THE EFFECT OF LAND TREATMENT AND SEEDING METHODS ON ESTABLISHMENT OF THREE RANGE GRASSES IN THE SEMI-ARID RANGELANDS OF MAKUENI DISTRICT, KENYA

By

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DECLARATION:

THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY.

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DATE: 20th August 1992.

THIS THESIS HAS BEEN SUBMITTED FOR EXAMINATION WITH OUR APPROVAL AS UNIVERSITY SUPERVISORS.

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DATE: 20th August 1992

DEDICATION

THIS THESIS IS DEDICATED TO MY DEAR PARENTS.

MR. JOHN NJENGA AND MRS. LEAH MUMBI

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ABSTRACT

The problem of vegetation degradation in Kenya's semi-arid areas must be addressed, if these areas are to support the increasing human and livestock population. However, efforts to revegetate denuded rangelands will be beneficial only if the right species and cultural practices are employed.

This study evaluated methods of establishing grasses in the semi-arid rangelands of Makueni District, Kenya. Three methods of land preparation and two seeding methods were compared for their effectiveness in the establishment of three range grasses. These were tractor ploughing, oxen ploughing and burning. Drilling and broadcasting as seeding methods were investigated. The grasses used were *Eragrostis superba* (Pyer), *Cenchrus ciliaris* L and *Enteropogon macrostachyus* (Hochst and A. Rich) Munro ex Benth. Height, tiller production and grass seedling mortality were the parameters measured as indicators of seedling establishment.

Land preparation treatments involving ploughing were significantly different from burning ($P<0.1$). The burned plots had the shortest plants with the least number of tillers and suffered from the highest seedling mortality. However, the burned plots had the highest density of volunteer annual grasses. There were no significant differences ($P<0.1$) between tractor and oxen ploughed plots. The method of seeding did not significantly affect tiller production and seedling mortality.

Significant response to seeding method was observed in height only. On average the drilled plots showed better establishment.

Response of the three grasses to land preparation and seeding was significantly different ($P < 0.1$). *Eragrostis superba* had the better establishment than *Cenchrus ciliaris* and *Enteropogon macrostachyus*.

From this study, oxen ploughing was shown to have the same effectiveness as tractor ploughing in pasture establishment. Vegetation degradation can therefore be controlled if suitable species, and cultural practices which are easily adoptable are used. Oxen ploughing and broadcasting *Eragrostis superba* are recommended for the Kibwezi area according to the findings of this study.

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CHAPTER 1

1.0 INTRODUCTION

Land based resources in Kenya are currently under intense human pressure especially in the high potential areas of the country. This has been caused by a high population growth rate of 3.7% per annum (Government of Kenya - G.o.K. 1989) and a skewed human population distribution. Over 75% of the people in Kenya live on less than 20% of the Country's land area while the rest live on approximately 80% of the land area. The latter supports more than half the livestock population (G.o.K. 1989). A high population growth combined with a high population density in the high potential areas has lead to non-sustainable exploitation of land resources in those areas and therefore inadequate supply of both food and cash crop needs at the household and national levels.

To meet these demands, people are migrating from the high potential areas to the rangelands. The excessive expectation of these people with respect to the production potential of the rangelands has resulted in the introduction of crop agriculture (Pressland and Graham 1989). Crop failures leave the land exposed to the forces of erosion (Mburu 1983). Climatic and ecological constraints limit the extent of land exploitation for agricultural purposes. The advance of the cultivation frontier into the high potential rangelands has therefore seen the pastoralist's resource base shrinking as they are increasingly confined in less productive rangelands. (Naveh 1966, Kenya National Livestock Development Policy - KNLDP 1980, G.O.K. 1989, Farah 1990).

The increased pressure on range resources has resulted in economic and subsistence marginalization of pastoral households (Lamprey 1983, Cossins 1985, Hansen *et al* 1986). The ability of the rangelands to recover from mismanagement has been reduced as a result of sedentarization and individualization of holdings (Grandin 1987). Common resource use strategies existing there before cannot help in the control of resources (Horrowitz and Little 1987, Farah 1990, Farah and Haji 1990). Vegetation degradation resulting from the high pressure on land has to be checked if the rangelands are to be used on a sustained basis.

Revegetating the bare and denuded lands is one avenue of rehabilitating such lands. Natural revegetation provides the best means of restoring ground cover. However, natural revegetation takes a long time depending on climate, species present, soil and the degree of denudation of the site (Jordan 1957, Naveh 1966, Valentine 1977, Heady and Heady 1982). Resting the land for such a time to allow natural restoration of ground cover may not be feasible given that the resources are limited and every year the people have to depend on the same piece of land.

Where soils and climate allow, artificial re-vegetation provides an alternative means for restoring vegetation cover. Grasses are relatively easier to establish as grasses take a short time to mature. In addition to providing ground cover, grasses provide the principle source of forage for livestock (Kategile *et al* 1989) especially in the semi-arid rangelands where supplementation is almost non existent.

The grasses also help in nutrient cycling, provision of organic matter and reducing soil erosion.

Cultural methods should be simple and within the means of most people in the rangelands. Reseeding, however, is not a panacea of range denudation problems and hence should not be divorced from sound management programmes based on sound ecological knowledge of these fragile ecosystems.

1.1 Objectives

The specific objectives of the study were:-

i) To determine a simple and effective method of land preparation for grass establishment.

ii) Establish an efficient seeding method that can easily be adopted by agro-pastoralists and ranchers in the semi-arid rangelands of Kenya.

iii) Evaluate the responses of *Cenchrus ciliaris* (L)., *Eragrostis superba* (Pyer) and *Enteropogon macrostachyus* (Hochst and A. Rich) Munro ex Benth to various land preparations and seeding treatments.

1.2 Hypothesis

To achieve the above objectives, the following hypothesis were postulated.

(i) Land preparation methods do not affect the establishment of grasses.

(ii) The method of seeding has no effect in grass establishment.

(iii) There is no difference in the response of the three grasses to land preparation and seeding methods.

CHAPTER 2

2.0 LITERATURE REVIEW

In the rangelands, moisture conditions suitable for active plant growth are usually short-lived, unpredictable and in many instances unreliable (Perry and Moser 1975, Jordan 1983). Active plant growth therefore follows these fluctuating moisture regimes. Thus there is need to maximize the use of these spells of favourable plant growth. In plant establishment this may be achieved through use of land preparation and seeding methods which offer the best growth, survival and establishment within the moisture limit.

Plant establishment is a function of many factors, some of which are genotypic in origin while others are environmental in nature, (Herriot 1958, Sarukhan *et al* 1984). The interaction between the two sets of factors play a decisive role in the success or failure of a species in a given environment. The manipulation of genetic factors take a longer time to produce a plant which has the best establishment within the confines of climate. Plant environment manipulations on the other hand are relatively easy and are the most widely employed in plant establishment.

Of the environmental variables, the soil is the most widely manipulated. The soil condition dictates the ease of availability of moisture and nutrients to the growing plant.

Most revegetation work has therefore laid emphasis on cultural practices which through soil manipulation will increase the chances of plant establishment.

The principle aim of any cultural method is to provide the seed or any other propagule with the right suitable microclimatic conditions for each species requirements. This allows rapid growth and establishment. Rangeland reseeding in most cases require soil disturbances. This helps in replenishing deficient plant species or introducing new ones by allowing seed penetration to the ground through provision of conditions suitable for germination emergence and subsequent establishment of the species (Singh 1987). The success will therefore depend on the number of safe sites (Harper 1977) offered by a given land treatment and seeding method.

2.1 Effects of Land Preparation Methods on Plant Establishment

Land preparation methods seek to provide the propagule with an environment free from competing plants and which meet the germination, emergence and growth requirements of the species.

The exclusion of competing plants is important since the resulting plant population will be a result of individual plant performance and the interaction with its neighbours (Harper 1977, Houle and Philip 1989, Clark 1990). Other plant species will therefore have a major effect on the growth and establishment of a grass stand. Various land treatments have been evaluated over the years on their effectiveness in excluding competing plants and providing optimum grass growth conditions. The importance of land disturbance in the establishment of grasses was noted by Jordan (1957) working in Kitui district. Scratch ploughing on contours, in Kitui produced satisfactory grass establishment with respect to the seeds and the species sown. Douglas *et al* (1960) compared burning and ploughing as land preparation methods. Their work showed that burning was only effective where the plants present were not fire resistant, otherwise ploughing offered the best results. The unburned and unploughed plots produced the worst establishment.

Seedbeds which received a soil treatment were found to have a high grass population than those which received none (Pratt 1963a, 1963b). Similar results had been obtained by Humpreys (1959) working with *Cenchrus ciliaris*. He noted that the best establishment was obtained on the cultivated plots while in the uncultivated plots establishment was unsatisfactory. Burning did not improve establishment in absence of cultivation. He further observed that establishment, was roughly proportional to the degree of cultivation. This is in agreement with the findings of Owen and Bryzostowski (1967) and Marieta and Britton (1989). Contrary results concerning burning were obtained by Hull and Klomp (1967), who reported an equal grass production in ploughed plots and those in which the woody vegetation had been burned. When seeds were sown on untreated plots, more seedlings per unit area were obtained than in ploughed plot, however, only 0.8% of those seedlings lived up to one year compared to 37% on the ploughed plot.

In central Tanzania, Owen and Bryzostowski (1967) reported that tilling had a significant effect on grass response compared to the non-tillage treatment. The effect being more in the year of sowing and becoming less in subsequent years. Plant mortality was low on tilled plots and up to 86% established was reported in these plots.

Intense competition adjusted plant numbers downwards and sparse grass populations were easily encroached by undesirable plants. Improper cultivation resulted in grass establishment failure and the intensity of tillage was directly proportional to establishment.

The intensity of tillage has also been shown to affect plant size. In alfalfa and clover, Taylor *et al* (1969) reported an increase in plant size with the intensity of tillage. This is probably due to better water penetration, aeration, mineralization and even exclusion of competing weeds with increase in cultivation. Lavin *et al* (1979) showed that ploughing excluded most competing weeds with the highest emergence and survival being recorded on ploughed plots. Establishment, however depended more on species and to a less extent on the seedbed preparation method. On crusting soils, Karl *et al* (1982) observed that ploughing did not increase seedling emergence but tended to enhance seedling establishment. Work by Cook (1984) further revealed that seedbed preparation resulted in a large variation in the emergence of sown grasses. No interaction was reported between the grass species and seedbed preparation. High survival rates were observed on cultivated seedbeds. Survival was found to be a function of the degree of competition at the seedling stage. Competition was a function of the intensity of cultivation and subsequent weather conditions. Similar results were obtained by Frischknecht (1983) who pointed that weed control was important in grass establishment. Disking and ploughing removed nearly all competition from herbaceous plants.

The existing vegetation therefore needs to be disturbed for successful grass establishment. Burning with no other disturbance failed to produces good establishment (Thomas *et al* 1983). This negates the findings of Mott (1982) that the seedbed left after burning favoured establishment of sown pastures. A satisfactory stand may however take several years to attain due to low rates of establishment, persistence and production of the sown grass pastures. Production and persistence was more on ploughed plots.

Cultivation has also been shown to stimulate volunteer grasses and herbaceous plants. Cox *et al* (1986) found the highest number of volunteer grasses on cultivated plots. King *et al* (1989) also found the highest density of annual grass on the tilled seedbed. On the untilled seedbeds most of the grass seeds which germinated died before shoot emergence. Broadleafed plants had their highest incidence on the untilled seedbeds. Therefore a clean seedbed as produced by disking may stimulate a large number of competing weeds (Oldfather *et al* 1989). Such a seedbed may also increase soil erosion in soils prone to wind erosion. In situations where soil moisture is also limiting moisture losses could be high in a clean seedbed. A seedbed with stubble and mulch to ameriolate moisture conditions at the soil-seed interphase has been recommended (Evans and Young 1970, Marieta and Britton 1989). Such mulch has however been shown to have allelopathic properties (Baker 1981, Martin *et al* 1990) and may obstruct light from reaching the germinating seedling and also prevent better contact between the seed and the soil (Kocher and Stubbendieck 1986).

2.2 The Effect of Seeding Method on Plant Establishment.

All seeding methods seek to place the seed in a position which gives maximum contact between the seed and the soil. Such a contact should facilitate water and nutrient uptake, easier root growth and offer protection from desiccation. Seeding methods can be broadly classified into those in which the seed is covered and those which do not cover the seed.

Seed covering was shown to increase the establishment of *Cenchrus ciliaris* seedlings (Humpreys 1959). Covering the seeds increased radicle entry by increasing the relative humidity between the soil-seed interphase (Campbell and Swain 1973). Moisture loss during germination and early seedling growth is also minimised. Those seeding methods which covered the seeds were shown to give good establishment. Stubbendieck *et al* (1973) observed that the best establishment and germination was obtained where the seeds were drilled. Drilling the seed into untilled seedbeds and covering the seed with litter offered better results as the mulch covered the seeds thus providing a better germination and growth environment. Drilling was also considered a better seeding method as it provided a better and firmer seedbed (Haferkamp *et al* 1987, Dovel *et al* 1990). This was in agreement with the findings of Owen and

Bryzostowski (1967) in central Tanzania where more grasses emerged on drilled plots and even lower seed rates were used than in the broadcast plots.

Hull and Klomp (1967) had also shown that planting methods that covered the seeds were better than those that did not. Drilling gave the best results but after years of protection both the broadcast and drilled plots had the same number of plants. Drilled stands however reached maturity faster and withstood competition from weeds better than broadcast plots. These findings agree with those of (Douglas *et al* 1960) that the rate of stand development and total annual production were more in the drilled plots than in the broadcast plots. Uncovered seeds encounter severe environmental conditions (McWilliam and Dowling 1970), seed losses and failure rates are therefore high. Campbell and Swain (1973) reported losses of up to 46% due to ants only, lighter seeds being more susceptible than heavier ones. When a dry spell followed seeding, seed losses were even higher.

Broadcasting seeds on native grassland gave poor survival and establishment (Cook 1984) hence the observation that broadcasting grasses was only suitable where competition could be checked. (Lavin *et al* 1979, Karl *et al* 1982, Haferkamp *et al* 1987).

Other workers have reported no difference between the drilled and broadcast plots after several years (Grant and Clatworthy 1984). Frischknecht (1983) concluded that broadcasting seeds before or during leaf fall could produce a successful grass stand with no need of covering the seeds.

Cox *et al* (1986) found that the mean density of grass seedlings was less on the drilled plots than on the broadcast plots during initial growth. Hand broadcast plots had 5 - 3.2 plants/m^2 more than the drilled plots. However, the mean forage yield was more on the drilled plots than on the broadcast plots.

The findings of various workers, indicate the need of drilling seeds, although the cost of drilling equipment and the land preparation which goes along with drilling makes it prohibitive Moreover physical conditions in the rangelands may not be amenable to drill seeding (Dovel *et al* 1990). Since the principle aim of drilling is covering the seeds in a firm seedbed, methods which can be used to provide the seeds with such a seedbed while at the same time covering the seeds, can result in good establishment.

The findings of the various workers are in conflict as to which is the best land preparation and seeding method. The inconsistency of these findings indicate the importance of area specific studies when investigating suitable land preparation and seeding methods for revegetation. Climatic and soil variability limit the extrapolation of finding to other areas. Furthermore, the level of technology and resources available to the people require that findings from other areas be tested and adjusted to suit local conditions. In addition much of the existing information is derived from areas outside East Africa where the climate and the soils may be different. Revegetation work in Kibwezi has not been done before and the findings obtained will be useful in making recommendations for reseeding the area.

2.3 Importance of species chosen for reseeding.

The species chosen for reseeding are particularly important in determining the success of establishment. Tolerance to grazing and drought and the ability to establish fast during spells of favourable climatic conditions are very important traits. In Kenya perennial grasses which naturally occur in semi-arid areas have been used for reseeding. The main ones being:

2:3.1 *Cenchrus ciliaris* (L), Buffel grass or African foxtail grass.

This is a tufted perennial grass with short stout rhizomes and is widespread in dry areas of Kenya. The species exhibits drought resistance and tolerance due to its strong and deep rooting system (Humpreys 1974, Whiteman 1980). It can also withstand grazing once established from seeds although it is a poor seed producer. The seeds form in clusters of spikelets which are surrounded by hairy bristles. Each fascicle or cluster contains up to three seeds though majority of the spikelets may be empty. These seeds exhibit post-harvest dormancy which decreases with storage and reaches a minimum 12-18 months after harvesting (Owen and Bryzostowski 1967, Bogdan and Pratt 1967, Humpreys 1974). *Cenchrus Ciliaris* has been recommended for reseeding areas receiving 350-900 mm of rain per year. Whole seeds of this species have been shown to result in better grass stands than when hulled seeds are used (Chakravaty *et al* 1966, Owen and Bryzostowski 1967).

2:3.2 *Eragrostis superba* (Pyer) - Maasai love grass.

This is also a tufted perennial with leafy herbage and is widespread in the semi-arid areas of Kenya where it is common in bush grassland and rocky ground (Bogdan 1958).

The grass is persistent and palatable when young but with age it becomes very stemmy. At early flowering stage, a crude protein content of 12% has been reported on dry matter basis (Bogdan and Pratt 1967). The grass is a good seeder. The seed is in form of a large flat spikelet which has numerous florets. Most of these spikelet are however empty with only one to three having live caryopsis. The florets do not detach from the spikelet and hence the spikelet is used as the seed unit. The grass has been used for reseeding in moderately dry rangelands in Kenya and it readily establishes from seeds.

2:3.3 *Enteropogon macrostachyus* (Hochst and A. Rich) ex. Benth - Bush Rye.

This is a tufted perennial which depending on the environment may be leafy and stemmy. It occurs from 300-1600 m above sea level where it is found growing in bush and forests and to some extent in open grasslands (Bogdan 1958). The grass is a good seed producer and is reported to have good seed quality and rapid germination (Bogdan and Pratt 1967). It is well grazed by animals and although stemmy provides good grazing in the semi-arid areas.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Description of Study Site

The field experiment was carried out in Kibwezi 2°,12'S and 38°, 2'E) at the University of Nairobis' Kibwezi Dryland Field Station. The Station is located in Kibwezi division of Makueni district. (Figure 1). According to Pratt *et al* (1966) the area falls under ecological zone V though its more of a transition zone between zone IV and V.

The mean altitude is approximately 1000 metres above sea level. The area is characterized by a bimodal rainfall pattern which displays spatio-temporal variability both within and between seasons. A long term mean annual rainfall of 600mm has been recorded for the area (see appendix I, II and III). Short rains occur between October and December and show more reliability in both amount and distribution. Approximately 50 - 67% of the annual rainfall is received during this time (fig 2). The long rains show less reliability accounting for 35 - 50% of the annual total (fig 3).

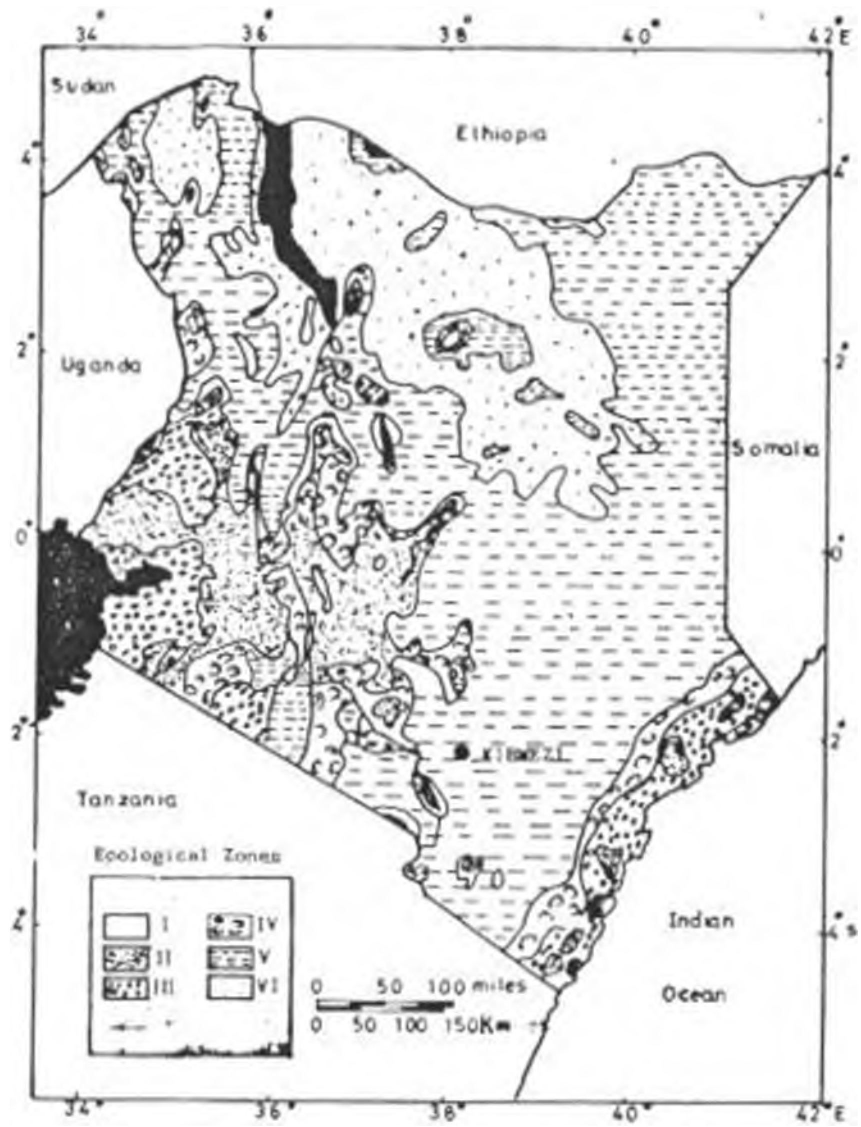


Fig. 1: The Ecological zones of Kenya and the location of study area (after Pratt and Gwyne 1977).

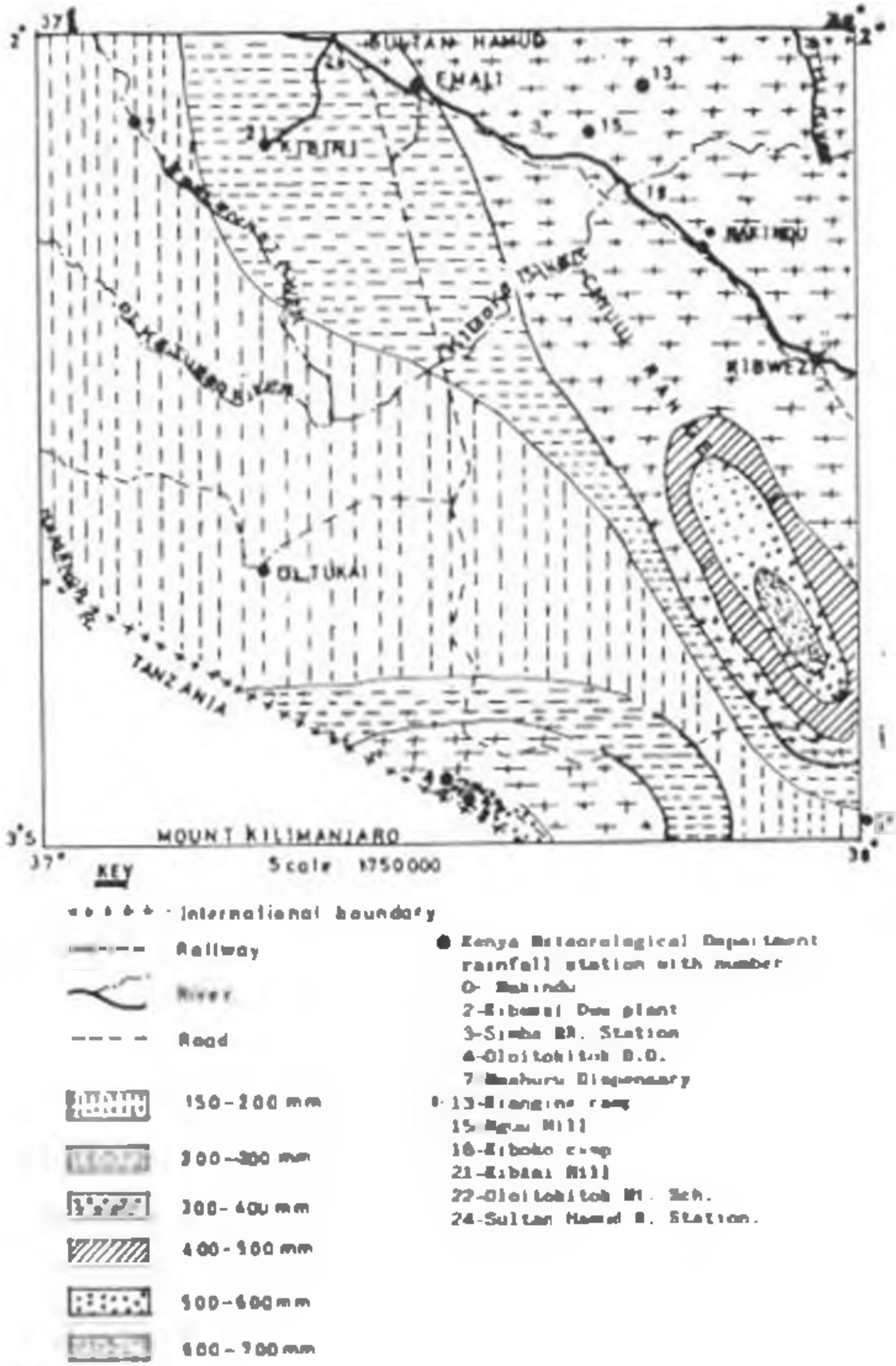


Fig. 2: Average rainfall during the short rains in the study area (Oct.-Jan.) (after Touber 1983).

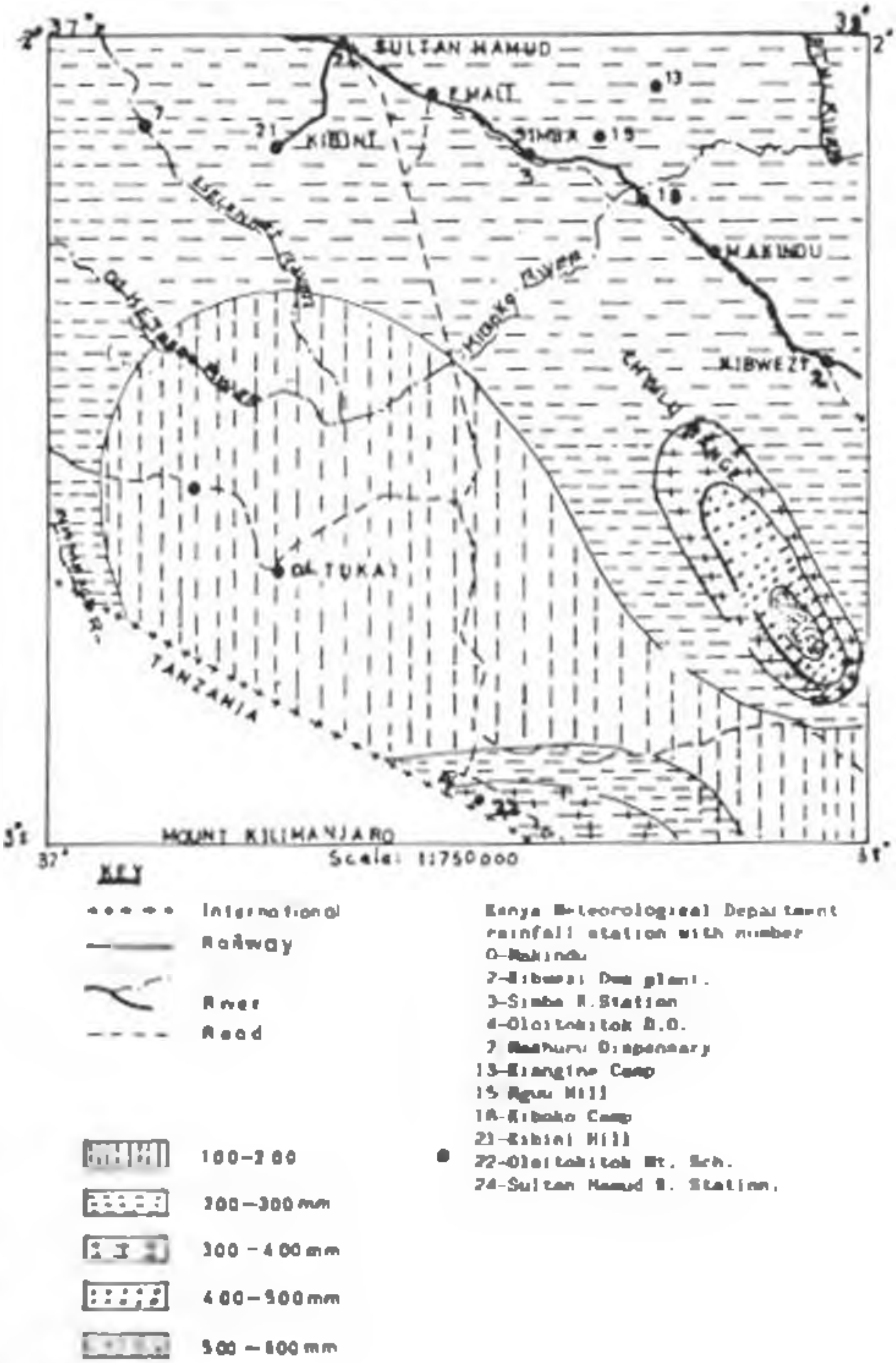


Fig. 3: Average rainfall during long rains in the study area (March-May) (after Touber 1983).

The rainfall is concentrated within a short period of the season. Gachimbi (1990) quoting Braun showed that 50% of the rainfall comes in the first 18 days of the season with more than 40mm being received within the first three days. The mean annual temperature is about 24°C while the mean potential evaporation is about 2000mm (Touber, 1983). The mean annual rainfall is only 30% of the evapotranspirational demand.

The soils of the study site have been described as Ferral-chromic luvisols which are well drained dark reddish and moderately deep. (Touber 1983). The soils have a well developed A-horizon and have a problem of water infiltration due to surface sealing (Touber 1983, Gachimbi 1990).

The vegetation consists of an Acacia-Commiphora bushland with scattered *Adansonia digitata*. The main perennial grasses are *Chloris roxburghiana, Cenchrus ciliaris* and *Eragrostis superba*. These grasses may succumb to continuous over use over a long time giving way to annuals (Pratt *et al* 1966, Gachimbi 1990).

3.2 Grass Species Studied

Three grass species common in the semi-arid rangelands of Kenya were used in this study. These were *Cenchrus ciliaris* (L.), *Eragrostis superba* (Pyer) and *Enteropogon macrostachyus* (Hochst and A. Rich) Munro ex Benth. These species were selected due to their abundance and hence importance as pasture species in most semi-arid rangelands in Kenya.

3.3 Laboratory Experiment.

The quality of any seed lot determines the potential of that seedlot to produce healthy plants which can establish competitively in a given environment. Seed quality is affected by factors such as the soil nutrient status of the mother plant environment, time of harvesting, post harvesting handling and subsequent processing and storage. Some species on the other hand have some inherent dormancy period after harvesting which has been shown to decrease with storage (Bogdan and Pratt 1967, Humpreys 1974, Oreilly 1975). It is, thus, important to know the quality of the seedlot before planting.

3.3.1 Aim of The Laboratory Experiment.

The Laboratory experiment was, designed to examine one aspect of seed quality, that is, the germination capacity of the grass species. The seeds used were obtained from Marigat in Baringo District and all were over one year old. The seeds were obtained away from the experimental site since all the three species could not be obtained from Kibwezi. To minimize the ecotypic variations which may arise when some species were collected from different locations, all the seeds were collected from one location. The germination tests were carried out at the Department of Range Management, University of Nairobi Laboratory. Whole seeds were used for these tests. The test were carried out as described in United States Department of Agriculture

(USDA) manual for testing agricultural and vegetable seeds (1952). Random samples of seeds were obtained from which 100 seeds were again randomly picked. These 100 seeds were put on a moist Whatman filter paper in a petri-dish. The petri dishes were moistened everyday. Eight replicates were used for each species.

The petri-dishes were then put in an incubator at 25°C for 14 days. Every day the seeds which germinated were counted and removed. At the end of 14 days all germinated seeds were expressed as a percentage of total seeds per petri-dish ie 100 seeds. The average germination percentage of the eight petri-dishes was then obtained and used as the germination percentage for a given grass species. Germination was considered to have occurred if a clearly identifiable radicle emerged from the seed.

3.4. Experimental Field Design.

Within the study site an experimental plot measuring 0.9 ha located in an area with open grassland and very short shrubs was selected. Thirty six sub-plots measuring 10 x 10m were laid out. These sub-plots were separated from each other by a five metre wide strip. The experimental layout used was a complete randomized block design with treatments combined factorialy as described by Steel and Torrie (1980). These treatments were replicated twice. The land preparation treatments were tractor ploughing, oxen ploughing and burning. In the ploughing treatments the operation involved a one-run over by the implement without the removal of the stubble.

The seeding methods involved :

i) Broadcasting the seeds without covering them.

ii) Putting the seeds into rills made by a tractor harrow and covering them with soil using a garden rake. This method was a close simulation of drilling.

Treatments were assigned to the grass species at random.(Table 1).

Table 1 Outline of the field layout.

Replicate 1			Replicate 2		
B.D.Es.	B.D.Ent.	T.Br.Es.	B.Br.Ent	O.Br.Ent	T.D.Cc
O.Br.Cc.	O.D.Es.	T.Br.Ent	T.Br.Ent	B.D.Cc.	B.D.Es.
O.Br.Es.	O.Br.Ent	T.D.Cc.	O.Br.Ent	B.D.Cc.	O.Br.Cc.
O.D.Cc.	T.D.Ent	T.D.Es.	B.Br.Cc	O.D.Ent	B.D.Es
O.D.Ent	B.Br.Es.	B.Br.Cc.	T.D.Es.	T.Br.Cc	T.D.Ent
B.Br.Ent	B.D.Cc.	T.Br.Cc.	O.D.Es.	T.Br.Es.	O.Br.Es.

B = Burning T = Tractor ploughing O = Oxen ploughing
D = Drilling Br. = Burning — Broad Casted
Cc = *Cenchrus ciliaris*
Ent = *Enteropogon macrostachyus*
Es = *Eragrostis superba*

All the seeds were treated with Fernasan D which is a mixture of 20% Lindane - Y - Hexachlorocyclohexane and 25% Thiram - Tetra methyl-thioperoxydiocarbonic diamine (Buchel 1983). The former is an insecticide while the latter is fungicide. This treatment was done to prevent seed loss through insects and low germination due to fungal diseases. The land was prepared during the dry season just before onset of the October-December rains of 1990. In the burned plots, a back fire was used to ensure that all the dry material left after the dry season were all burned. The seeds were sown in mid November when the rains started.

3.5. Data Collection.

After the various grass species could be identified, thirty plants per plot were randomly selected and tagged with white plastic tags for identification.
These plants were monitored weekly for twelve weeks. The height of these plants was measured on weekly basis. The height was measured on the primary tiller from the soil surface to the base of the top-most set of leaves to the nearest centimetre. The number of live tillers on each plant were also counted on each plant. Any tiller visible above the soil surface was counted. The number of the plants which died was also counted on weekly basis for twelve weeks. Height, tiller production on all live plants as well as mortality were used as indicators of establishment in the twelve weeks. The average total height and number of tillers on the tagged plants in each plot were used.The data from these tagged plants was used for analysis of variance.

At the end of the twelve weeks, data on density of volunteer annuals was obtained using a $0.25m^2$. quadrat. The dominant annuals chosen were *Aristida spp.*, *Rottboellia exaltata* l.f and *Tetrapogon tenellus* (Roxb.), Chiov. The data on height, tiller production and mortality at the first, third, sixth, ninth and twelfth weeks was subjected to analysis of variance. The data was analysed using SYSTAT (Wilkinson 1988) statistical package. The means for above parameters were separated using least significant difference (Steel and Torrie, 1980).

CHAPTER 4

4.0 RESULTS

4.1 Laboratory germination of *Cenhrus ciliaris*, *Enteropogon macrostachyus* and *Eragrostis superba*.

Cenchrus ciliaris showed the highest germination percent under laboratory conditions. A germination percent of 33% was recorded with germination commencing on fourth day of the laboratory test (Fig 4a). *Cenchrus ciliaris* had the longest time between the start of germination and the attainment of maximum germination rate. It attained maximum rate of germination four days after germination was first observed in the species (Fig.4b).

This high germination percentage of *Cenchrus ciliaris* was probably due to the use of whole fascicles instead of single caryopses. These fasciles are known to contain more than one live caryopsis.

The germination percentage of *Eragrostis superba* was in between that of *Cenchrus ciliaris* and *Enteropogon macrostachyus*. A germination percent of 17% was attained. Germination started on the third day and proceeded rapidly such that by the fourth day maximum germination rate had been reached (Fig. 4b).

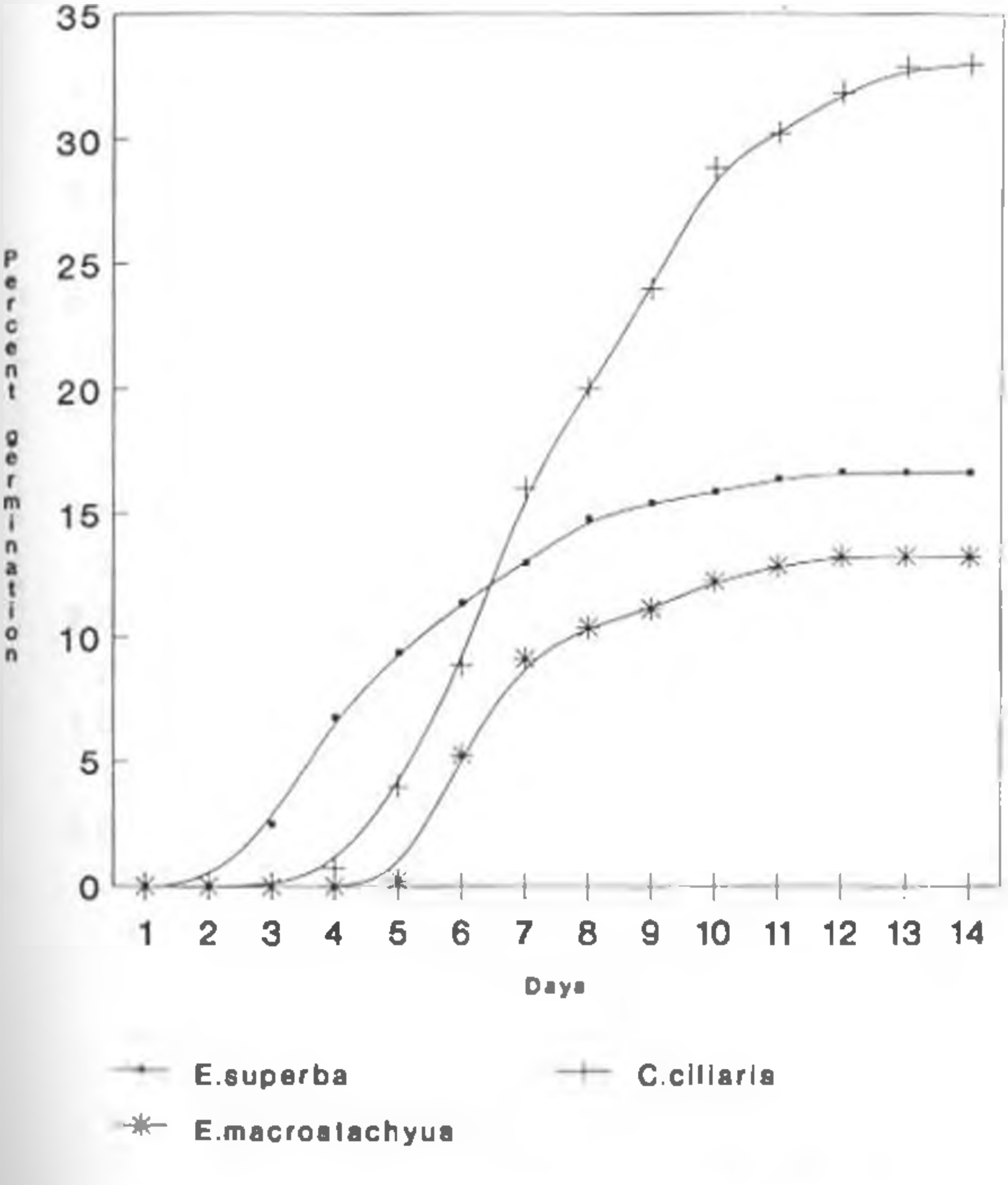


Fig. 4a Germination percentage of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus* in the laboratory.

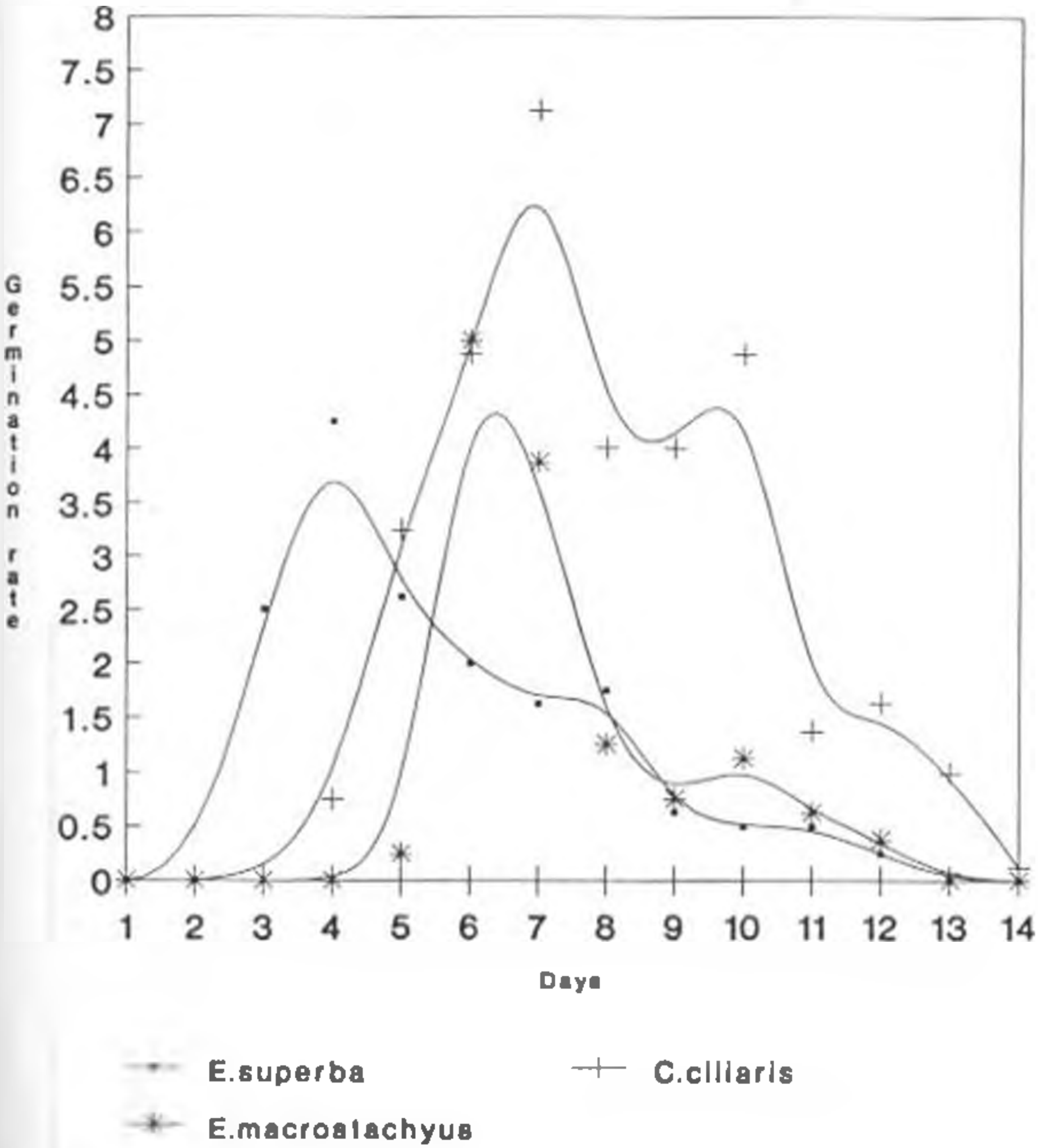


Fig. 4b Germination rates of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus* in the laboratory.

The lowest germination percent was recorded in *Enteropogon macrostachyus*. Only 13.3% of the seeds germinated. The rate of germination for this species was less than that of *Cenchrus ciliaris*. Germination commenced on the fifth day and maximum germination rate was attained on day six.

4.2.1 The effect of land preparation on height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*

The mean total height of the surviving plants was affected by the method of land preparation.(Table 2).

Table 2 Analysis of variance table showing F values for height and their significance during weeks 1,3,6,9 and 12.

Treatment	Week 1	Week 3	Week 6	Week 9	Week 12
land preparation	5.082*	5.386*	7.491*	7.384*	9.187*
seeding method	0.605	3.222*	5.769*	4.990*	9.042
species	11.519*	8.555*	12.713*	11.013*	8.514*
land preparation by seeding method	0.749	1.880	1.700	1.604	4.028*
land preparation by seeding method	1.787	1.860	2.175	1.429	0.993
seeding method by species	0.207	0.298	0.932	0.789	1.293
land preparation by seeding method by species	2.267	1.601	1.635	1.301	1.113

* Significant at ($P \leq 0.1$)

The tractor ploughed plots and the oxen ploughed plots did not significantly differ in height throughout the twelve weeks. The burned plots had the shortest plants throughout the 12 week period. (Fig.5a). The height of these plants was significantly different ($P \leq 0.1$) from that of the tractor and oxen ploughed plots.

Plots under land treatments in which the soil was disturbed showed a gradual increase in mean total height despite the mortality which was occurring. This shows that the surviving plants were growing fast to compensate for any height reduction occurring as a result of mortality. The burned plots showed fluctuations in mean total height throughout the 12 weeks. This is possibly due to the high mortality which was occurring in these plots; such that the rate of growth of the surviving plants could not compensate the height reduction due to mortality.

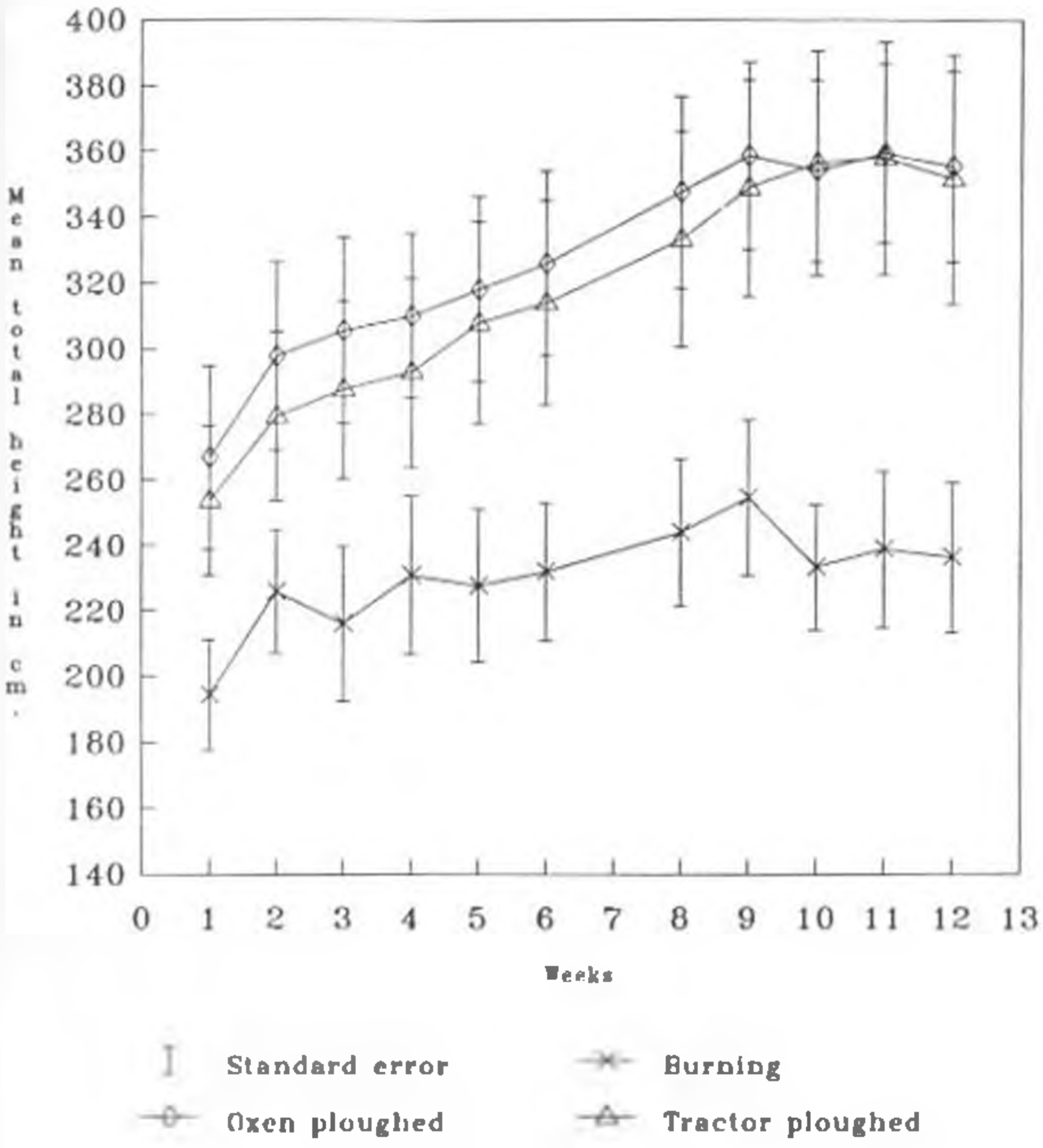


Fig. 5a The effect of land preparation on the height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.2.2 Effect of seeding methods on height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

The method of seeding did not show any significant effect on the height of the grasses ($P \leq 0.1$) during the first three weeks. (Fig 5b). From the sixth week up to the twelfth week, the difference in height between the two seeding was statistically significant ($P \leq 0.1$).

4.2.3 Species effect on height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

The three species showed significant ($P \leq 0.1$) difference in height throughout the twelve weeks. *Enteropogon macrostachyus* significantly shorter plants than *Eragrostis superba*. Significant differences in the height of *Cenchrus ciliaris* and *Eragrostis superba* were only noted in the last week, while the difference between *Cenchrus ciliaris* and *Enteropogon macrostachyus* was no longer significant at the twelfth week.(fig.5c)

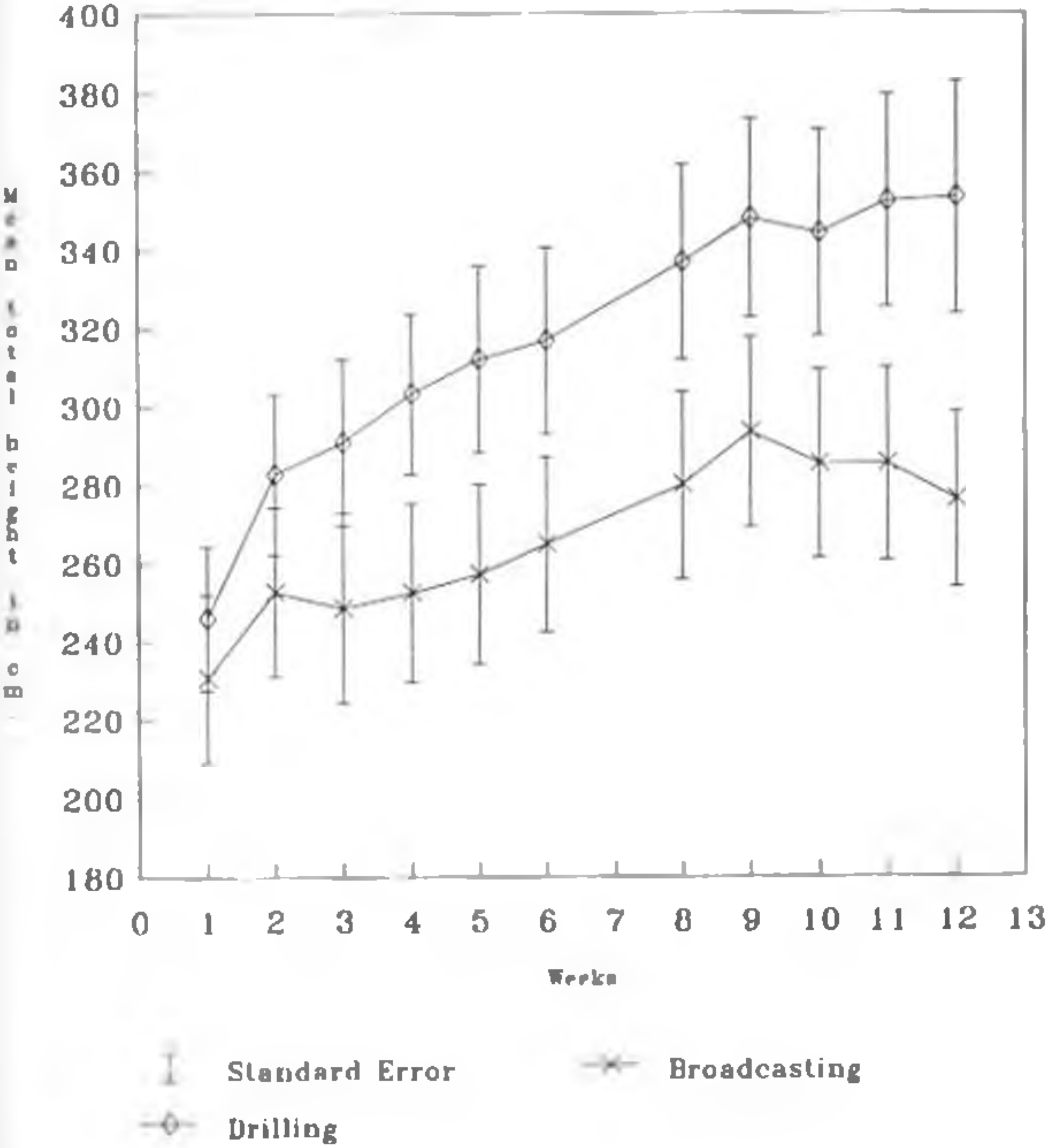


Fig. 5b The effect of seding method on the height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

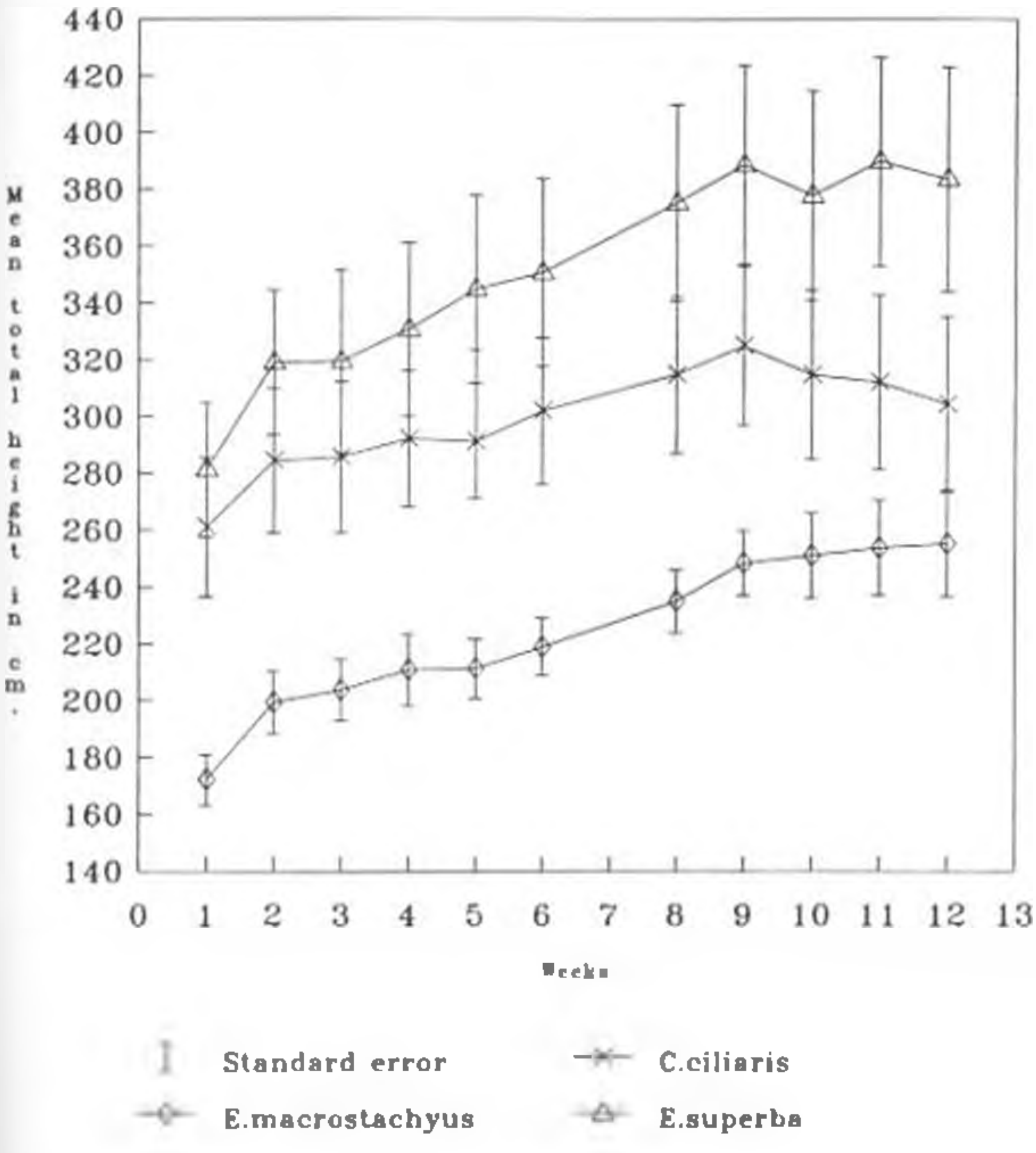


Fig. 5c The effect of species on the height of *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.3.0 Effect of land preparation on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

The method of land preparation significantly affected tiller production.(Table 3)

Table 3. Analysis of variance table showing F values for tiller production and their significance during weeks 1, 3, 6, 9 and 12.

Treatment	Week 1	Week 3	Week 6	Week 9	Week 12
land preparation	14.488*	12.819*	12.530*	10.771*	11.411*
seeding method	2.146	0.137	0.657	0.957	2.964
species	3.759*	1.720	3.859*	2.738*	10.094*
land preparation. by seeding method	0.810	0.914	0.370	0.758	2.113
land preparation. by seeding method	0.635	0.236	0.213	0.107	0.781
seeding method. by species	0.051	0.030	0.118	0.044	1.031
land preparation by seeding method by species	0.103	0.011	0.118	0.074	0.186

* Significant at ($P \leq 0.1$).

The tractor ploughed plots had the highest number of tillers, right from the first week up to the twelfth week. Plants on the burned plots had the least number of tillers. The differences in the number of tillers were statistically significant ($P \leq 0.1$).

The production of tillers under the three land preparation regimes showed a general increase with time except at the t and 9 week (Fig 6a). This may be due to the prevailing weather conditions since in all plots the response was the same.

At the fourth week, the gradual increase in the number of tillers could be explained by the drying up of annual grasses especially *Aristida spp* thus reducing competition. Dry weather conditions after the fourth week may explain the resulting general decline in the number of tillers. Here tiller mortality as well as individual grass mortality explains the decline. After the 9th week, tiller production was up due to some rains which were received during this time.

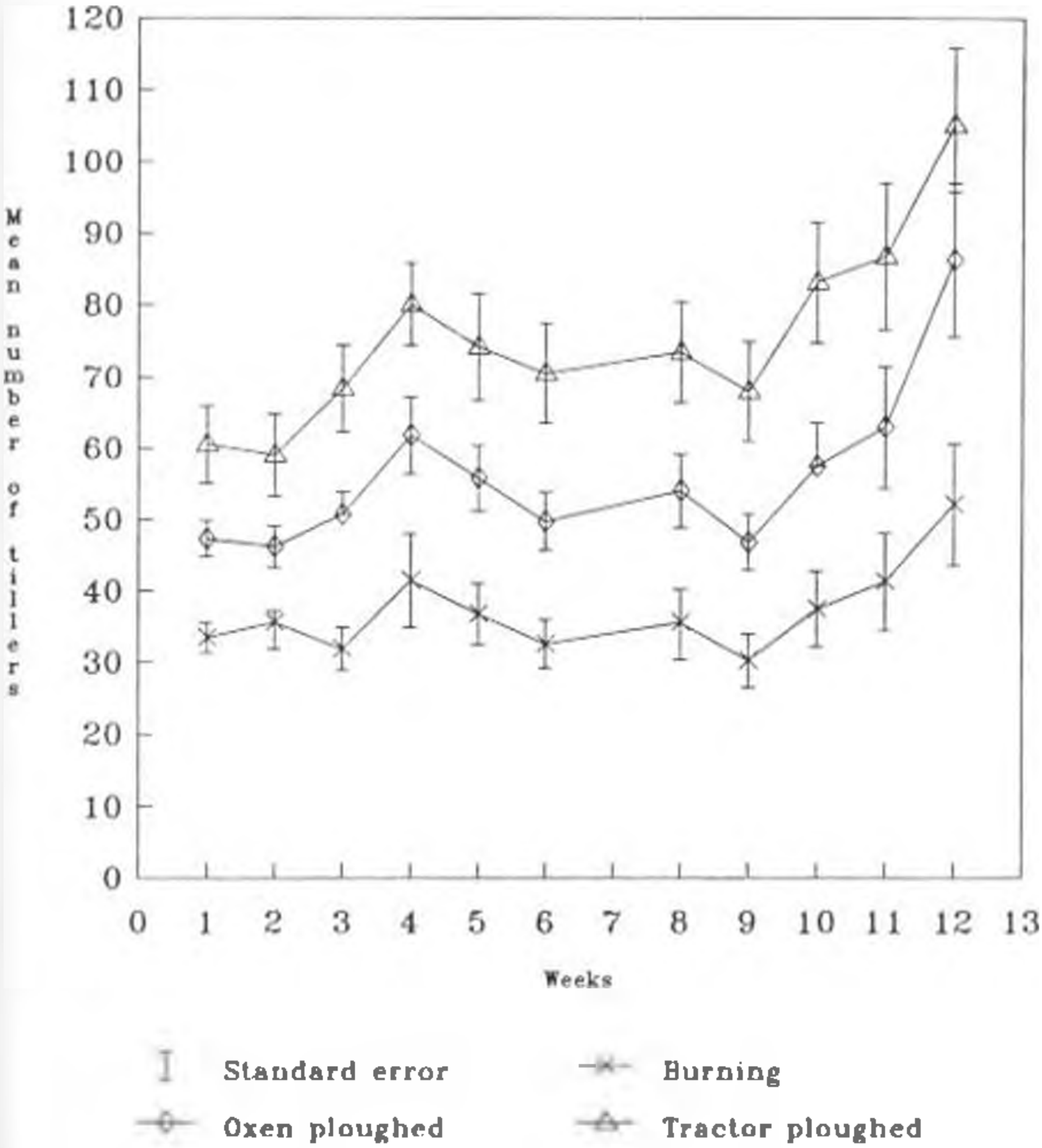


Fig. 6a The effect of land preparation on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.3.1. Effect of seeding method on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

Seeding methods had no significant ($P \leq 0.1$) effect on the number of tiller produced, though the drilled plots had more tillers than the broadcast plots (Fig 6b).

4.3.2. The effect of species on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

The three grass species showed statistically significant difference ($P \leq 0.1$) in tiller production. On the first week, *Enteropogon macrostachyus* had plants with the highest number of tillers and *Cenchrus cilliaris* the least. There after, *Eragrostis superba*, had the most tillers and maintained the trend up to the twelfth week. (Fig 6c). The fluctuations in tiller production during the experiment can be explained by the weather conditions which prevailed and ramet and or genet mortality.

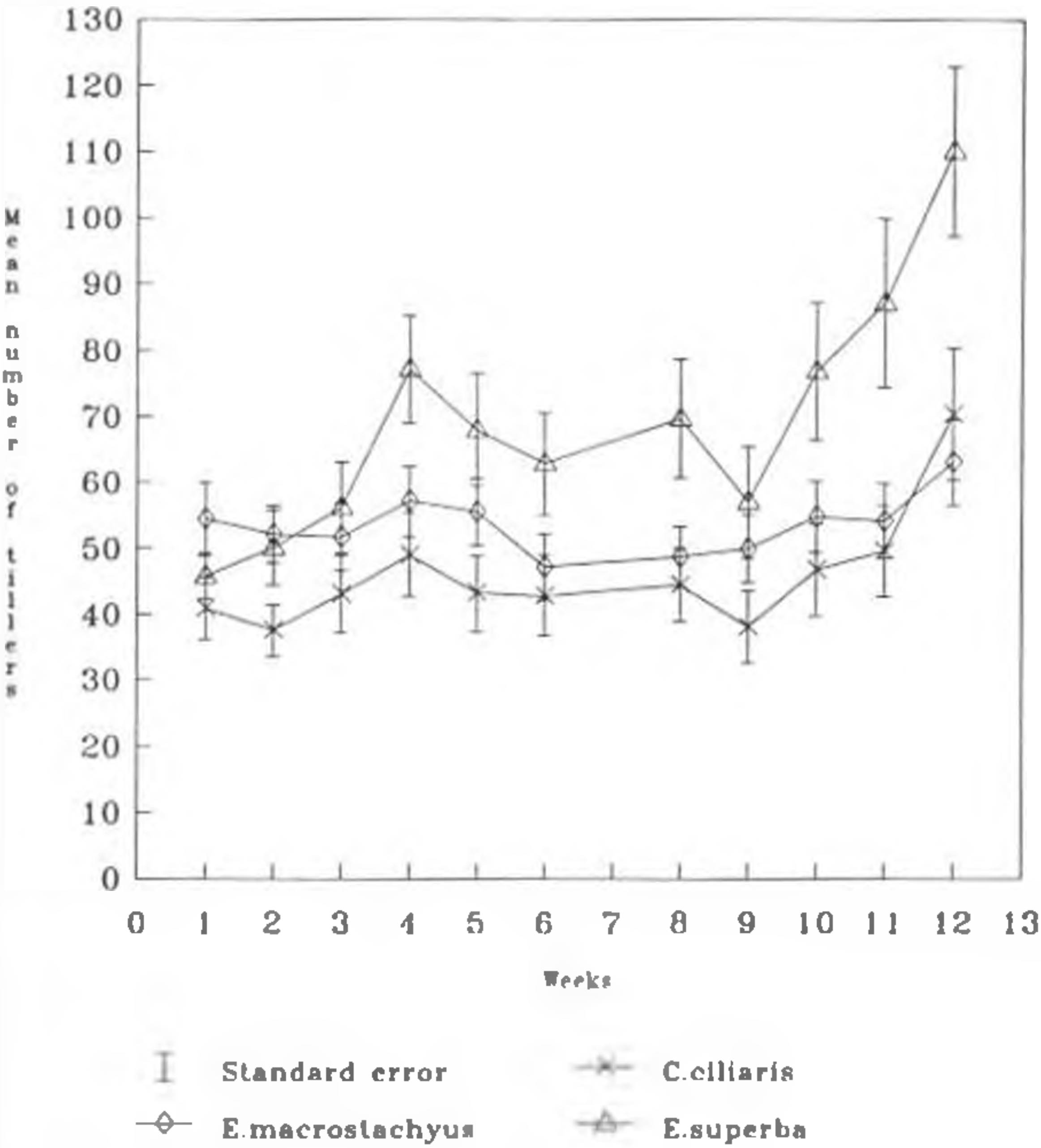


Fig. 6b The effect of seeding method on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

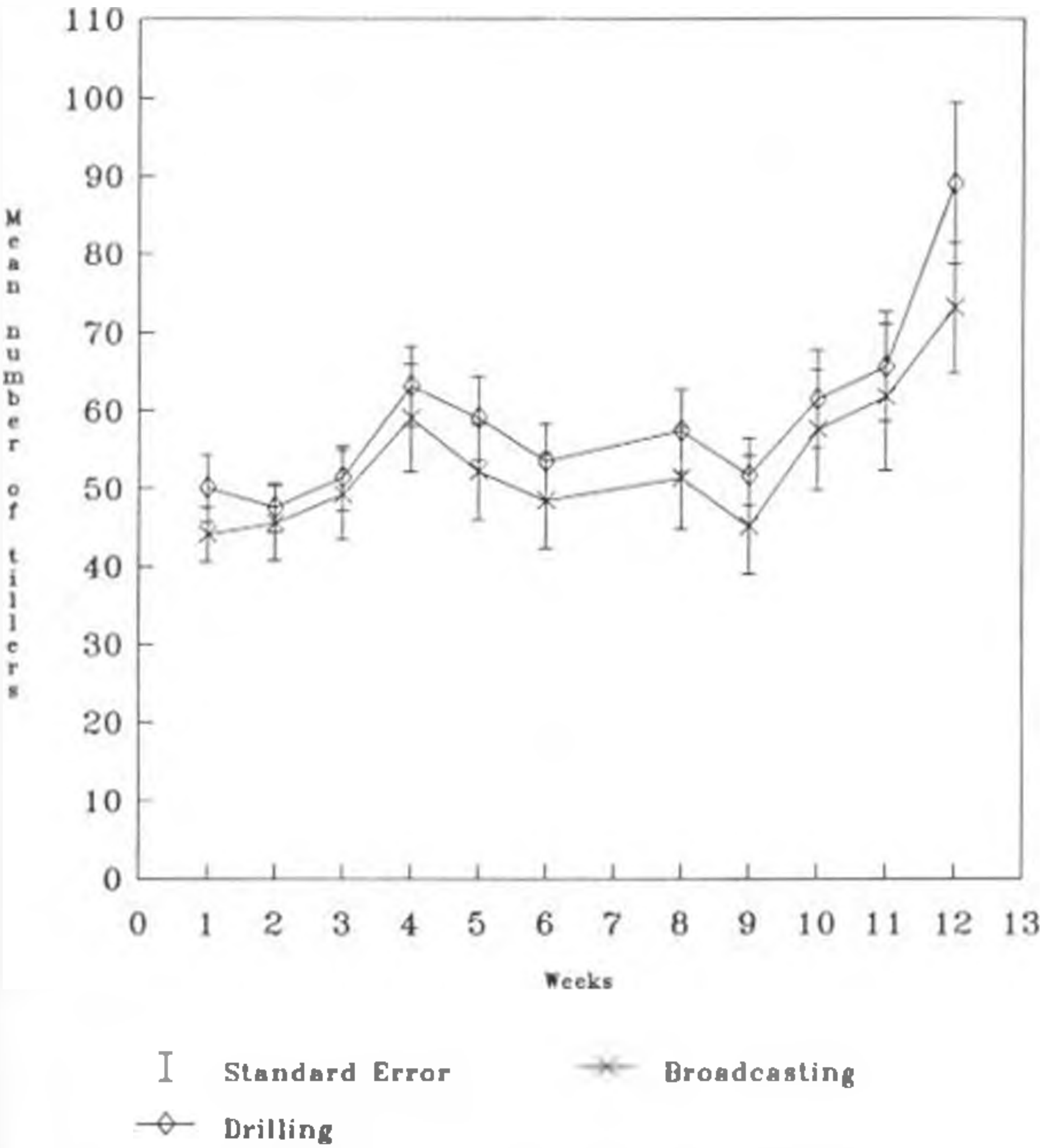


Fig. 6c The effect of seeding method on tiller production in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.4.0 The effect of land preparation on percent seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

The method of land preparation in this study, was found to influence the seedling mortality of the three grasses.(Table 4).

Table 4. Analysis of variance table showing F values for percent seedling mortality and their significance during weeks 1, 3, 6, 9 and 12.

Treatment	Week 3	Week 6	Week 9	Week 12
land preparation	1.341	3.392*	5.885*	5.781*
seeding method	0.297	0.019	1.137	3.793*
species	0.451	0.039	0.447	0.232
land preparation by seeding method	2.966*	2.818*	3.269*	09268
land preparation by species	0.454	0.432	1.165	0.733
seeding method by species	0.357	0.937	0.285	0.419
land preparation by seeding method by species	0.240	0.434	1.120	0.180

* Significant at (P$\leq$ 0.1)

There were significant differences ($P \leq 0.1$) in mortality under the three land preparation methods. Least mortality occurred in the tractor ploughed plots and the highest in the burned plots (Fig. 7a). The difference in mortality between the oxen and tractor ploughed plots was not significant throughout the twelve weeks. Mortality in the burned plots was significantly different from that in the oxen and tractor ploughed plots.

The percentages used for mortality analysis were arcsine transformed prior to the analysis of variance to minimize the risks of violating the assuptions of analysis of variance (Sokal and Rohlf 1987). The data in table 4 show anova results of the transformed data.

4.4.1 The effect of seeding method on percent seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

No statistically significant ($P \leq 0.1$) difference was detected in seedling mortality between the drilled and the broadcast treatments. The plants on the drilled plots however, had lower mortalities than on broadcast plots (Fig. 7b)

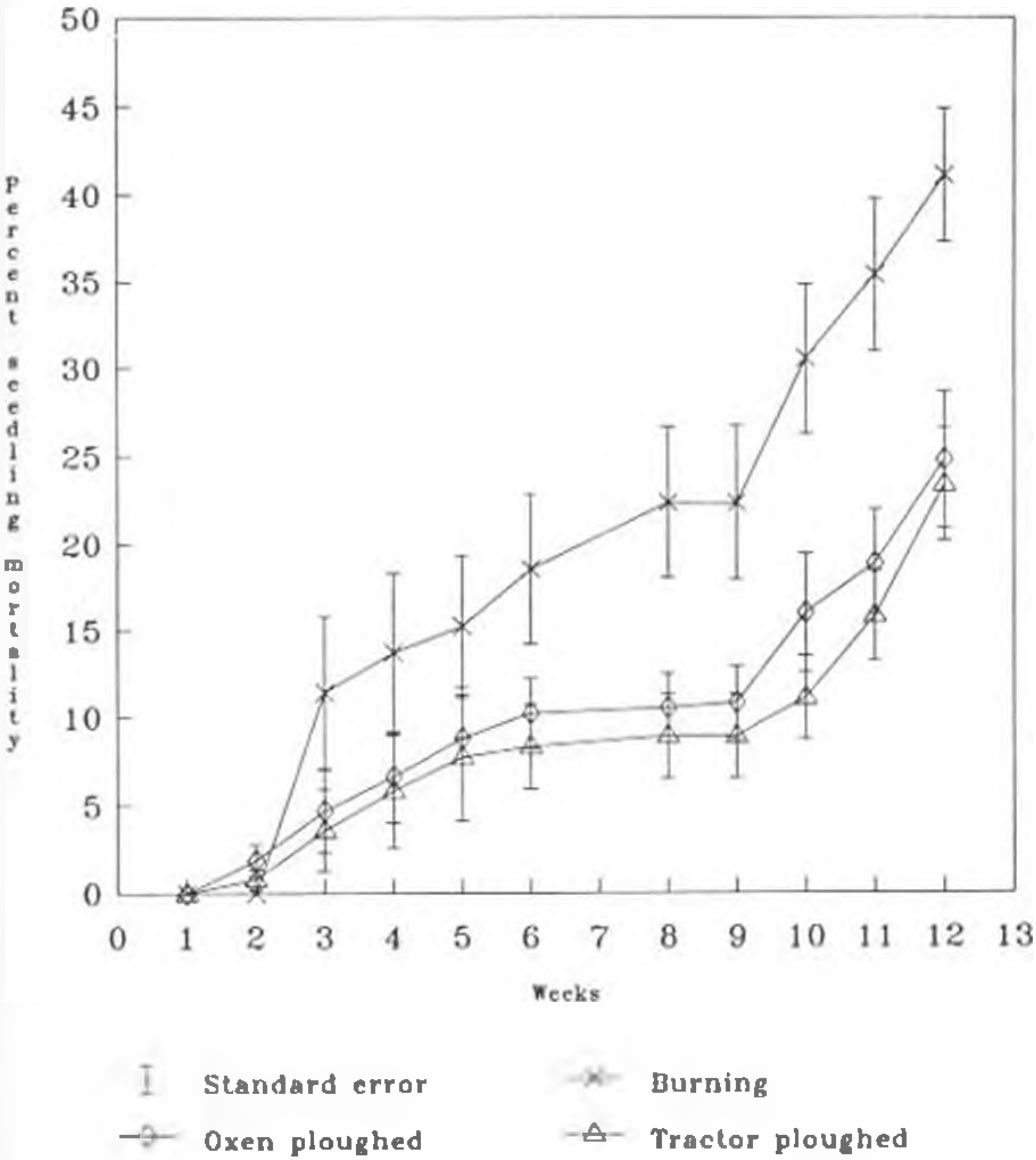


Fig. 7a The effect of land preparation on seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

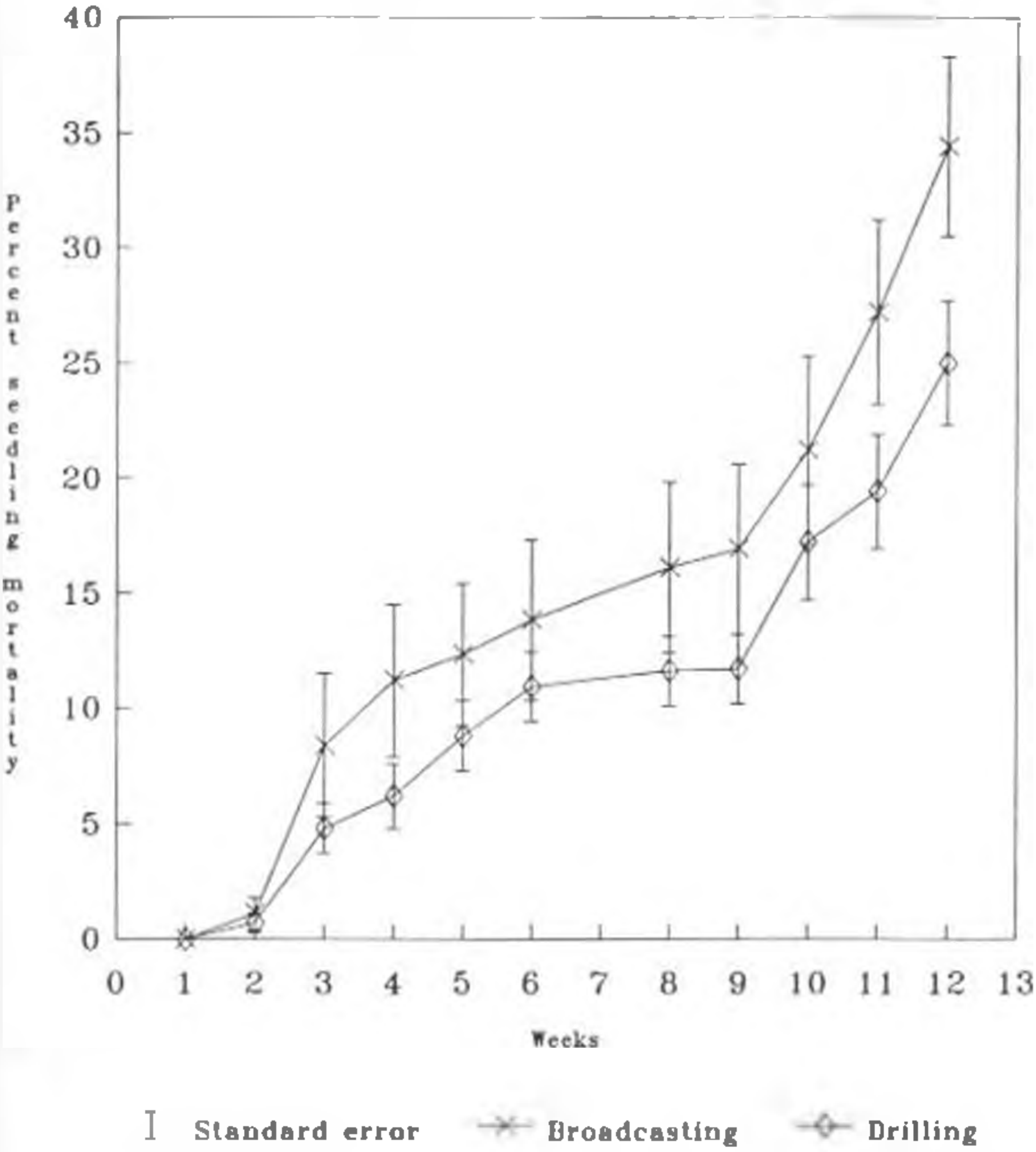


Fig. 7b The effect of seeding method on seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.4.2 Species effects on percent seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

No significant differences were detected on species with regard to mortality *Eragrostis superba* had the lowest mortality while *Cenchrus ciliaris* had the highest. (Fig 7c).

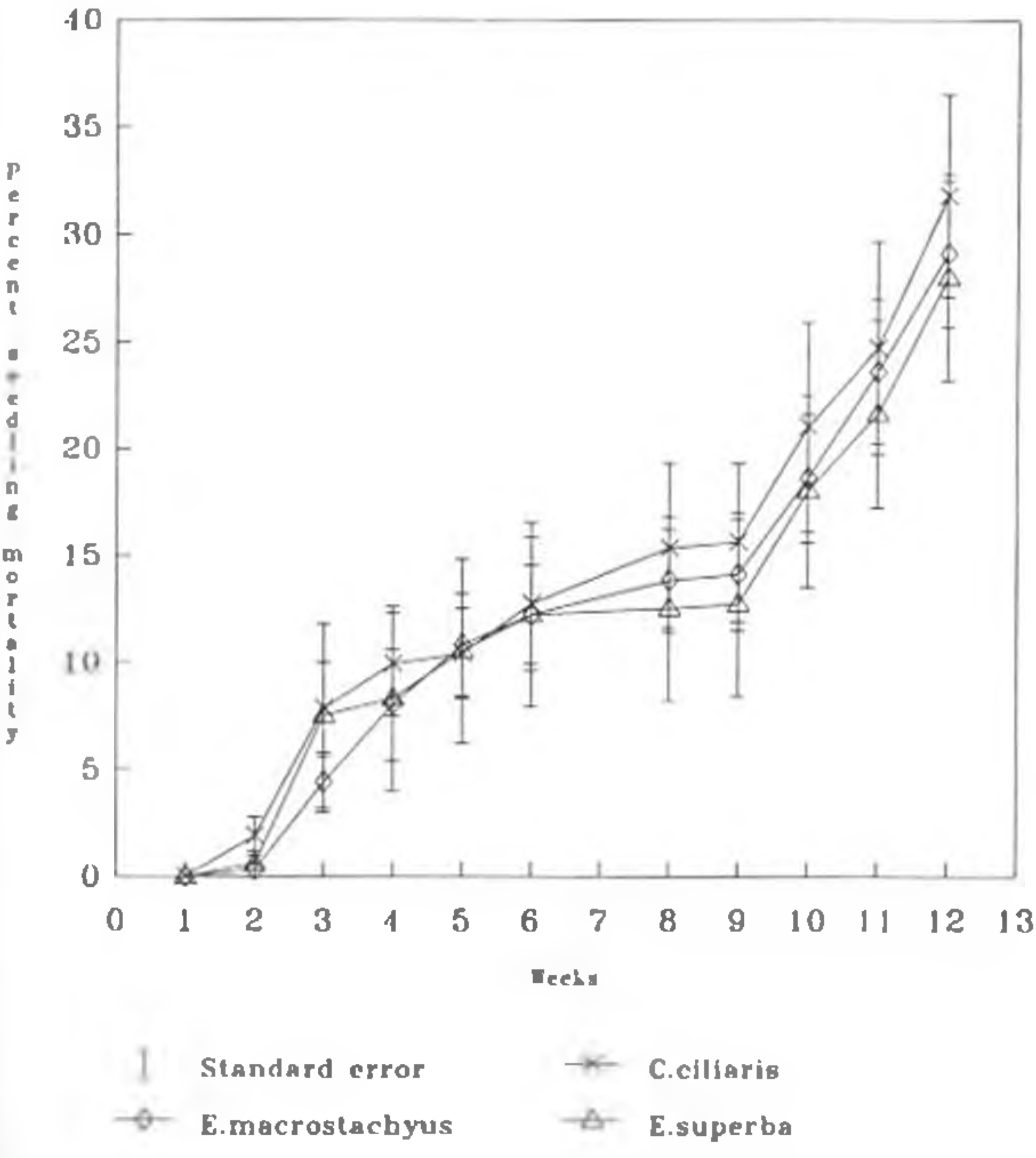
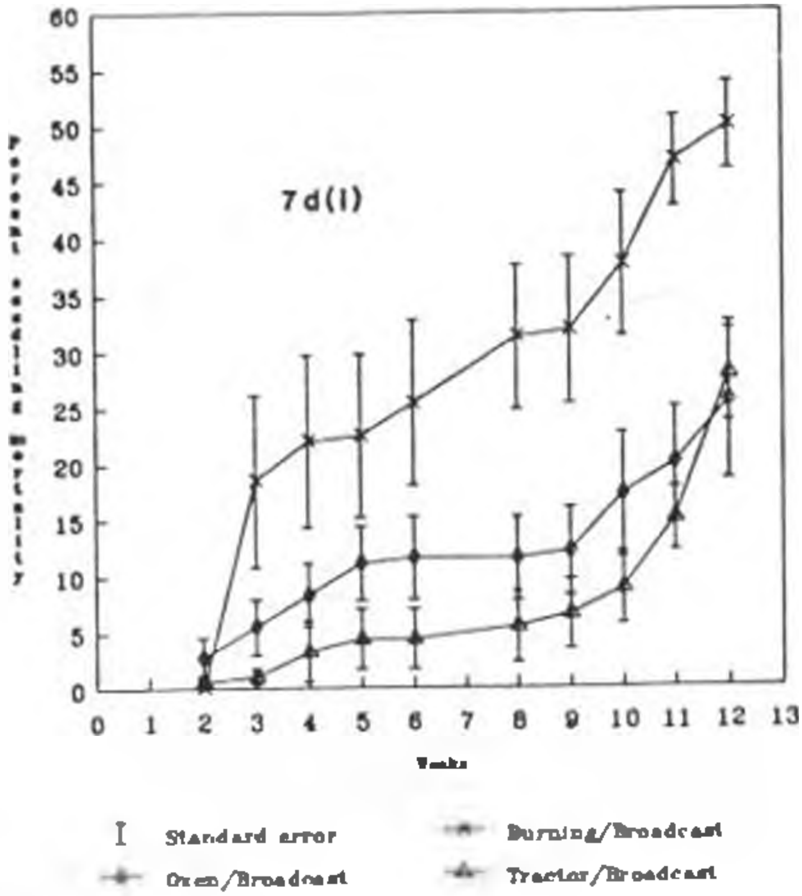


Fig. 7c The effect of seeding method on seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

4.4.3 The effect of land preparation and seeding method on percent seedling mortality in *Cenchrus ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus*.

There was a significant interaction between seeding method and land preparation ($P \leq 0.1$) on seedling mortality. There was significantly higher mortality in the broadcast plots irrespective of the land preparation method. Burning and broadcasting produced a significantly high seedling mortality.(fig.7d-a) In the drilled plots mortality was lower and did not vary significantly between the three methods of land preparation.(fig.7d-b)



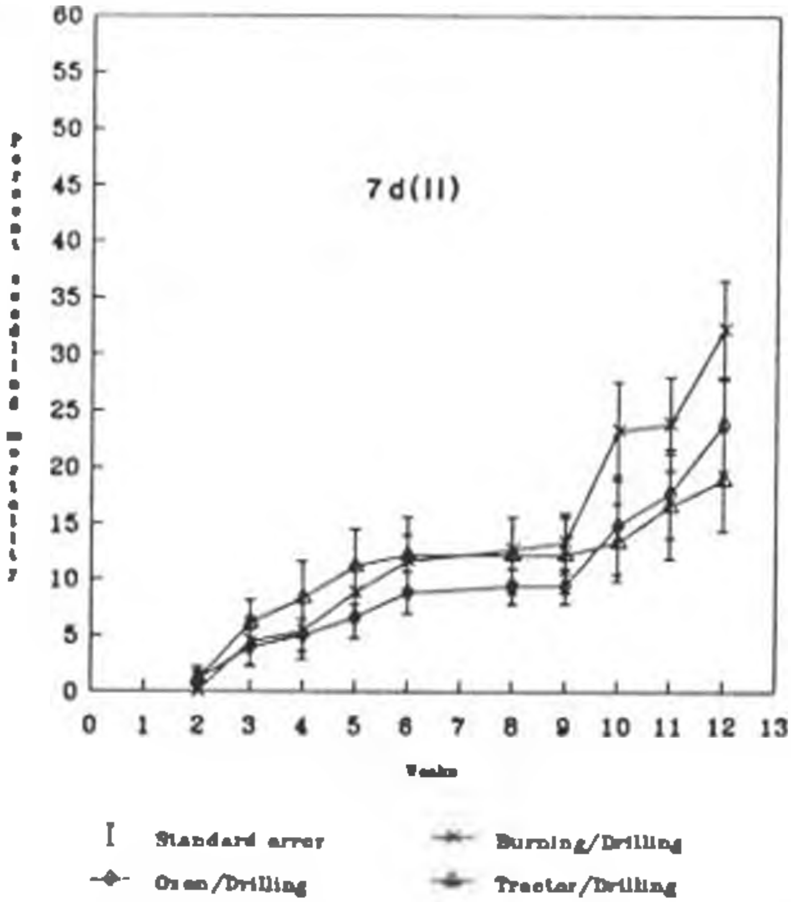


Fig. 7d The effect of seeding method on seedling mortality in *Cenchrus ciliaris*, superba and *Enteropogon macrostachyus*

4.5 Density of volunteer annual grasses

Land preparation in this study had a significant effect on the density of annual grasses. The tractor ploughed plot had a mean density of annuals of 130.4 plants per m^2. These included *Aristida spp*, *Rottboelia exaltata* l.f and *Tetrapogon tenellus* (Roxb), Chiov. *Rottboelia exaltata* had the highest density in the tractor ploughed plots. This species grew very fast and attained more than 1.5m in height.

The burned plots had a mean density of annuals of 215.4 plants/m^2. The dominant species in these plots was *Aristida spp* with a density of 201 plants/m^2 while *Rottboelia exaltata* had the least density. The density of annuals in the oxen ploughed plots was the lowest at 36.7 plants/m^2.(Table 5)

Table 5: Density of volunteer annual grasses (plants/m^2) under the three land preparation methods.

Land preparation	*Aristida.spp*	*R.exaltata*	*T.tenellus*	mean density
Tractor ploughing	81.4	43.7	5.3	130.4
Oxen ploughing	92.7	15.7	1.6	110.0
Burning	201.0	2.7	11.7	215.4
$LSD_{0.1}$	33.3			

LSD = Least significant difference.

CHAPTER 5

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Seed Germination

The period of suitable moisture and temperature conditions which favour plant growth is limited in the rangelands. Plants which produce quickly germinating seeds will thus have an advantage over those whose seeds take some time to germinate. Delayed germination and emergence may have far reaching consequences on the fate of the plant (Silvertown 1984). The faster a seed moves from the seed and seedling stages the higher the chances for survival and subsequent establishment if there is no selective predation based on large size. These two stages have been shown to be the most vulnerable in the development history of a plant. (Agevine and Chabot 1979, Cook 1979). Where competition is strong and seedling density high, rapid germination gives the plant a competitive advantage since later germinating and emerging plants may encounter, a change in environmental conditions. In addition, the fast emerging seedlings may capture a larger share of resources and suppress new ones as they emerge (Silvetown 1984).

Differences in germination and emergence time, has been shown to result in size heirachy. This plays on important role in the performance of the emergent plant. Such components of fitness like survivorship and fertility have been shown to be influenced more by size than by age. Bazzaz *et al* (1982) showed that size was determined by time of germination, vigour of the plant and the amount of competition it encountered. The smallest individuals in a population which are usually late germinators have the highest risk of mortality. (Cook 1979, 1980; Solbrig *et al* 1980, Parker 1982, Silvertown 1984, Begon *et al* 1990).

The rate of germination in this study and the time taken for maximum germination to be attained could explain the performance of the three grasses under field conditions. Most of the studies on size dependant performance are carried out in one species and not between species. Germination in *Eragrostis superba* started the earliest and took the shortest time to attain maximum germination rates. This implies that once conditions favouring the germination of *Eragrostis superba* occur, most seeds germinate within a very short time. This rapid germination favours the species with an advantage over the other two. Throughout the experiment, the *Eragrostis superba* had the tallest plants and with most tillers. It also suffered the least mortality at the end of the twelve weeks.

Enteropogon macrostachyus commenced germination last but took the same time as *Eragrostis superba* to attain the maximum rate of germination. Under field conditions it had the shortest plants and had an average more tillers than *Cenchrus ciliaris*. The short growth habit could be due to the open habitat where it was grown. *Enteropogon macrostachyus* normally grows under shade of trees and shrubs (Bogdan 1958).

Cenchrus cillaris had the highest germination percentage and the highest germination rate, it had the longest time between commencement of germination and the attainment of maximum germination. In the field the species had plants with the least number of tillers and taller plant than *Enteropogon macrostachyus*. The mortality rates of *Enteropogon macrostachyus* and *Cenchrus ciliaris* were almost the same at the end of the twelve weeks.

All three species had at least two germination peaks the most prominent one being that of *Cenchrus ciliaris*. This shows that the seedlots were not uniform thus resulting in the observed polymorphism in germination. Germination polymorphism has been shown to occur if seeds are from different sites, plants or even position on the same plant. The physiological state during harvest and subsequent storage conditions could also give rise to germination polymorphism (Cavers and Harper 1966). Some species, have also been reported to have seed size dimorphism. Lahiri and Kharaba (cited in Winkworth 1971) found that *Cenchrus ciliaris* had two caryopsis sizes. Large and small caryopses. The larger one was about three times heavier and displayed higher germinability.

Germination polymorphism may be an important survival strategy. It protects the species against time specific mortality causing factors (Cavers and Harper 1966). For example, when a short wet period is followed by a long dry spell. Not all seeds will germinate. A reservoir of seeds is thus ensured at any given time.

5.2 Effects of Land Preparation

The findings of this study are in agreement with those of other workers (Jordan 1957, Humpreys 1959, Douglas *et al* 1960, Pratt 1963a, 1963b; Bryzostowski and Owen 1966, Owen and Bryzostowski 1967, Lavin *et al* 1979, Marieta and Britton 1989) that some degree of land preparation is required for successful establishment of pastures.

The results clearly point the advantages of reducing competition through land preparation and providing the seed with the optimal growth requirements. This is particularly important in rangelands where suitable growth conditions are both erratic and transient. There is need to minimize competition from weeds if the seeded pastures are to benefit from these sporadic growing periods. Establishment will hence depend on how well a cultural practice is able to exclude competing plants.

The tractor ploughed plots showed the best plant performance in terms of tiller numbers and survival during the twelve week period of the study. During the course of the twelve weeks, oxen ploughed plots had taller plants than the tractor ploughed plots. The difference in height performance between these two methods of land preparation was not statistically significant ($P \leq 0.1$). Non-significant differences between tractor and oxen prepared plots were also noted in the mortality of the plants. Burning as a land treatment produced the worst results in terms of plant performance. Here the shortest plants with few number of tillers and suffering the highest mortality were found.

In the evaluation of the three land treatments, there are no much differences between the tractor and oxen ploughing as land preparation methods. Size and mortality under the two regimes were not statistically different. Hence in comparison with burning the other two land preparation methods offered the seed and the seedling growth conditions which afforded faster growth. Large plants with numerous tillers have been shown to have lower mortality risks (Abdul-Fatih and Bazzaz 1980, Cook and Dolby 1981, Cook 1984, Parker 1982, Sarukhan *et al* 1984). This results further attests the observation of Taylor *et al* (1969) that plant size increase with the intensity of cultivation.

From this study, it can be concluded that oxen ploughing when properly done can be quite as effective as tractor ploughing in land preparation. The use of animal draught power in Kenya is however not widespread. Mathewman (1987) observes that animal draught is used by only 13% of the small scale farmers for cultivation. Handtools and tractor account for 84 and 3% respectively. Despite their widespread use handtools limit the area that can be tilled by one person. A higher number of workdays is needed compared to animal draught. In addition the cost of labour may be prohibitive for most small scale farmers. As plot sizes continue to decrease, fallow periods will decrease, and the cost of mechanical farming per unit area will increase. The use of animal drought will be called for. This will be possible where diseases are not a problem. In Kibwezi the use of animal draught power, especially the oxen is not a new practice. The use of animal draught power has been shown to save-labour compared to manual cultivation, allowing the expansion of the land under cultivation and increase the timeliness of operations (Anderson 1985). This is nevertheless possible where the crop being grown does not require subsequent operations which cannot use animal draught power. In situations where the crops require such activities like weeding which employs manual labour, the benefits of animal draught power in expanding the area under cultivation cannot be realised. The costs of such operations will offset the benefits of animal draught.

Animal draught power have an advantage over tractor power in terms of costs of acquisition and maintainance. Few farmers in an area like Kibwezi have access to tractors. Even those who may have, the area under cultivation is small making the use of tractors economically unrealistic.

In semi-arid areas, the availability of animal feed is seasonal and closely follows the local climatic regime. In such areas the maintainance of draught animals during periods of low feed availability is a major problem. After the dry season the animals are usually in poor body condition. This is the time when they are needed for cultivation, and their full tractive, potential is therefore not realised. The costs of maintaining the animals during these periods when there is no cultivation is high. A solution to this problem can be the use of the animal for tractive as well as productive purposes (Mathewman 1987). In Kibwezi oxen are usually used for draught power. The use of cows for draught power will be advantageous in that when there are no cultivation operations, the cow will be used to produce milk. This will result in a lower number of animals.

The poor performance in terms of plant height, tiller production and mortality agrees with previous findings that burning does not provide a suitable seedbed (Humpreys 1959, Thomas *et al* 1983).

This contradicts Hull and Klomp (1967) and Mott (1982) who reported no difference between the cultivated and the burned treatments. The poor plant performance in the burned plots could be explained by the nature of the soil and the degree of competition. The soils of Kibwezi have a tendency to seal at the surface (Touber 1983, Gachimbi 1990). This surface layer reduces infiltration and increases surface run-off and soil erosion. On such a surface a seed will not be able to push its radicle quickly into the soil before desiccating conditions set in. Fast radicle entry has been shown to be advantageous in plant establishment (Campbell and Swain 1973, Peart 1984, Peart and Clifford 1987, Gachimbi 1990).

The loss of mulch on the burned plots could also have resulted to the observed poor performance. Mulch in the soil surface ameriolates soil moisture conditions (Evans and Young 1970, Stubbendieck *et al* 1973, Ludwig and McGinnies 1978, Farah 1982, Marieta and Britton 1989). The micro-environment around the seedling is thus modified. Due to the lack of mulch in the burned plots evaporative moisture losses were high in comparison with the other plots which had mulch on them. Gachimbi (1990) noted that land preparation methods which leave some residue on the surface reduce the impact of raindrops on the soil and as well as encourage the invasion of soil borne organisms. These organisms help in breaking the soil seal where formed.

Land preparation does not create suitable growth conditions for the desired species only. Volunteer species which compete with the seeded species also come up. The burned plots had the highest density of volunteer annual grasses. This may further explain the poor performance in the burned plots. The high density of annuals and their characteristic growth rate could have resulted in interference and competition. The tractor ploughed plots had a higher density of annual grasses than the oxen ploughed plots. Tractor ploughing seemed to have created optimal conditions for germination of *Rottboelia exaltata* which had its highest density in tractor ploughed plots. May be the depth of ploughing encouraged the germination of this species. The depth of ploughing was more under tractor ploughing than under oxen ploughing. Deep ploughing could have broken the dormancy of seeds buried deep in the soil, in addition deep ploughing may have facilitated rapid root penetration into the soil, promoting faster growth for the species.

5.3 Effects of Seeding Method

The method of seeding significantly affected height of the grasses only. Other indicators of establishment such as survival and number of tillers showed no statistically significant differences ($P \leq 0.1$). Inspite of lack of significant difference in survival and tiller production under the two methods of seeding, drilled plots had higher survival and more tillers than the broadcast treatments. The lack of any significant difference apart from height, negates earlier observations that seeding treatments which covered the seed were superior than those that afforded no cover to the seed. (Humpreys 1958, Bryzostowski and Owen 1966, Owen and Bryzostowski 1967, Hull and Klomp 1967, Haferkamp *et al* 1987, Dovel *et al* 1990). From this study it can be concluded that covering the seed only affected the height of the plants. Any difference which could have been detected may have been masked by the exceptionally good rains received in the area at the start of the experiment. The short rains during 1990 were generally above average as shown by monthly rainfall totals from Dwa sisal estate which was approximately 20km from the study site. (Appendix IV).

5.4 Effects of Grass Species

The three grass species showed a difference in their response to land preparation and seeding methods. This shows that the performance of a plant is mainly an interaction of the genotype and the physical environment (Herriot 1958, Sarukhan *et al* 1984). Overtime, each species has undergone selection which have favoured certain fitness enhancing traits. *Eragrostis superba* produced taller plants which had more tillers than the rest. This could be a fitness enhancing mechanism. The fast growth rate resulting in taller plants helps the plant's growing points escape from grazing. Prolific tillering is an adaptation for spreading mortality risks. The probability of genetic extinction is highest in single tillered plants (Cook 1979). As tillering increases, the risk decreases since the ramets will have their own mortality fates. A plant with many tillers will thus have a higher chance of contributing its genes to the next generation (Kays and Harper 1974, Sarukhan *et al* 1984, Billington *et al* 1990). In addition the high tillering ability and large size of *Eragrostis superba* makes it a better herbage producer. Herbage yield is a product of size and tiller density. In comparison with the other species, *Eragrostis superba* is therefore a better biomass producer.

Cenchrus ciliaris showed better performance in terms of height than *Enteropogon macrostachyus* which nevertheless produced more tillers than *Cenchrus cillaris*. Generally it would be expected that *Enteropogon macrostachyus* would have taller plants than *Cenchrus cillaris*. *Cenchrus cillaris* grows up to 1m while *Enteropogon macrostachyus* can attain 1.2m (Pratt and Gwyne 1977). *Enteropogon macrostachyus* generally grows under bushes (Bogdan 1958). Growing this grass in the open habitat may have affected its growth potential. Biotic and abiotic factors of the environment have a direct effect on the performance of the plant (White 1980, Boutin and Harper 1991). Several species can thus be used where a diversity of sites to be reseeded exist e.g. open and bushed sites.

5.5 CONCLUSIONS AND RECOMMENDATIONS

This study shows that the method of land preparation affects plants performance and subsequent establishment. Ploughing treatments were therefore better than burning. The differences between the two ploughing treatment were however not significant. In land preparation, oxen ploughing is recommended in Kibwezi as it was just as effective as tractor ploughing. In addition oxen ploughing is an old practice in the area.

The method of seeding was found to have no significant effects on the establishment of plants. It only affect plant height. In light of the high rainfall during the experimental period it cannot be concluded that the method of seeding had no effect on establishment.

Drill seeding requires special equipment and land preparation which are not available in range areas. The soil and the terrain may also make drill seeding not feasible. In Kibwezi, if the seeds can be protected from insect damage, broadcasting should be used. Broadcasting requires no special equipment, land preparation or skill.

Response of the grasses to both land preparations and seeding treatments was different. That means, that the three grasses have different potentials in pasture establishment as dictated by their genetic constitution. *Eragrostis superba* is the most suitable grass species for revegetation and pasture production in the area.

The findings of this study only acts as a pointer on the expected performance and establishment of pasture grasses in the semi-arid rangelands of Kenya. The short duration of the study limits both extrapolability and predictability of the data. Such studies require long-term monitoring of the seeded plants for comprehensive conclusions and recommendations to be made. A study covering more than two seasons would yield more information on the establishment of pastures under the three land predations methods and the two seeding treatments.

Further work should also be done in the cost effectiveness of tractor and oxen ploughing as methods of land preparation.

More range-grasses should also be studied so as to widen knowledge of the plant resources which may be used to boast forage production and halting degradation in the rangelands.

LITERATURE CITED

Abdul-Fatih, H. A.and F. A. Bazzaz. 1980. The biology of *Ambrisia trifida* L. IV. Demography of plants and leaves. New Phyto.84:107-111.

Angevine, W. and B. F. Chabot. 1979. Seed germination syndromes in Higher plants. **In:** Topics in Plant population Biology. Edited by Solbrig, O.T., Subodh J., G. B. Johnson, and P. H.Raven. Columbia University Press.

Anderson, M. F. 1985. Draught animal power in sub-saharan Africa: Their production impact and research needs. **In:** Draught animal power for production. Proceedings of an international workshop held at James Cook University, Townsville, Qld, Australia 10-16 July, 1985. Ed. J.W. Copland.

Baker, J.C. 1981. Techniques of overdrilling for the introduction of improved pastures species in temperate grasslands. **In:** The proceedings of the XIV International Grassland Congress held in Lexington, Kentucky U.S.A. June 15 - 24 1981.

Bazzaz, F.A., D. A. Levin and M. R. Schmierbach. 1982. Differential survival of Genetic variants in crowded populations of *Phlox*. J.Appl. Ecol. 19:891-900.

Begon, M., J. L. Harper and C. R. Townsend. 1990. Ecology: Individuals,Populations and Communities. (second edition) Blackwell Scientific Publications. 1990.

Billington, H. L., A. M. Mortimer and T. McNeilly. 1990. Survival and Reproduction in adjacent grass populations: Effects of clone, time and environment. J. Ecol.78:1-14.

Bogdan, A. V. 1958. A revised list of Kenya grasses. Government Printer Nairobi.

Bogdan, A . V. and J. D. Pratt. 1967. Reseeding Denuded Pastoral and Land in Kenya. Ministry of Agriculture and Animal Husbandry.

Boutin, C. and J. L. Harper 1991. A comparative study of the population dynamics of five species of *Veronica* in natural habitats. J. of Ecol. 79:199-221.

Bryzostowski, H. W. and Owen, M. A. 1966. Production and Germination Capacity of Buffel grass *(Cenchrus ciliaris)* seeds. Trop. Agr. Trinidad 43:1-10.

Buchel, K. H. (ed) 1983. Chemistry of herbicides. John Wiley and Sons.

Campbell, M. H. and F. G. Swain.1973. Factors causing losses during the establishment of sown pastures. J. Range Manage. 26:355-359.

Cavers, P. B. and Harper, J.L. 1966. Germination polymorphism in *Rumex crispus* and *Rumex obtusifolius*. J. Ecol. 54:367-382.

Chakravaty, A. K., R. D. Roy, C. M. Verma and R. B. Daso. 1966. Study of pasture establishment techniques. Annals of arid zones 5 (1) 1966.

Clark, J. S. 1990. Integration of Ecological levels. individual plant growth, population mortality and ecosystem process. J. Ecol. 78:275-299.

Cook, S. J.and G. R.Dolby. 1981. Establishment of Buffel grass, Green panic and siratro from seed broadcast into a spear grass pasture in Southern Qeensland. Aust. J. Agric. Res. 32: 749-759.

Cook, S. J. 1984. Establishment of four pasture grasses and Siratro from seed oversown into dense and open spear grass pastures. Aust. J. Exp. Agric.24:360- 369.

Cook, R. E. 1979. Asexual reproduction. A further consideration. Am. Nat. 113:769-772.

Cook, R. E. 1980. Germination and size dependent mortality in *Viola blanda*. Oecologia. 47:115-119.

Cossins, N. J. 1985. The Productivity of pastoral systems ILCA Bulletin No. 21.

Cox, R. J., Martha, H. M., F. A. Ibarra-F. and H. L. Morton. 1986. Establishment of Range grasses on various seedbeds at Creosotebush *(Larrea tridentata)* sites in Arizona, U.S.A. J. Range Manage. 39:540-546.

Douglas, S. D., A. L. Hafenrichter and K. H. Klages. 1960. Cultural methods and their relation to the establishment of Native and Exotic grasses in range seeding. J. Range Manage. 13:53-57.

Dovel, R. I., M. A. Hussey and E. C. Holt. 1990. Establishment and survival of Illinois bundle flower interseeded into an established Kleingrass pasture. J. Range Manage. 43:153-156.

Evans, A. R. and J. A. Young. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Sci. 18:697-703.

Farah, K. O. 1982. A comparative study of plant water relations in *Chloris gayana* Kunth and *Setaria sphacelata* S.H. Msc. Thesis, University of Nairobi.

Farah, K. O. and Haji, A. J. 1990. African Pastoralism in Transition: The Case of North-Eastern Kenya; A paper presented S.S.R.C. (New York) Symposium's on African Arid and Semi-arid Lands and Ecological Vulnerability. Zimbabwe.Dec.3-7,1990.

Farah, K. O. 1990. Pastoralists at Crossroads. Resources Vol.1 (3) 1990.

Frischknecht, N. C. 1982. Plants adapted to summer grasslands, **In:** Managing intermountain rangelands - improvement of range and wildlife habitats. Proceedings of symposia September 15 - 17 1981, Twin Falls Idaho and June 22 -24 1984. Elke, Nevada 1983 compiled by S. B. Monsen and N. Shaw.

Gachimbi, L. N. 1990. Land degradation and its control in Kibwezi area, Kenya. M.Sc. Thesis, University of Nairobi.

Government of Kenya. 1989. National Development Plan 1989 - 1993. Government Printer, Nairobi.

Grandin, B. E. 1987. Pastoral culture and range management. Recent lessons from Maasai land. ILCA Bulletin No. 28.

Grant, P. J. and J. Clatworthy. 1984. Methods of pasture establishment. **In:** Pasture establishment and research in Eastern and Southern Africa. Proceedings of a workshop held in Harare Zimbabwe 17 - 1 September 1984. Edited by Kategile J. A.

Haferkamp, M. R., D.C. Ganskop, R. F. Miller and F. A. Sneva. 1987. Drilling versus imprinting for establishing crested wheat grass in Sagebrush-Bunch grass steppe. J. Range manage. 40:524-530.

Hansen R. M., B. M. Woie and R. D. Child. 1986. Range Development and Research in Kenya. Proceedings of a conference. Agricultural Resources Centre, Egerton College Njoro, Kenya. April 1 - 5 1986.

Harper, J. L. 1977. Population biology of plants. Academic Press inc. Limited

Heady, H. F. and Heady, E. B. 1982.: Range and wildlife production in the tropics. Longmans, London.

Herriot, J. B. D. 1958. The establishment of Herbage species in Great Britain. Herb. Abstr. 28:73-82.

Horowitz, M. M. and Little, D. P. 1987. African pastoralism and poverty: Some implications for drought and famine. In Drought and Hunger in Africa. Ed. Michael H. Glantz. Cambridge University Press.1987.

Houle, G. and D. L. Phillips. 1989. Seed availability and Biotic interactions in Granite outcrop plant communities. Ecol. 70:1307-1316.

Hull, A. C. Jr. and G. J. Klomp. 1967. Thickening of crested wheatgrass stands on southern Idaho ranges. J. Range manage. 10:227-235.

Humpreys, L. R. 1974. A guide to better pastures for the tropics and sub-tropics. Wright, Stephenson and Co (Australia) Pty. Ltd.

Humpreys, L. R. 1959. Studies in the germination, early growth, drought survival and field establishment of buffer grass (*Cenchrus ciliaris*) with particular reference to Yelloroi district. Herb. Abstr. 30:185.

Jordan, L. G. 1983. Plant limitation for arid and semi-arid and salt desert shrublands. In: Managing intermountain rangelands-improvement of range and wildlife habitats. Proceedings of symposia September 15-17 1981. Twin Falls Idaho and June 22 - 24 1982. Elke Nevada 1983. Compiled by S. B. Monsen and N. Shaw.

Jordan, S. M. 1957. Reclamation and pasture management in semi-arid areas of Kitui district Kenya. E. Afr. Agric. For. 23:84-86.

Kategile, J. A., B. H. Dzowela and P. N. de Leew. 1989. Is grass really forgotten. Panesa Newsletter No.10.

Karl, W. M., K. E. Eckert Jr., W. H. Blackburn and F. F. Peterson. 1982. Influence of crusting soil surfaces on emergence and establishment of crested wheatgrass, squirrel tail, Thurber needlegrass and fourwing saltbush. J. Range Manage 35:282-287.

Kays, S. and Harper, J. L. 1974. Regulation of plant and tiller density in a grass sward. J. Ecol. 62:97-106.

Kenya National Livestock Development Policy. 1980. Ministry of Livestock Development. Government Printer, Nairobi.

King, M. A., Steven, S. W., L. Moser and J. L. Stubbendieck. 1989. Seedbed effects on grass establishment on abandoned Nebraska sandhills cropland. J. Range Manage. 42:183-187.

Kocher, E. and J. Stubbendieck. 1986. Broadcasting Grass Seeds to Revegetate Sandy Soils. J. Range Manage. 39: 555-557.

Lamprey, H. F. 1983. Pastoralism yesterday and today, the overgrazing problem. In: Ecosystems of the world, tropical savannas. Edited by Francis Bourtiere. Elseview Scientific Publishing company 1983.

Lavin, F., F. B. Gomm and T. N. Johnsen Jr. 1973. Cultural, seasonal and site effects of Pinyon - Juniper rangeland planting. J. Range Manage. 22:279-285.

Ludwig, J. R. and W. J. McGinnies. 1978. Revegetation Trials on a saltgrass meadow. J. Range Manage. 31:301-311.

Marieta, K. L. and C. M. Britton. 1989. Establishment of seven high yielding grasses on the Texas high plains. J. Range Manage. 42:289-294.

Martin, U. L., E. L. McCoy and W. A. Dick. 1990. Allelopathy of crop residues influence corn seed germination and early growth. Agron. J. 82:555-560.

Mathewman, R. W. 1987. Draught animals and the role and future potential of draught cows in African farming systems. Draught animal news No.8.

Mburu, D. M. 1983. A Study of soil erosion associated with new settlement in Longonot-Kijabe area of Kenya and Proposals for it's control. Post Graduate Dip. thesis University of Nairobi, 1983.

McWilliam, J. R. and P. M. Dowling. 1970. Factors influencing the germination and establishment of pasture seeds on the soil surface. In: the proceedings of the XI International Grassland Congress 1970.

Mott J. J. 1982. Fire in improvement of pastures of Northern Australia. Tropical grasslands 16 (3) 1982.

Naveh, Z. 1966. Range research and development in the dry tropics with special reference to East Africa. Herb. Abstr. 36:77-78.

Oldfather, S., J. Stubendieck and S. S. Waller. 1989. Evaluating revegetation practices for sandy cropland in the Nebraska Sandhills. J. Range Manage. 42:257-259.

O'Reilly, M. V. 1975. Better pastures for the tropics. Yates Seeds Limited.

Owen, M. A. and H. W. Bryzostowski. 1967. Grass establishment under semi-arid conditions in Central Tanganyika. Trop. Agr. Trinidad. 44:275-291.

Parker, A. M. 1982. Association with mature plants, protects seedlings from predation in an arid grassland shrub *Gutierrezia microcephala*. Oecologia 53:276-280.

Peart, M. H. 1984. The Effect of Morphology, orientation and position of grass diaspores on seedling survival. J. Ecol. 72:437-453.

Peart, M. H. and Clifford, H. T. 1987. The Influence of diaspore Morphology and soil surface properties on distribution of grasses. J. Ecol. 75:569-576.

Perry, L. J. Jr. and L. E. Moser. 1975. Seedling growthrate of three switch grass strains. J. Range Manage. 28:391-393.

Pratt, D. J. 1963a. Reseeding denuded land in Baringo District Kenya. E. Afr. Agric. For. 29:78-91.

Pratt, D. J. 1963b. Reseeding denuded land in Baringo District Kenya. II- Technique for dry alluvial sites. E. Afr. Agric. For. 29:243-259.

Pratt, D. J. and Gwyne, M. D. 1977. Range Management Ecology in East Africa. Hodder and Stoughton, London.

Pratt, D. J., P. J. Greenway and M. D. Gwyne. 1966. Classification of East African rangelands. J. Appl. Ecol. 3:369-382.

Pressland, A. J. and Graham, T. W. G. 1989. Approaches to restoration of rangelands - the Queensland experience. Aust. Range. J. 11:101-109.

Rossiter, J. and J. G. Ndegwa. 1974. Pastures and Fodder on medium potential areas of Kenyan. Ministry of Agriculture, Kenya pasture research project. Technical report No.11.

Sarukhan, J., M. Martinez-Ramos and D. Pinero. 1984. The analysis of demographic variability at the individual level and its population consequences. **In:** Perspectives on plant population ecology, by Rodolfo Dirzo and Jose'Sarukhan (Eds) Sinaver association Inc.

Singh, R. P. 1987. Pasture development in Bhutan. **In:** Rangeland resources and management. Proceedings of the National rangeland resources and management. IGFRI Jhansi. November, 9-12 1987. Panjab and Singh and P.S. Pothak (Eds).

Silvertown, J. W. 1984. Introduction to Plant Ecology. Longman Inc. New York, 1984.

Solbrig, O. T., Sandra, J. N. and D. T. Kincaid. 1980. Population biology of genus *Viola*. I. The Demography of *Viola sororia*. J. Ecol. 68:521-546.

Sokal, R. R. and F. J. Rohlf. 1987. Introduction to biostatistics. W. H. Freeman and company. NewYork. 363p.

Steel, R. G. D and J. H. Torrie. 1980. Principles and procedures of statistics. A biological approach. McGraw-Hill book company.

Stubbendieck, J., P. T. Koshi and W. G. McCully. 1973. Establishment and growth of selected grasses. J. Range Manage. 26:39-41.

Touber, L. 1983. Soils and vegetation of Amboseli Kibwezi area. Reconnaissance soil survey report No. R6 198d. Kenya soil survey. National agriculture laboratories Edited by B.J.A.Van de pouw and V.W.P. Van Engelen.

Taylor, T. H., E. M. Smith and W. C. Templeton 1969. Use of minimum tillage and herbicide for establishing legumes in Kentucky blue grass (*Poa pratensis* L.) swards. Agron. J. 61:961-766.

Thomas, D. B., J. G. McIvor and G. J. Gardner. 1983. The effect of seedbed type on the establishment of legumes and grasses at four sites in Northern Queenland. Tropical Grassland. 17(1).

United States Department of Agriculture 1952: Manual for testing agricultural and vegetable seeds.

Valentine, F. J. 1977. Range development and improvements. Bringham Young, University Press, Provo Utah.

Whiteman, P. 1980. Tropical pasture science. Oxford University Press.

White, J. 1980. Demographic factors in plant population. In: Demography and Evolution of Plant Populations. Ed. Otto T. Solbrig. Blackwell scientific publications.

Wilkinson, L. 1988. SYSTAT: The system for statistics. Evanston, IL. SYSTAT, Inc.1988

Winkworth R.E. 1971: Longevity of Buffel grass seed sown in an arid Australian range. J. Range Manage. 24:141-145.

APPENDIX I RAINFALL (MM) FROM DWA SISAL ESTATE

MONTH	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	LONG TERM AVERAGE
JAN	1.27 (1)	4.83 (3)	8.38 (4)	37.5 (1)	6.00 (7)	15.5 (6)	14.00 (8)	145.60 (10)	49.70 (7)	12.50 (9)	12.50 (5)	38.50
FEB	0.51 (1)	0 (0)	68.83 (6)	0.50 (2)	109.90 (9)	0.60 (1)	0 (0)	0.20 (1)	0 (0)	38.60 (9)	0 (0)	31.20
MAR	167.64 (15)	29.40 (2)	81.79 (2)	20.30 (2)	75.30 (5)	10.60 (5)	11.60 (3)	148.90 (7)	21.90 (4)	232.10 (16)	65.10 (5)	86.30
APR	218.20 (10)	172.20 (13)	24.64 (5)	26.20 (7)	43.40 (15)	169.50 (17)	55.50 (10)	119.40 (11)	243.40 (15)	188.50 (10)	79.60 (5)	119.30
MAY	30.00 (7)	28.45 (9)	14.46 (7)	0.70 (2)	27.10 (5)	64.80 (11)	68.00 (10)	10.40 (1)	31.90 (5)	9.20 (4)	80.90 (6)	28.90
JUNE	0 (0)	0 (0)	0.25 (1)	0 (0)	0 (0)	0 (0)	81.0 (2)	3.40 (1)	0 (0)	0 (0)	37.60 (11)	4.00
JULY	230 (3)	5.08 (3)	6.76 (1)	1.80 (1)	0.80 (2)	0 (0)	0.70 (1)	0 (0)	0 (0)	0 (0)	-	3.00
AUG	2.54 (3)	2.03 (1)	0 (0)	0 (0)	0 (0)	5.20 (2)	5.10 (5)	2.70 (2)	0 (0)	0 (0)	-	1.90
SEPT	9.10 (2)	12.45 (5)	0.76 (1)	2.30 (2)	1.80 (1)	0.30 (1)	0 (0)	5.60 (3)	0.80 (2)	0 (0)	-	4.00
OCT	34.30 (4)	134.11 (14)	0 (0)	88.20 (9)	82.10 (7)	111.50 (4)	0.50 (1)	0 (0)	79.50 (7)	12.50 (1)	-	26.50
NOV	160.02 (11)	374.65 (16)	75.20 (8)	367.14 (20)	141.20 (11)	198.90 (15)	142.60 (12)	304.90 (16)	207.00 (18)	253.50 (18)	-	117.50
DEC	92.6 (14)	182.88 (17)	148.60 (11)	88.00 (7)	131.20 (15)	120.80 (15)	36.00 (4)	297.70 (17)	139.60 (16)	352.00 (17)	-	136.20
TOTAL	713.34 (71)	946.08 (83)	430.69 (46)	632.64 (46)	618.80 (77)	697.70 (77)	342.10 (56)	1038.80 (69)	764.80 (72)	1098.90 (84)	275.50 (32)	597.30

() -Number of days in which the rain was received per month.
LONG TERM MONTHLY AVERAGE :- from 1913 and collected for 68 years:from Kenya meterological department

Appendix II rainfall (mm) from T.A.R.D.A. farm

MONTH	1984	1985	1986	1987	1988	1989	1990	1991
JAN		5.70 (4)	7.10 (3)	18.30 (5)	118.5 (11)	-	33.30 (13)	45.60 (4)
FEB		111.10 (9)	1.00 (3)	0 (0)	0 (0)	-	33.20 (6)	0 (0)
MAR		30.00 (4)	62.20 (4)	3.40 (2)	144.30 (6)	-	193.90 (17)	44.90 (4)
APR		72.80 (9)	130.20 (13)	43.4 (4)	216.90 (7)	-	131.50 (10)	46.30 (6)
MAY		17.80 (4)	58.30 (13)	93.30 (5)	25.20 (3)	-	27.80 (6)	46.60 (6)
JUNE		0 (0)	0.30 (1)	23.50 (2)	2.80 (1)	0 (0)	0 (0)	0 (0)
JULY		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-
AUG		1.1 (1)	4.60 (1)	7.6 (3)	-	0 (0)	0 (0)	-
SEPT		0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	-
OCT	81.70 (7)	43.30 (7)	107.40 (3)	1.13 (3)	0 (0)	86.90 (4)	0 (0)	-
NOV	460.30 (16)	127.80 (16)	162.50 (11)	91.7 (9)	292.8 (16)	243.90 (16)	275.0 (16)	-
DEC	106.50 (7)	165.7 (13)	201.70 (14)	72.30 (5)	-	143.00 (12)	300.80 (18)	-
TOTAL		575.30 (67)	735.30 (66)	354.83 (38)	800.50 (44)	473.80 (32)	995.50 (86)	

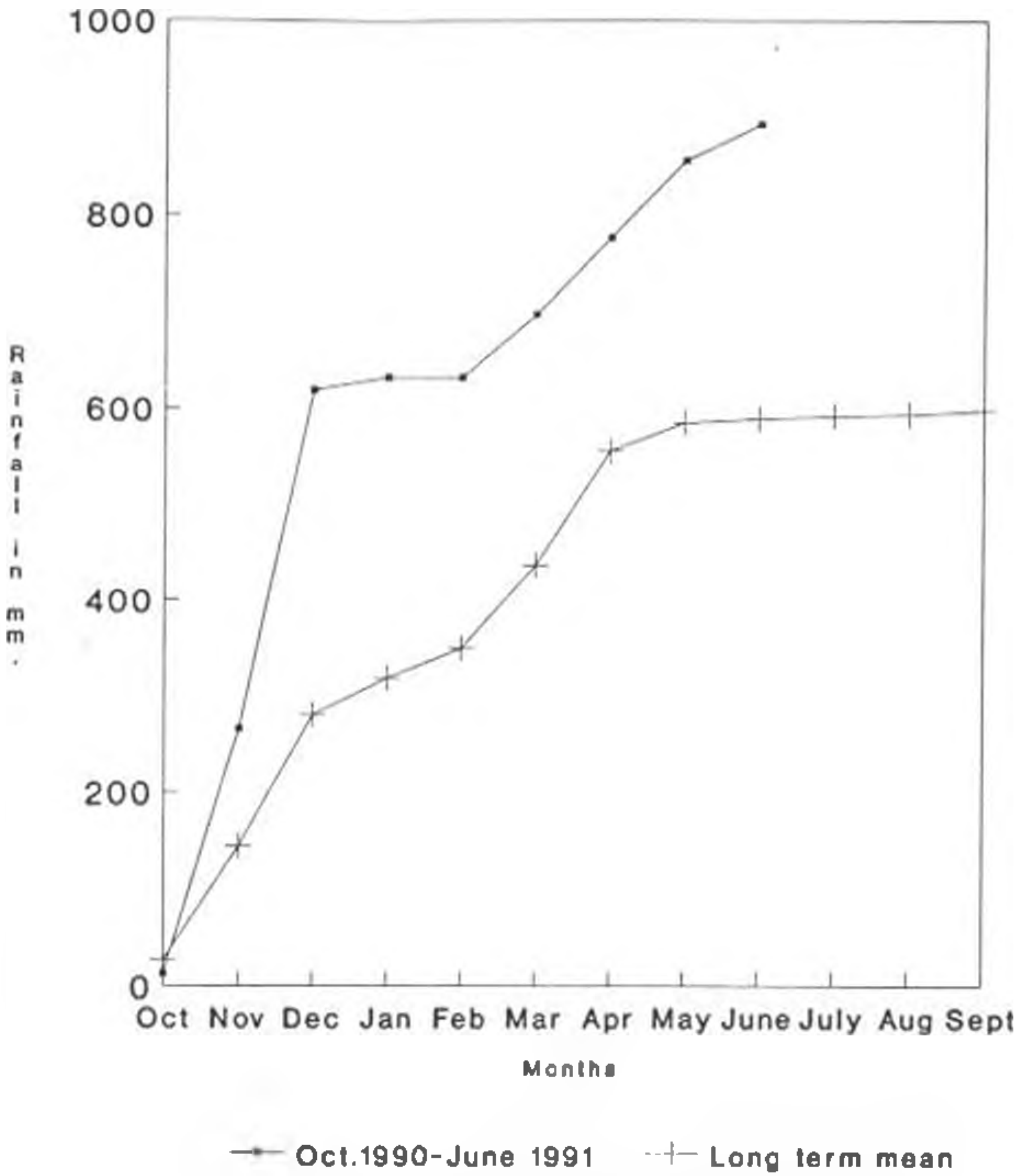
T.A.R.D.A.=TANA AND ATHI RIVERS DEVELOPMENT AUTHORITY
- No data available
() Number of days the rain was received per month

Appendix III Rainfall (mm) from Makindu

MONTH	1986	1987	1988	1989	1990	1991	LONG TERM AVERAGE
JAN	19.70 (2)	16.50 (4)	79.50 (5)	131.40 (6)	44.90 (3)	28.00 (4)	39.50
FEB	0.10 (0)	0 (0)	1.00	1.20 (1)	87.70 (5)	0 (0)	29.10
MAR	36.30 (5)	16.10 (2)	175.00 (9)	76.60 (5)	130.30 (11)	37.90 (5)	73.10
APR	169.50 (12)	62.90 (6)	99.40 (8)	260.60 (15)	109.30 (12)	58.20 (5)	115.10
MAY	20.40 (5)	55.60 (4)	6.30 (1)	49.80 (3)	8.70 (2)	30.00 (6)	28.90
JUNE	6.50 (1)	19.50 (2)	7.10 (1)	0.20	0 (0)	2.00 (1)	2.10
JULY	0 (0)	1.00	1.30 (1)	0 (0)	0 (0)	-	0.70
AUG	3.0 (1)	2.00	1.10	0.70	0 (0)	-	0.90
SEPT	0 (0)	0 (0)	2.10 (1)	0.60	0 (0)	-	2.00
OCT	20.40 (2)	0.50	2.40 (1)	125.30 (6)	5.50 (1)	-	30.10
NOV	181.80 (13)	108.90 (9)	176.50 (12)	186.10 (16)	180.77 (13)	-	172.00
DEC	120.10 (17)	10.40 (1)	160.20 (15)	143.40 (11)	199.80 (14)	-	115.80
TOTAL	577.80 (58)	293.40 (28)	711.5 (54)	975.90 (61)	172.00 (62)	156.10 (21)	609.30

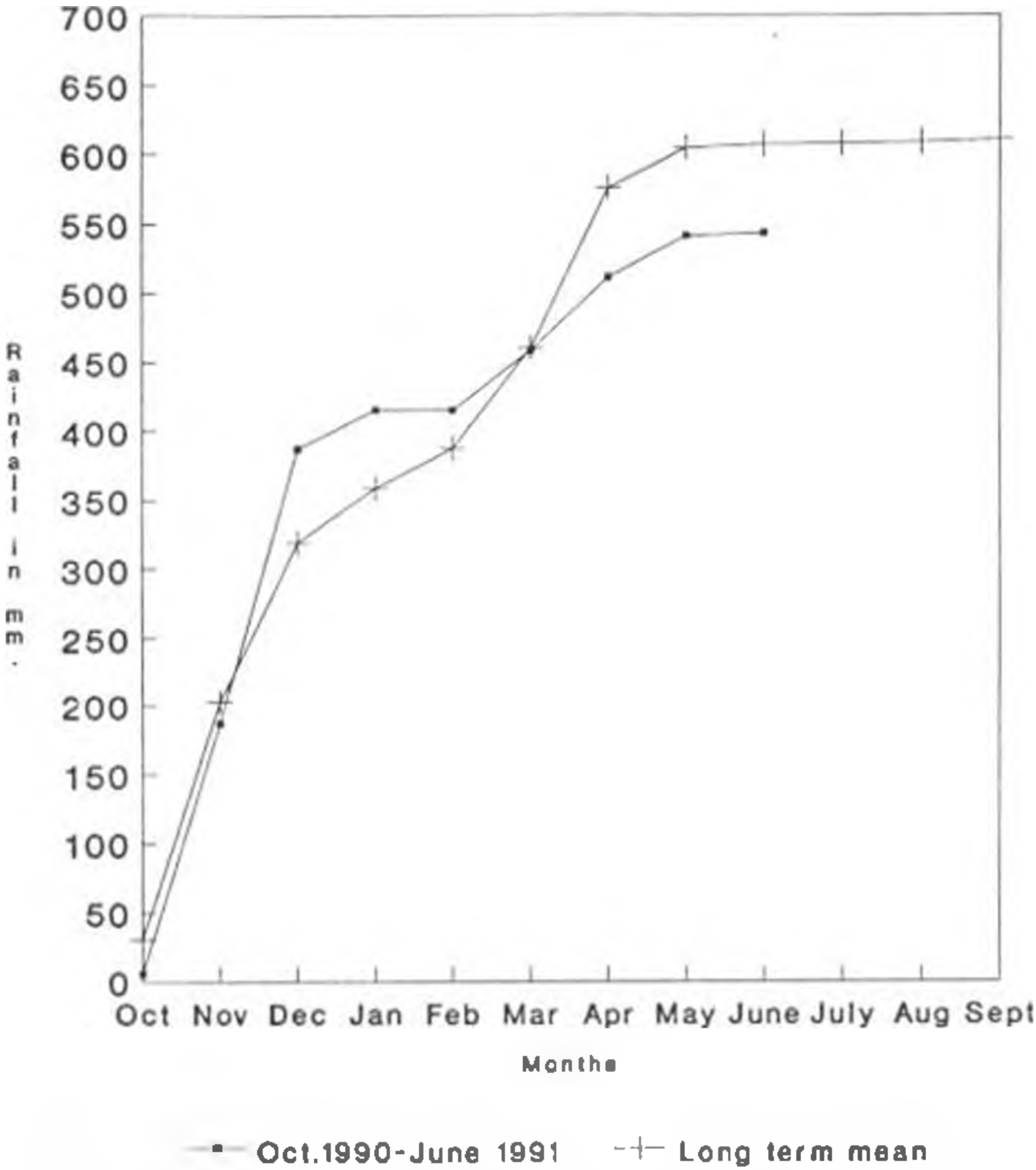
() -Raindays
LONG TERM MONTHLY AVERAGE : Taken from 1904 and collected for 83 years.
Source: Kenya Meteorological department

Appendix IV Cumulative long term mean monthly rainfall at Dwa sisal estates compared to rainfall at the study site during the study.



Long term monthly means are based on records from 1913 to 1981,source: Kenya meteological department.

Appendix V Cumulative long term mean monthly rainfall at Makindu meteorological station compared to rainfall at the study site during the study.



Long term monthly means are based on records from 1904 to 1987, source: Kenya meteorological department

Appendix VIa Anova results for height at week 1,3,6,9 and 12.

Week	Source	DF	SS	MS	F	P
1	replications	1	2721.361	2721.361	0.773	0.392NS
	land prep.	2	358000.222	17900.111	5.082	0.019*
	seeding	2	2131.361	2131.361	0.605	0.447NS
	species	2	81152.889	40576.444	11.519	0.001*
	land*seeding	2	5276.222	2638.111	0.749	0.488NS
	land*species	4	25182.778	6295.694	1.787	0.178NS
	seeding*Spp.	2	1456.222	728.111	0.207	0.815NS
	land*S.*Spp	4	31941.444	7985.361	2.267	0.105NS
	Error	17	59881.139	3522.420		
3	replications	1	850.694	850.694	0.170	0.685NS
	land prep.	2	53786.000	26893.000	5.386	0.015*
	seeding	1	16086.694	16082.694	3.222	0.090*
	species	2	85440.500	42720.250	8.555	0.003*
	land*seeding	2	18744.889	9387.440	1.880	0.183NS
	land*species	4	37147.000	9286.750	1.840	0.164NS
	seeding*Spp.	2	2972.389	1486.194	0.298	0.748NS
	land*S.*Spp.	4	31978.778	7994.694	1.601	0.220NS
	Error	17	84887.806	4993.400		
6	replications	1	1067.111	1067.111	0.254	0.621NS
	land prep.	2	62933.389	31466.694	7.491	0.005*
	seeding	1	24232.111	24232.111	5.769	0.028*
	species	2	106804.056	53402.028	12.713	0.000*
	land*seeding	2	14283.389	7141.694	1.700	0.212NS
	land*species	4	36538.444	9134.611	2.175	0.116NS
	seeding*Spp.	2	7830.056	3915.028	0.932	0.413NS
	land*S.*Spp.	4	27466.444	6866.611	1.635	0.211NS
	Error	17	71409.899	4200.582		
9	replications	1	2131.361	2131.361	0.396	0.537NS
	land prep.	2	79441.056	39720.528	7.384	0.005*
	seeding	1	26841.361	26841.361	4.990	0.039*
	species	2	11841.556	59240.778	11.013	0.001*
	land*seeding	2	17253.722	8626.861	1.604	0.230NS
	land*species	4	30756.111	7689.028	1.429	0.267NS
	seeding*Spp.	2	8486.222	4243.111	0.789	0.470NS
	land*S.*Spp.	4	27996.444	6999.111	1.301	0.309NS
	Error	17	91443.139	5379.008		

12	replications	1	1213.361	1213.361	0.205	0.656NS
	land prep.	2	108592.389	54296.194	9.187	0.000*
	seeding	1	53438.028	53438.028	9.042	0.008*
	species	2	100636.722	50318.361	8.514	0.003*
	land*seeding	2	47615.056	23807.528	4.028	0.037*
	land*species	4	23485.111	5871.278	0.993	0.438NS
	seeding*Spp.	2	15280.722	7640.361	1.293	0.300NS
	land*S.*Spp.	4	26304.444	6576.111	1.113	0.383NS
	Error	17	100467.139	5909.832		

Appendix VIb Anova results for tiller production at week 1,3,6,9 and 12.

Week	Source	DF	SS	MS	F	P
1	replications	1	604.444	604.444	4.030	0.601*
	land prep.	2	4374.500	2187.250	14.888	0.000*
	seeding	2	324.000	324.000	2.146	0.161NS
	species	2	1135.167	567.583	3.759	0.044*
	land*seeding	2	244.500	122.250	0.810	0.461NS
	land*species	4	383.333	95.833	0.635	0.645NS
	seeding*Spp.	2	15.000	7.750	0.051	0.950NS
	land*S.*Spp	4	62.000	15.500	0.103	0.980NS
	Error	17	2566.556	150.974		
3	replications	1	78.028	78.028	0.252	0.622NS
	land prep.	2	7922.667	3961.333	12.819	0.000*
	seeding	1	42.250	42.250	0.137	0.716NS
	species	2	1063.167	531.583	1.720	0.209NS
	land*seeding	2	564.667	282.333	0.914	0.420NS
	land*species	4	292.167	73.042	0.236	0.914NS
	seeding*Spp.	2	18.500	9.250	0.030	0.971NS
	land*S.*Spp.	4	13.833	3.458	0.011	1.000NS
	Error	17	5253.472	309.028		
6	replications	1	641.788	641.788	1.875	0.189NS
	land prep.	2	8578.000	4289.250	12.530	0.000*
	seeding	1	225.000	225.000	0.657	0.429NS
	species	2	2642.000	1321.000	3.859	0.042*
	land*seeding	2	253.167	126.583	0.370	0.696NS
	land*species	4	291.500	72.875	0.213	0.928NS
	seeding*Spp.	2	80.667	40.333	0.118	0.890NS
	land*S.*Spp.	4	257.167	64.292	0.188	0.942NS
	Error	17	5819.222	342.307		

9	replications	1	84.028	84.028	0.212	0.651NS
	land prep.	2	8556.222	4278.111	10.771	0.001*
	seeding	1	380.250	380.250	0.957	0.342NS
	species	2	2174.889	1087.444	2.738	0.093*
	land*seeding	2	602.000	301.000	0.758	0.484NS
	land*species	4	169.778	42.444	0.107	0.979NS
	seeding*Spp.	2	34.667	17.333	0.044	0.957NS
	land*S.*Spp.	4	117.333	29.333	0.074	0.989NS
	Error	17	6752.472	397.208		
12	replications	1	12.250	12.250	0.016	0.901NS
	land prep.	2	17372.167	8686.083	11.411	0.001*
	seeding	1	2256.250	2256.250	2.964	0.103NS
	species	2	15366.500	7683.250	10.094	0.001*
	land*seeding	2	3216.500	1608.250	2.113	0.152NS
	land*species	4	2379.333	594.833	0.781	0.553NS
	seeding*Spp.	2	1569.500	784.750	1.031	0.378NS
	land*S.*Spp.	4	566.000	141.500	0.186	0.943NS
	Error	17	12940.250	761.191		

Appendix VIc Anova results for tiller production at week 1,3,6,9 and 12.

Week	Source	DF	SS	MS	F	P
3	replications	1	0.007	0.007	0.168	0.687NS
	land prep.	2	0.108	0.054	1.341	0.288NS
	seeding.	2	0.012	0.012	0.297	0.593NS
	species	2	0.036	0.018	0.451	0.645NS
	land*seeding	2	0.240	0.120	2.966	0.079*
	land*species	4	0.073	0.018	0.454	0.768NS
	seeding*Spp.	2	0.029	0.014	0.357	0.705NS
	land*S.*Spp	4	0.039	0.010	0.240	0.912NS
	Error	17	0.687	0.040		
6	replications	1	0.002	0.002	0.047	0.831NS
	land prep.	2	0.219	0.110	3.392	0.058*
	seeding	1	0.001	0.001	0.019	0.891NS
	species	2	0.003	0.001	0.039	0.961NS
	land*seeding	2	0.182	0.091	2.818	0.088*
	land*species	4	0.056	0.014	0.432	0.783NS
	seeding*Spp.	2	0.060	0.030	0.937	0.411NS
	land*S.*Spp.	4	0.056	0.014	0.434	0.782NS
	Error	17	0.549	0.032		

9	replications	1	0.002	0.002	0.089	0.769NS
	land prep.	2	0.299	0.150	5.885	0.011*
	seeding	1	0.029	0.029	1.137	0.301NS
	species	2	0.023	0.011	0.447	0.647NS
	land*seeding	2	0.166	0.083	3.269	0.063*
	land*species	4	0.118	0.030	1.165	0.361NS
	seeding*Spp.	2	0.014	0.007	0.285	0.0756S
	land*S.*Spp.	4	0.114	0.028	1.120	0.380NS
	Error	17	0.432	0.0025		
12	replications	1	0.012	0.012	0.455	0.509NS
	land prep.	2	0.300	0.150	5.781	0.012*
	seeding	1	0.098	0.098	3.793	0.068*
	species	2	0.012	0.006	0.232	0.795NS
	land*seeding	2	0.048	0.024	0.926	0.415NS
	land*species	4	0.080	0.020	0.773	0.558NS
	seeding*Spp.	2	0.022	0.011	0.419	0.664NS
	land*S.*Spp.	4	0.019	0.005	0.180	0.945NS
	Error	17	0.441	0.026		