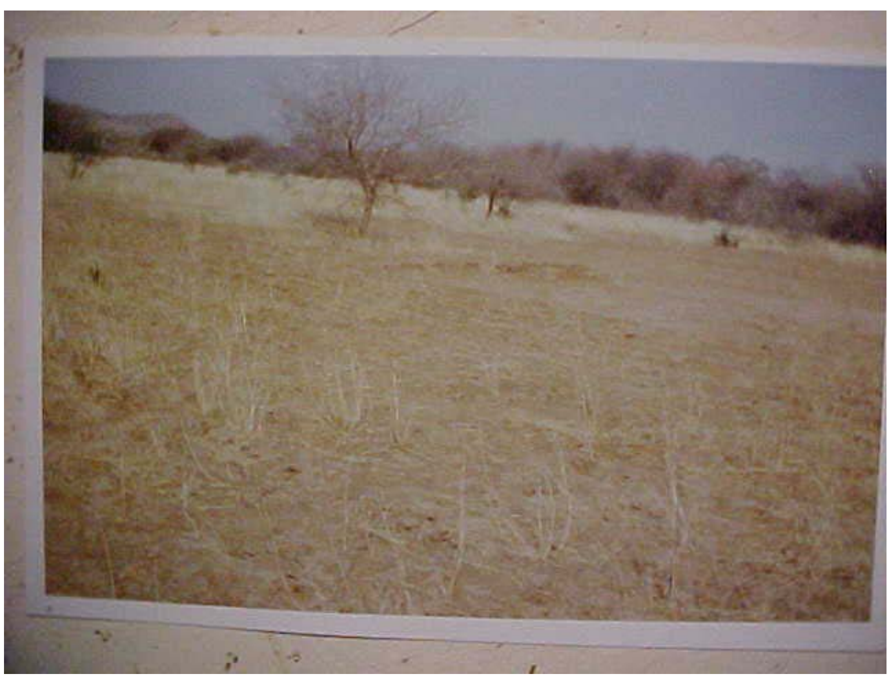

Plate 4.7. Improved range exclosure after grazing

HAPTER FIVE

DISCUSSION

5.1. Effect of treatments on soil moisture content (%) plant growth and yield:

5.1.1 Effect of pasture species

Generally, the pasture species had no significant effect on soil moisture content. The effect that appeared at the upper soil layer (25cm) as well as at the lower layer (75cm) at the beginning and the end of rainy season, could be due to the soil moisture availability, and the competition efficiency of pasture species to absorb soil moisture at different depths. This is in agreement with Renner (1995) who found that pasture mixture had a diversity in root distribution, which help in fully utilization of available moisture and soil nutrients.

On the other hand, pasture species had affected plant growth attributes, particularly. Plant density, % vegetative cover and % survival rate. However, *Stylosanthes hamata* and *Cenchrus ciliaris* as a mixture and *Stylosanthes hamata* as pure stand had the highest plant density. This might be explained by, that these two pasture species have the ability to tolerate drought and to compete effectively with other pasture species for soil moisture and nutrients in semi-dried areas. This is in agreement with Skerman and Riveros (1989) and Crowder (1982). They concluded that *Cenchrum ciliaris* is characterized by hardiness, deep-rooting ability to grow in arid areas and usually dominate weeds, while *Stylosanthes hamata* is characterized by vigorous growth and compete well with weeds, and both pasture species are persistence and drought tolerance. Low plant densities were scored by *Clitoria ternatea* and *Macroptilium atropurpureum.* This may be attributed to unsuitable seedbed preparation and poor seeds coverage because of their bigger seed size. In addition to that the total amount of rainfall during the two seasons did not exceed 250mm and this could be below the plant water requirement of the two species. This is in line with Skerman *et al*. (1988) who reported that *Clitoria ternatea* and *Macroptilium atropurpureum* grow well under annual rainfall of 400mm and 600mm respectively.

During the experimental period, the higher plant survival rate percentage scored by *Stylosanthes hamata* as pure stand and as a mixture with *Cenchrus ciliaris,* while *Clitoria ternatea* scored the lower percentage. This could be explained on that, these perennial pasture species, *Stylosanthes hamata* and *Cenchrus ciliaris,* have higher competitive ability to utilize soil moisture and dominate other plants in semi-arid conditions, whereas *Clitoria ternatea* was not. This is in agreement with Penning (1983) and Marietta and Britton (1989). They found that many seedlings and germinating seeds died shortly after germination because of prolonged dry periods between rains. Only an average of about 10% of germinated seeds survived.

Regarding percent vegetative cover during the study period, the pasture species had a significant effect on percent vegetative cover. This effect could be attributed to the different pasture species, and their ability to compete with other plants for the limited soil moisture and nutrients. In the first season in experiment one, it was observed that the percent vegetative cover increased as the pasture plant growing period advanced, but in the second season in experiment one, at the second period the percent vegetative cover was lower than the first period of the same experiment. This may be due to low amount of rainfall and long drought period. It was also noticed that in the first season in experiment one, the percent vegetative cover in plots ploughed by spike toothed harrow was higher than that ploughed by spring toothed cultivator. This could be due to the small removed area of native plants by spike toothed harrow compared to spring toothed cultivator. In the second season in experiment one the percent vegetative cover results were reversed. The percent vegetative cover of plots ploughed by spring toothed cultivator were higher than that ploughed by spike toothed harrow. This could be explained on that, deep ploughing ease infiltration rate of rain water and thus soil moisture could be available within the plant root zone and hence the pasture species can grow vigorously and covered a large area.

During the two seasons in experiments one and two, pasture species had a significant effect on forage yield. This may be explained on that each pasture species has different ability to compete with other plants for plant growth and development factors such as soil moisture, soil nutrients, air and temperature, in order to germinate, establish and produce dry matter and seeds.

Among the introduced pasture species in the first season only *Stylosanthes hamata* and *Cenchrus ciliaris* were established well and produced forage and seeds. Moreover, *Stylosanthes hamata* with *Cenchrus ciliaris* as a mixture outyielded *Stylosanthes hamata* as a pure stand. This is in agreement with Pyke and Archer (1991). They reported that a diversity of species and growth forms may provide a more stable cover and productivity than a monoculture on sites characterized by environmental variability. In both seasons indigenous pasture species outyielded the introduced species and this could be attributed to the adaptability of indigenous species to the local environment, whereas exotic species may need a period of time to adopt itself to the new environment. This in line with Cook and Lowe (1977). They found that native and weed species present in a certain area are often better adapted to indigenous environment than the introduced pasture species.

5.1.2. Ploughing methods:

Generally, in both seasons the ploughing methods had no significant effect on percent soil moisture content. This could be attributed to variability in annual rainfall in terms of amount, interval, intensity and distribution. This is in agreement with Cowder (1982), Ridder (1982) and Call and Roundy (1991). They concluded that rainfall is the greatest single factor affecting plant growth and herbage dry matter production in most of the tropics and sub-tropics, Suliman (1980) also found that precipitation is regarded as the most single factor influencing emergence, growth and productivity of pasture plants in arid environment.

Moreover, ploughing methods had no significant effect on plant growth attributes and forage yield, but it was noticed that, plots which were ploughed by spring toothed cultivator, produced dry matter slightly higher than that produced by spike toothed harrow. This could be explained on that deep ploughing may conserve more soil moisture for better plant growth and development.

5.1.3. Grazing management:

It was noticed that grazing management had no significant effect on percent soil moisture content, plant growth attributes such as plant density, percent vegetative cover, plant survival rate percentage as well as forage yield and ploughing methods during the experimental period. The effect of grazing management on soil moisture at upper soil layer (25cm) during the first period in the first season, in the area which allocated for grazing, had higher percent soil moisture content than the ungrazed range site. This could be attributed to previous land use practices such as cultivation, in grazed areas.

Regarding plant growth attributes, the grazing of rams for a period of two years, it may not be enough time to give its impact on revegetation of range land of introduced perennial pasture species in semi-arid zone. That may need ample time to adapt to the local environment and get well established. According to our several years of experience in the study area the introduced perennial pasture may need five years or more to establish well and then the effect of grazing could be clear (Western Savanna Development Project Annual Reports 1982-1997) . This in agreement with Ellis and Swift (1988); who found that livestock may, in the long-run, alter the structure and composition of the plant community.

In the second season in experiment one, it was noticed that the introduced pasture species within the grazed exclosure produced dry matter slightly lower than the ungrazed one. This could be due to the fact that the introduced perennial pasture species in the first season had been selectively grazed by rams and consequently its regrowth during the second season become low. Sprague (1979), stated that the young growth made by introduced plants is highly palatable. All grazing of newly seeded areas should be prohibited until the new species have produced a crop of seed. Further protection is needed to be provided by good management to maximize forage production on continuing basis. Moreover, Ellis and Swift (1988), reported that livestock grazing have no role in regulating yearly plant production, only a minor role in regulating biomass levels and consequently little or no role in regulating the amount of forage available. Interactions between all treatments could be due to previous land use practices in the study area, such as overgrazing, shifting cultivation and tree cutting (Appendices 4-10).

Seeds produced by introduced species were low compared to the seed produced by the same species under favourable environmental conditions. Renard (2001) found that under favourable conditions in the arid and semi-arid zone, *Cenchrus ciliaris* and *Stylosanthes hamata* produced a minimum of 100 and 75 kg/ha respectively, in the growing season, whereas the average seeds produced during the two growing seasons was 75 kg/ha of *Cenchrus ciliaris* and 5 kg/ha of *Stylosanthes hamata*. This could be attributed to the low and erratic annual rainfall. In addition, some seeds may be harvested by ants and eaten by birds, which are considered as a seed loggers.

5.2. Evaluation of current status of rangelands vegetation in the study area:

5.2.1 Forage quality

It is a fact that normally pasture legumes are rich in crude protein and low in crude fiber, while grasses are low in protein and high in fiber depending on their age. The chemical composition of the studied pasture species indicated that annul indigenous grass *Dactyloctenium aegyptium* was superior to introduced perennial grass

Cenchrus ciliaris in both crude protein and crude fiber contents. Moreover, among the introduced and indigenous pasture legumes, *Macroptilium atropurpureum* was rich in crude protein followed by *Alysicarpus ovalifolius* which is an annual indigenous legume. In general indigenous legumes showed low crude protein and high crude fiber compared to introduced species. This study indicated that there may be many indigenous pasture species both legumes and grasses could be of high quality and may be used in reseeding of degraded rangelands of arid and semi-arid areas.

Generally, the results indicated that indigenous pasture species in the study area are rich in crude fiber and low in crude protein. This is in agreement with Mohamed (1991) who stated that native species are relatively deficient in protein and rich in fiber contents. Therefore, pasture is not sufficient even to provide the maintenance requirements of the animals.

5.2.2. Plant composition and frequency:

The result of the vegetation survey indicated that plant composition consisted of 24% grass, 40% forbs and 36% trees and shrubs. Concerning herbaceous composition and occurrence, there was no clear differences between grazed and ungrazed exclosure in the two seasons. This could probably be due to the fact that the clear impact of range management and improvement practices such as reseeding, livestock grazing and mechanical treatments may require a longer period (more than two years) in order to make a clear change in plant composition in the study area. The most dominant pasture species were found to be *Zornia glochidiata, Oldlandia senegalensis, Cenchrus ciliaris* and *Aristida spp.* This could indicate that these pasture species had ability to tolerate drought and most adapted to local environment. These species may be considered as moderately palatable and increasing in numbers and occurrence. Thus, these species can be ranked as increasers. The current existing palatable pasture species in the study area were found to be fewer in numbers and rare in occurrence and can be considered as decreaser. These include *Alysicarpus ovalifolius, Blepharis linariifolia, Dactyloctenium aegyptium* and *Sporobolus iocladus.* The decreasing number of these palatable species could be mainly attributed to overstocking during early growing season in the study area. Among the plant community, fewer unpalatable plants such as *Alliums pp*, *Geigeria alata* and *Vigna sum-hum,* were noticed. These species might have appeared in the study area as a result of overgrazing and could be ranked as invaders. These species could decreased in number if rangelands is properly managed or (their numbers could be increased if rangelands is poorly managed).

5.3. Carrying capacity and livestock performance:

The results indicated that there was a significant difference in body weight gain between treated and controlled rams. In the first season of the grazing trial, the average body weight gained by treated rams, at the first and the second grazing periods was 10% and 3.4%, respectively, while body weight declined by 2% at the third period. During the second season the body weight gain of the treated rams followed the same trend. This could be explain on that the introduced pasture species which contributed to the total dry matter production by 20% may provide adequate quality and quantity of forage to the grazing rams during the first grazing period. This high quality forage might start to decline in quality due to selective grazing of rams during the first and the second grazing periods. This is in agreement with Sprague (1979), who found that growth and weight gains cease when feed supply is in adequate; and weight losses are gained very slowly when feeds are again more adequate.

On the other hand, the average body weight of rams grazing traditional open grazing areas increased by 3% in the first grazing period. In the second and the third grazing periods the rams body weights declined by 1.4% and 4% respectively. This could be due to the fact that the rangelands of the study area is annually decreasing, because annual traditional rainfed cultivation is increasing. Moreover, livestock heavily grazed these areas during the growing season. Therefore, the remaining forage could be below grazing rams requirements during long dry season, and thus rams body weight loss may occur. This is in line with Ellis and Swift (1988). They stated that in most livestock species, diet quality drops to maintenance level by the mid-dry season, and loss of condition and reduction of production continue for several months, until the following rainy season. Generally, the results of the grazing trial, indicated that as grazing period advance towards the end of the dry season, rams body weights declined for both rams that grazing inside the exclosure and that grazing the traditional open areas. This is in agreement with Crowder; (1982) and Lt'mannetie (1976). They concluded that a rapid decline in herbage nutritive value of predominantly grass-based grazing lands imposes an additional constraints, so that animals loose a high proportion of the live weight gained in the rainy season.

Summary and conclusion

The results of this investigation revealed that, the introduced perennial pasture species, namely *Stylosanthes hamata* c.v. *verano* and *Cenchrus ciliaris* are likely to be suitable for revegation of degraded rangelands under rainfed in semi-arid conditions, when proper ploughing and grazing management methods are used. Among the introduced pasture species *Stylosanthes hamata* as pure stand and in mixture with *Cenchrus ciliaris* scored better results in plant density % vegetative cover, survival rate and forage yield.

In general ploughing by spring toothed cultivator resulted in a better soil moisture content, plant growth attributes and forage yield compared to the spike toothed harrow.

It was found that the study area was dominated by herbs (40%) e.g. *Zornia glochidiata* and *Oldlandia senegalensis*, followed by trees and shrubs (36%) e.g. *Bosica senegalensis* and *Acacia tortilis,* and grasses (24%) e.g. *Aristida* spp and *Chloris virgata.* The plant composition and frequency in both exclosures (grazed and ungrazed) were almost the same. Among the introduced pasture species *Cenchrus ciliaris* and *Stylosanthes hamata* were able to compete well with indigenous species. In general forage quality of pasture legumes was higher in crude protein content and lower in crude fiber compared to the pasture grasses.

Regarding grazing trial, it was found that utilization of improved pasture by rams according to estimated carrying capacity resulted in a significant difference in body weight gain compared to the rams that utilized the traditional grazing area at the same time.

Future prospect and recommendations

Prospects of pasture implementation of rangelands improvement by reseeding is likely to be successful and encouraging if appropriate land use and planning are practiced e.g. utilization of land should be according to its potential and grazing rights should be applied to allocated grazing areas.

Further research is needed to determine effective establishment techniques for those perennial pasture species that were able to be maintained in the study area namely *Stylosanthes hamata* and *Cenchrus ciliaris,* and the indigenous species namely Dactyloctenium ageyptium, Alysicarpus evalifolius and Chloris virgata

Based on the findings of the study, it is recommended the following points to be tested at farm level:

a Introduction of fodder bank into farming systems.

b Establishment of community exclosures.

c Introduction of crop residues treatments

d Hay and silage making.

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Appendices

Appendix 1. Monthly rainfall (mm) data at the experiments site during the first and second seasons

First season 2000/01		Second season 2001/02	
Date / month	Amount in mm	Date / month	Amount in mm
2.6	3.5	27.5	3.0
30.6	3.5	10.6	3.0
9.7	14.0	14.6	6.0
20.7	5.0	27.6	7.0
24.7	33.0	28.6	30.0
30.7	3.5	4.7	38.0
3.8	22.0	8.7	14.0
13.8	15.0	12.7	11.0
16.8	4.0	6.8	11.0
26.8	24.0	9.8	28.0
11.9	22.0	10.8	3.5
14.9	24.0	23.8	6.0
25.9	30.0	9.9	6.0
7.10	35.0	11.9	46.0
		13.9	14.0
		17.9	20.0
Total	**238.5mm**		**246.5mm**

Appendix 3. The form of the analysis of variance and expected mean squares of nested design.

Source of variance	d.f.	TSS	MS	$F_{cal.}$	$F_{tab.}$
Replication (R)					
Main plot factor (A)					
Management (M)					
Ploughing (P)					
Error (a)					
Sub plot factor (b)					
Plant species					
Total					

Where:

r = number of replications.

a = main factor level (management + ploughing)

b = sub plot factor level (plant species).

$m_1, m_2, \ldots, m_n$ = mean square.

Appendix 4. Effects of treatments interactions on soil moisture content percentage at 50cm and 75cm depths during July 2000-2001 (first season)

Experiment 1

Treatment		Depths	
Grazing Management	Ploughing	50cm	75cm
M_1	PL_1	6.44b	3.12c
	PL_2	7.91a	4.70a
M_2	PL_1	7.06ab	4.47ab
	PL_2	6.45b	3.69bc

M_1= Animals are allowed to graze.

M_2= Animal are not allowed to graze.

Appendix 6. Effects of treatments interactions on % vegetation cover at flowering stage (8 weeks) during 2000-2001 (first season)

Experiment 1

Treatments	Grazing Management	
Pasture species	M_1	M_2
Stylosanthes hamata	40.83^{bc}	40.83^{bc}
Macroptilium atropurpureum	60.83^{a}	45.83^{ab}
Clitoria ternatea	52.50^{ab}	20.00^{e}
Stylosanthes hamata + cenchrus ciliaris	40.83^{bc}	42.50^{bc}
Macroptilium atropurpureum + cenchrus ciliaris	38.33^{bc}	20.00^{e}
Clitoria ternatea + cenchrus ciliaris	23.33^{de}	30.00^{cd}

Appendix 7. Effects of treatments interactions on % vegetation cover at flowering (23/9/2000) and maturity (23/10/2000) stages during 2000-2002

Experiment 1

Treatment		Stage of growth	2000/01	2001/02
Grazing Management	Ploughing			
M_1	PL_1	Flowering	32.50ab	32.50ab
	PL_2	Flowering	53.05a	24.44ab
M_2	PL_1	Flowering	27.50b	48.05ab
	PL_2	Flowering	38.88ab	31.94ab
M_1	PL_1	Maturity	38.05c	51.38ab
	PL_2	Maturity	53.61a	30.27b
M_2	PL_1	Maturity	46.66ab	53.88a
	PL_2	Maturity	45.00bc	34.72b

Appendix 8. Effects of treatments interactions on % vegetation cover at different periods of plant growth during 2001/02

Experiment I

Treatments		Flowering 23/9/2000	Maturity 24/11/2000
Plant species	Ploughing		
Stylosanthes hamata	PL_1	42.50ab	62.50ab
	PL_2	33.33bc	39.16bc
Macroptilium atropurpureum	PL_1	24.16cd	33.33c
	PL_2	36.66bc	40.00bc
Clitoria ternatea	PL_1	25.83cd	37.50bc
	PL_2	23.33d	23.33c
Stylosanthes hamata + cenchrus ciliaris	PL_1	54.16a	55.00ab
	PL_2	25.00cd	30.00c
Macroptilium atropurpureum + cenchrus ciliaris	PL_1	48.33ab	59.16ab
	PL_2	20.83d	25.00c
Clitoria ternatea + cenchrus ciliaris	PL_1	46.66ab	68.33a
	PL_2	30.00bc	37.50bc

Appendix 15: Design of El Odaya town perimeter