EFFECTS OF WOODY SPECIES THINNING ON HERBACEOUS LAYER

CHARASTERISTICS OF A WOODED GRASSLAND COMMUNITY IN

KIBWEZI, MAKUENI DISTRICT KENYA.
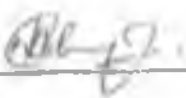
By

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTER OF SCIENCE IN RANGE MANAGEMENT,

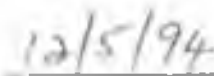FACULTY OF AGRICULTURE, UNIVERSITY OF NAIROBI.

SEPTEMBER 1996

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.
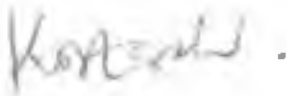
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Michael Kinma Gachanja   Date

This thesis has been submitted for examination with our approval as university supervisors.

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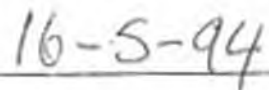Dr. Kassim O. Farah,   Date

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DEDICATION

This thesis is dedicated to my parents, Mr. Boniface Gachanja and Mrs. Grace Wairimu for their encouragement and patience when I was undertaking my project.

III

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

VI

LIST OF TABLES

LIST OF FIGURES

APPENDICES

XI

ABSTRACT

In Kibwezi Dryland Field Station, Makueni district, the
vegetation has changed physiognomically from grassed shrubland
to dense wooded shrubland making the area unsuitable for
cattle grazing. In October 1992 a study was initiated to
document overstorey-understorey relationships following tree
and shrub thinning.

Four treatments of varying tree and shrub density each
replicated four times were randomly imposed in plots measuring
20m by 15m. They consisted of thinning trees and shrubs to the
following canopy covers, 0% (complete clearing), 35.5% (500
shrubs and 167 trees/ha), 55.3% (1167 shrubs and 167 trees/ha)
and an average of 67.6% (unthinned treatment with
approximately 1800 shrubs and 400 trees/ha).

A clipping method was used to determine the biomass of
herbaceous species while their basal cover and frequency was
obtained by the point frame method. Average biomass production
and basal cover of herbage components (grasses and forbs) for
the study period in relation to woody canopy cover was
analysed using F-test statistic. To quantify these
relationships, simple linear and quadratic regression analyses
were conducted.

Canopy cover reduction had significant effects ($P<0.05$) on increases in biomass production and basal cover of grasses, forbs, and total herbage. There was a strong relationship between biomass production, basal cover and frequency of herbaceous species with the overstorey canopy cover. The relationship between woody canopy cover and herbage production was described by a 2nd degree polynomial equation, i.e. $y^- = 3493.4 - 9.806x - 0.171x^2$ ($p=0.0001$, $r^2=0.946$, $n=16$). The equation $y^- = 12.07 - 0.013x - 0.0005x^2$ ($p=0.0001$, $r^2=0.966$, $n=16$) described the relationship between woody canopy cover and basal cover of total herbage. When linear regression equations were fitted for the two vegetal classes (forbs and grasses) at varying woody canopy cover, the overall rate of biomass and basal cover increase for grasses was slightly higher than forbs. Forbs did better at the lightly thinned treatments.

Competition between woody and herbaceous species both in the tree and shrub canopy zone and in their root zone reduced performance of herbaceous species in the lightly thinned treatments. A degree of protection from competition will give herbaceous species advantage over woody species; this can be achieved through thinning as shown by results of this study.

XIII

It was concluded from the data that in order to maximize herbage production, tree and shrub density should be reduced to achieve a canopy cover of not more than 35.5%. After achieving the desired production potential, a balance between herbaceous plants and woody species should be maintained through cattle grazing and fire.

1.   INTRODUCTION

    The rangelands of Kenya are important resources
covering 80% of the total land area of the country (Pratt
and Gwynne 1977). They have low productive potential and for
a long period have been used by wildlife, pastoral and semi-
pastoral communities. This is mainly due to inadequate
rainfall to support rainfed agriculture.

    The livestock industry is an important economic
activity in the rangelands of East Africa (Ayuko 1981).
Rangelands in Kenya provide a major portion of forage
required for livestock production. It is therefore necessary
they be managed to provide a sustained production of
livestock and other range resources.

    Some rangelands are dominated by woody vegetation and
other undesirable species rather than perennial grasses and
forbs preferred by livestock for grazing (Carlton 1984). In
the drier tropics the invasion of shrub thickets tends to
approach epidemic proportions resulting in a thorn-scrub
vegetation useless for grazing. The perennial herb species
constitute an important forage for domestic livestock,
especially cattle and sheep, and wildlife. The take-over by
thickets therefore poses a threat to the livelihood of the
farmers.

Different tree and shrub densities, with their associated canopy cover have variable effects on herbaceous cover and production, with the quantity of available forage being reduced by competition with increasing density. This negative role of woody plants on rangelands has provided the impetus for intensive research on control methods and their implementation on hundreds of hectares of rangelands. Because woody plants are long-lived, manipulation of grazing intensity (or cessation of grazing) alone will not restore the productivity of the rangelands with respect to cattle and sheep production. To increase livestock production on rangelands it may be necessary to manipulate the present vegetation by mechanical, chemical or biological control means (Carlton 1984).

Kibwezi Dryland Field Station located in Makuani district (Eastern province of Kenya) is a typical example of a semi-arid area where tree and shrub stands have thickened on some sites. Within this area, there has been a marked increase of the woody component of the vegetation as from 1960 (Farah 1990). During this period the vegetation changed physiognomically from grassed shrubland to dense wooded shrubland. These changes occurred either due to natural causes, e.g. marked shifts in rainfall regimes and/or patterns of land management practices associated with man's attempt to exploit natural resources, e.g. grazing of

domesticated stock, human induced fire, or vegetation
clearing (Farah 1990).

From 1960 sources of mortality such as fire were
reduced. During exceptionally wet seasons a large number of
tree and shrub seeds germinated leading to a massive
increase in recruitment. These seedlings established and
due to absence of fire they suppressed grass growth. Once
they established themselves, these long-lived plants
resisted the entry of subsequent cohorts of grass seedlings
and dominated, resulting in a wooded bushland community.
These dense thickets have little or no herb understorey and
have therefore limited the availability and exploitation of
forage resources for cattle production.

At the moment the Station specializes in goat
production but has an objective of introducing cattle.
Cattle are known to be grazers and their grazing activities
on a continuous basis usually shifts vegetation composition
towards woody type. To increase cattle production,
production of sparse grass understorey in the bush thickets
have to be increased by arresting succession through
thinning. After thinning more frequent brush control
treatments should be introduced to maintain the achieved
grass production in a more productive state. However, during
thinning, some trees and shrubs should be left for provision

of nutritious food during critical periods such as in dry season when grasses and forbs are dry. They also maintain soil nutrients and water.

Information pertaining to the kind and magnitude of responses of vegetation to selective bush thinning is important in assessing benefits and planning of rangeland improvement programs. In most cases of bush clearing, assessment of changes are made largely as visual estimates and interpretation of production is superficial. Quantitative data on cover changes and subsequent forage production is necessary for multiple-use management of bushlands (Rollins and Bryant 1984). In rational management of a wooded bushland community, it is important to obtain a tree and shrub density that will give a good grass stand and production. Knowledge of plant production is important in range management as production directly influences the grazing capacity of the range for both native and domestic herbivores. An accurate assessment of the available forage biomass on a given piece of rangeland is an indispensable information for all range management decisions (Schwartz et al. 1988).

Understanding the interactions of woody plants required in certain amounts as food and cover for game animals and the production of herbaceous range forage vital

for livestock production is critical to development of effective brush management systems (Scifres et al. 1982). In Kibwezi, there is no research data concerning this inter-relationship which can be generated through thinning the woody component to different levels.

Research efforts should therefore be devoted to obtaining quantitative relationships between woody canopy on one hand and herbaceous species cover and production on the other.

This study was initiated in early October 1992 to document overstorey-understorey relationships following tree and shrub thinning. This investigation was aimed at improving forage production for cattle production, it had the following as the specific objectives.

1. To determine the effect of tree and shrub density on biomass production of some selected grass and forb species.
2. To assess the effects of tree and shrub density on basal cover of some selected grass and forb species.
3. To evaluate the impact of tree and shrub density on frequency of some herbaceous species.

The following hypotheses were tested.

1. The density of the woody component of the vegetation has no effect on biomass production of the herbaceous layer.
2. The density of the woody component of the vegetation has no effect on basal cover of the herbaceous layer.
3. The density of the woody component of the vegetation has no effect on frequency of the herbaceous layer.

Foot note:

The first two hypotheses were tested with the assumption that there is no functional relationship between the density of the woody component on one hand and biomass production and cover of herbaceous species on the other ($b=0$).

LITERATURE REVIEW

2.

2.1 Effects of trees and shrubs on herbaceous species.

Woody plants are normally considered detrimental to the understorey herbaceous vegetation (Whysong and Bailey 1975). Results have shown that although trees and shrubs differ physiologically and morphologically, they have with few exceptions, identical impacts on their environments. Belsky et al. (1989) suggested that the effects of trees on their neighbouring environments are not tree species- specific phenomena, but are common to many tree species. They noted that it is possible that the similar morphology of all the species, i.e their ability to shade the ground, bring nutrients to the surface of the soil in their litter, intercept rainfall and provide perches for birds and shade for mammals may be equally or more important than physiological differences.

Woody plants are an important component of all semi-arid lands throughout the World. Their desirable qualities are dependent to a considerable extent on the presence of a fair percentage of perennial grasses. However, the amount of rainfall in rangelands is insufficient to maintain these grasses if they have to compete with woody vegetation because they are better adapted to withstand an arid climate (Whysong and Bailey 1975). Woody vegetation has extensive

lateral root systems, often accompanied by deep tap root,
high sprouting ability, presence of thorns and low
palatability. These characteristics provide competitive
advantage over grasses and forbs for drought survival
(Jacoby 1986). They compete vigorously with other plant
species in the community for light, moisture, space,
nitrogen and other environmental and edaphic factors
necessary for maximum growth (Whysong and Bailey 1975).
Woody plants may affect associated herbaceous vegetation by
altering species composition, plant density and plant vigor.
One of the most commonly cited interactions between woody
species and herbs is competition for soil water (Johsson et
al. 1988, Glendening 1952, Paulsen 1953, Reynolds and
Bohning 1956, Cable and Tschirley 1961).

Trees and shrubs adversely affect the performance of
herbaceous species growing around them. For example,
clearings in a forest produce much more herbaceous material
than do similar areas with a dense tree cover. Potential
yield of understorey forage may be reduced by the effect of
associated shrubs and trees (Blaisdell 1949, Johnson and
Smoliak 1968, Robertson 1947). The presence of woody plants
on rangelands has therefore been of concern to land managers
interested in increasing forage production (Bailey et al.
1979).

Benefits of diverse vegetation types include the lessening of seasonal forage variations, the better utilization of energy, soil nutrients and water, the lower risk of toxicity and nutrient deficiency for herbivores, as well as minimizing pests and diseases for plants (Lailhacar 1986).

Increased canopy zone productivity appears to be associated with lower tree density savannah (Kennard and Walker 1973) deserts (Patten 1978) and high soil fertility (Belsky et al. 1989). Decreased productivity is most often associated with higher-tree-density woodlands (Beale 1973, Sandford et al. 1982) and low soil fertility (Belsky et al. 1989).

In general, increased grassland productivity under tree canopies is due to the ameliorating influence of shade in hot, dry environments and increased soil fertility under the canopies due to litter, while decreased productivity is a result of reduced rainfall and increased competitive interactions between trees and shrubs (Ward and Cleghorn 1964, West 1969, Beale 1973, Clary and Jameson 1981, Dye and Spear 1982. Walker et al. 1986). Belsky et al. (1989) found that if competition between woody and herbaceous species occurred in the canopy and at root zone, its negative effects on grassland productivity were more than could be

compensated for by positive effects such as increased soil
fertility and improved plant water relations.

Obviously it is desirable to retain as many trees and
shrubs as are commensurate with the maintenance of an
economic level of grass and herb production and a stable
plant-soil-animal system. Other factors to be considered are
shade and shelter, ease of husbandry operations involving
domestic livestock and the preservation of habitats for
native birds and other animals (Walker et al. 1972). Some
woody species provide feed in times of drought, others have
ameliorating effects on the environment of plants and
animals. But more often the woody species become undesirable
from a livestock management point of view especially in the
semi - arid zone near the tropics (Jacoby 1986).

2.2 Bush control.

The decision to control noxious plants by chemical or
other means is one of many decisions which the rancher must
make in ranch management (Ethridge et al. 1987). Some
grazing lands in the semi-arid lands of Kenya have a high
potential in terms of grass production and livestock grazing
capacity. On much of this land, bush in varying degrees of
density lowers the present production through direct
competition with the grass (Bentley 1963). Deteriorating
grass understorey results in decreased beef production and

animal returns. The implication is that it may be possible to make more money if the grass understorey can be maintained in a more productive state through more frequent brush control treatments (Torell and Mcdaniel 1986).

Forage production could be increased if woody vegetation is reduced, i.e, if there is a drastic reduction in the bush cover and the development of a stable grass cover which can be maintained indefinitely with little additional bush control effort (Bentley 1963). Grasses in general have important attributes in the natural vegetation (De vos 1969), these include:-

1. Provision of soil cover, reduction of evaporation, provision organic matter and improvement of water conservation.

2. Nutrient recycling; Cenchrus and Cynodon species are some of the deep rooted genera with roots penetrating deeper than 200 cm.

3. Maintenance of soil structure.

4. Provision of food for livestock. Grasses contribute 80-100% of the feed to grazing domestic livestock.

Reasons for controlling brush are similar in that brush control allows for more ease in managing livestock and generally increases forage production (Child et al. 1986 and

Jacoby 1986). The latter's benefit may be affected by rainfall, management, site potential and species present, along with other locally important factors. In addition to these primary benefits, increased land value, potential for future cultivation and insect control have motivated brush control (Jacoby 1986). Methods of control fall into the following categories.

1. Burning
2. Mechanical control
3. Chemical control
4. Hand clearing
5. Biological control

Several points must be considered in choosing a technique for brush control, whether mechanical or chemical (Child et al. 1987). Among these are effectiveness on the target species and other less desirable plants, potential damage to desirable species, effects on regeneration by seed and by sprouts, matching of equipment and procedure to the size of the problem, erosion hazards, environmental considerations and cost/benefits of expected results.

Fire has been used to control brush; it tends to selectively kill woody vegetation and promote graminoid species mainly because the perennating organs of the former are above-ground and hence killed by fire (Farah 1990).

In mechanical methods, we have discing, root plowing, roller chopping, shredding and railing. Discing and root plowing uproot woody plants and are most effective especially on shallow rooted-plants but they also destroy most herbaceous plants and should be limited to areas where plant removal will be followed by reseeding. Railing, shredding, chaining, land imprinting and roller chopping remove the tops of plants but usually kill fewer plants than discing or root plowing (Morton and Melgoza 1991).

Herbicides such as tebuthiuron, dicamba picloram and others have also been used extensively to control woody species on rangelands because of the ease of application to large areas and cost advantage over mechanical alternatives but they also have lower degrees of control on many stemmed life forms (Jacoby et al. 1990). Use of Fenuron has given useful results in Kenya though its value is limited by cost. Promising results have also been obtained in Kenya on Acacia drepanolobium. using a picloram/2,4-dichloro-phenoxyacetic acid mixture (Pratt and Gwynne 1977).

Hand clearing is the only acceptable means of brush control where machinery is inefficient or damage to other resources is suspected (Child et al. 1987). The common hand tools are the axe, grubbing hoe, brush hook, chain saw and backpack power saw. According to Child et al. (1987) hand clearing is labour intensive and of limited value where

labour is expensive. However, it is the common method in developing countries where funds are scarce and the area to be cleared is small. The major advantage of hand clearing is that the target species can be selected without error, it also has a high degree of success. In Kenya, hand clearing has been used to obtain a direct cash return by converting the woody vegetation into charcoal by the UNDP/FAO Range Management Project (Pratt and Gwynne 1977).

Although the relative costs of these practices are high, the potential benefits may also be great. According to Carlton (1984) control of unwanted plants, re-vegetation, and/or fertilization can increase forage production 10-1,000 percentage within 1-3 years. He concluded that if these risky, costly practices are used, only superior management will reduce the probability of failure and heavy financial losses.

The release of herbaceous forage following reduction of brush canopy can produce dramatic increase in grazable biomass for domestic livestock. Greatest responses are generally seen in areas having a high degree of competition for available moisture, less dramatic results are seen in areas where moisture competition is minimal. Forage responses after brush treatment vary with the type of method used, composition of the pre-treatment plant community,

relative degree of treatment impact on existing plants,
environmental conditions and post treatment management
(Jacoby 1986).

2.3 Overstorey - understorey interrelationships.

Thinning or degree of disturbance can be expressed as
the number of woody plants left per unit area,the reduction
of basal area or canopy, or the proportion of the tree and
shrub biomass left in the system (Walker et al. 1972). Trees
have therefore been expressed in various ways and related to
herbage production for other communities(Beale 1973).

Tree spacing, tree canopy cover and tree basal area are
closely interrelated in their effects on understorey
vegetation. These effects are influenced by climate
especially rainfall (McConnell and Smith 1965). Because of
competition for light, water and nutrients and possible
antagonistic chemical effects, this relationship is inverse
and is entirely reasonable and has been reported in the
literature (Jameson 1967). Because of variety of
conditions,the strength of this relationship has been
variable. In general these studies have shown that as the
density of canopy cover of woody plants increases,
herbaceous standing crop decreases.

In these interrelationships, tree basal area has been used (Gaines, Campbell and Brassington 1954, McConell and Smith 1965, Jameson 1967, Clary 1969 and Beale 1973). Walker et al. (1972) have used a quantity derived from tree and shrub biomass designated percentage thinning and related this to herbage yield in southern Queensland *Eucalyptus populnea* communities. Others have used tree and/or shrub canopy cover.

Canopy cover is one of the primary factors influencing understorey vegetation (Pieper 1990). Basic relationships between canopy cover and understorey biomass have been determined for Pinyon-Juniper woodlands in Arizona (Anold et al. 1964, Clary 1971, Clary et al. 1974, Jameson 1967, Clary and Jameson 1981, Pieper 1983) and in Western New Mexico (Short et al. 1977) and Nevada (Tausch and Trueller 1977). Others who have used tree canopy cover include (Pond 1961, McConell and Smith 1965 and 1970 and Luis et al. 1990). Such studies have elucidated some of the basic ecological relationships among the species involved and have served as a guide to expected increase in herbaceous biomass following reductions of the canopy (Pieper 1990). These relationships are curvilinear with polynomial or exponential equations describing the influence of canopy cover on understorey production.

Pond (1961) showed that basal cover of weeping love grass (*Eragrostis* *curvula* (Schrad.) Nees.) tended to be inversely proportional to cover of live oak. There was a good linear relationship between basal cover of grass and reduction in oak canopy during the first years following canopy cover reduction. The relationship tended to depart from linearity each year, production of weeping love grass was also inversely proportional to reduction of shrub live oak canopy.

Pase (1958) showed that herbage production decreases with crown cover. This relationship was explained by a regression equation. Species reacted differently to changes in crown canopy. Cooper (1960) obtained a regression equation relating grass production to percentage crown cover. On projection this equation indicated no herbaceous vegetation at crown densities above 75%. Scifres *et* *al*. (1982) indicated that the influence of huisache canopy on grass production is most pronounced in years when rainfall amount and/or distribution are most favourable for growth of warm season species. The composition of herbaceous vegetation changed markedly as huisache canopy cover increases.

In the analysis of the relationship between understorey yield and growing area per tree , McConnell and Smith (1965)

showed a significant difference between thinned and unthinned plots but no difference between levels of thinning when pine canopy and pine basal area were each considered. However, significant yield increases occurred at all thinning levels.

In his experiment investigating herbage response to tree and shrub thinning in Eucalyptus populnea shrub woodland, Walker et al. (1972) found that herbage yield was positively related to percentage thinning, i.e, inversely related to the residual woody canopy cover. This relationships consistently had the same form and closely fitted a transition sigmoid curve.

19

3.

MATERIALS AND METHODS

3.1 Study area.

3.11 Location and Physical Features.

The study was conducted at Kibwezi dryland Field Station of the University of Nairobi (Makueni District) in Eastern province of Kenya (Fig.1). The Station covers an area of 4,770 hectares and is situated 220 km South of Nairobi, along Nairobi-Mombasa highway (Fig.2). This area lies in agro-climatic and Eco-climatic zone V (Braun 1977, Pratt and Gwynne 1977, Pomeroy and Service 1986). It is characterized by low and unreliable rainfall, marginal agricultural lands, dispersed population and low fertility soils.

3.12 Climate.

Rainfall is distributed bimodally, with long rains from March to May and short rains from November to December. Short rains are more reliable in time than long rains and are the most important. Mean annual rainfall for the two nearest stations to the study area is 683.5mm (1982-1991) with highest rainfall of 1244.4mm recorded at Kibwezi, DWA Plantation Limited in 1982 and lowest rainfall of 259mm recorded at Makindu Meteorological Station in 1983. During the study period (October 1992-June 1993), rainfall data was obtained from Kibwezi Meteorological Station situated within the station. During this period the area received a total of
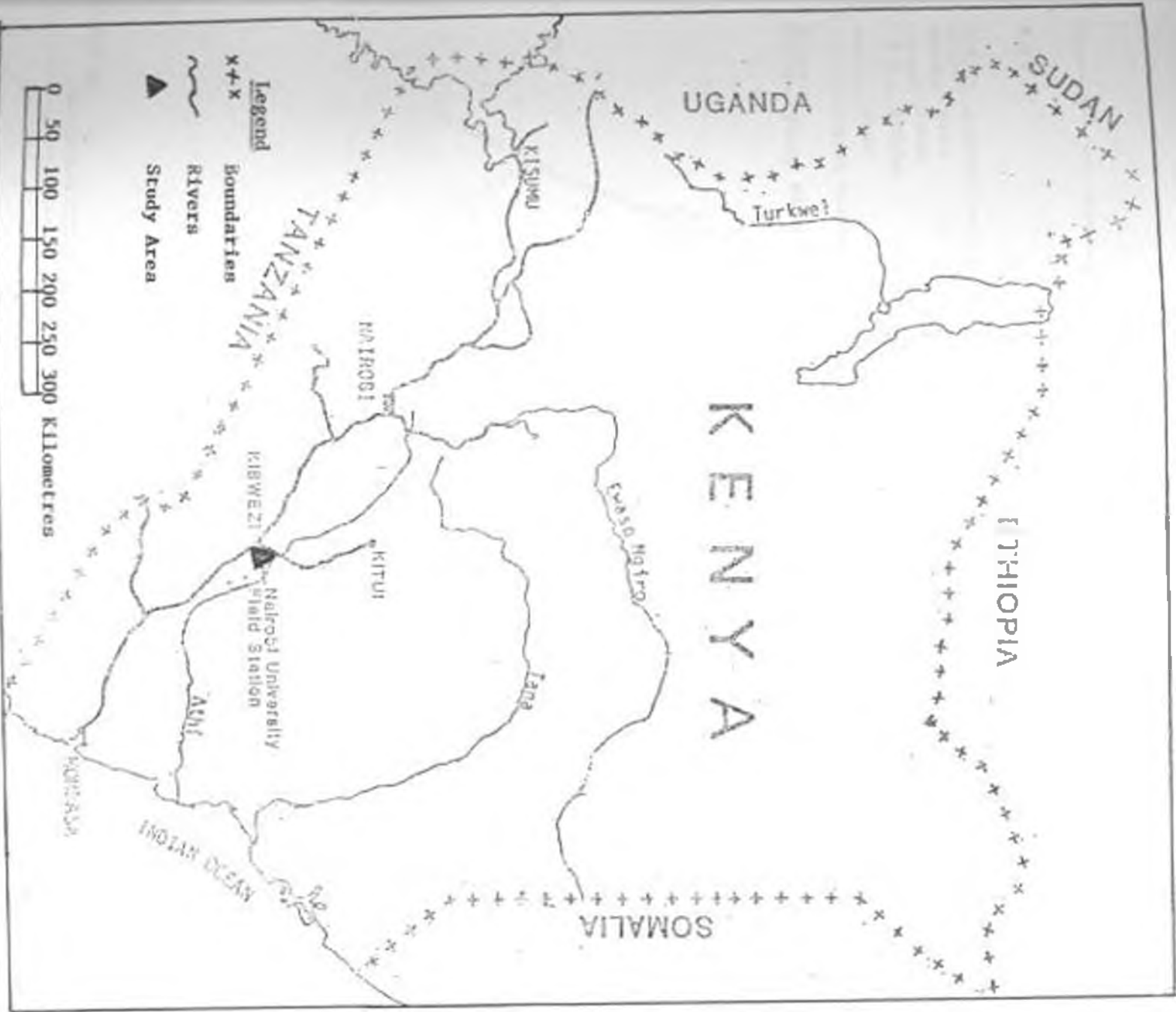
Figure 1. Location of the National University Field Station, Kibwezi

Legend
x+x   Boundaries
∿   Rivers
▲   Study Area

0 50 100 150 200 250 300 Kilometres

SUDAN

UGANDA

KISUMU

Turkwel

TANZANIA

NAIROBI

KIBWEZI

Nairobi University Field Station

KITUI

KENYA

Tana

Ewaso Ngiro

Athi

MOMBASA

INDIAN OCEAN

ETHIOPIA

SOMALIA
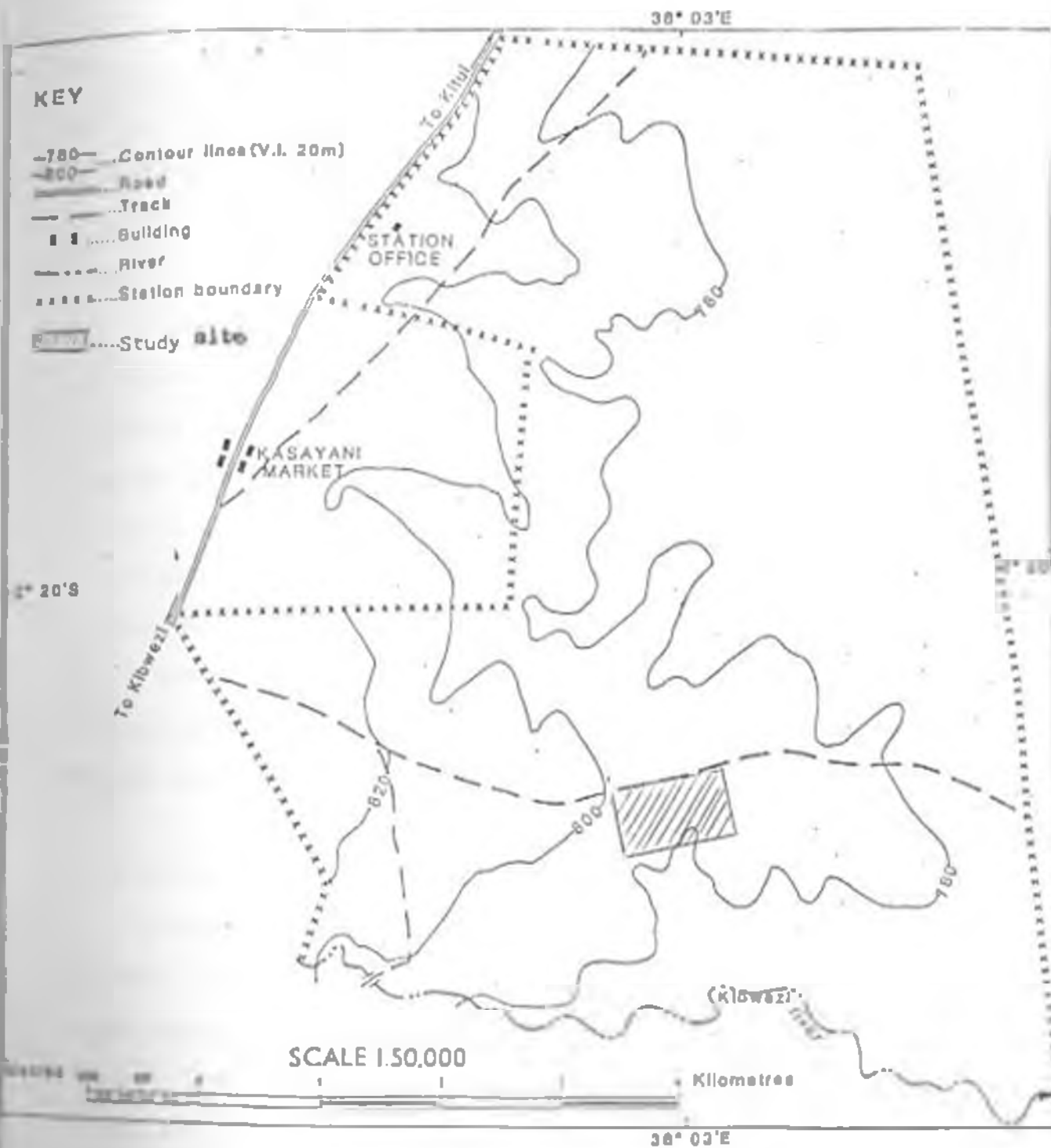
Figure 2:   Location of experimental site at the Kibwezi
             Dryland Field Station.

994.6mm of precipitation. The 10-year mean monthly rainfall for the two nearest stations to the study area and the monthly precipitation for the study period are presented in Fig.3.

March-May rains came early resulting in high precipitation in January. There is a lot of variability in rainfall amounts both in time and space. Rainfall data suggest quite strongly that years of "good" and "poor" rainfall follow a grouped rather than a random pattern (Gachimbi 1990, Pratt and Gwynne 1977). Mean annual air temperature extrapolated from Makindu Meteorological Station for a 10-year period is 22.9°c. Braun (1977) gave the average potential evaporation rate as 2094mm per year. This figure assumed a continuous supply of water.

3.13 Soils

Touber (1983) classified Kibwezi soils as ferral-chromic Luvisols. They are well drained, moderately deep, dark reddish brown soils with a well developed A horizon. A horizon has a characteristic dark-reddish brown sandy clay loam to sandy clay. The B horizon has a characteristic dark-reddish brown to dark red sandy clay loam to clay. The dominant type of soils at Kibwezi Dryland Field Station is sandy clay loam. Black cotton soil and lateritic soil (murram) cover small parts of the station.
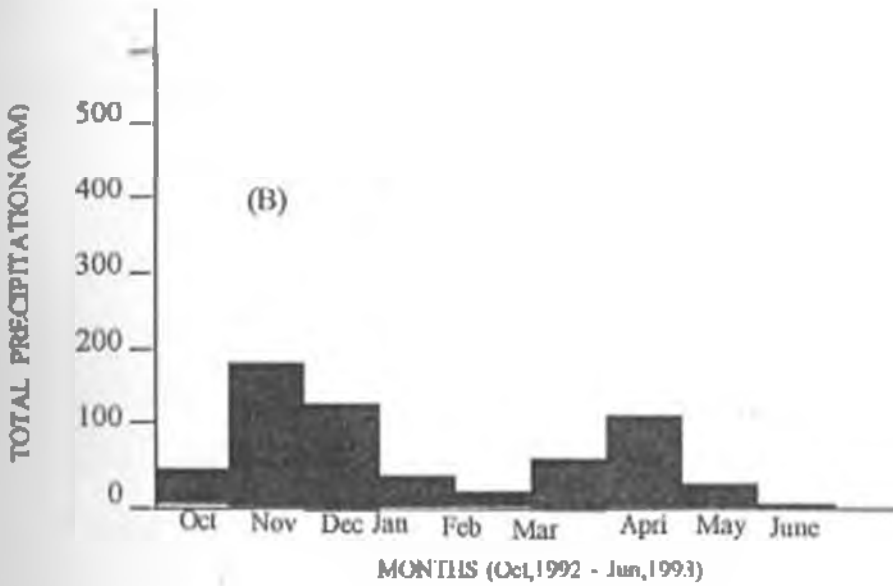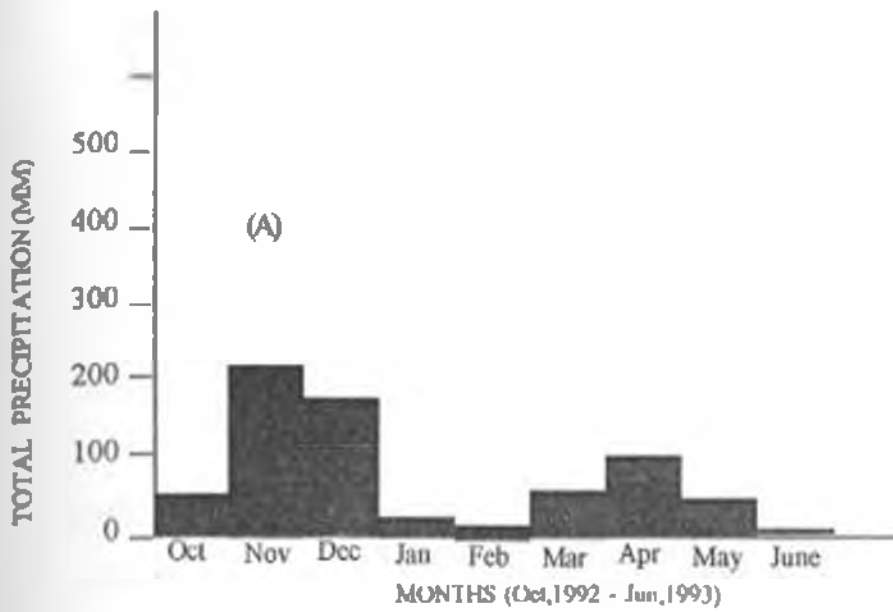
FIG.3 The 10 -year mean monthly rainfall for Kibwezi DWA plantation limited(A) and Makindu Meteorological Station (B). The monthly precipitation for Kibwezi Meteorological Station (Oct,1992- June,1993) is shown in (C)

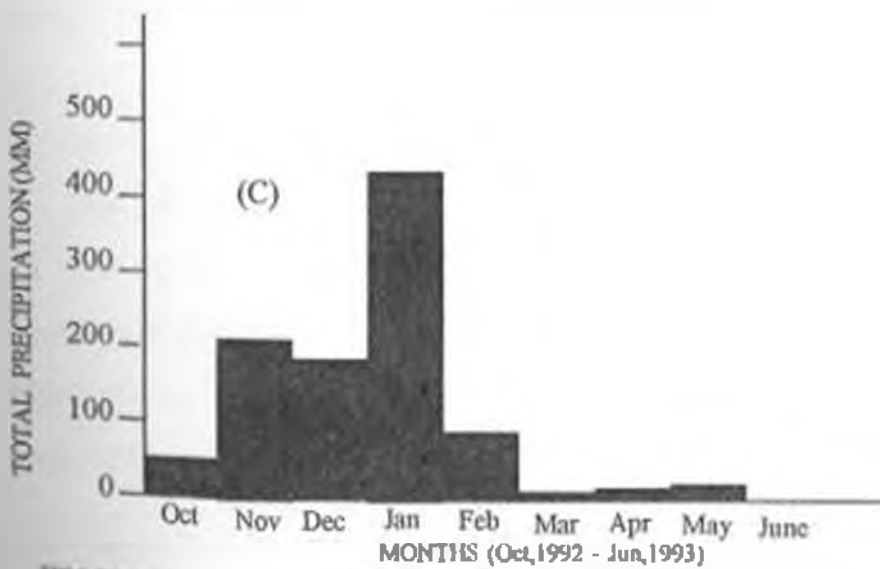3.14 Vegetation and Present Land Use.

The distribution of the vegetation in the area is controlled by a number of complex interrelated factors, climatic, geological formation, soil types and presence or absence of groundwater (Gachimbi 1990). According to Pratt and Gwynne (1977) and Touber (1983), the area is dominated by Commiphora, Acacia and allied genera, many of shrubby habits. There are stands of Commiphora africana, Commiphora campestris, Commiphora exalatum, Acacia tortilis, Acacia mellifera. shrubs include Grewia bicolor, Boscia coriaceae, Taphrosia villosa, Ochna insculpta and Premna hostlii, among others. Grass species include Eragrostis superba, Enteropogon macrostachyus, Aristida keniensis, Panicum reptans, Panicum deustum, Panicum maximum and Chloris roxburghiana. Common forb species include Barlaria submollis, Blepharis integrifolia, Commelina benghalensis, Osmum basillicum, Macrotyloma axillare and Leucas grabrata. A full list of trees, shrubs, grasses and forbs common in Kibwezi area is presented in Appendix 1.

3.2 Study sites.

The study sites were situated on the southern part of the Station. These areas supported dense bushland thickets tractable for research. It consisted of a relatively uniform stand which was classified as Acacia commiphora community. Apart from the vegetation structure and plant species

composition, the soil was also homogenous.

The vegetation consisted of stands of Commiphora
africana and Acacia tortilis interspersed with stands of
Acacia reficiens, Acacia brevispica, Commiphora baluensis,
and Combretum aculeatum. Numerous species of shrubs were
also present, e.g, Grewia bicolar, Grewia similis, Grewia
villosa, Premna hilderbrandtii, Duosperma kilimanjarica.
Common perennial grasses included Enteropogon macrostachyus,
Chloris roxburghiana and Panicum duosteum. Annual grass
species included Bracharia semiundulata, Bracharia repens
and Mariscus species. Dominant perennial forb species
included Barlaria submollis, Osmum basillicum and Commelina
benghalensis. For annuals, the common forb species were
Macrotyloma axillare, Ipomoea mombassania (both species were
creepers) and Blepharis integrifolia.

3.3 Methodology.

A preliminary survey was conducted to determine the
kind and magnitude of woody species present in the study
area. The density of the woody component was determined
using 10m by 30m belt transects (Mueller and Ellenberg
1974). Four belt transects were established and individual
trees and shrubs counted, the counts were then converted
into numbers per hectare (Table 1). To avoid leaving some
trees and shrubs from being left uncounted,

Table 1. Original tree and shrub Density (Nos./ha) at the study area.

Species	Density (Nos./ha)
Trees	
Comaiphora africana	178
Acacia tortilis	42
Acacia mellifera	42
Other tree species	55
Total tree density	317
Shrubs	
Premna hilderbrandtii	792
Grewia similis	250
Grewia bicolar	117
Other shrub species	457
Total shrub density	1616
Total tree/shrub density	1933

the counted trees and shrubs were marked and the counting process was repeated more than once in each belt transect

Two plots, 100m apart from each other and measuring 80m by 30m each were selected randomly in the surveyed area, fenced off with barbed wire and reinforced by cut tree bushes. These excluded animals during the study period. Each of the two plots was further subdivided into eight sub plots, each measuring 20m by 15m to give a total of sixteen sub plots for the study.

Prethinned vegetation consisted of small shrubs interspersed with trees. In mid October 1992, four treatments of varying tree/shrub density were randomly imposed in the subplots. They consisted of hand cutting trees and shrubs to varying canopy covers: 0% (complete clearing), 35.5% (500 shrubs and 167 trees/ha.), 55.3% (1167 shrubs and 167 trees/ha.) and an average of 67.6% (unthinned treatment with approximately 1800 shrubs and 400 trees/ha.). The 0%, 35.5%, 55.3% and 67.6% canopy covers represented the woody density reduction of 100%, 30%, 61%, and 0% respectively. Each treatment was replicated four times in a randomized experimental design. After imposing these treatments, cut trees and shrubs were removed from the subplots.

The woody canopy cover for each treatment was measured using the crown diameter method (Mueller and Ellenberg 1974) since the shape of the canopy of these trees and shrubs was more circular than elliptical. An average value was obtained and taken as the canopy cover of a treatment because there was minimal variation in canopy cover of replicates.

3.4 Soil properties

The study sites were situated in an area with sandy clay type of soils. Eight random samples of the top soil per study plot were collected at 0-15cm soil depth by augering. The samples were dried and analysed for soil particle size, organic matter and exchangeable ions at Kabete campus, soil science department. An average value was then taken.

Particle size was determined by hydrometer method as detailed by Hinga et al. (1980). The percentage silt, sand and clay together with soil pH (in water) were determined.

Soil organic matter was determined by Walkley-Black procedure (Black 1965). Exchangeable ions were extracted in ammonium acetate (1mol^{-1}) and ion concentration measured using an atomic absorption spectrophotometer (Chapman 1965).

3.5   Herbaceous production.

Clipping is probably the most common method for determining herbage weight for research purposes (Milner and Hughes 1968). Although the method is time consuming, it yields a direct and objective measure of herbage weight. Consistency is needed in terms of clipping heights and separation into live and dead components (Culley et al. 1933).

Herbaceous species biomass was obtained by clipping all herbaceous material at ground level in square quadrats measuring 0.5m and 0.5m in the subplots. This was done on a monthly basis after treatment (November 1992 to June 1993). Prior to treatment, biomass data was obtained for the month of September 1992. The location of sample plots is crucial to provide efficient, unbiased samples and to provide for the necessary random assumptions. Six quadrats were placed randomly within the central 15m by 10m of each sub plot, the area outside being a border zone, and clipped. Clipped herbage samples were separated into species and weighed to obtain fresh wet weight. From the fresh herbage samples, subsamples were taken and oven dried at 70°C for 48 hrs and then reweighed. The fresh weights were converted to dry matter and expressed as dry matter per unit area (Kg/ha).

3.6 Herbaceous cover.

This is defined as the proportion of the ground covered or occupied by herbaceous species. Basal cover was measured with a 10- point frame. Point frame method was selected because compared to line intercept method, it is less time consuming (Brun and Box 1963). A line is also difficult to stretch between two points in tall, dense vegetation. The main draw back in point- frame method is that it gives higher estimates of cover when compared to other methods. This has been noted by several investigators working in many vegetation types (Whitman and Siggeirson 1954, Johnstone 1957).

Twenty frames were randomly located within the central 15m by 10m of each subplot to give a total of 200 points per subplot. The pins of the point frame were lowered and the percentage of basal hits on a plant species represented its percentage basal cover.

3.7   Species frequency.

Frequency is based on presence or absence of plant species or vegetation groups within the same sampling apparatus, usually a plot (Whysong and Brandy 1987). The determination of vegetation frequency in nature is affected by plot size resulting from the spatial interrelations between vegetation distribution and sample area (Whysong and

Miller 1987). Soil properties, the kind of overstorey, and the degree of micro-climate moderation all influence herbaceous species frequency and abundance (Raymond et al. 1991).

Species frequency was obtained using point frame sampling where each frame was randomly located within the central 15m by 10m of each subplot. Twenty frames were randomly located within the central 15m by 10m of each subplot to give a total of 200 points per subplot. The pins of the point frame were lowered one at a time to ground level and every species touched by each pin point was recorded. For each species, the percentage of hits represented its frequency.

Schultz et al. (1961) demonstrated that the use of systematically placed points provided over-estimates of cover from an artificial community having random dispersion, with cover being analogous to frequency. However, they also presented results indicating that good estimates were obtained from point frame sampling. Whysong and Miller (1987) suggested that frequency obtained from systematic observations of populations demonstrating varying degrees of aggregation may be biased.

3.8 Statistical analysis.

The experimental design was a completely randomized design whereby the treatments were randomly assigned to the subplots in a relatively uniform area. Subplots were considered as the experimental units.

Average biomass production and average basal cover of herbage components (grasses and forbs) for each treatment was obtained by averaging the eight monthly measurements of the sampling plots and analysed using the F-test statistic. Means were separated using the Duncan's Multiple Range test at $P<0.05$ level of significance (Steel and Torrie 1980).

To quantify the relationship of woody canopy cover with biomass production and basal cover of selected species, herbage components and total herbage in the sixteen subplots, averages of the eight monthly measurements were used. Simple linear and quadratic regression analyses were conducted using Stat View 512+ software on a McIntosh II computer. The best fit curves were then selected based on high coefficient of determination (r^2), low standard errors and level of significance of the model. Coefficient of variation (CV) for the best fit curve was also determined.

RESULTS

4.

4.1 Correlations between density and canopy cover of woody species.

There were some important changes in woody canopy cover as density of woody species increased. As shown in Fig.4, a significant positive curvilinear relationship exists between percentage woody canopy cover and tree/shrub density. Regression analysis indicated that a 2nd degree polynomial equation best described this relationship ($p=0.0001$, $r^2=0.993$). This high correlation between these two variables suggested that woody canopy cover can be used to explain the effects of tree and shrub density on production, cover and frequency of herbaceous species.

4.2 Soil properties

Physical analysis showed that the soil consisted of 72.6% sand, 9.4% silt and 18% clay. Soil pH was 6.2. Soil organic matter at 0-15cm soil depth was 2.2%. The ion concentration of K, Na, Ca and Mg (0-15cm soil depth) was 0.63, 0.21, 3.32 and 1.32 Me/100g soil respectfully, while Phosphorus was 3.18 ppm.

4.3 Effects of woody canopy on production of herbaceous species

Comparative effects of treatments on forbs and grass biomass; and total herbage production are presented in
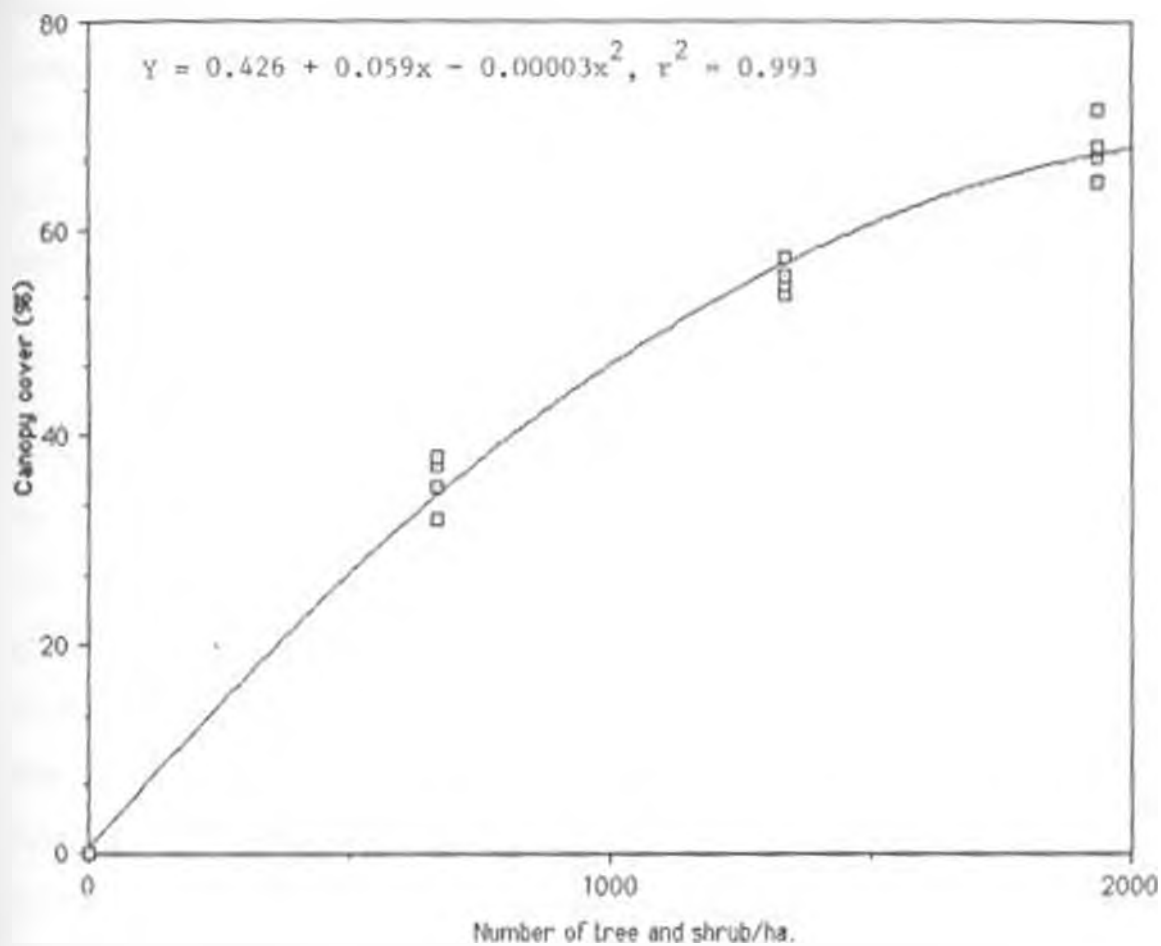
Fig 4 Comparison of relationship between woody canopy cover and tree/shrub density (n=16).

Figs.5 and 6, respectively. Comparative effects of
treatments on individual species biomass are also presented,
for _Chloris roxburghiana_, _Enteropogon macrostachyus_,
Macrotyloma axillare and _Barlaria submollis_, Appendices 2,
3, 4 and 5 respectively. Maximum biomass production for
grasses either individually or collectively occurred between
January and February, while that of forbs occurred between
March and April. When grass and forb biomass production were
combined into total herbage, maximum biomass production
occurred between January and February in the heavily thinned
treatments (0% and 35.5% canopy covers) and between March
and April in 55.3% and 67.6% canopy covers.

Analysis of variance indicated that biomass production
of grasses, forbs and total herbage increased significantly
($p < 0.05$) with increasing degree of thinning (Table 2).
The two heavy thinnings (0% and 35.5% canopy covers)
produced significantly greater grass and forb biomass than
light thinnings (55.3% and 67.6%). Grass and forb biomass
means for the light thinnings were similar. In the case of
total herbage, all the treatment means were significantly
different from each other.

To compare rate of biomass increase of the two vegetal
classes (forbs and grasses) at varying woody canopy cover,
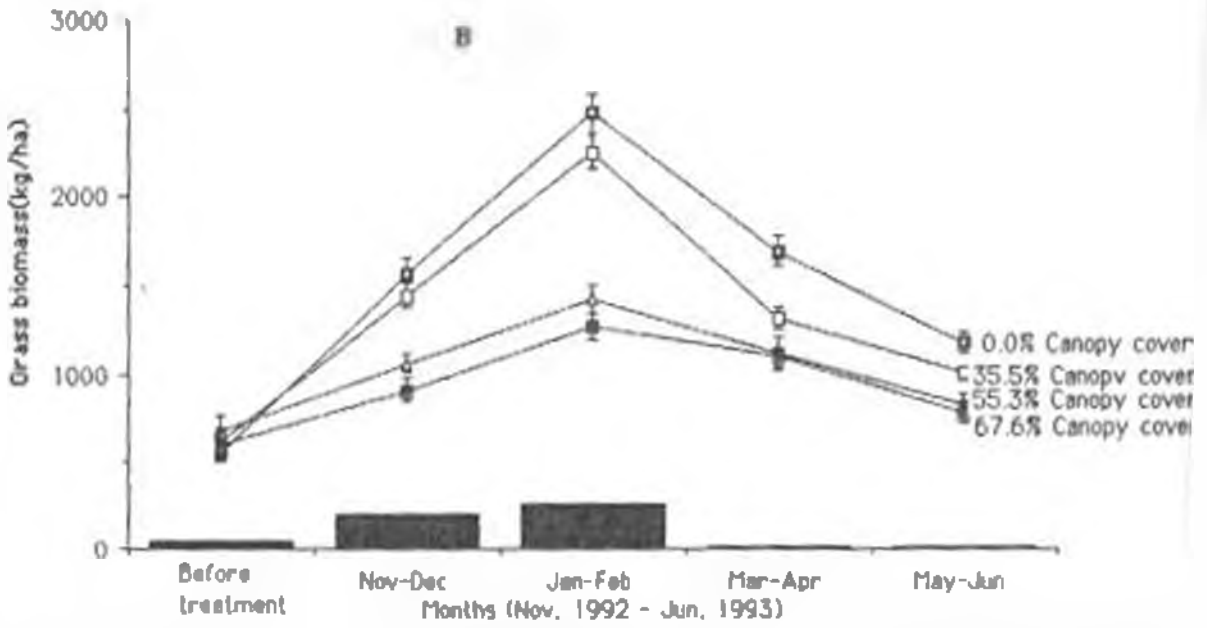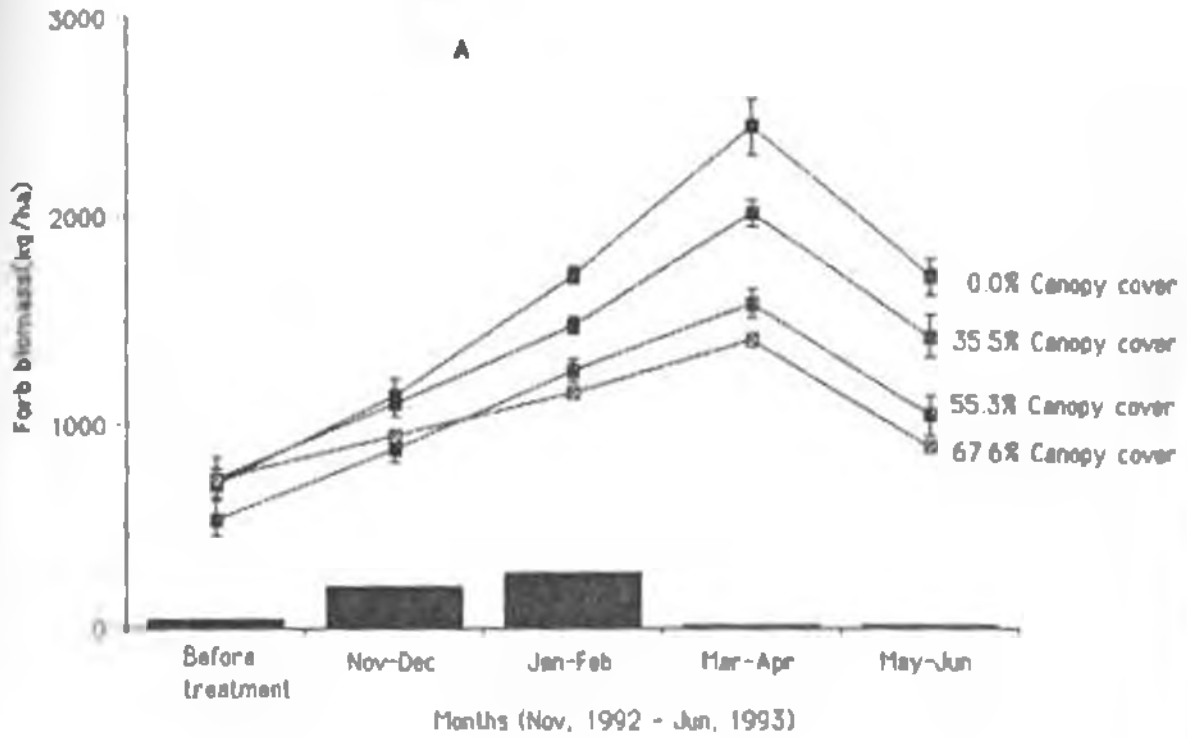
Fig 5. Comparative effect of treatments on biomass of forbs (A) and grasses (B) (Biomass means and rainfall (Shown in bars) are averaged for 2-monthly periods following treatment). Vertical lines are standard errors

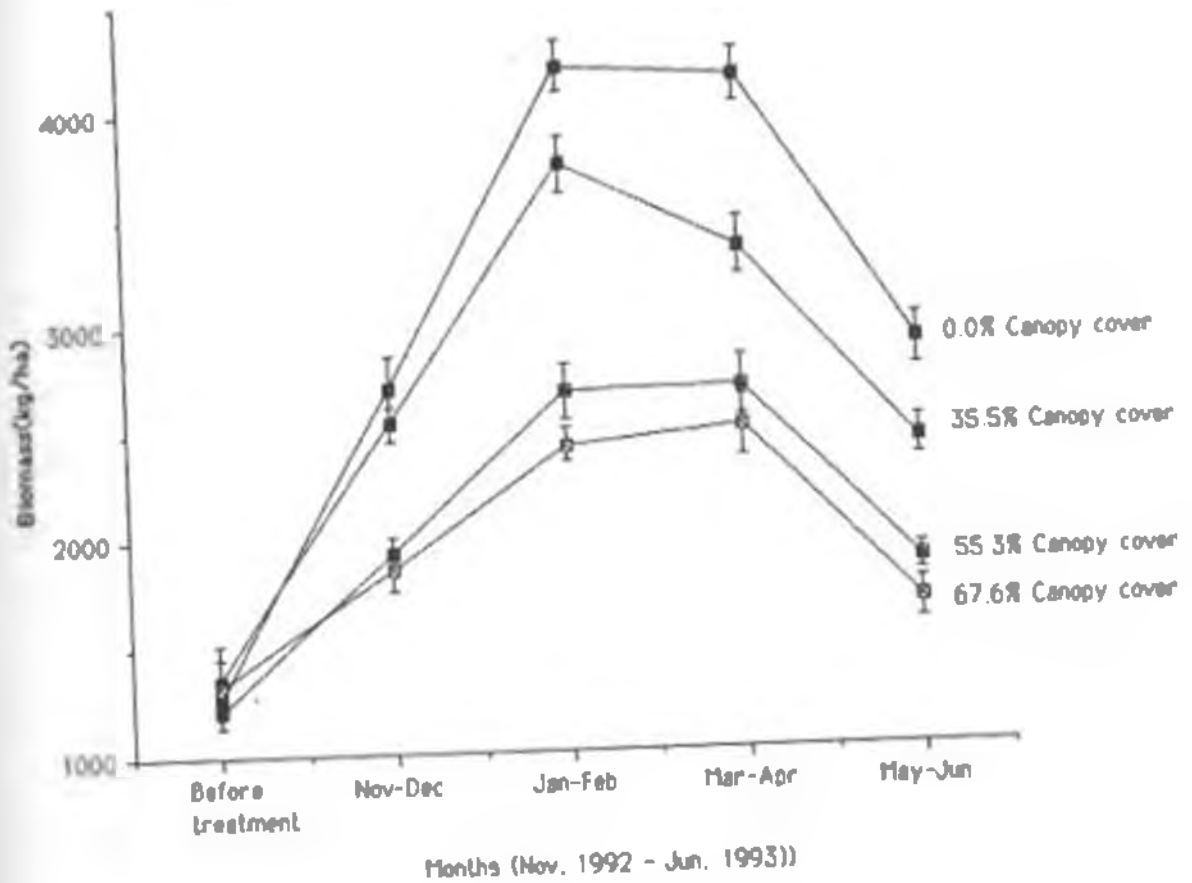

Fig 6 Comparative effect of treatments on total herbage (Biomass means are averaged for 2-monthly periods following treatment). Vertical lines are standard errors.

Table 2. Average biomass production (Kg/ha) for the 8-
monthly harvests following treatment.

Treatments	Herbage components		
Woody canopy cover(%)	Grasses	Forbs	Total herbage
0	1726[a]	1754[a]	3480[a]
35.5	1506[b]	1503[b]	3009[b]
55.3	1103[c]	1195[c]	2298[c]
67.6	1015[d]	1102[d]	2117[d]

Means within the same column followed by the same letter are
not significantly different ($P < 0.05$) according to Duncan's
new Multiple Range Test.

linear regression equations were fitted (Fig.7). Regression analysis revealed significant trends in these relationships, for forb biomass (p-0.0001) and for grass biomass (p=0.0001). There was a grass biomass increase of 11.0kg/ha for each 1% decrease in canopy cover. For forbs, 1% decrease in canopy cover increased forb biomass by 9.9 kg/ha.

A 2nd degree polynomial equation best described the relationship of woody canopy cover and herbage production (Fig. 8). A significant curvilinear trend was evident (P=0.0001).

The initial rates of increase in biomass of individual species, grasses, forbs and total herbage in the imposed treatments as compared to the control treatment is presented in Table 3. These individual responses contributed greatly to the significance of the overall treatment effects. Apart from the biomass of other grass species in the 35.5% canopy cover and that of Barlaria submollis in all the treatments, greater percentage gains in biomass of selected species and species groups were obtained on the thinned treatments than on the unthinned treatment, with the big percentage gains being recorded on the heavier thinnings. The increment of total grass biomass across the treatment levels was slightly higher than that of forbs.

Biomass production of most species and species groups was strongly related to overstorey canopy cover as shown in Table 4. Linear regression analysis showed that woody canopy cover explained only 17.3% of the variation of other grass species biomass and about 47.8% of the variation in other forb species biomass .

Behaviour of some of the important individual species was also of interest. The relationships between woody canopy cover and biomass of Chloris roxburghiana (Fig. 9), Barlaria submollis (Fig. 10) and Enteropogon macrostachyus (Fig. 11) were best described by 2nd degree polynomial equations. Relationship between woody canopy cover and biomass of Macrotyloma axillare (Fig.12) was best described by a linear regression equation. Only one forb species, namely Barlaria submollis was positively related to woody canopy cover; all the other selected species showed negative relationships with woody canopy cover.

On regression analysis, the relationships between woody canopy cover and biomass production of Chloris roxburghiana (p=0.0001), Enteropogon macrostachyus (p=0.0167), Macrotyloma axillare (p=0.0001) and Barlaria submollis (p=0.0001) were significant (p $\leq$ 0.05).
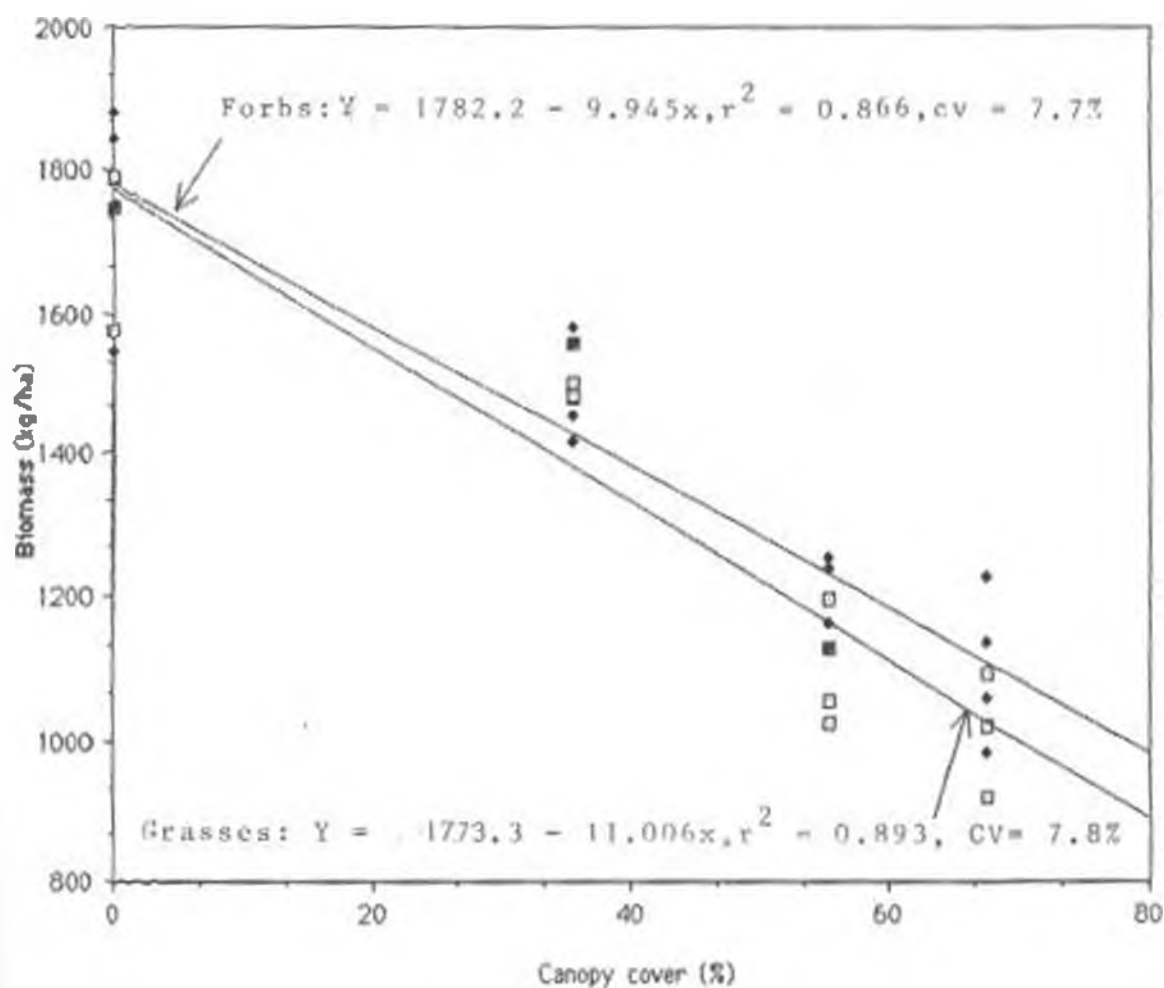
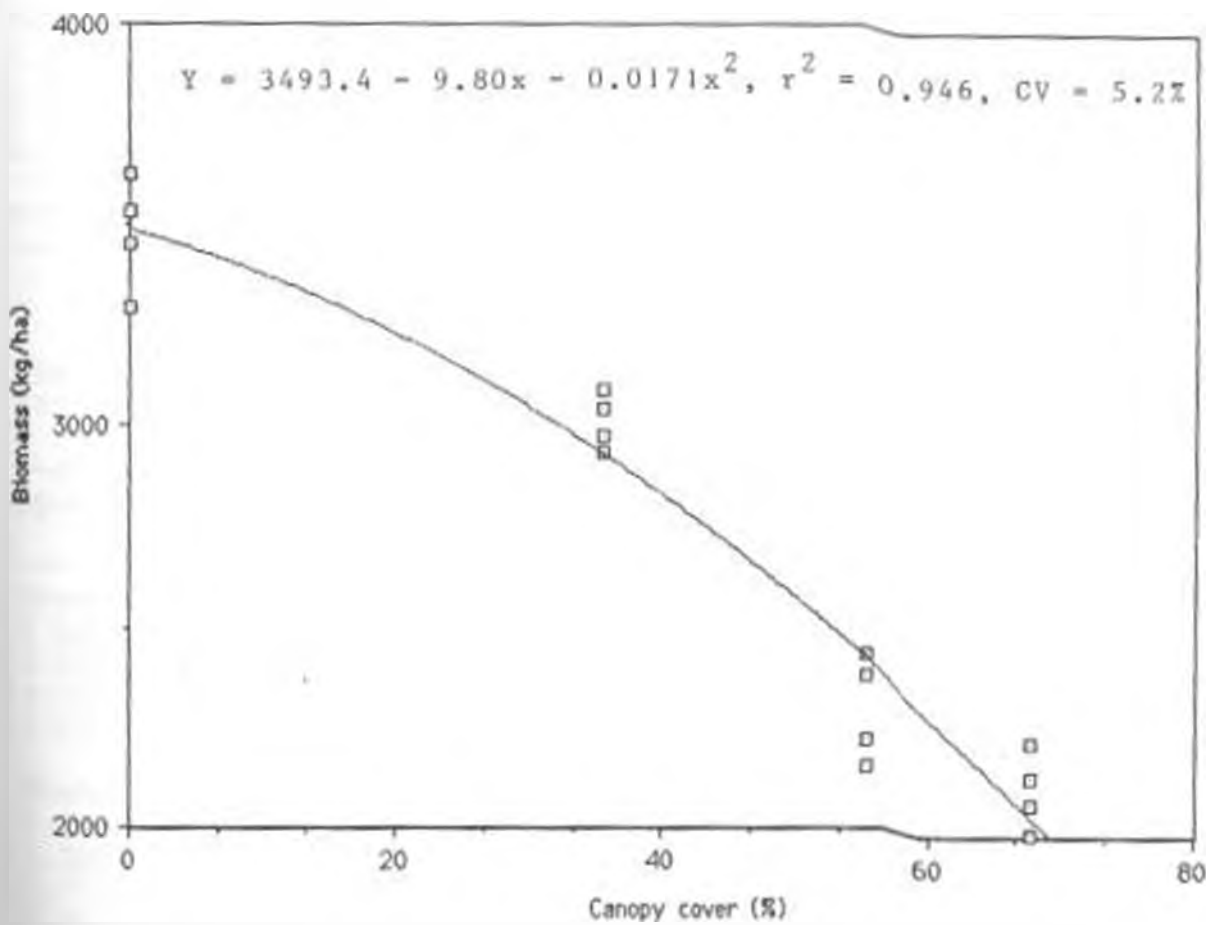Fig 7. Relationship of woody canopy cover with biomass of grasses and forbs (n=16)

Fig 8 Relationship of woody canopy cover with biomass of Total herbage (n=16)

$Y = 3493.4 - 9.80x - 0.0171x^2$, $r^2 = 0.946$, $CV = 5.2\%$

Table 3. Percentage biomass increment on the imposed treatments as compared to the control treatment.

Species	Residual canopy cover (%)		
	0.0	35.5	55.3
Grasses			
1.Enteropogon macrostachyus	39.5	25.3	5.8
2.Chloris roxburghiana	275.3	173.1	67.7
3.Other grass species	41.0	42.6	15.2
4.All grasses combined	70.0	48.4	8.7
Forbs			
1.Macrotyloma axillare	263.5	122.2	30.5
2.Barlaria submollis	-56.6	-39.1	-25.1
3.Other forb species	85.3	75.3	33.1
4.All forbs combined	59.2	36.4	8.4
Total herbage(grasses and forbs)	64.4	42.1	8.5

Table 4. Percentage variation in species biomass attributable to variation in woody canopy cover.

Species	% variation explained by canopy cover	*CV (%)
Grasses		
1.Enteropogon macrostachyus	46.7	15.7
2.Chloris roxburghiana	86.1	20.4
3.Other grass species	17.3	49.9
4.All grasses combined	89.3	7.8
Forbs		
1.Macrotyloma axillare	90.5	18.0
2.Barlaria Submollis	80.1	16.2
3.Other forb species	47.8	23.3
4.All forbs combined	86.6	7.7
Total herbage (grasses and forbs)	94.6	5.2

*CV=Coefficient of Variation

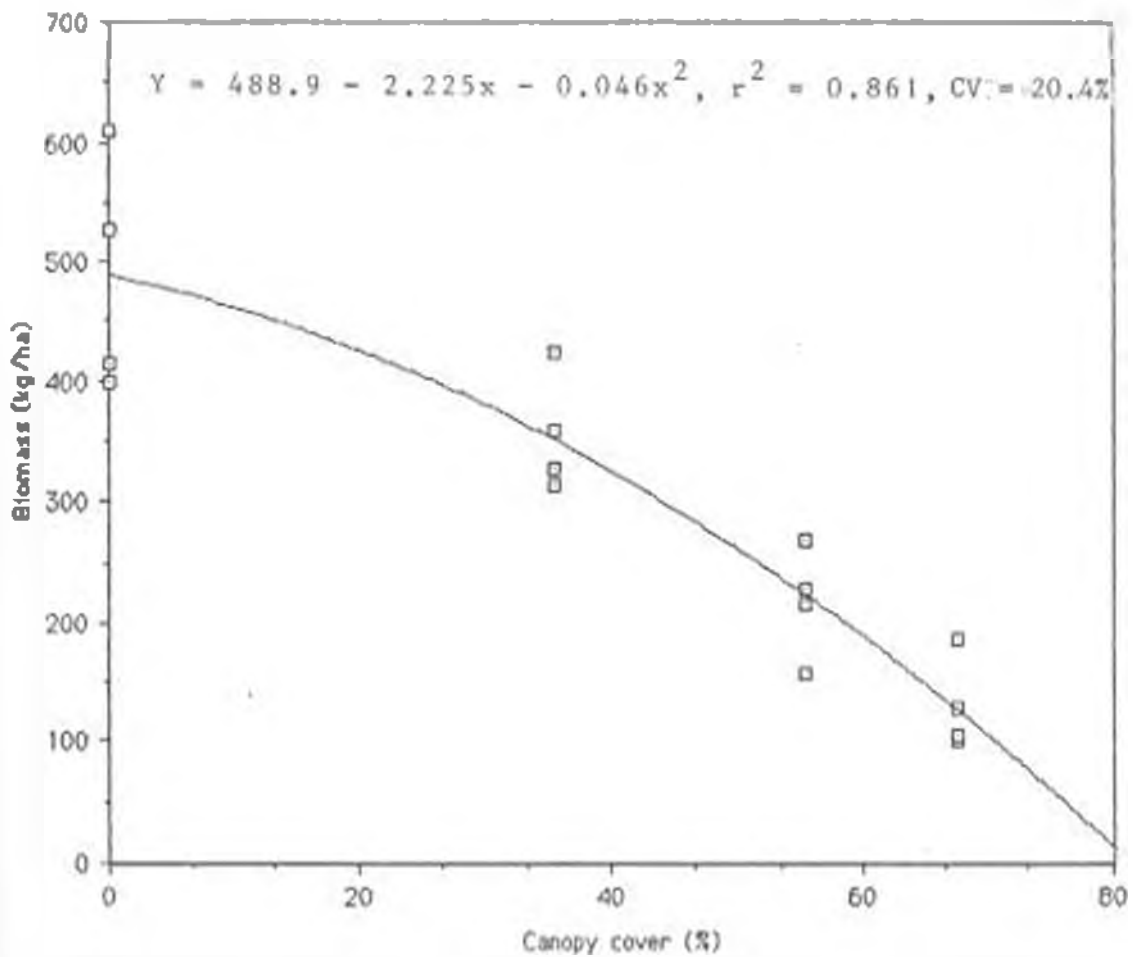$$Y = 488.9 - 2.225x - 0.046x^2, \quad r^2 = 0.861, \quad CV = 20.4\%$$

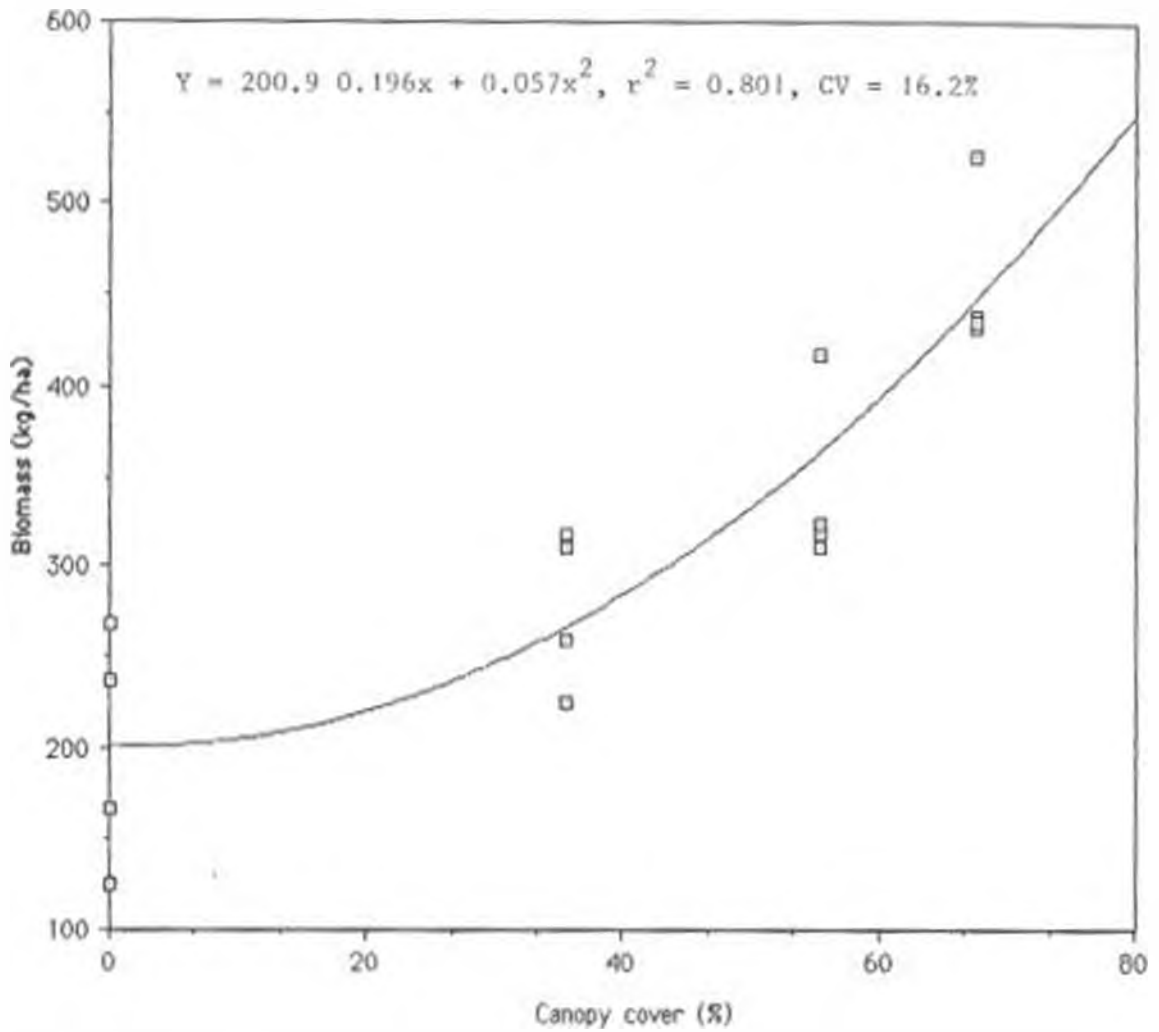Fig.9. Relationship of woody canopy cover with biomass of Chloris roxburghiana (n=16).

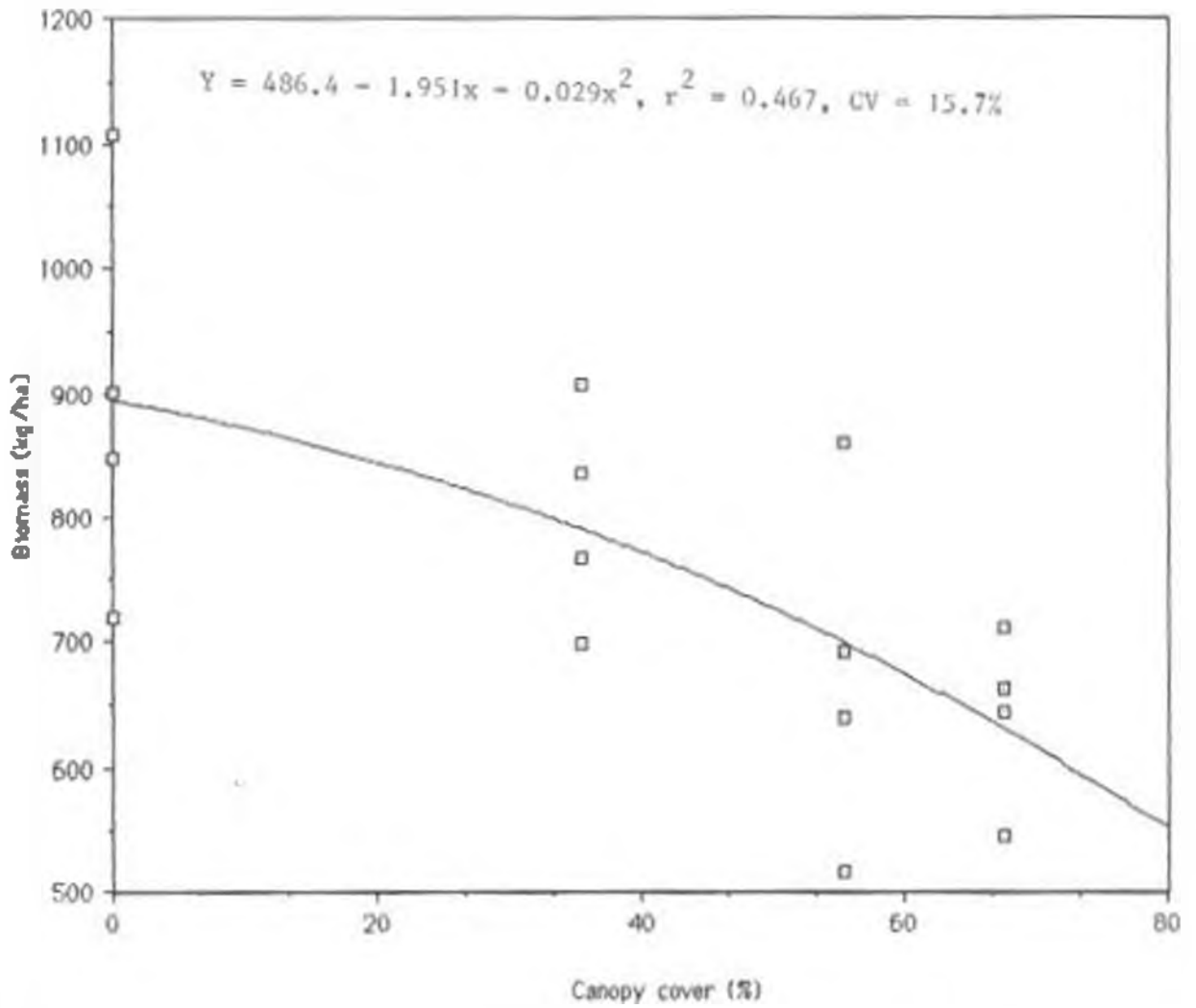Fig 10. Relationship of woody canopy cover with biomass of Barlaria submollis (n=16)

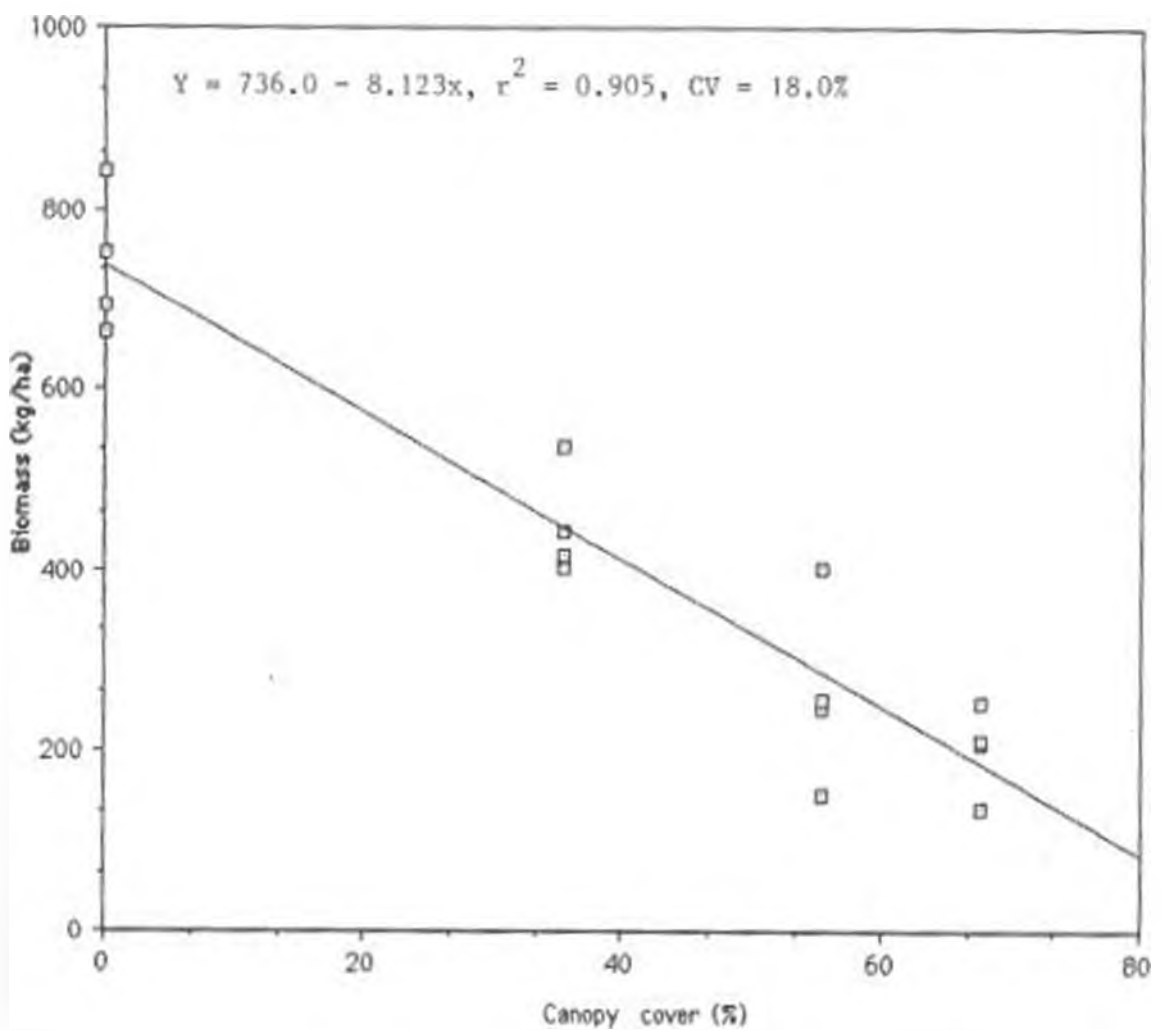Fig 11 Relationship of woody canopy cover with biomass of Enteropogon macrostachyus (n=16)

Fig 12 Relationship of woody canopy cover with biomass of Macrotyloma axillare (n=16)

4.4 Effects of woody canopy cover on basal cover of herbaceous species.

The monthly changes in basal cover (%) for forbs and grasses; and all herbaceous species are presented in Figs.13 and 14 respectively. Maximum basal cover for these herbage components occurred towards the end of the rainy period (between January and February).

Monthly changes in basal cover of individual species that contributed to the overall basal cover of herbage components e.g *Chloris roxburghiana*, *Enteropogon macrostachyus*, *Macrotyloma axillare* and *Barleria submollis* are presented in Appendices 6,7,8 and 9 respectively. Just like herbage components, their maximum basal cover occurred between January and February.

Analysis of variance revealed that basal cover of grasses, forbs and all herbaceous species increased significantly (p ≤ 0.05)with canopy cover reduction. The separated treatment means for the study period using Duncan's Multiple Range test (p<0.05) are indicated on Table 5. The basal cover means for grasses in the four treatments were different from each other. For forbs, the basal cover mean for control treatment was not different from the mean of 55.3% canopy cover, but was different from the rest. The basal cover means for 55.3%, 35.5% and 0.0% canopy covers
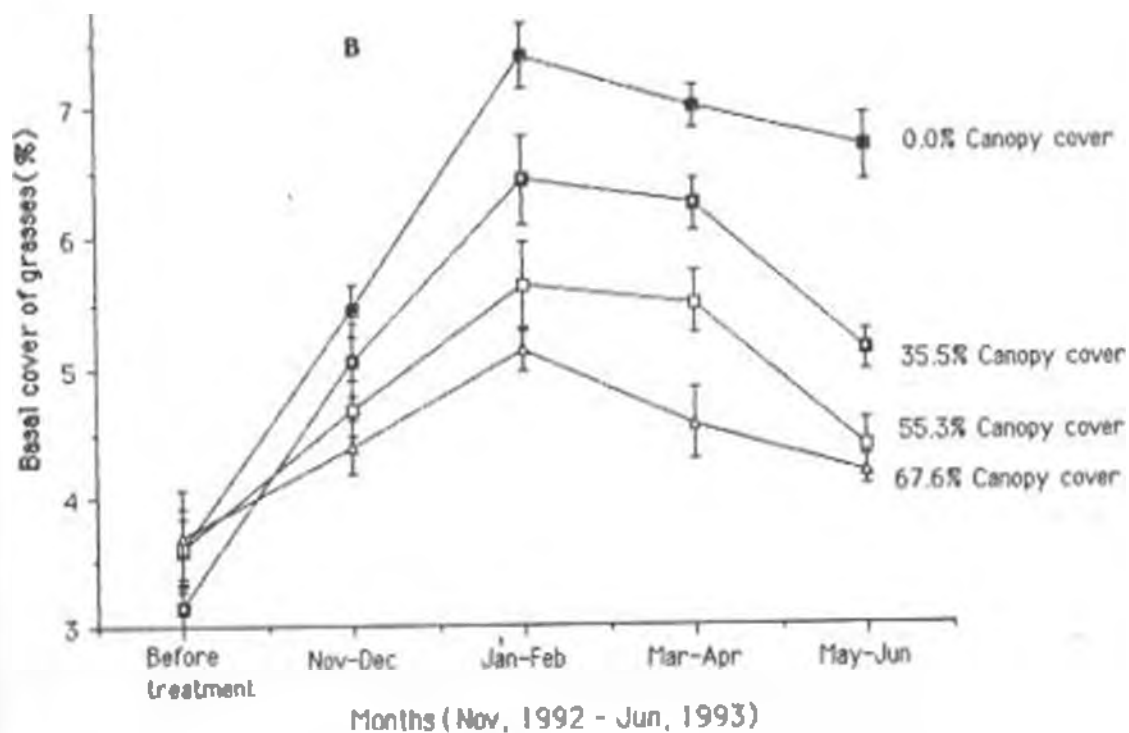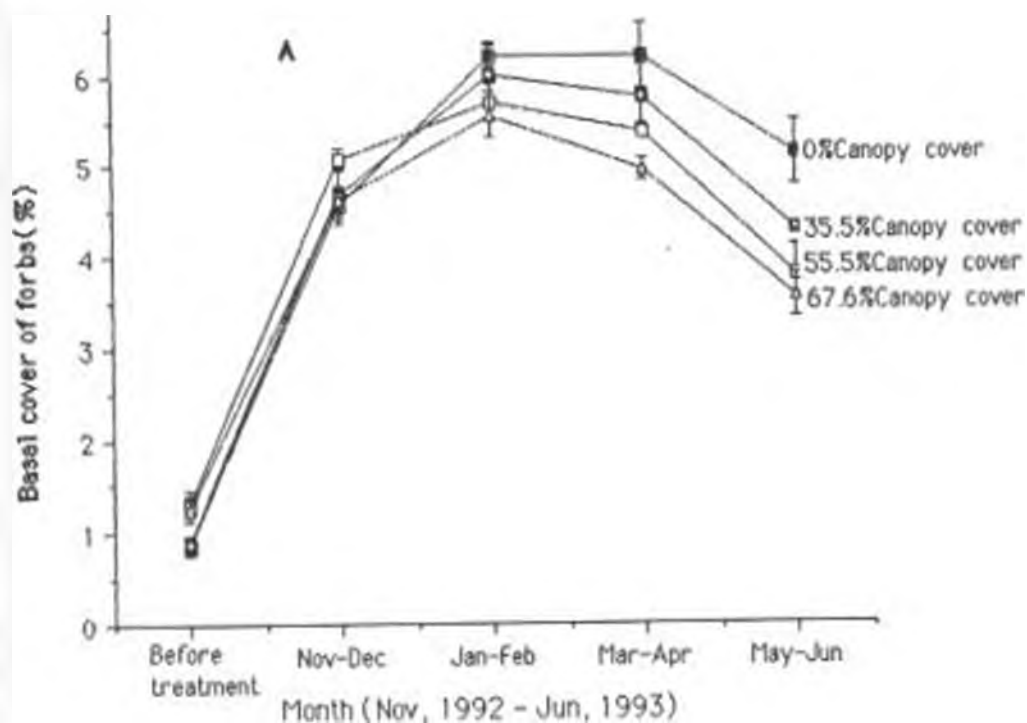
Fig 13. Comparative effect of treatments on basal cover of forbs (A)
and grasses (B) (Basal cover means are averaged for 2-monthly periods
following treatments). Vertical lines are standard errors.
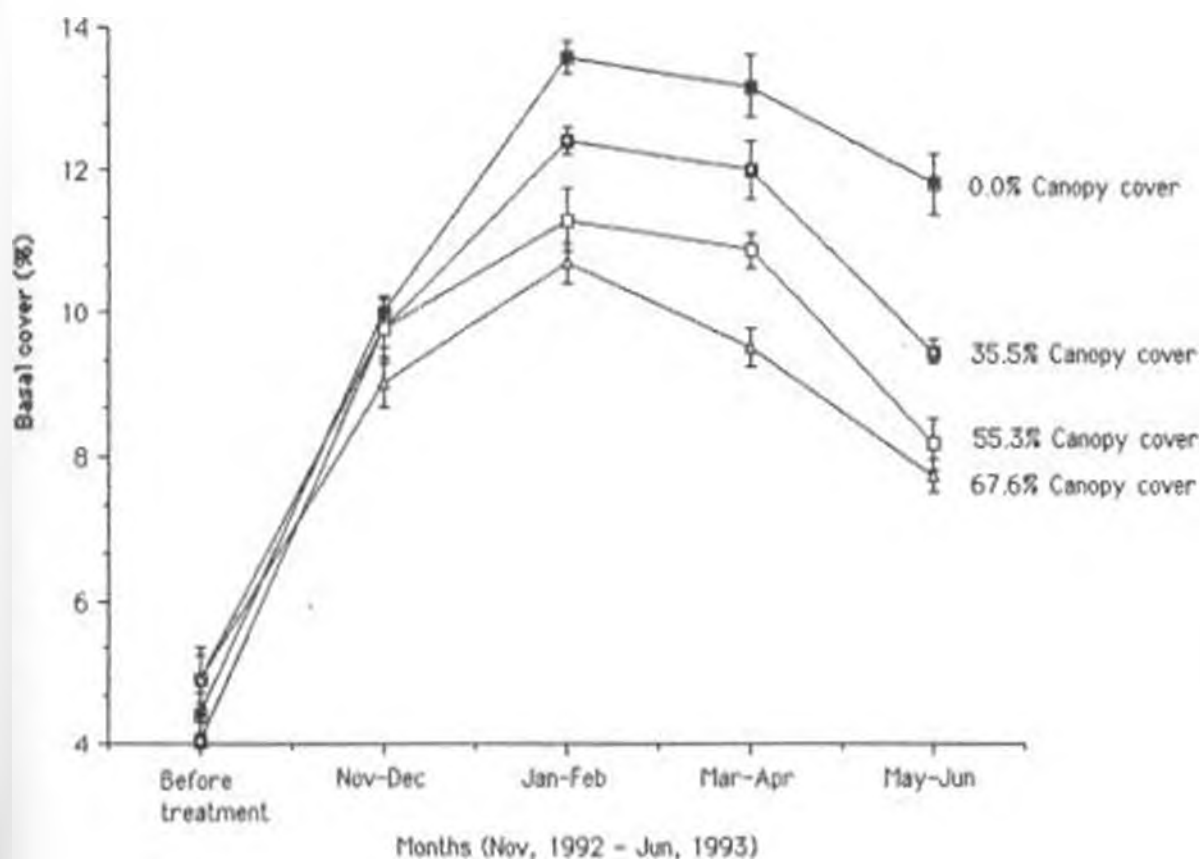
Fig 14 Comparative effect of treatments on basal cover of
all herbaceous species (Basal cover means are averaged for 2-monthly
periods following treatment). Vertical lines are standard errors.

Table 5. Average basal cover (%) for the 8-monthly harvests following treatment.

Treatments	Herbage Components.		
Woody canopy cover(%)	Grasses	Forbs	Total herbage
0.0	6.64^a	5.44^a	12.08^a
35.5	5.61^b	5.32^a	10.93^{ab}
55.3	5.05^c	4.96^{ab}	10.01^{bc}
67.6	4.47^d	4.66^b	9.13^c

Means within the same column followed by the same letter are not significantly different (P$\leq$0.05) according to Duncan's new Multiple Range test.

were not different. When forbs and grasses were combined, the basal cover means in the following treatment groups were not different; 0% vs 35.5%, 35.5% vs 55.3% and 55.3% vs 67.6% canopy covers.

Linear regression equations were fitted to forbs and grasses (Fig.15). Significant trends were revealed between woody canopy cover and basal cover for grasses (p=0.001) and forbs (P=0.0065). The overall rate of increase in basal cover of grasses was higher than that of forbs. For each 1% decrease in canopy cover, grass basal cover increment was about 0.03%. The corresponding increase for forbs was 0.01%. Although grasses had a higher rate of increase in basal cover than forbs, that for forbs exceeded grasses in dense canopies.

A 2nd degree polynomial equation best described the relationship between woody canopy cover and basal cover for all herbaceous species. This is presented in Fig. 16. This relationship showed a significant negative curvilinear trend (P=0.0001).

The contribution of basal cover for the selected species and species groups in the thinned treatments as compared to unthinned treatment is presented in Table 6. Apart from the basal cover of other grasses and that of

Barlaria submollis, greater percentage gains in basal cover
of other selected species and species groups were recorded

on the heavier thinnings. Like biomass, increment of basal
cover for all grass species across the treatment levels was
higher than that of forbs.

The variation in basal cover attributable to variation
in woody canopy cover and coefficient of variation for
Enteropogon macrostachyus, Chloris roxburghiana, Macrotyloma
axillare, Barlaria submollis and species groups are shown in
Table 7. Linear regression analysis showed that woody canopy
cover explained only 0.02% of the variation of basal cover
of other grasses, 59.2% of the variation in basal cover of
other forbs and about 42.2% of the variation in basal cover
of all forb species.

The relationship between woody canopy cover and basal
cover of Enteropogon macrostachyus (Fig.17) was best
described by a linear regression equation. This relationship
was significant (p=0.0001). The relationships between woody
canopy cover and basal cover of Chloris roxburghiana
(P=0.0001), Macrotyloma axillare (P=0.0001) and Barlaria
submollis (P=0.0003) were best described by 2nd degree
polynomial equations (Figs. 18, 19 and 20 respectively).
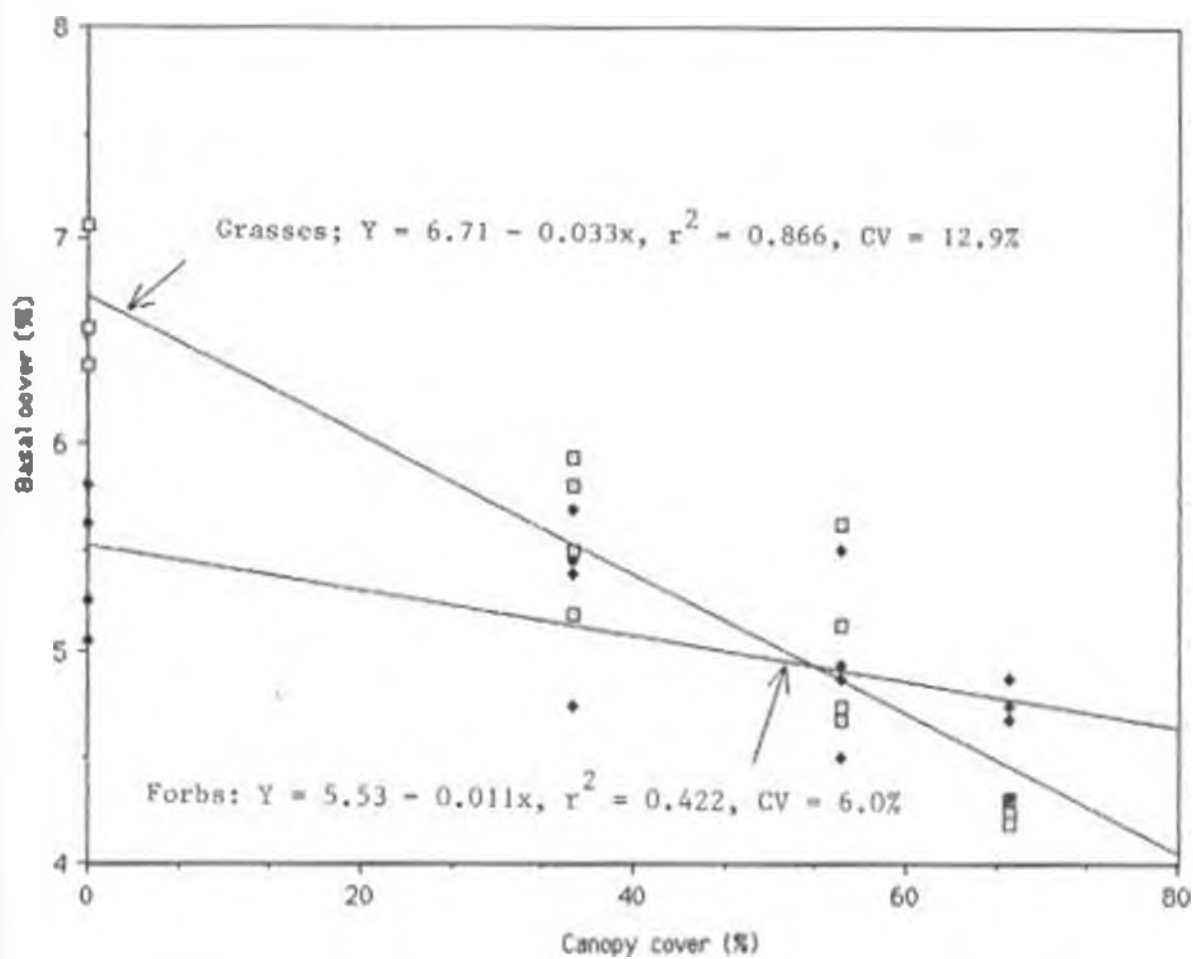These relationships were significant at $P \leq 0.05$.

Fig 15 Relationship of woody canopy cover with basal cover of grass and forb species (n=16)
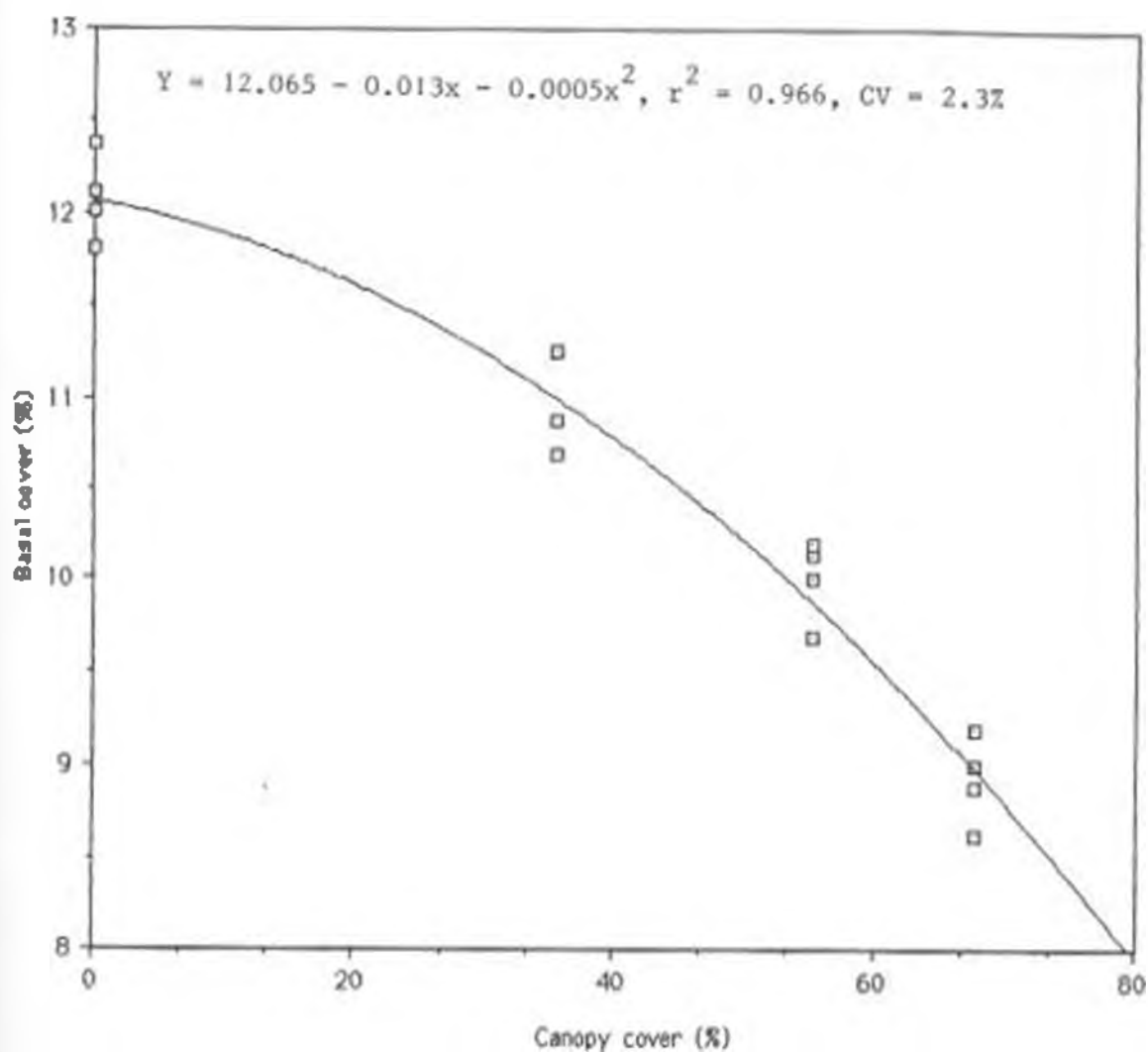
Fig 16 Relationship of woody canopy cover with basal cover of all herbaceous species (n=16).

Table 6. Percentage basal cover increment on the imposed
treatments as compared to the control treatment.

Species	woody canopy cover(%)		
	0	35.5	55.3
Grasses			
1. Enteropogon macrostachyus	67.5	30.0	19.6
2. Chloris roxburghiana	158.1	61.3	32.3
3. Other grass species	-15.4	8.1	5.1
4. All grasses combined	48.5	25.5	13.0
Forbs			
1. Macrotyloma axillare	144.0	96.0	16.0
2. Barlaria submollis	-38.5	-20.0	-11.3
3. Other forb species	57.7	39.1	23.2
4. All forbs combined	16.7	14.2	6.4
Total herbaceous species	32.3	19.7	9.6

Table 7. Percentage variation in basal cover attributable to
variation in woody canopy cover.

Species	% variation attributable to Variation in canopy cover	*CV(%)
Grasses		
1. Enteropogon macrostachyus	70.9	12.9
2. Chloris roxburghiana	78.3	19.5
3. Other grass species	0.02	9.2
4. All grasses combined	86.6	6.1
Forbs		
1. Macrotyloma axillare	90.3	13.4
2. Barlaria submollis	71.0	11.9
3. Other forb species	59.2	13.9
4. All forbs combined	42.2	6.0
Total herbaceous species	96.6	2.3

*CV=coefficient of variation.

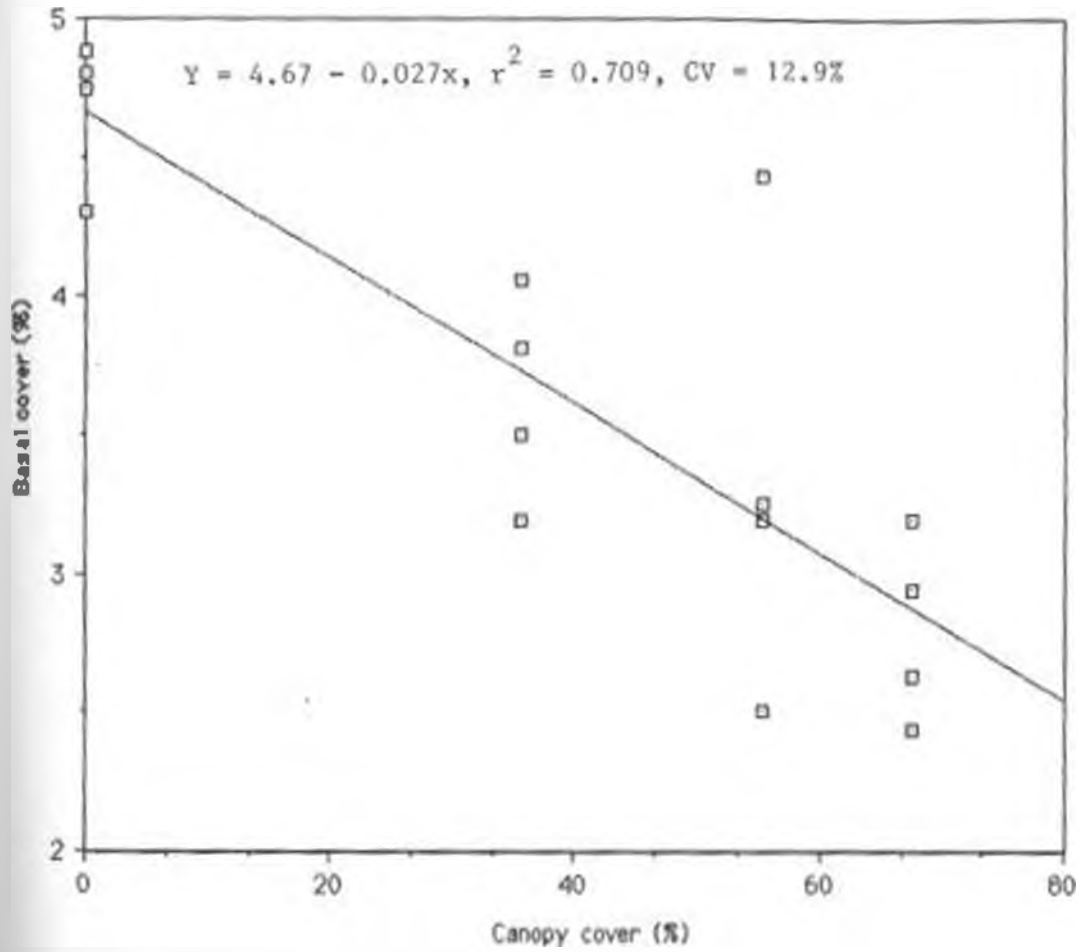Fig. 17 Relationship of woody canopy cover with basal cover of
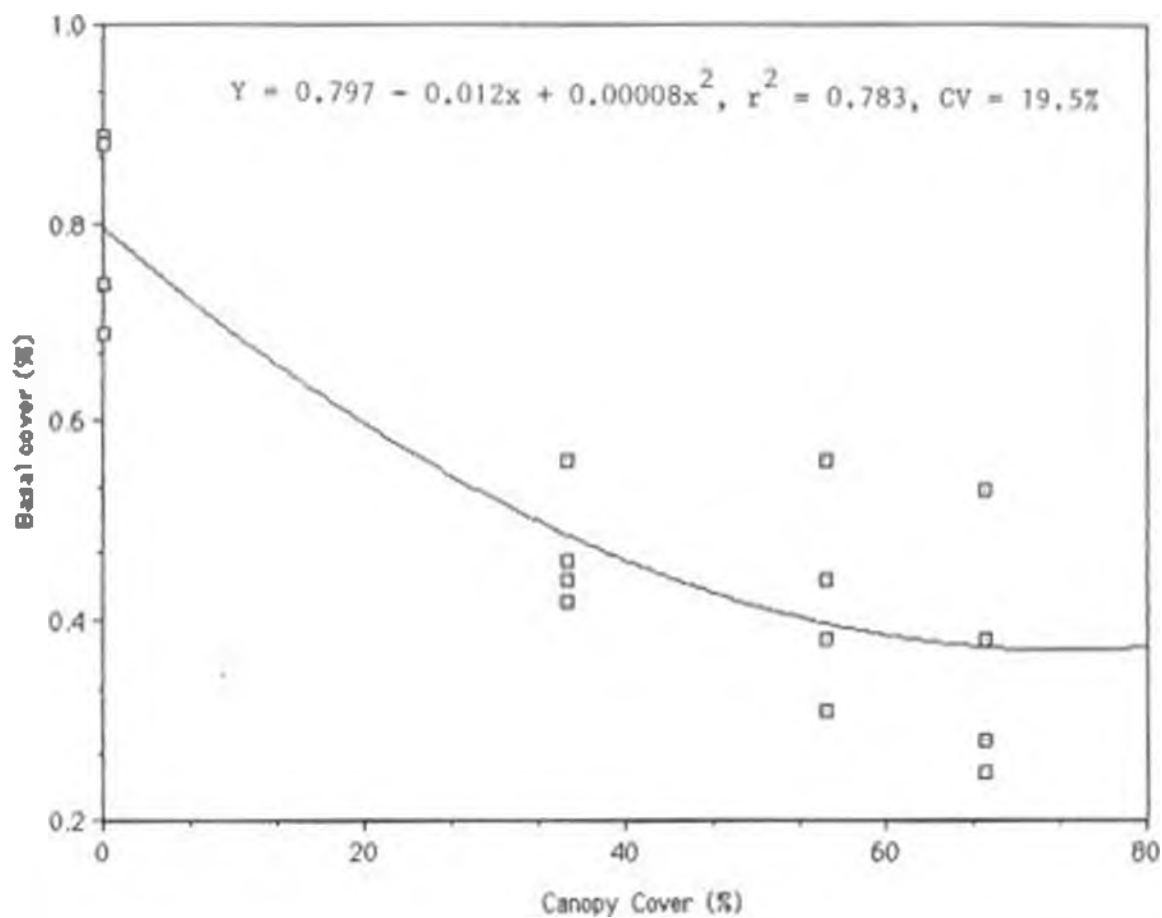Enteropogon macrostachyus (n=16)

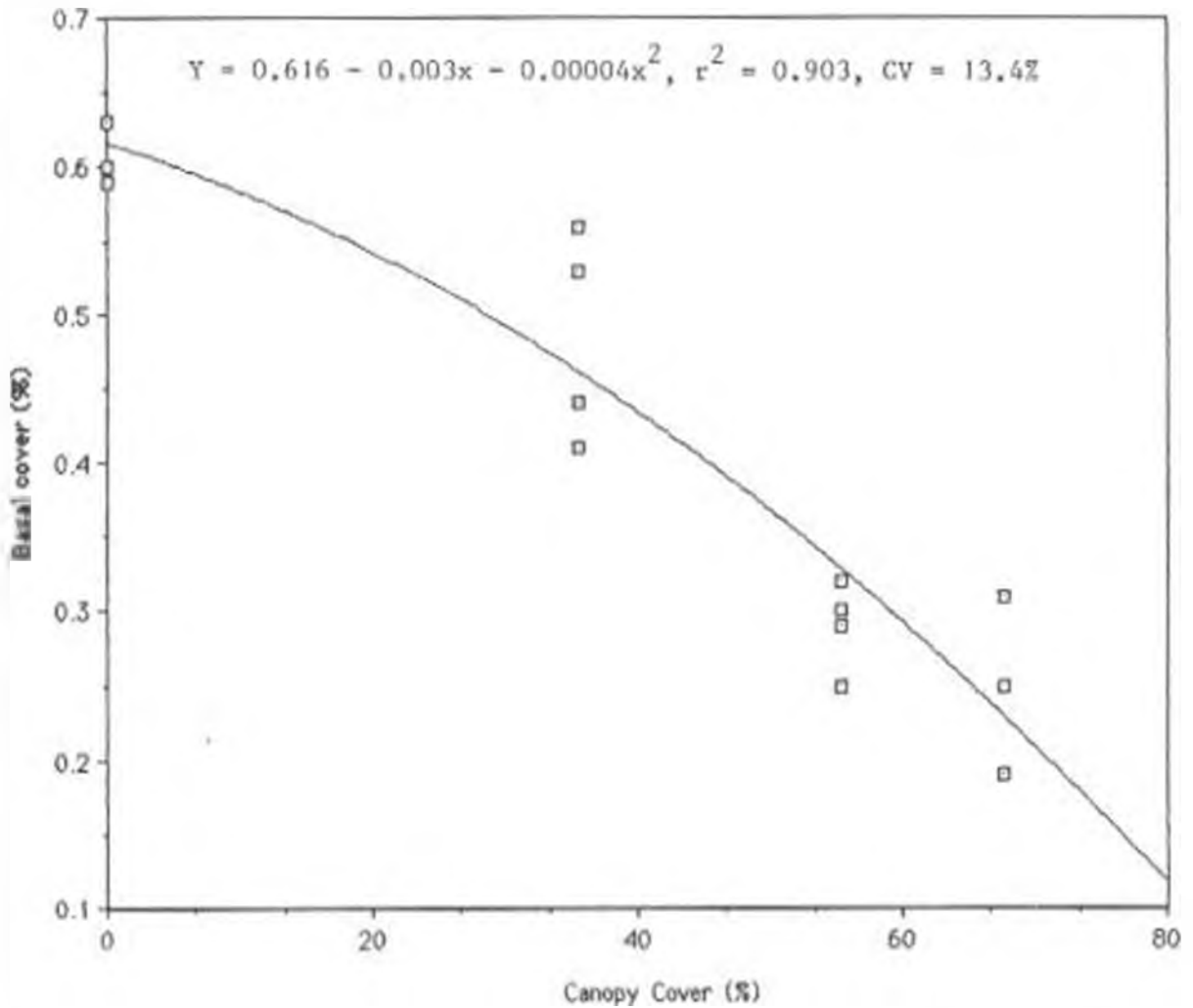Fig 18 Relationship of woody canopy cover with basal cover of Chloris roxburghiana (n=16)

Fig 19 Relationship of woody canopy cover with basal cover of Macrotyloma axillare (n=16).
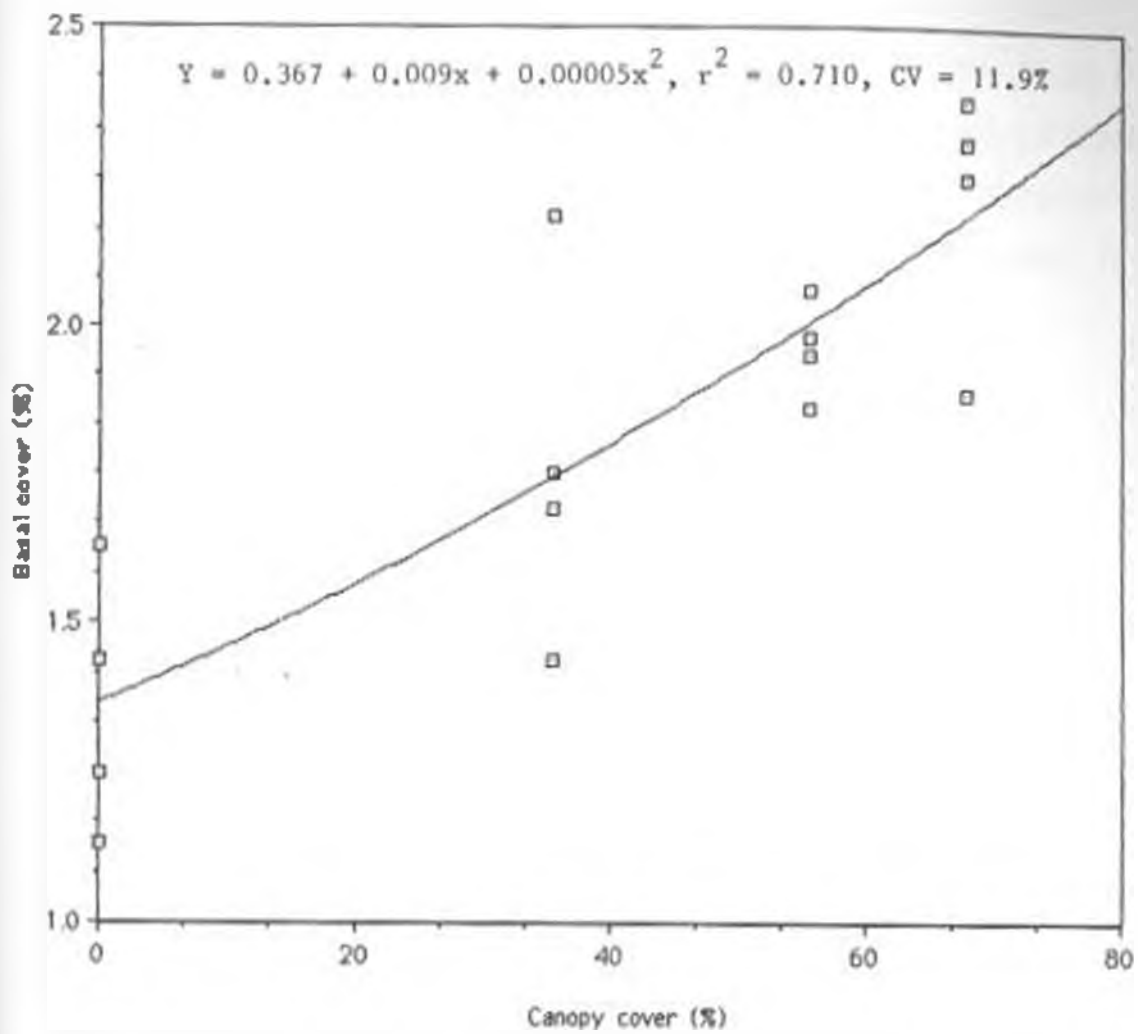
Fig 20 Relationship of woody canopy cover with basal cover of Barlaria submollis (n=16).

4.5 Effects of woody canopy cover on frequency of herbaceous species

The monthly changes in frequency of <u>Chloris</u> <u>roxburghiana</u>, <u>Enteropogon</u> <u>macrostachyus</u>, <u>Macrotyloma</u> <u>axillare</u> and <u>Barlaria</u> <u>submollis</u> are presented in Figures 21,22,23,and 24 respectively. Maximum frequency for the two grass species and that of <u>Barlaria</u> <u>submollis</u> occurred between January and February. For <u>Macrotyloma</u> <u>axillare</u> it occurred between March and April. <u>Enteropogon</u> <u>macrostachyus</u> and <u>Macrotyloma</u> <u>axillare</u> were the most frequent species in the thinned treatments while in the control treatment it was <u>Barlaria</u> <u>submollis</u>.
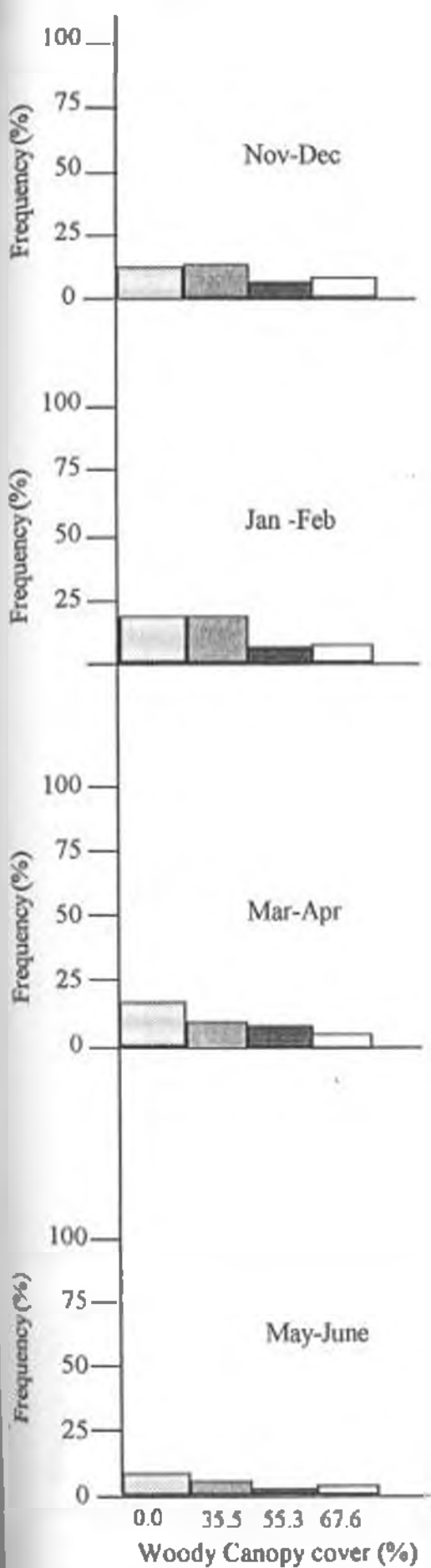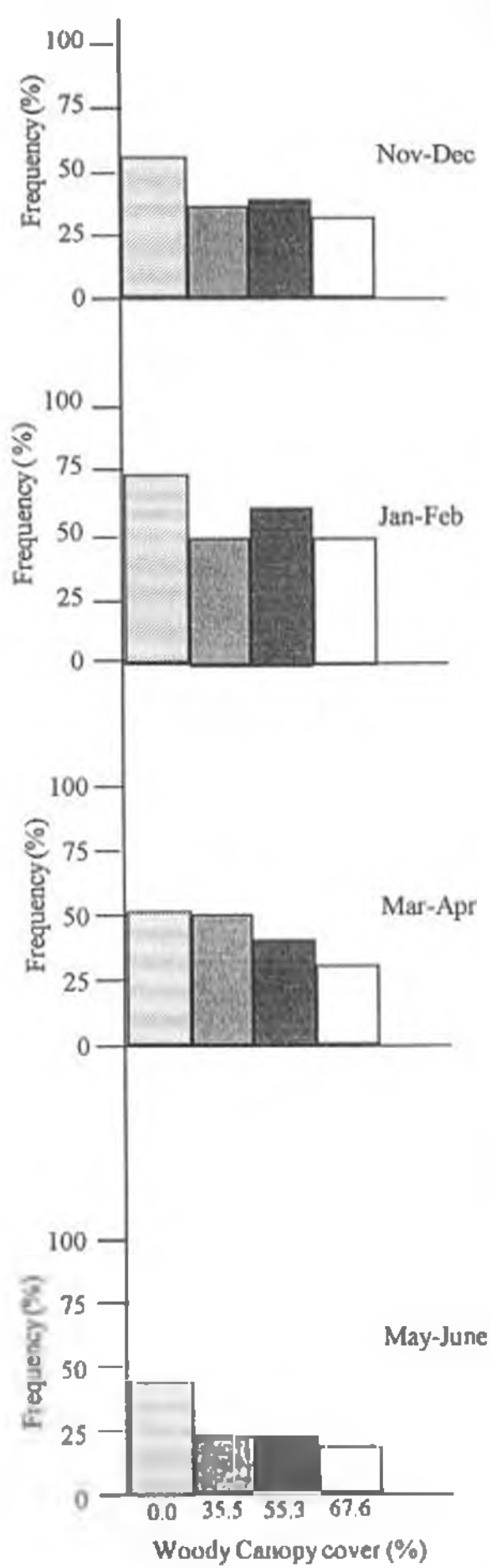
Fig. 21 Monthly changes in frequency of *Chloris roxburghiana* after treatment averaged for 2- monthly periods

Fig. 22 Monthly changes in frequency of *Enteropogon macrostachyus* after treatment averaged for 2-monthly periods
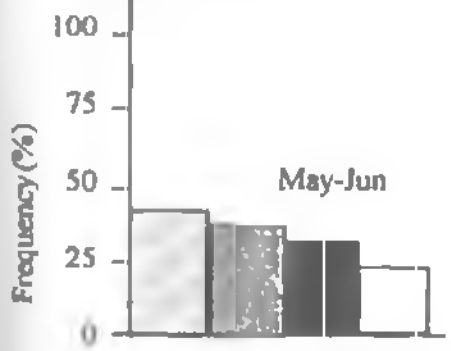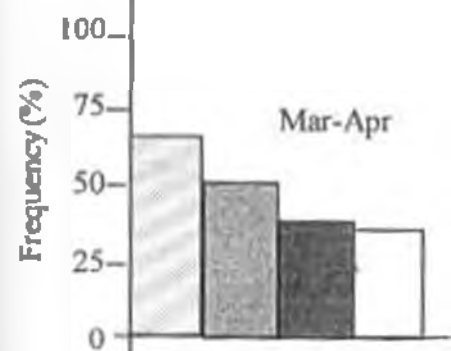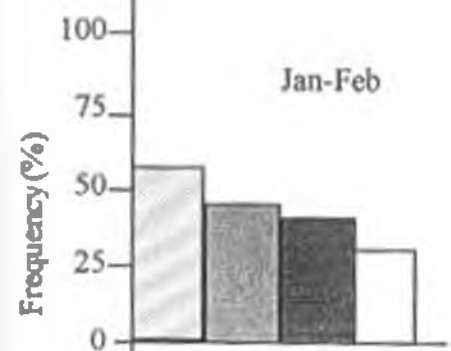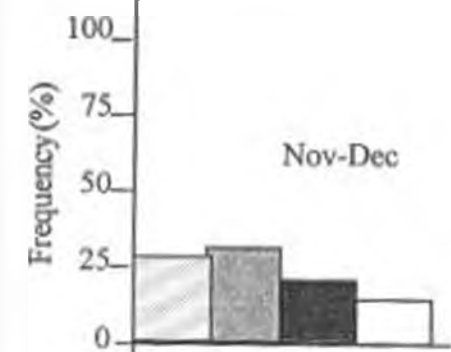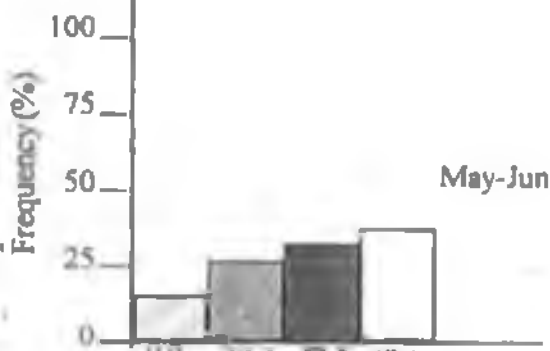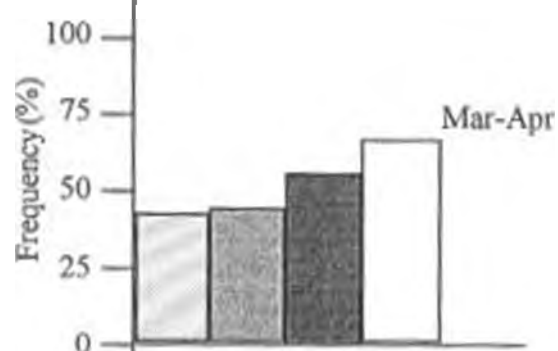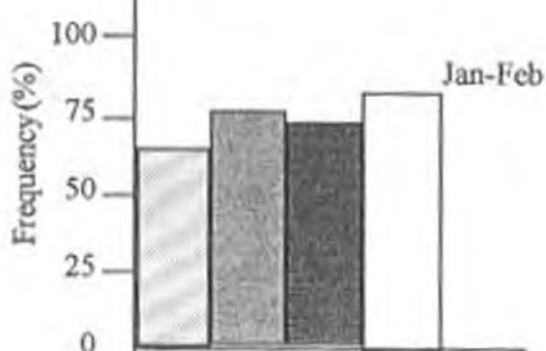
Fig. 23 Monthly changes in frequency of *Macrotyloma axillare* after treatment averaged for 2-monthly periods

Fig. 24 Monthly change in frequency of *Barlaria submollis* after treatment averaged for 2-monthly periods

5.   **DISCUSSION**

        Both physical and chemical properties of the soil
affect production and basal cover of plant species. Soil
properties indicated that the vegetation in the study area
is supported by sandy and infertile soils. For example, the
total exchangeable cation concentration (K, Na, Mg, Ca) was
5.48 Me/100g soil. Organic matter was also low (2.2%). The
soil is also deficient in Phosphorus.

        Results showed that biomass production and basal
cover of forbs, grasses and total herbage were positively
related to thinning, i.e., heavy thinning produced more
biomass and had a higher basal cover than dense canopies.
The frequency of most species was also high in the thinned
treatments.

        Biomass and basal cover of grasses started to decline
from February. This was due to a decrease in rainfall from
February. They also started to dry up due to the rapid
increase in creepers such as Macrotyloma axillare which
covered them.

        Apart from creepers, some forbs such as Osmum
basillicum and Leucas grabrata started to dry up as rainfall
decreased, this slightly reduced basal cover of forbs as

from February. However the growing period of most forbs was longer than that of grasses and their biomass continued to increase up to April.

Comparative effect of treatments on total herbage showed that the presence of trees and shrubs in the lightly thinned treatment increased the growing period of herbage. For example in 55.3% and 67.6% canopy covers, maximum herbage occurred between March and April while in 0% and 35.5% canopy covers it occurred between January and February. This was possibly due to the ameliorating effect of woody species on the environment of herbaceous species. For example, improved plant water relations in dense canopies is known to increase productivity (Belsky et al. 1989).

The data showed that woody canopy cover associated with dense tree and shrub thickets suppressed grasses more than they suppressed forbs. McConnell and Smith (1965) and (1970) found that as canopy cover diminished grass biomass was higher than forb biomass. Apparently this trend was not observed in Figure 7. This is because as canopy cover diminished, forbs with creeping habits covered the tree/shrub openings. These creepers increased forb biomass with increasing degree of thinning. The result was that forb biomass exceeded grass biomass at all the canopy cover

levels.

When biomass and basal cover equations of herbage components were extrapolated (Figs.8 and 15 respectively), forbs produced about 887 Kg/ha whereas grasses yielded 783 Kg/ha under a 90% canopy cover. As the canopy opened, the difference in biomass production between these two vegetal classes diminished and at 0% canopy cover, forb and grass biomass were approximately equal. Under a 90% canopy cover, the basal cover of forbs increased about 4.53% compared to 3.71% for grasses. The superiority of forbs diminished as canopy diminished and at 53.1% canopy cover, both classes had similar rates of increase. As the canopy continued to open up, the situation reversed and grasses showed larger increases than forbs.

In dense canopy covers, forbs are expected to do better than grasses because they are more efficient users of low light due to their more horizontally disposed leaf habits that enables them to achieve a fuller canopy of foliage. In contrast, the leaves of grasses are disposed at various levels and angles; they do not form such a continuous cover of foliage (Donald and Black 1958).

The contrast between the response of Barlaria submollis and Macrotyloma axillare may possibly be explained by their

growth habits. For example, the later species grows in tree
and shrub openings and is therefore a light dependant
species while the former species is prominent under tree and
shrubs as a shade tolelant forb.

Biomass and basal cover of most herbaceous species in
the treatments were best explained by variations in woody
canopy cover, with the exception of Enteropogon
macrostachyus. Though this species did better at the heavily
thinned treatments, its biomass production in replicates of
the treatments was highly variable ($r^2=0.467$). According to
Bogdan (1958) this grass species grows in bush and after
clearing dense bush thickets it is often the only perennial
component of the grass cover for 1 or 2 years.

Percentage variation in biomass and basal cover of
other grass and forb species attributable to woody canopy
cover was very low. Species of this groups possibly reacted
in a different manner to woody canopy cover. For example,
biomass and basal cover of some species may have increased
with increased thinning levels while others showed a
negative response.

Only a small percentage was explained by woody
canopy cover when the basal cover of all forbs was combined.
This was probably due to variability in the replicates of

35.5% and 55.3% canopy covers. Often those replicates with high basal cover values in the lightly thinned treatments had weak herbaceous species. Possibly, this was due to increased competition for resources.

Results of this study showed that biomass production and basal cover of herbaceous species were inversely related to woody canopy cover. They emphasize that the major factors affecting herbaceous species within the treatments are tree/shrub density and their associated canopy covers.

Reduced performance of herbaceous species in the lightly thinnned treatments occured as a result of competition between woody and herbaceous species both in the tree and shrub canopy zone and in their root zone. According to Fowler (1986), as plants are competing for resources in the dense tree/shrub stands, their growth rates, frequency and the magnitude of viable seed production is decreased. The more closely plants are crowded together the more they interfere with each other's acquisition of same essential resources.

For species population a crucial advantage is a degree of protection from competition which can be achieved by thinning as shown by results of this study. Thinning results in fewer plants competiting for available supplies

of soil moisture and plant nutrients and this in turn means
that these fewer plants growing under more favourable
conditions will be able to grow and reproduce.

The effects of tree and shrub shading in moderating
light intensity, air and soil temperature and soil moisture
in the unthinned treatment may be limiting herbage
production. Visual assessment in this treatment also reveals
presence of a thick mat of undecomposed litter which may be
reducing the performance of herbaceous species. Weaver and
Tomanek (1951) and Ehrenreich (1959) found that accumulation
of mulch depresses herbage yield and reduces the number of
plant species. Matizha and Dahl (1991) also found that
phytotoxicity from tree/shrub litter reduces or eliminates
radicle and root development in grass seedlings.
However, litter is known to increase the soil moisture
content by decreasing runoff (Pressland 1976), erosion and
infiltration rate. It also improves germination, growth and
development of grass seedlings through moderation and
stabilization of surface soil temperatures and surface soil
moisture (Army and Hudspeth 1960, Silcock 1973). Some degree
of tree and shrub thinning will reduce litter accumulation
and its beneficial effects may then be realized.

The results in this study agree with the findings of
Farah (1990) that increased shrubs or woodlands in this

region as from 1960 has lowered the grazing capacity of the primary resource base. Increased woodediness in the Station may be explained by lack of fire and its interaction with variable climatic regime.

The results of this study showed that the area has a high herbaceous species productive potential after bush control. When considering the available options for bush control, attention should be directed to those methods that are cheap, easy to apply and effective. They should also avoid herbaceous species destruction. For example, fire alone cannot effectively control the already well established trees and multi-stemmed shrubs in the Station. Because the herbaceous species are sparsely distributed under overstorey species, hand clearing and mechanical methods such as railing, shredding. chaining, land imprinting and roller chopping which avoid herbaceous species destruction may have an advantage over use of herbicides.

6. LIMITATIONS OF THE STUDY

1. Although the objective was to determine impact of tree and shrub thinning on production, cover and frequency of herbaceous species, it was not possible to fully eliminate competition between cut woody species and herbaceous species because the cut trees and shrubs remained as stumps which did not die completely during the study period.

Uprooting the woody species eliminates competition, however this method destroys most of the herbaceous species. Since the aim was to evaluate the initial response of established herbaceous species, it was necessary to avoid their destruction by using hand cutting method to impose the treatment inspite of its limitation.

2. The crown diameter method used in measuring woody canopy cover provides better estimates as compared to relying on visual estimates. However, it was not possible to thin the replicates to the same canopy cover but apart from the unthinned treatment where the highest variation in replicates was 7.0%, the variation in the thinned treatments did not vary by more than 5.9%.

7.   CONCLUSIONS AND RECOMMENDATIONS

It is evident that woody canopy is closely related to understorey vegetation in its effects. This relationship is an inverse one with decreased production potential and basal cover of herbaceous species being associated with higher tree and shrub canopy cover. The data suggested that decreasing overstorey canopy cover tends to increase highly productive grass and forb species such as Enteropogon macrostachyus, Chloris roxburghiana, and Macrotyloma axillare. As canopy cover increased, the understorey herbaceous vegetation shifted to more shade tolerant species such as Barlaria submollis.

Removal of trees and shrubs allowed establishment of grass species critical for improving the nutritional status of cattle diets. The data provides some indication of herbage production potential under different levels of woody canopy cover.

The management of bushland thickets in Kibwezi cannot be a compromise since these dense thickets are presently left with no use. Thinning trees and shrubs will increase stocking rate and allow even animal distribution throughout the year. It can be concluded from the data that to maximize herbage production, tree and shrub density should be reduced

to achieve a canopy cover of not more than 35.5%.

Managing this increased production may be worthwhile in terms of animal production. However, management should focus on the creation of a combination of forms of vegetation, such a vegetation will best exploit the site potential and meet the year-long food requirements of all the grazing animals, will secure the soil stability, protect the watersheds, serve hydrological purposes and improve the aesthetic value of the landscape, therefore complete brush eradication should be avoided.

The following are some of the recommendations arising from the research findings;

1. Though high biomass production was achieved in complete clearing than in the other thinning levels, positive effects of woody species justifies the need to leave some trees and shrubs. The data suggested that the best productive potential can be achieved under a canopy cover of not more than 35.5% (500 shrubs and 167 trees/ha).

2. Data collection for these treatments for longer periods (1-3 years) is recommended. These data will generate enough information necessary for comprehensive conclusions and recommendations to be made.

3. Forage responses after thinning varies with type of method used. To select the best method, a study investigating biomass production under different methods should be initiated.

4. Removal of trees and shrubs allowed early establishment of grass species. However, this establishment is complicated by the ability of associated brush species to sprout vigorously. Introduction of a grazing and/or prescribed fire management plan after brush control should be investigated for controlling bush encroachment.

5. The economics of bush control should be investigated to determine the most effective methods.

6. An experiment with objectives of determining production and basal cover changes of understorey species following thinning in different type of soils within the Station should be conducted. This will help in determining what areas may profitably be treated.

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Appendix 1. Common tree, shrub, forb and grass species in Kibwezi Dryland Field Station.

Trees and shrubs
Abutilion mauritianum
Acacia brevispica
Acacia mellifera
Acacia nilotica
Acacia tortilis
Acalypha fruticosa
Albizia antihelmintica
Asparagus recemosus
Boscia angustifolia
Boscia coriaceae
Combretum molle
Combretum exalatum
Combretum macrostigmatum
Commiphora neoli
Commiphora riperia
Commiphora africana
Croton dichogamus
Duosperma kilimandscharicum
Grewia bicolar
Grewia similis
Grewia villosa
Glycine weghtii
Hermannia alhensis
Hibiscus oponeurus
Holslundia opposite
Lepidagathis scariosa
Lippia javanica
Maerua trichophylla
Ochna insculpta
Pavania patens
Premna holstii
Ruttya fruticosa
Solanum incanum
Tephrosia villosa

FORBS
Astripomea hyoscyamoides
Barlaria submollis
Blepharis integrifolia
Crabea velutina
Commelina benghalensis
Ipomoea mombassania
Justicia discliptera
Leucas glabrata
Macrotyloma axillare
Osmum basillicum
Oxgonium sinuatum

GRASSES
Aristida keniensis
Bracharia repens
Bracharia semiundulata
Chloris roxburghiana
Digitaria velutina
Enteropogon macrostachyus
Eragrostis racemosa
Eragrostis cilianensis
Eragrostis superba
Heteropogon contortus
Panicum duostaum
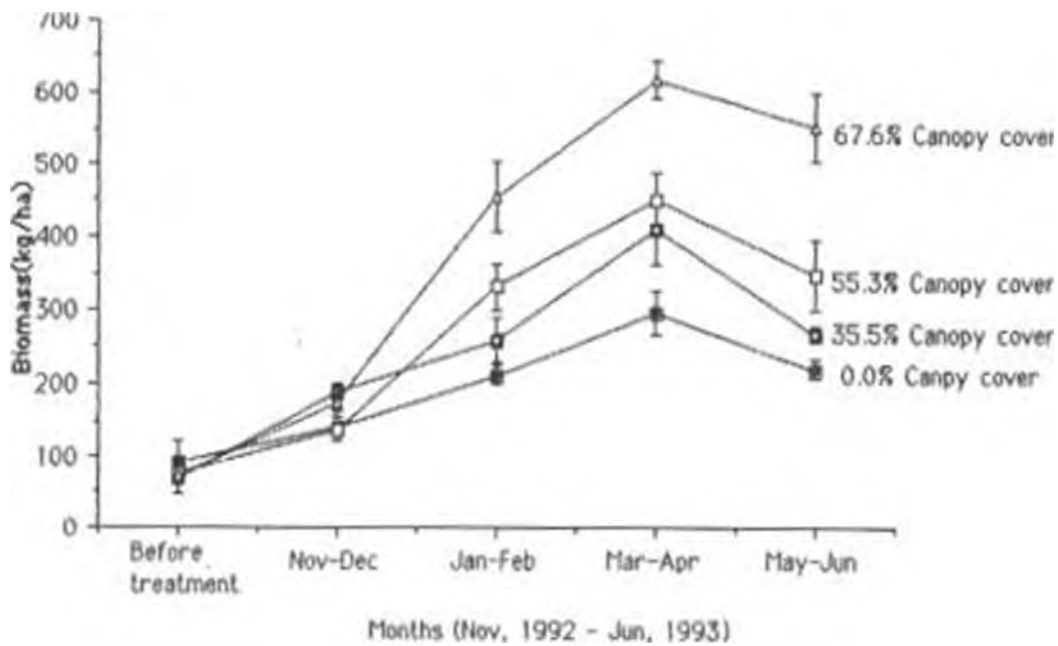Panicum maximum
Perotis hilderbrandtii
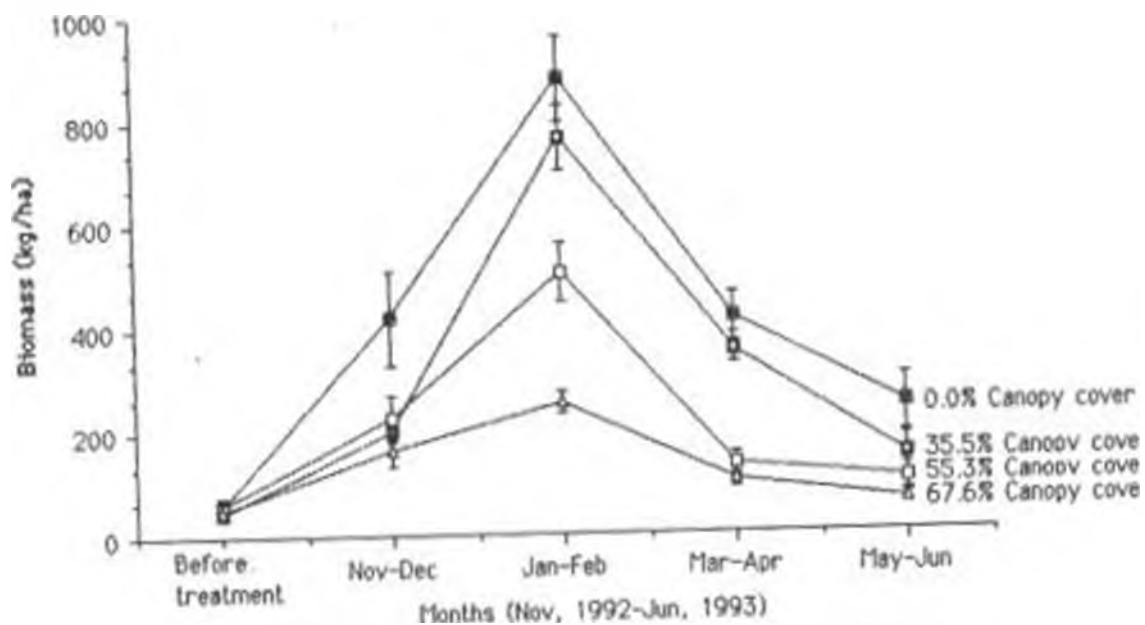
Appendix 2 Comparative effect of treatments on biomass of
Chloris roxburghiana (Biomass means are averaged for 2-monthly
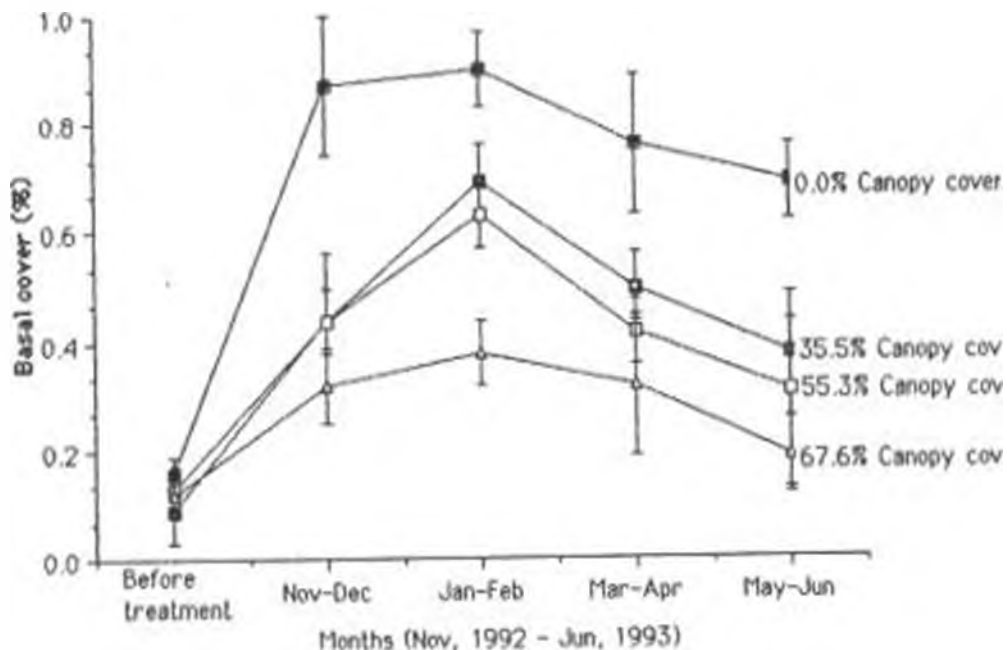periods following treatment). Vertical lines are standard errors
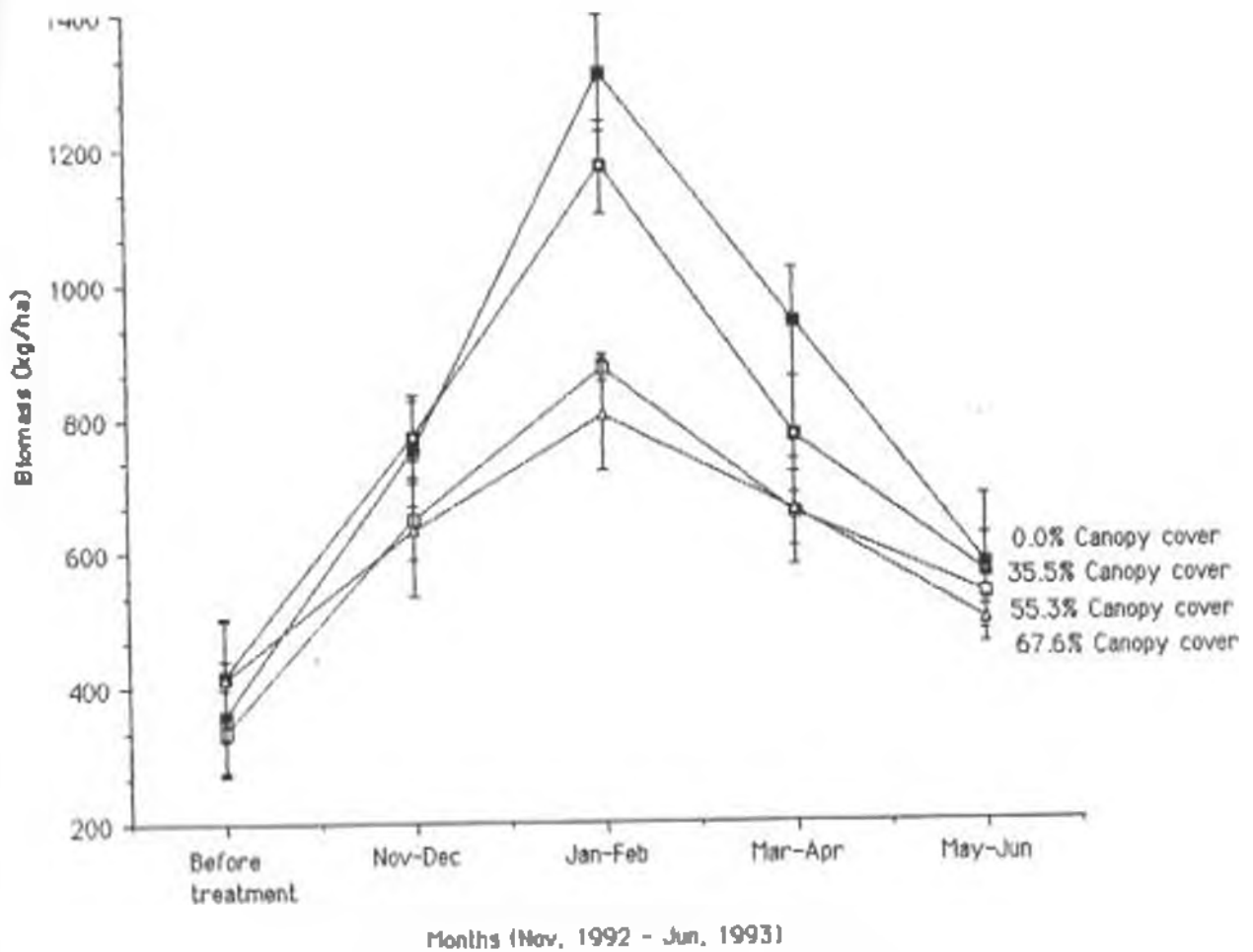
Appendix 3. Comparative effect of treatments on biomass of
Enteropogon macrostachyus. (Biomass means are averaged for 2-monthly
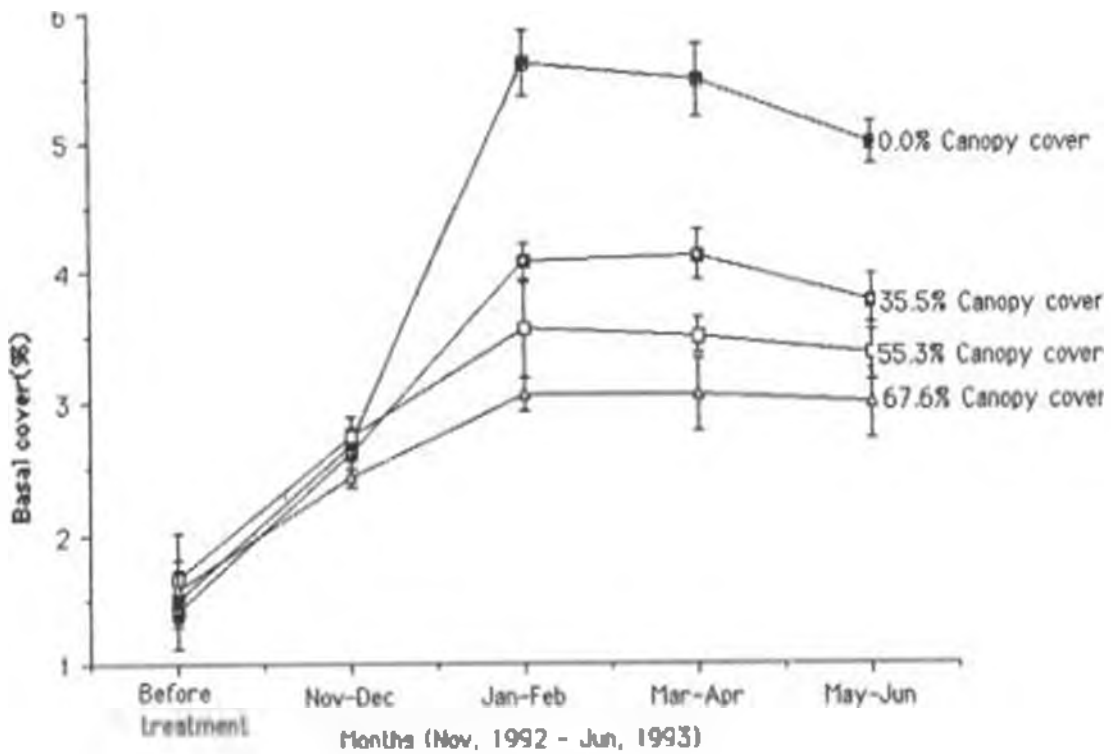periods following treatment). Vertical lines are standard errors.
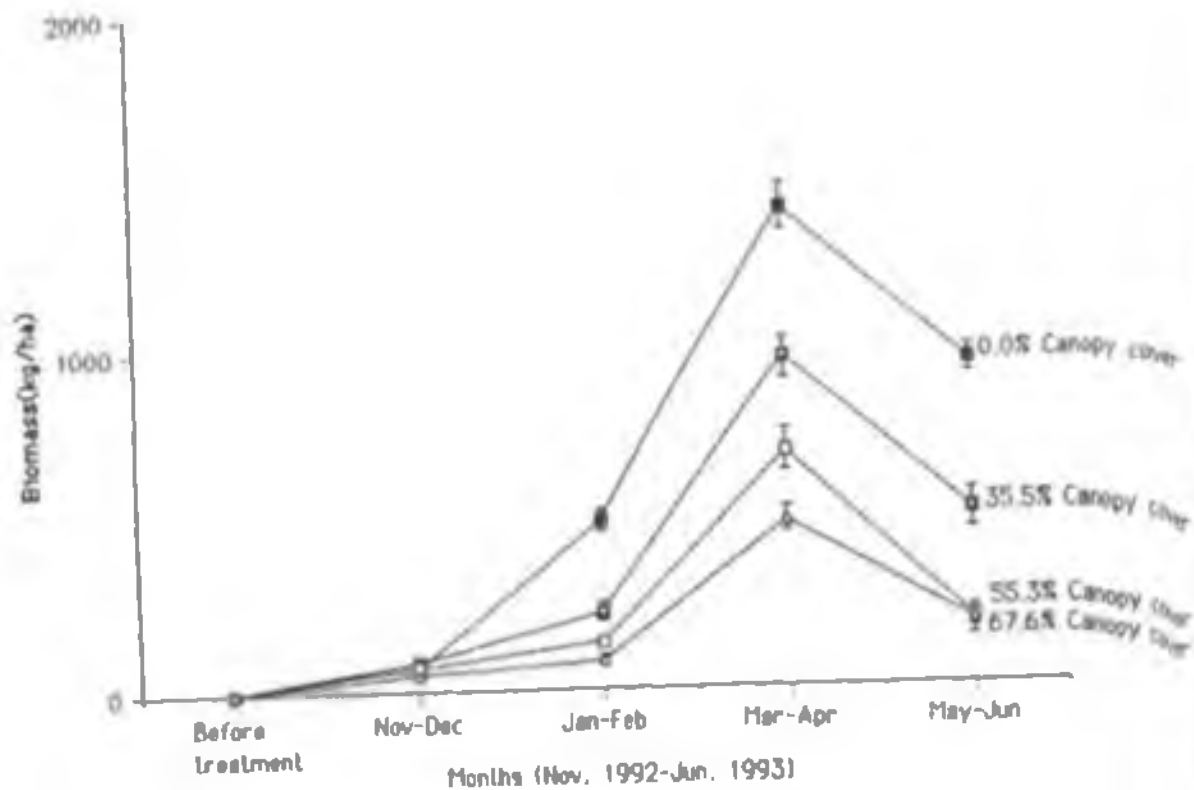
Appendix 4. Comparative effect of treatments on biomass of Macrotyloma axillare.(Biomass means are averaged for 2-monthly periods following treatment) Vertical lines are standard errors.
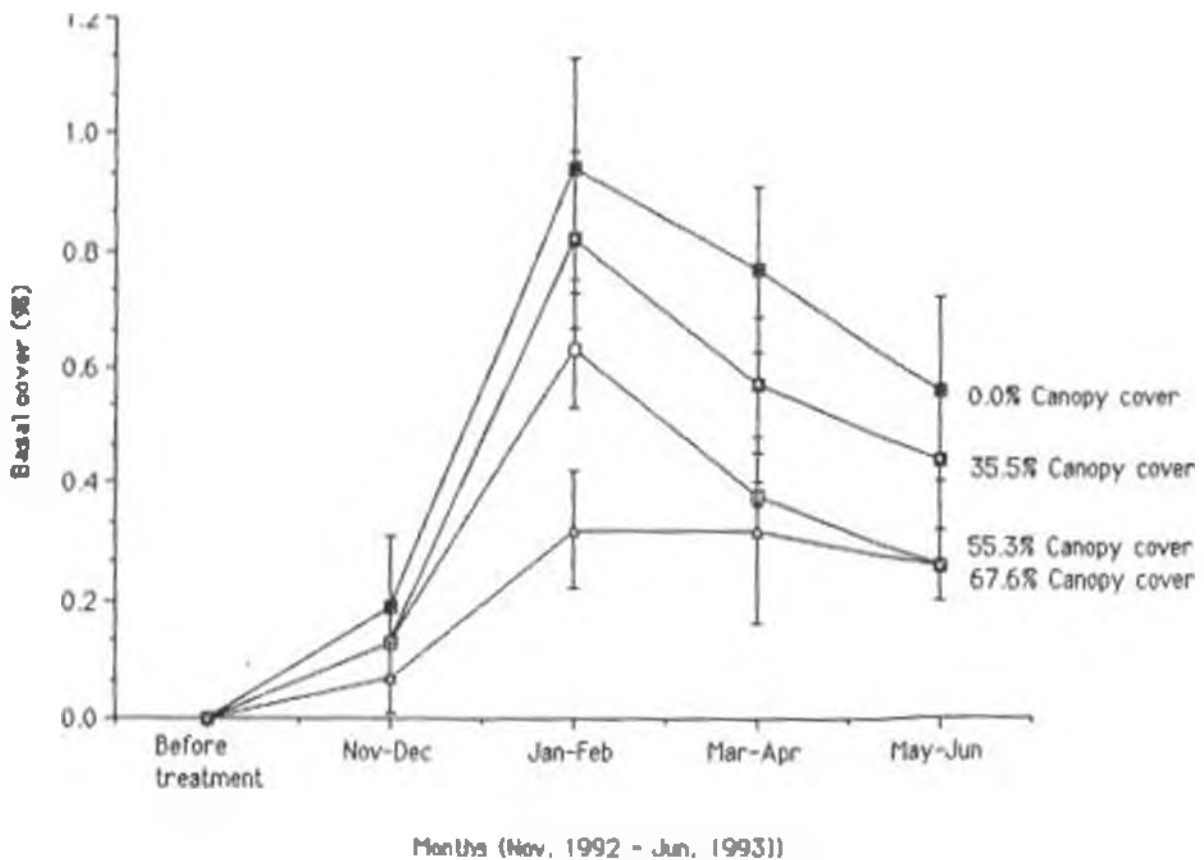
Appendix 5 Comparative effect of treatments on biomass of
Barlaria submollis (Biomass means are averaged for 2-monthly
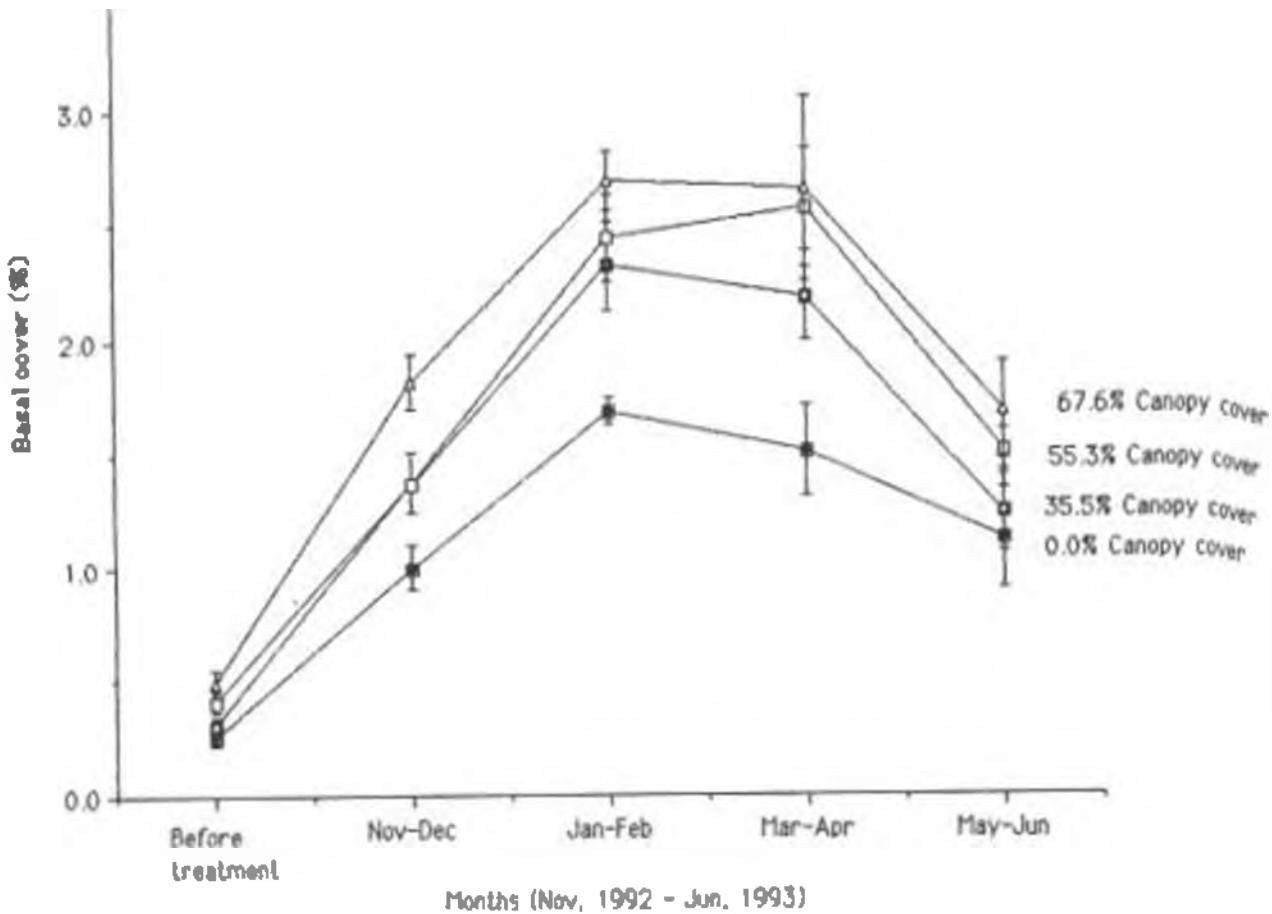periods following treatment) Vertical lines are standard errors

Appendix 6. Comparative effect of treatments on basal cover of
Chloris roxburghiana (Basal cover means are averaged for 2-monthl
periods following treatment). Vertical lines are standard errors.

Appendix 7. Comparative effect of treatments on basal cover of
Enteropogon macrostachyus (Basal cover means are averaged for 2-month!
periods following treatment) Vertical lines are standard errors

Appendix 8. Comparative effect of treatments on basal cover of Macrotyloma axillare (Basal cover means are averaged for 2-monthly periods following treatment). Vertical lines are standard errors.

Appendix 9. Comparative effect of treatments on basal cover of
Barlaria submollis. (Basal cover means are averaged for 2-monthly
periods following treatment). Vertical lines are standard errors.