FACTORS AFFECTING THE ESTABLISHMENT

OF

LEPTOSPERMUM SCOPARIUM J.R. et G. Forst. (MANUKA)

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INTRODUCTION

L. scoparium is one of New Zealand's most important weeds of unploughable infertile hill country. The plant is an indigenous shrub, characteristic of the early stages of succession to forest in a wide range of habitats (Cockayne, 1928).

In the eight years prior to 1959/60 nearly 40,000 acres of unimproved grassland reverted to scrub, fern and second growth each year. L. scoparium is one of the most important components of the scrub, fern and second growth category. By 1959/60 the total area of reverted land in New Zealand was 5.7 million acres of which 3.65 million were in the North Island. (Rigg, 1962).

Control of L. scoparium on unploughable hill country has been limited to pulling, cutting, or cutting and burning, depending on stage of growth. Chemical methods and standing burns have generally proved unsuccessful. Most methods are expensive.

Levy (1932, 1940, 1946) postulated that establishment of L. scoparium in pasture could be prevented by good farming techniques. Today there is a growing body of practical evidence to support this hypothesis (Suckling, 1959; New Zealand Farmer 83 (42, 43, 45)).

This study was carried out to determine what intrinsic factors favour the establishment of L. scoparium, and the quantitative effect of farm management techniques on this process.

SECTION I

REVIEW OF LITERATURE

1. DEFINITION OF ESTABLISHMENT

Establishment is a process, starting from the arrival of the propagule in the habitat, during which the plant germinates, attains independence from propagule reserves, and becomes an individual capable of surviving the prevailing environmental conditions. Whether or not establishment occurs is determined by the environment. The process is also influenced by the species genotypes, mode of reproduction, reproductive capacity, propagule characterstics and efficiency of propagule dispersal. The importance of reproductive capacity and efficient propagule dispersal in weed establishment was stressed by Harper (1960) who attributed the success of many weeds to an efficient dispersal mechanism enabling colonization ofnew areas from a distance, and high seed output enabling rapid expansion in an infected area. Species reproducing apomicticly have considerable advantages in propagule production and/or establishment because these processes are not affected by the environment to the same degree as in sexually reproducing plants.

2. THE PLANT

Few experimental studies have been conducted into the biology of L. scoparium but there is considerable information based on observation. The majority of the knowledge has been contributed by Silvester (1962), Burrell (1963), Cockayne (1928) and Levy (1923). Unqualified references in this text apply to these publications.

The genus Leptospermum (Myrtaceae) comprises some 35 species, mostly Australian (Allan, 1961). The haploid chromosome number of most members of the Myrtaceae is 11 and of 12 Australian species of

Leptospermum only one exhibits polyploidy (Darlington and Wylie, 1955). Three species of Leptospermum are found in New Zealand, L. scoparium being the most widespread and abundant. Allan (1961) regarded the New Zealand Leptospermum species as endemic but L. scoparium is present in Tasmania and Victoria (Hoy, 1959). Oliver (1953) regarded L. scoparium in New Zealand as a tertiary immigrant from Australia.

L. scoparium is extremely plastic in growth form. It may be a shrub of diverse habit or a small tree. (Allan, 1961). Cockayne recorded the plant as a prostrate mat on subalpine moor. Within a stand the species varies in size, shape, and colour of the leaf, texture of bark, time of flowering, sepal colour, and whether the leaves change colour with season. Some characters such as colour of the young stem growth, and the growth form are relatively constant (Burrell, 1963). Allan (1961) listed 5 variants of the type which had earlier been classed as separate varieties. As he stated "the status of the multitudinous forms is very imperfectly known". Burrell suggested that the greater part of the morphological variation is environmentally induced.

L. scoparium is a pioneer prominent in the early seral stages of succession on a wide diversity of sites. More or less permanent communities of the species may occur in swamps, windswept areas, dunes, acid soils and other adverse habitats (Cockayne, 1928). Communities have been described by the following workers: Mark, Scott, Sanderson and James (1964), Percy (1955-56), Bellingham (1955-56), Atkinson and Percy (1955-56), Wheeler (1963), Burrell (1963), Silvester (1962).

It was postulated by Cockayne that, except adjacent to

active volcanoes, large areas of L. scoparium must have been rare in primitive New Zealand. The present abundance and distribution of L. scoparium is due principally to human disturbance of the habitat. By the late eighteenth century possibly 33% of all virgin North Island forest had been destroyed and replaced by scrub forest, L. scoparium scrub, and Pteridium aquilinum var. esculentum (bracken fern) as a result of fires started by Polynesian man. (New Zealand Forestry, 1964). Habitat disturbance on as great, or greater scale, and certainly within a shorter time occurred under the influence of European man. Between 1890 and 1920 ten million acres of forest and scrub covered land, mainly in Taranaki, King Country, Hawkes Bay and Wellington districts, were cleared and sown to pasture. (Rigg, 1962). Much of this land was steep and infertile, and L. scoparium and other native secondary growth plants quickly invaded the poor open pastures present after the initial fertility from the bush burn had gone. It was estimated in 1925 that 1.1 million acres of hill grassland in the North Island had reverted in the previous eight years. (Special Committee Report, 1925).

3. INTRINSIC FACTORS AFFECTING ESTABLISHMENT

3.1 MODE OF REPRODUCTION

L. scoparium reproduces by sexual means only. Flowers are pollinated principally by a mosquito-like fly of the genus Bibio. Other insects observed visiting the flower in Otago include honey and bumble bees, houseflies and bluebottles. (Burrell, 1963). Burrell also demonstrated that the species is self-compatible.

3.2 AGE AT FLOWERING AND FLOWERING SEASON

Plants have been observed flowering at 3 - 5 years (Small, 1961; Burrell, 1963; Marshall, 1962) and at 5 cm. in height (Cockayne, 1928).

In Otago L. scoparium flowers from November to February with a peak in December. Male and hermaphrodite flowers are produced. Over the winter male flowers only are produced (Burrell, 1963). Silvester recorded flowering from August to November in the Hunua Ranges.

3.3 SEED MATURATION AND TIME OF SHEDDING

From current season's flowers seed becomes mature during summer or autumn depending on the environment (Levy, 1923; Silvester, 1962; Burrell, 1963).

Season of seed shed also appears to vary with environment. In the Hunua Ranges most seed is shed in February - March (Silvester, 1962), while in Taranaki most seed is shed in August (Levy, 1923).

A small proportion of capsules remain closed (Levy, 1923; Burrell, 1963) and capsules tagged by Burrell remained unopened for three years, the seed retaining viability. Capsules may open after the adult plant has been cut or burnt, so providing a source of infection for re-establishing the stand (Levy, 1923; Burrell, 1963).

3.4 SEED NUMBERS, WEIGHT, AND VIABILITY

L. scoparium produces from 200 - 500 seeds per capsule, (Silvester, 1962; Small, 1961). Levy regarded the profuse seed production of the species as the main reason for its importance as a weed.

The average seed weight of L. scoparium in the Hunua Ranges is 0.07 mg. (Silvester, 1962).

Germination percentage varies from 12 - 16% (Silvester, 1962) although Burrell recorded germination percentages as high as 20%. Silvester found initial viability was strongly related to capsule size and Burrell noted a considerable variation in percentage viable seed between capsules from different bushes and from the one bush.

3.5 SEED DISPERSAL

Wind appears to be the usual form of seed dispersal agent in L. scoparium. Burrell observed young plants one-quarter mile down wind from an isolated bush and Marshall (1962) found cleared ground downwind and up to half a mile away from a stand was subject to re-invasion. Sheep carrying seed in their wool are also thought to act as dispersal agents (Small, 1961; Marshall, 1962). Silvester attributed much of the success of the species to the efficient dispersal of its minute seed, and Small (1961) and others stressed the importance of minimizing seed dispersal in controlling L. scoparium invasion of pasture.

3.6 SEED DORMANCY

It has been observed that seeds of L. scoparium germinate soon after they are shed, appearing to have no dormancy. However, investigation by Silvester showed that germination will not occur in darkness. A light requirement for germination was also suggested by Levy. Because the seeds are exalbuminous Silvester hypothesized that radicle emergency depends on the embryo first photosynthesizing. He found that

0.5% normal daylight in winter and 0.25% normal daylight in summer was sufficient for germination. Silvester also noted a perceptible increase in germination occurred with stratification at 5°C (41°F) for three or more days, but otherwise the temperature at which seeds were germinated did not affect the final germination percentage. Burrell on the other hand found no dormancy effects due to light or temperature requirement.

Levy regarded the apparent readiness of L. scoparium to germinate as the weak point in its life cycle. By cutting, and then burning the bushes after the seed has shed and germinated, all sources of infection within the area are destroyed. Silvester stated "the prime limiting factor in establishment of L. scoparium is its requirement of light for germination and later, seedling development."

3.7 SEED LONGEVITY

Viability of seed of L. scoparium in storage rapidly reduces to 2% six months after harvesting and by two years all seed is inviable (Silvester, 1962).

3.8 GROWTH RATE

The growth rate of L. scoparium seedlings is slower than that of the majority of herbacious plants, especially annuals and grasses, and scrub hardwoods (Silvester, 1962).

4. ENVIRONMENTAL FACTORS AFFECTING ESTABLISHMENT

4.1 LIGHT

As noted previously (Section 3.6), light may be necessary for germination.

For seedlings of L. scoparium to survive relatively high illuminance is necessary. Silvester found that the growth rate of seedlings of the species was negligible compared with scrub hardwood species below 9% daylight, due possibly to the severe depression in root growth of L. scoparium at low illuminance. He also calculated the theoretical compensation point for seedlings as 2.6% daylight, yet within L. scoparium communities no seedlings of the species occur until illuminance is greater than 12% daylight. Bieleski (1959) also found light levels under L. scoparium stands were normally too low for regeneration of the species. Silvester suggested that root growth below 12% daylight was insufficient to allow the plant to survive soil surface desiccation.

4.2 TEMPERATURE

Silvester found that at 46°F germination took 30 days, but only 3.5 days at 77°F. The delay of germination at low temperature was attributed to the effect of the low temperature on the rate of pre-emergence photosynthesis.

Silvester also found that the growth rate of seedlings was limited below 65°F and above 72°F.

Frost may have a significant effect on survival in some areas. Cockayne observed that almost constant frost for six weeks with temperatures not below -11°C (12°F) killed adult L. scoparium.

4.3 MOISTURE

Silvester found that under conditions of adequate light and suitable temperatures seed germinates on contact with water, the seed coat apparently offering little resistance to water entry.

Burrell recorded L. scoparium as growing in areas of Otago receiving less than 50 cm. (20 in.) of rain per year and Cockayne found the species present in areas of high precipitation and maximum dryness.

4.4 ALTITUDE

L. scoparium occurs from sea level to 800 - 900 meters (2620 - 2950 ft.) above sea level in Otago, with the species being restricted to northerly aspects at high altitudes (Burrell, 1962). Silvester gave the altitude range of the species as from sea level to 4500 feet (1370 m.) on Mt. Ruapehu.

4.5 SOILS

The species may be found on alluvium, clays, loess, sand, gravel, calcareous or non-calcareous soils, and on volcanic debris of different sorts. It is frequently dominant on poor soils (Cockayne, 1928). Apparently the species does not occur on brown-grey earths (Burrell, 1963).

4.6 INTERACTION WITH PASTURE SPECIES

It was recognized by Levy that L. scoparium would not germinate and establish within a grass sward intercepting practically all the light. Silvester postulated that the reason L. scoparium has not established in abandoned pasture in the Hunua Ranges is because of complete light interception by the undisturbed grass cover. Any factor weakening the sward decreases light interception and consequently increases the chance of weed invasion (Levy, 1940). The main environmental factors controlling pasture vigour and density are (Levy, 1940; Glue, 1957):

soil fertility,

grazing animal effects,

moisture extremes,

temperature extremes,

insect attack.

Soil fertility and animal grazing probably have most influence on the susceptibility of pasture to invasion by L. scoparium.

Under the low fertility conditions characteristic of unimproved hill country, high-fertility demanding grasses and clovers e.g. Lolium perenne (perennial ryegrass), Dactylis glomerata (cocksfoot), Trifolium repens (white clover) do not thrive and much hill land reverted originally because these species were sown after bush burns. Initial establishment was often good but after the bush burn fertility was depleted these species weakened, leaving poor open pasture readily invaded by weeds. (Special Committee Report, 1925). To overcome this problem Levy (1932) advocated sowing such species as Agrostis tenius (Browntop) and Notodanthonia which could grow on low fertility country and maintain a close sward. However, Madden (1940) found that 7.98 million acres of North Island hill pastures composed of low fertility demanding species were most susceptible to invasion by L. scoparium.

The advent of aerial topdressing and clover oversowing provided an easy method of increasing pasture vigour. Practical experience of farmers showed that on land subject to reversion high fertility demanding grasses and clovers thrive after an initial dressing of 5 - 10 cwt. per acre of superphosphate plus deficient trace elements, followed by annual maintenance dressings of 2 - 4 cwt. per acre. Establishment of a vigorous sward with the associated increased stock carrying capacity results in L. scoparium ceasing to be a serious

problem (New Zealand Farmer, 83 (42, 43, 45)).

Grazing animals may influence pasture vigour. Dung and urine stimulate pasture growth but trampling and pugging cause opening of the sward. Possibly the most potent influence is in the manner and timing of defoliation. Hard, continuous close grazing is most conducive to weakening the sward and permitting weed invasion (Levy, 1940).

4.7 THE GRAZING ANIMAL

Glue (1957) and Levy (1940) have stressed the effect of the grazing animal, through trampling damage and nipping off the young plant, on weed seedling survival.

4.8 PARASITES AND DISEASE

The most important parasite of *L. scoparium* is *Eriococcus orariensis*, a scale insect. The presence of the insect is indicated by the covering of black mould growing on a honey dew produced by the parasite. Death of the host may result from removal of sap (Hoy, 1961), although Mulcock (1950) suggested reduction of photosynthetic activity by the black fungal coating shading the leaves may have an effect. The effectiveness of *E. orariensis* is limited by a fungus *Myrangium thwaitessi*, parasitic on the scale insect (Hoy, 1961), especially in high humidity areas of the North Island.

The roots of *L. scoparium* are parasitised in some localities by *Gastrodia minor* Petrie a non-green orchich (Campbell, 1963) but it is not known what influence this parasite has on vigour.

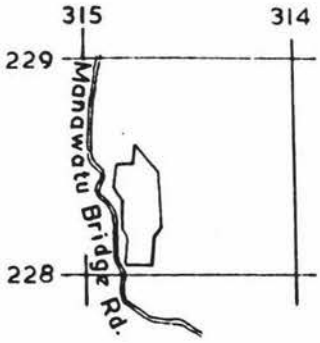
Seeds of the species can be destroyed by a capsule borer of

the *Carposina* genus (Dugdale, pers. comm.).

SECTION II

FIGURE 1

LOCATION OF TIRITEA FIELD AREA.



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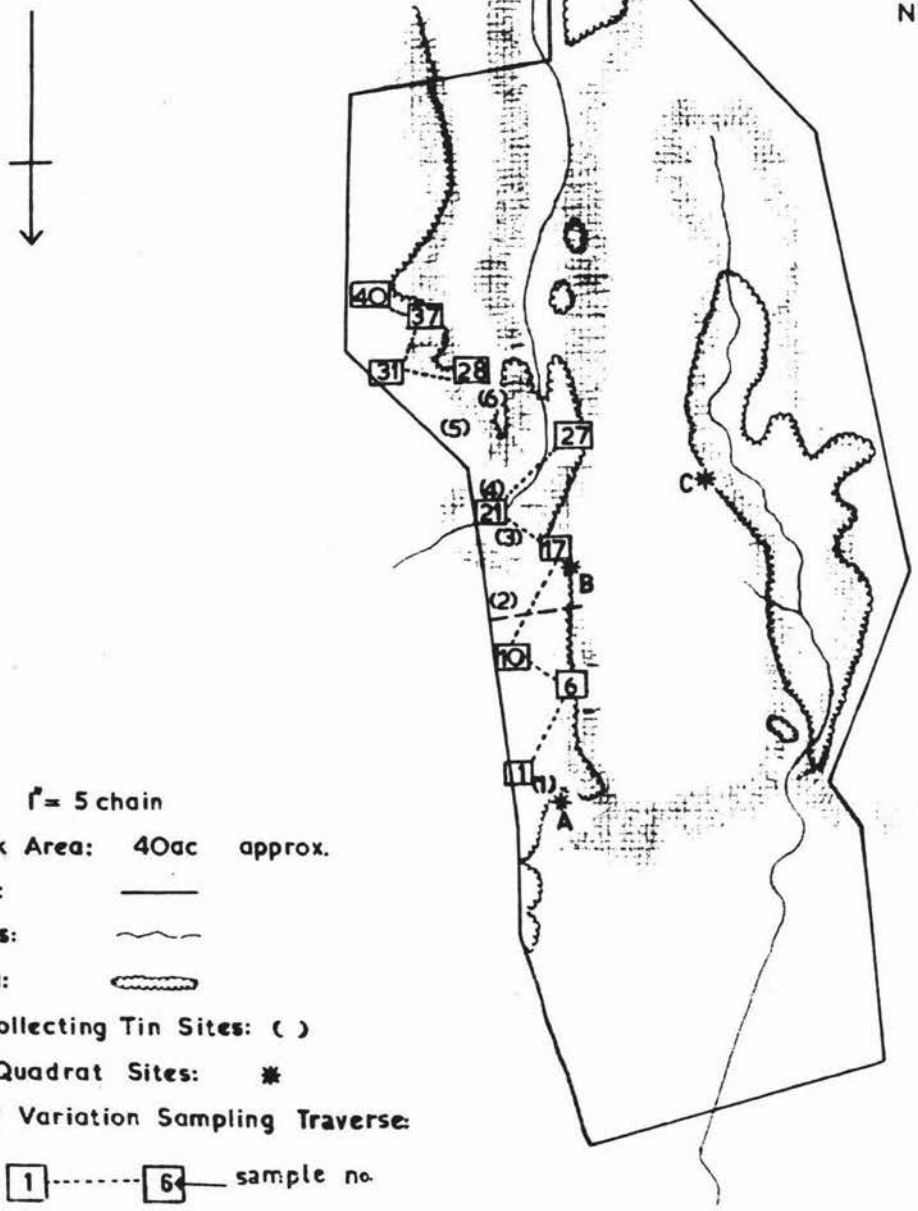


Scale: 1" = 5 chain

Paddock Area: 40ac approx.

Fences: ——

Streams: ~~~

Manuka:

Seed Collecting Tin Sites: ( )

Chart Quadrat Sites: ✱

Plan of Variation Sampling Traverse:

[1]·····[6] ← sample no.

Transect: — — —

5. FACTORS EXAMINED IN THE STUDY

Information was collected on seed characteristics and production in a local L. scoparium stand for comparison with the results of other workers, and an attempt was made to determine seasonal variation in seed shed. Because establishment is dependent on germination and seedling survival efforts were concentrated on examining:

(1) The effect of light, temperature, seed age, and exposure on seed germination, using a Tetrazolium test to indicate basic seed viability. (Burrell and Silvester had already examined the effect of light and temperature on germination but their results differed.)

(2) The effect of season on germination and seedling survival on bare ground and in pasture.

(3) The effect of cover, applied fertilizer, and cutting frequency in grassed and bare plots on germination and seedling survival.

Establishment of L. scoparium in some districts may be favoured by plants genetically capable of faster growth. Variation in growth rate between plants from different districts was studied in a uniform environment. Supplementary phenological and morphological information was collected.

6. THE STUDY AREAS

6.1 LOCATION

Studies were carried out on two areas in the Manawatu. All plot experiments and the variation experiment were carried out on an

area of flat, apparently homogeneous land at Massey University. Field studies were carried out in a farm paddock containing a stand of L. scoparium. The paddock borders part of the Palmerston North City Council water reserve in the Tiritea area and is typical of a belt of country, running along the Tararua foothills, (see Fig. 3) which is subject to invasion by scrub plants. The location of the paddock, the areas covered by scrub and the siting of sample points are shown in Fig. 1. Indications of the nature of the L. scoparium stand are shown in Figs. 2 and 4, and of the pasture bordering its edges in Figs. 6, 7, 8.

6.2 SOILS

The soil type of the field area is similar to Raumai sandy loam hill soil, a common terrace slope soil of the upper terraces in the Manawatu, and that of the plot area, to Ashhurst silt loam stony phase. Descriptions of these are given by N.Z. D.S.I.R. Soil Bureau, and Pollok (pers. comm.) respectively. The soil used in the experiment described in Section 13 consisted of a 4 in. overlay of a soil similar in type to the Raumai sandy loam hill soil, on the existing subsoil of the plot area.

Details of the chemical analyses of (a) the overlay soil used in the experiment, and (b) the existing topsoil on the remainder of the plot area are given in Table 1.

TABLE 1

Chemical Analyses of Soils

	pH	Quick Test Ca pp 40,000	Quick Test K pp 250,000	Quick Test P pp 50m	Exchangeable Ca m.e.%	Exchangeable K m.e.%	Total N %
(a)	5.2	3	4	1	1.8	0.11	0.09
(b)	4.9	7	11	1	5.9	0.6	0.40
	(5.6)		(7)	(10)		(0.3)	(0.3)

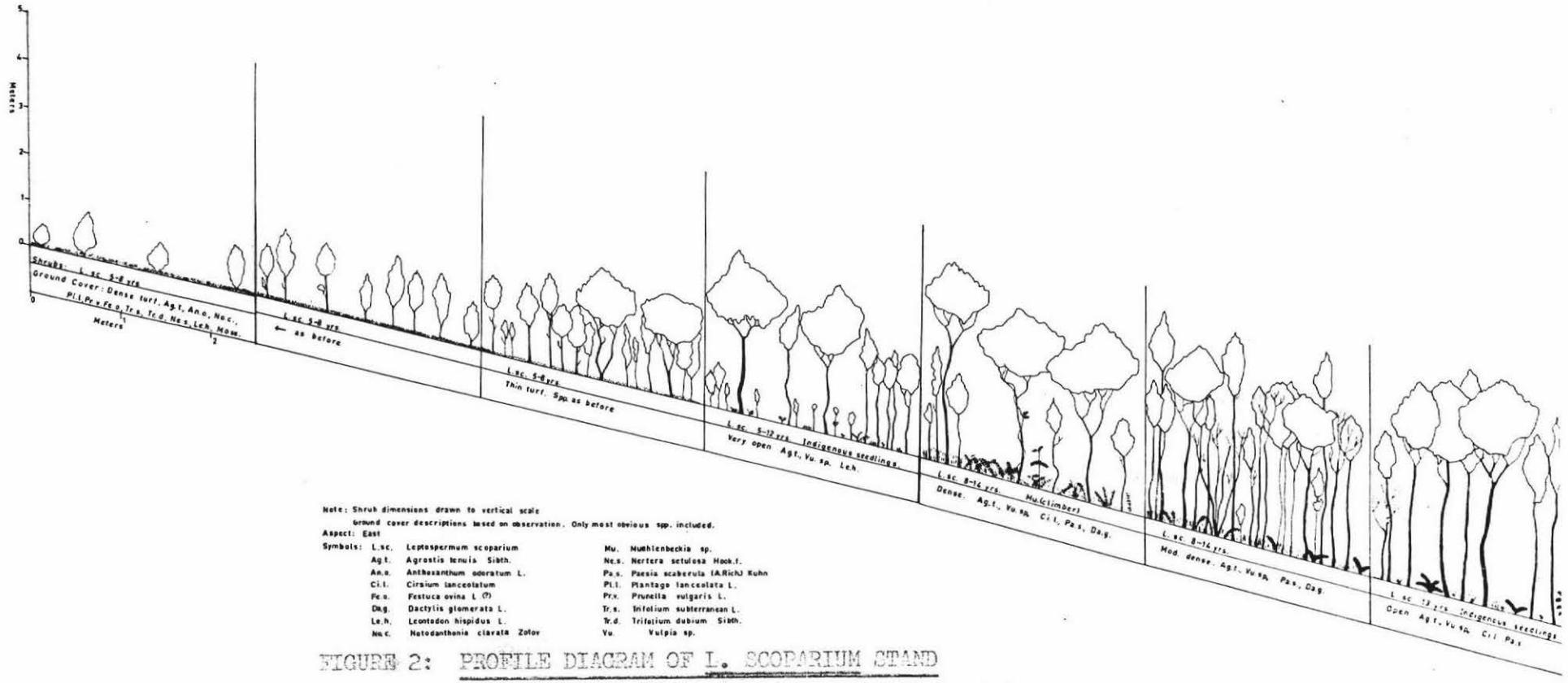
Analyses were carried out at Rukuhia Soil Research Station.
The possible levels below which a deficiency may exist are shown in brackets (based on information from Agriculture Department and Massey University Soils Department).

6.3 CLIMATE

Mean monthly rainfall, mean monthly temperature, and associated normal values during the period of the experiment are shown in Fig. 5 along with frost days recorded.

7. SEED

All L. scoparium seed for experiments in this study was collected from the Tiritea field area, with the exception of seed from other areas used in the variation trial. Part way through the study it was found to be possible to select viable seed with the aid of a binocular microscope. Non-viable seeds consist of brown empty testas. With proper adjustment of lighting, viable seeds can be distinguished by their creamy brown colour and plump appearance. Tests proved that seed so selected had 100% germination ability. This technique was subsequently used to provide seed samples of known viability so reducing the variability of experimental results.



Note: Shrub dimensions drawn to vertical scale
ground cover descriptions based on observation. Only most obvious spp. included.

Aspect: East

Symbols:

L.sc.	Leptospermum scoparium	Mu.	Muehlenbeckia sp.
Ag.t.	Agrostis tenuis Sibth.	Ne.s.	Nertera setulosa Hook.f.
An.o.	Anthoxanthum odoratum L.	Pa.s.	Paesia scaberula (A.Rich) Kuhn
Ci.l.	Cirsium lanceolatum	Pl.l.	Plantago lanceolata L.
Fe.o.	Festuca ovina L (?)	Pr.v.	Prunella vulgaris L.
Da.g.	Dactylis glomerata L.	Tr.s.	Trifolium subterranean L.
Le.h.	Leontodon hispidus L.	Tr.d.	Trifolium dubium Sibth.
No.c.	Notodanthonia clavata Zotov	Vu.	Vulpia sp.

FIGURE 2: PROFILE DIAGRAM OF L. SCOPARIUM STAND

Drawn from data collected on 2.5 m.sq. plots spaced 10 m. apart (centre to centre) along a transect in the Tiritea field area.

FIGURE 3: PATTERN OF REVERSION IN THE TIRITEA

L. scoparium and Ulex europaeus (Gorse) growing on gully sides in mid distance. Field area out of photo to left.

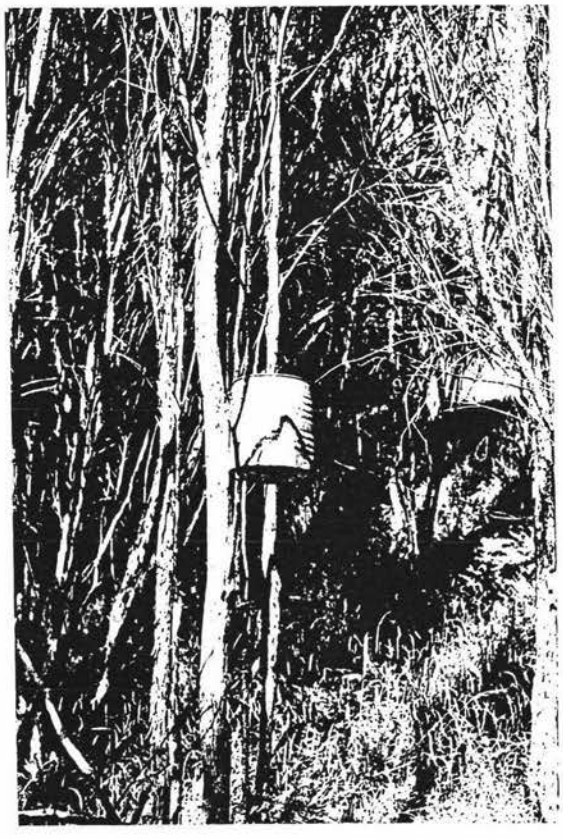


FIGURE 4: POSITIONING OF A SEED CATCHING TIN

Also showing interior of L. scoparium stand.

FIGURES 6, 7, 8

QUADRAT CHARTS A, B, AND C

Recorded in the Tiritea field area 22/3/65

Symbols: as for Figure 2, plus:

Ho.l. *Holcus lanatus*

 *Leontodon hispidus*

 *Plantago lanceolata*

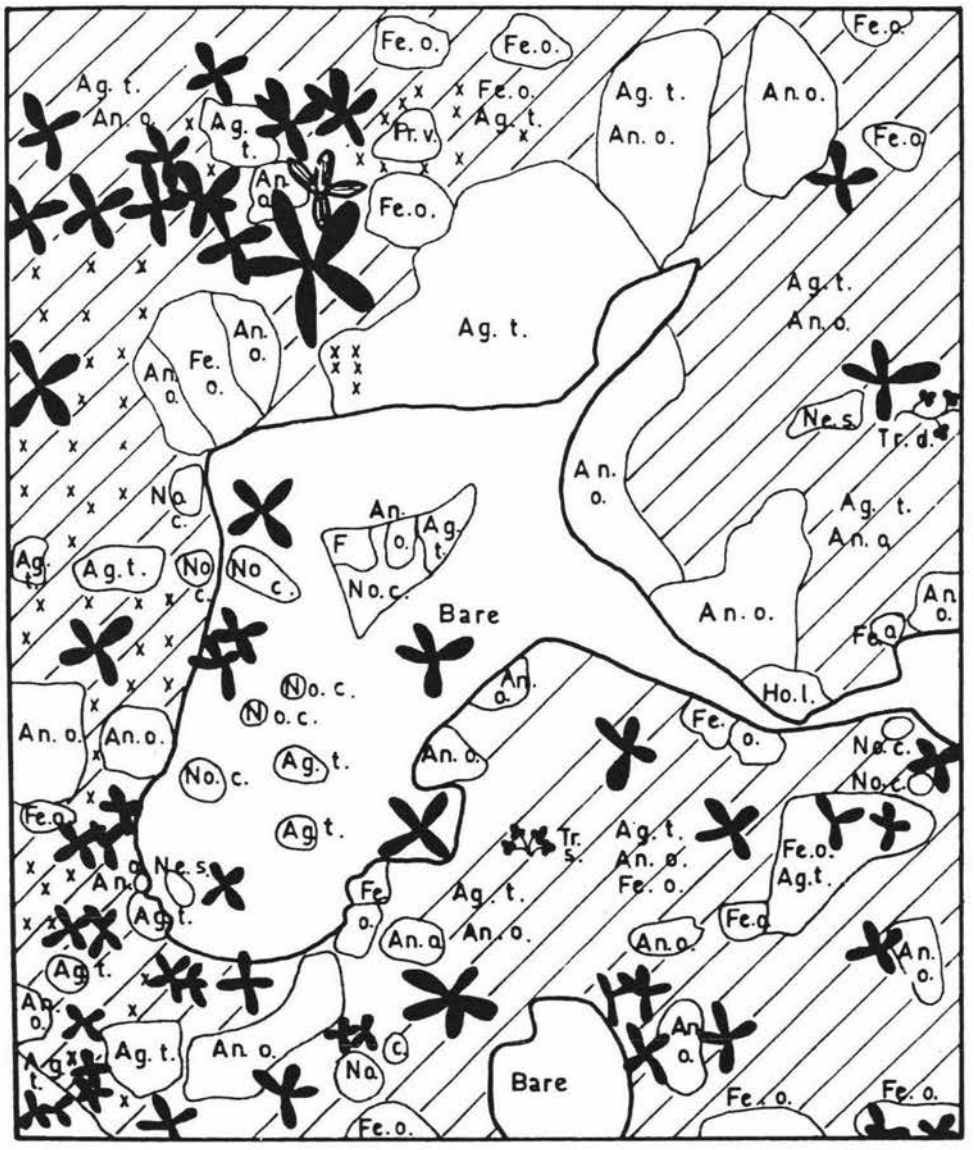
 *Pteridium aquilinum* var. *esculentum*

/ / / Intimate species mixture

× × × Moss (principally *Thuidium furfurosum*)

FIGURE 6

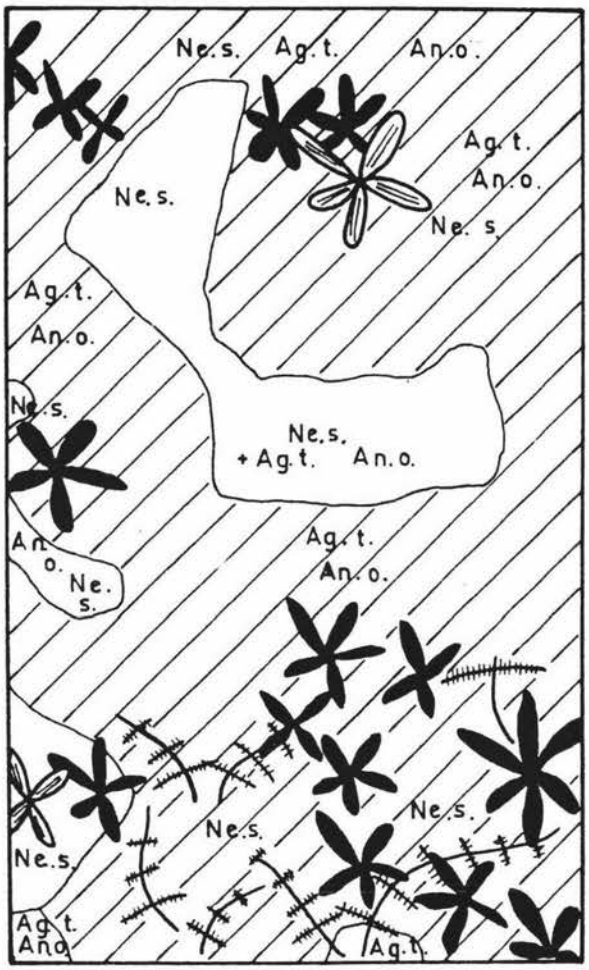
CHART OF QUAD. A. 22/3/65.



scale: 1in. = 10cm.

FIGURE 7

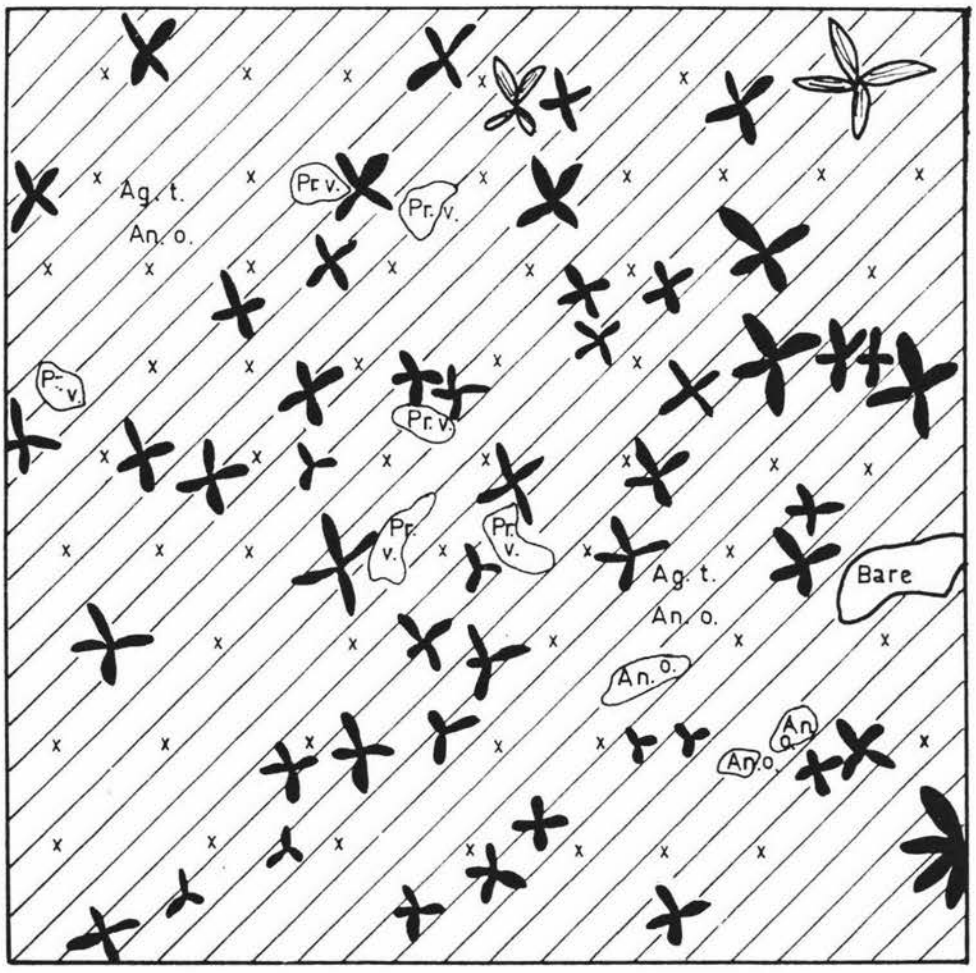
CHART OF QUAD. B. 22/3/65.



scale: 1 in. = 10 cm.

FIGURE 8

CHART OF QUAD. C. 22/3/65.



scale: 1in. = 10 cm.

FIGURE 5

VARIATION IN SOME FACTORS OF CLIMATE OVER THE STUDY PERIOD

Data extracted from the meteorological records of D.S.I.R., Palmerston North. A frost day is recorded when the grass minimum temperature is 30.3°F or below. Normal values (taken from New Zealand Gazette) based on period 1931-1960 for temperature and 1921-1950 for rainfall.

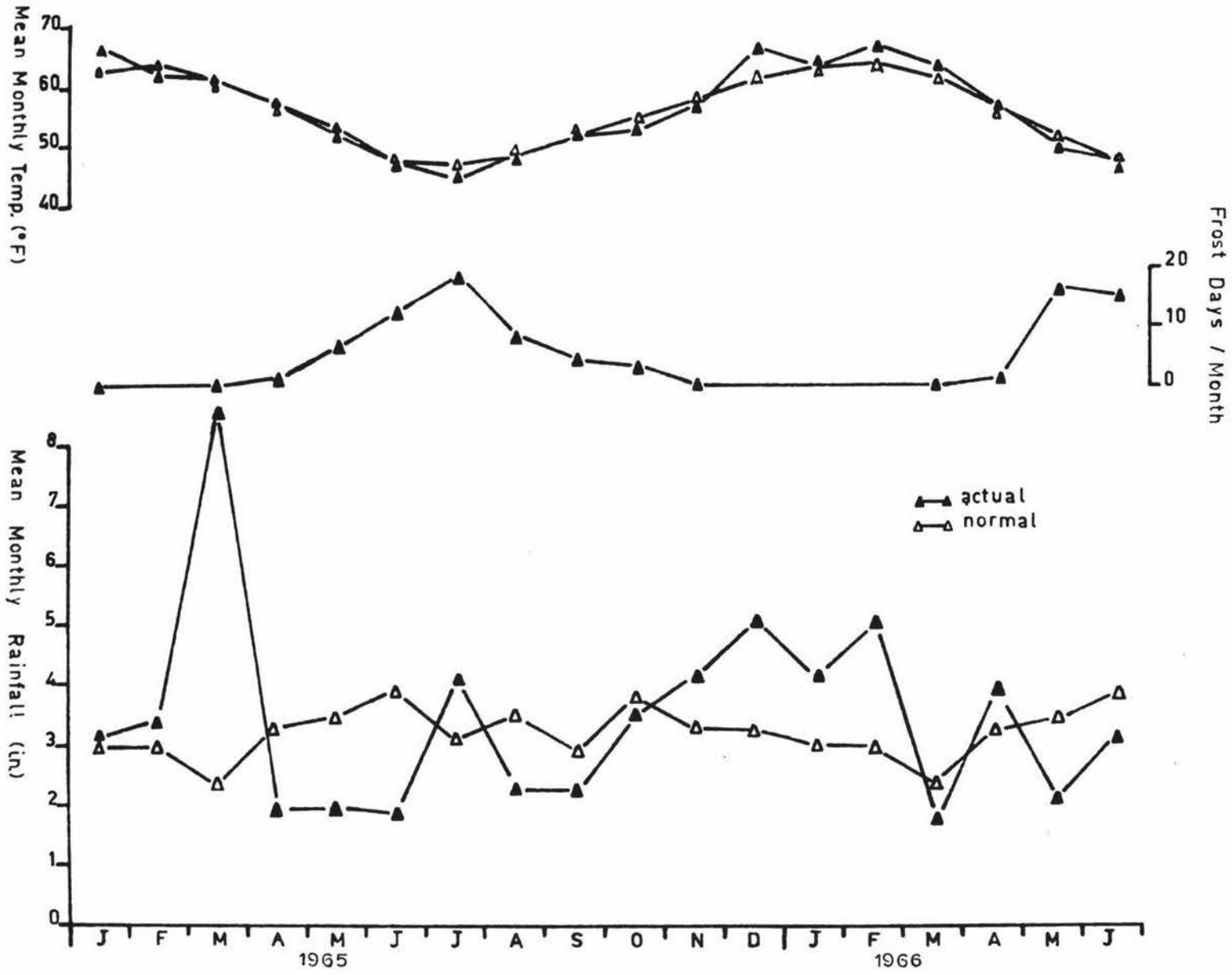

Mean Monthly Temp. (°F)
70
60
50
40
Frost Days / Month
20
10
0
Mean Monthly Rainfall (in.)
8
7
6
5
4
3
2
1
0
actual
normal
J F M A M J J A S O N D J F M A M J
1965
1966

FIGURE 5

8. DATA ANALYSIS

Experimental results were subjected to analyses of variance in conformity with experimental design, with the exception of all but one of the experiments examining factors influencing germination. In these the significance of treatment effects was determined by comparing means on a binomial % basis in which

$$S.E.\ \% = \sqrt{\frac{\%(100-\%)}{N}}$$

(Glenday, pers. comm.)

Differences between means were taken as significant if greater than three times the standard error of either mean. Results of the experiment determining the influence of seed age on germination were subject to analyses of variance on a one way classification basis.

Where the data range was great transformations to $\sqrt{x}$ or $\sqrt{x + \frac{1}{2}}$ were made. Percentages were transformed to arc sine $\sqrt{\%}$ and herbage yields to logarithms. None of the variation experiment data or the tiller count data was transformed prior to analysis. Substitutes had to be determined for missing values in some of the variation experiment data.

Where all replicates in a treatment gave more or less zero data this treatment was excluded from the analysis, except in the case of the experiment described in Section 13 which was factorial in design.

The pasture feature data of the experiment described in Section 13, being supplementary, was analysed only on a plot average basis.

Where treatments were shown to differ significantly by the variance ratio test individual treatment means were compared using the t-test.

SECTION III

OBSERVATIONS AND EXPERIMENTS

9. SEED WEIGHT, PRODUCTION, AND TIME OF SHEDDING

9.1 SEED WEIGHT

Seeds of L. scoparium are very small and light. The individual weight of 14,000 selected viable seeds (2.0 x 0.3 mm. in plan view with triangular to rectangular cross section) was 0.005 mg. This is about one-tenth of the seed weight given by Silvester.

Salisbury (1942) classified plants with seeds of this weight as pioneers of open habitats, the small seed being an important advantage in dispersal to new habitats, while the low food reserve is of little significance because of the lack of competition in such habitats. However, Grime and Jeffrey (1965) demonstrated that seedlings of many small seeded species were unable to grow out of a layer of shade no deeper than that found in herbaceous communities. Harper and Benton (1966) suggested that small seeds might be an advantage to pioneers of open habitats because they have a larger soil contact/surface area ratio than large seeds and so are less liable to desiccation.

9.2 SEED PRODUCTION

The main flowering season in the Tiritea stand was from November to January but flowering and seed setting occurred at a low rate throughout the year. This corresponded closely to observations by Burrell in Otago but she claimed that winter flowers were male only.

The number of seeds per capsule, 240 - 470 with the average around 300, was similar to that determined by other workers (Section 3.4).

9.3 THE EFFECT OF SEASON ON SEED SHED

To determine the seasonal variation in seed fall seed traps were set up in the L. scoparium stand.

9.3.1 METHOD

Six tins 15 cm. diameter x 20 cm. deep were placed above ground, to avoid interference from stock, throughout the stand (Fig. 4). Locations are shown in Fig. 1. A 30 cm. diameter filter paper held in place by a spring steel wire hoop, covered the perforated bottom of each tin. The filters were collected monthly, dried, and the number of L. scoparium seeds counted.

9.3.2 RESULTS

The results (Table 2 and Fig. 9) show that seed was shed throughout the year with a minor peak in autumn and a major peak in spring. (Original data, analysis of variance: Appendices 1.1, 1.2).

9.4 DISCUSSION

The difference in numbers of seed shed in the corresponding month at the beginning and the end of the experiment was probably due to a difference in environmental conditions affecting the rate of shed, or to a greater number of seed bearing capsules being formed in the season covered by the experiment than in the previous season.

As suggested by Levy and Silvester the production of large numbers of small, extremely light and readily dispersed seed, explains in part the high invasion potential of L. scoparium. This is reinforced by the major seed fall occurring in the periods of the year most favourable for germination. The shedding of some seed throughout

TABLE 2

THE EFFECT OF SEASON ON SEED SHED

Mean number of seeds per tin

Collection Date	Transformed Mean	True Mean
23/12	5.64	49
26/1	10.32	162
22/2	7.24	70
22/3	9.23	127
27/4	17.63	388
24/5	15.24	305
21/6	14.39	268
19/7	12.89	209
16/8	25.58	722
13/9	26.24	780
13/10	28.59	972
8/11	19.52	437
8/12	14.78	253
S.E. ±	1.53	
d.05(.01)	4.32(5.74)	

Note: Data transformed to $\sqrt{x}$

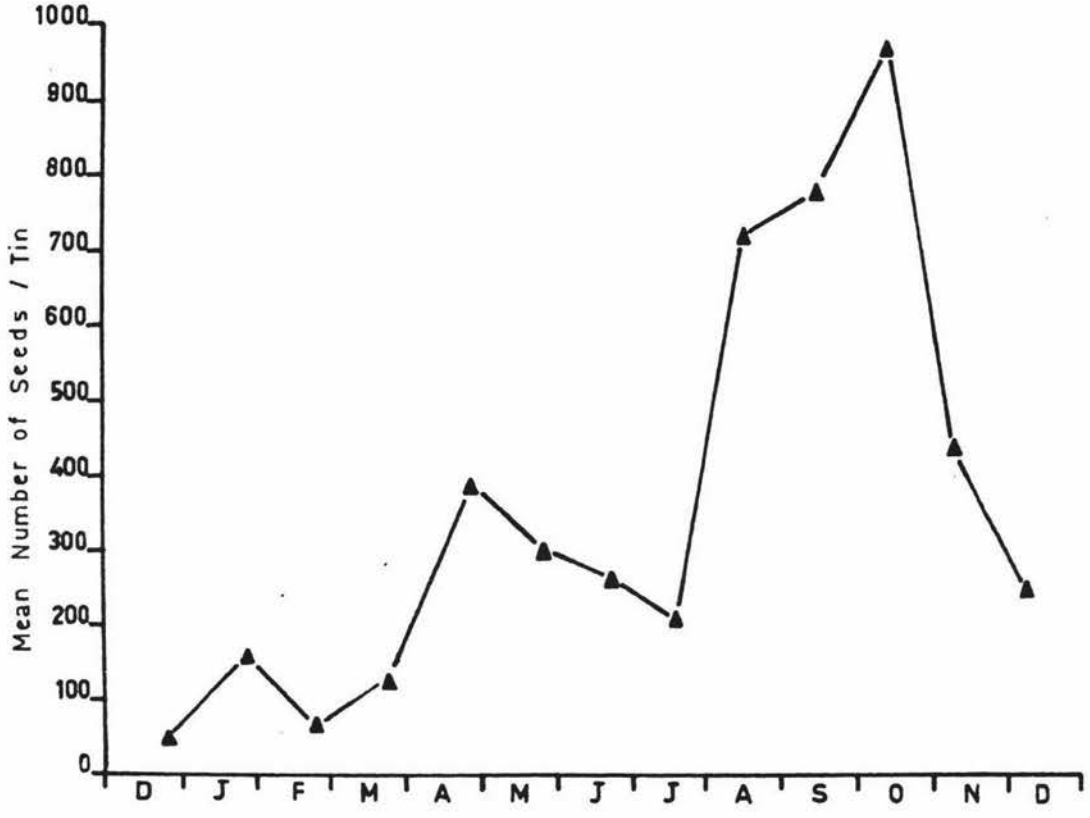


FIGURE 9: THE EFFECT OF SEASON ON SEED SHED

the remainder of the year enables germination with the occurrence of isolated opportunities.

10. GERMINATION

10.1 TETRAZOLIUM EMBRYO VIABILITY TEST

A Tetrazolium embryo viability test was carried out to provide information on basic seed viability for subsequent tests of factors affecting germination. Tetrazolium (2, 3, 5 triphenyl tetrazolium chloride), as a 1 - 2% aqueous solution soaked into seeds, is reduced by dehydrogenases present in the viable embryo resulting in a red colouration, due to the presence of formazin. A detailed account of the test is given by Smith (1952).

10.1.1 METHOD

Four samples each of 100 fresh unsorted seeds were tested by Seed Testing Station personnel for viability by the Tetrazolium method. Another four samples each of 400 seeds were germinated on moist blotter in an illuminated 100% humidity germination cabinet at 65°F. Counts were made as soon as the first cotyledons appeared (on the fourth day after setting out). At this stage all seeds showing signs of germination were counted. This process was repeated at weekly intervals but no further seeds germinated after the first count.

10.1.2 RESULTS

As indicated in Table 3 basic seed viability is low. There was no significant difference between the results of the Tetrazolium and the germination tests.

TABLE 3

COMPARISON BETWEEN TETRAZOLIUM AND GERMINATION TESTS

% germination per sample (a,b,c,d) per treatment

	Tetrazolium	Germination
a	10	17.5
b	23	17.5
c	15	22.5
d	27	18.7
Mean	18.75	19.05
S.E. %	1.95	0.98

Note: Data analysed on a binomial % basis.

10.1.3 DISCUSSION

These results verify the low germination % found by other workers (Section 3.4) and emphasize the importance of a large seed production. The apparent lack of dormancy (except in darkness) and rapid germination must partly offset the disadvantages of small seeds and seedlings in interspecific competition. However, rapid germination of all seed can be a disadvantage in itself as unfavourable conditions may destroy all the seedlings. Year round seed dispersal counteracts this effect.

10.2 THE EFFECT OF LIGHT

In a preliminary test unsorted seeds were kept on moistened blotter in a dark germinator except for exposure to about 100 foot candles of fluorescent light for periods varying from 5 to 40 minutes every day. There was no significant difference in % germination. To determine the effects of darkness and shorter exposure periods a

further experiment was carried out.

10.2.1 METHOD

Groups of unsorted seeds were exposed to about 100 foot candles of fluorescent light for periods of 1, 2, 3 and 5 minutes per day with one group of seeds kept as a control in complete darkness in a germinator at 20°C (68°F). Each group consisted of two lots of 400 unsorted seeds set out on moist blotter. Groups under the light treatments were covered with moist blotter topped by towelling and kept in the dark germinator with the control when not exposed. Counts were carried out as in the experiment described in Section 10.1.1.

10.2.2 RESULTS

As shown in Table 4, although germination was not completely inhibited by darkness, it was greatly reduced. Apart from a delay in germination at exposure levels of less than five minutes final germination % did not differ significantly between any of the treatments exposed to light. (Original data: Appendix 2).

10.2.3 DISCUSSION

These results support those of Silvester and the emphasis which he and Levy placed on light at ground level as a vital factor in the ingress of L. scoparium into pasture. It can only be presumed that in the experiment conducted by Burrell some small amount of light must have reached the seeds. Silvester suggested that photosynthesis had to occur before germination could proceed. However, the complexity of dormancy mechanisms in which light is the

trigger has been discussed in reviews by Mayer and Poljakoff-Mayber (1963), Leopold (1964) and others. Investigation of the basis of the light response in L. scoparium seeds was beyond the scope of this study.

10.3 THE EFFECT OF TEMPERATURE

The following experiment was carried out to determine the influence of temperature on germination.

10.3.1 METHOD

Groups of unsorted seeds were exposed to temperatures of 40, 60, 65 and 90°F inside illuminated germination cabinets. Each group consisted of two lots of 400 unsorted seeds set on moistened blotting paper. Counts were made as in the experiment described in Section 10.1.1.

10.3.2 RESULTS

From Table 5 it is apparent that temperature has a significant effect on final germination % and rate of germination below 65°F. However, although the time required for germination increased from 16 days at 60°F to 43 days at 40°F, the drop in germination % between 60°F and 40°F was negligible. (Original data: Appendix 3).

10.3.3 DISCUSSION

These results differ somewhat from those of Silvester who found that there was a decrease in rate of germination but not in final germination % with decrease in temperature. Perhaps the sudden drop in % germination at 60°F was due to a proportion of seeds reaching a mortality threshold but it could be expected that death due to decreasing temperature would increase progressively.

TABLE 4

THE EFFECT OF LIGHT ON GERMINATION

Mean germination % / treatment

Time after setting out		Exposure Time (min.)				
		0	1	2	3	5
9 days	Mean %	-	15.35	14.37	16.25	18.50
	± S.E. %	-	1.27	1.24	1.30	1.37
16 days	Mean %	0.62	19.75	16.00	17.37	18.50
	± S.E. %	0.88	1.41	1.29	1.34	1.37

TABLE 5

THE EFFECT OF TEMPERATURE ON GERMINATION

Mean germination % / treatment

Time after setting out		Temperature (°F)			
		40	60	65	90
9 days	Mean %	0	0	19.37	19.00
16 days	Mean %	0	14.62	19.37	19.00
43 days	Mean %	13.62	14.62	19.37	19.00
	± S.E.	1.21	1.25	1.39	1.38

Note: Data analysed on a binomial % basis.

Obviously temperature effects need to be studied at more levels over a greater range to give a clearer picture. As genotype and seed age influence the temperature response of germination (Crocker and Barton, 1953) these should also be taken into account.

From these results there is no apparent reason, with other conditions favourable, why germination cannot occur throughout the year in the field.

10.4 THE EFFECT OF SEED AGE

To examine the effect of this factor on seed germination the experiment described below was carried out.

10.4.1 METHOD

Unsorted seed was stored in a screwtop jar under normal room conditions. At monthly intervals four samples each of 200 seeds were placed on moist filter paper in Petri dishes and left to germinate. At some stages of the experiment a 65°F germination cabinet was not available. Under these circumstances the Petri dishes were placed on a bench above a water heated wall radiator, care being taken to ensure that desiccation did not occur. This change in experimental conditions may have influenced the results.

Counts of seedlings were made as in the experiment described in Section 10.1.1.

10.4.2 RESULTS

Over the 18-month period of this experiment no significant reduction in germination % occurred. Considerable variation is evident in the results (Table 6), both between months and between

TABLE 6

THE EFFECT OF SEED AGE ON GERMINATION

Mean germination %

	Transformed Means	True Means
16/10	24.52	17.25
17/11	23.72	16.25
18/12	26.65	20.12
18/1	26.45	19.87
18/2	25.90	19.12
24/3	25.35	18.37
21/4	23.08	15.50
20/5	25.11	18.12
18/6	25.73	18.87
19/7	26.52	20.00
18/8	24.20	16.87
18/9	26.15	19.50
18/11	27.60	21.50
17/1	25.28	18.25
14/2	26.23	19.62
14/3	26.45	18.87
11/4	26.16	19.50
18/5	23.52	16.00
S.E. ±	0.99	
d.05(.01)	2.82(3.78)	

Note: Data transformed to arc sine $\sqrt{\%}$

samples within months, possibly due to the change in experimental conditions mentioned above although this would not explain within month variation. (Original data, analysis of variance: Appendices 4.1, 4.2).

10.4.3 DISCUSSION

These results do indicate that although the seeds are small with a thin seed coat, they possess a degree of hardiness. Cocker and Barton (1953) emphasized the influence of storage conditions on seed longevity and it is probable that differences in storage conditions accounted for the difference in the above results and those obtained by Silvester.

10.5 THE EFFECT OF EXPOSURE

To determine the effect of exposure on germination the following experiment was conducted.

10.5.1 METHOD

Fine mesh nylon bags each containing 50 viable seeds were fixed to a bare soil surface, others being buried 1 - 2 in. in the soil, early in March. In each treatment there were six bags arranged in a randomized block design, replicated three times. Every two weeks three bags were removed from each treatment and the seeds tested for viability by germinating on blotting paper in Petri dishes as previously described. Germinations were recorded as normal, abnormal, or as having occurred while the seeds were exposed.

10.5.2 RESULTS

Seed on the soil surface had a relatively short life,

TABLE 7

THE EFFECT OF EXPOSURE ON AND BELOW THE GROUND SURFACE ON GERMINATION

Mean germination % / treatment.

		Time of Exposure					
		2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks
Seeds on surface	Mean % ± S.E.%	50.66(8.66) 4.08(2.29)	14.00(4.00) 2.83(1.60)	2.00 (0) 1.14	2.00 (0) 1.14	0 (0)	0 (0)
Seeds below surface	Mean % ± S.E.%	87.34 2.71	74.66 3.55	77.34 3.42	78.66(3.34) 3.35(1.46)	74.66(4.00) 3.55(1.60)	72.00(3.34) 3.66(1.46)

Note: Figures in brackets in the surface section represent % abnormal germinations with their associated % S.E.; those in the sub surface section, % seeds germinated underground and their % S.E.

Data analysed on a binomial % basis.

viability being low after four weeks (14%) and zero after eight weeks. After the first two weeks of exposure embryo damage resulted in abnormal germinations. The viability of seed buried in the soil suffered an initial drop (to 87%) but did not decrease significantly after this point (Table 7). (Original data: Appendix 5).

10.5.3 DISCUSSION

The nylon mesh bags, not being air-tight or waterproof were presumed not to have a great effect on the conditions to which the seed would have been subject if lying directly on or in the soil. In fact, the seeds on the surface were probably subject to much greater desiccation than if unenclosed because of the difficulty in keeping the bags tight against the soil. A small proportion of seed sown directly onto the soil surface in December 1965 survived 14 weeks in the experiment described in Section 11. Macro-fauna would not have the same opportunity for destroying seed enclosed in a bag. However, it was impractical to place seed directly on or in the soil because the minute size would make recovery for viability determination extremely difficult.

The germination of a small proportion of seeds while buried in the darkness of the soil supports the results of the experiment described in Section 10.2. It is doubtful if a buried seed not protected from micro- and macro-organisms by a substantial seed coat would last for any period longer than six months to a year. Also under field conditions the opportunities for burial and subsequent uncovery within the life of the seed would not be great. However, this ability to survive for a time under conditions that, except for

the absence of light, must be favourable to germination, could be of considerable significance to establishment within pasture where periodic defoliation may allow light penetration to ground level.

The demonstration of a negligible effective carry-over of dormant seed on or in the soil from one season to the next emphasizes the importance of year round seed shed.

Environmental conditions at the time of the experiment would have considerable influence on the results. The relative differences in survival between seed on the soil surface and buried in the soil would be likely to remain however.

11. THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL ON BARE GROUND

An experiment was laid down to determine the effect of season on germination and seedling survival on bare ground.

11.1 METHOD

Twelve plots 61 x 61 cm. were laid down in a randomized block design, replicated three times.

Each month 81 selected viable seeds were sown singly at 6.16 cm. square spacings in each appropriate plot.

Plots were hoed, raked and firmed prior to sowing. Spacings were determined by a hardboard template (similar to that in Fig. 19), the seed being placed on top of the soil in a small depression made with the end of a pencil. This hollow was intended to prevent the seed being blown away.

The sown plots were examined every fortnight and the number of seedlings recorded.

TABLE 8

THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL ON BARE GROUND.

Mean final seedling number per treatment

Sowing Date	Transformed Means	True Means
12/4	3.18	9.67
10/5	2.23	5.00
7/6	4.84	23.67
5/7	3.71	13.33
2/8	3.57	12.33
30/8	3.64	13.00
27/9	2.61	6.67
25/10	-	0
22/11	-	0.33
20/12	-	0.67
31/1	1.03	1.33
7/3	2.22	4.67
S.E. ±	0.41	
d.05(.01)	1.23(1.69)	

Note: Results from seed sown on 25/10, 22/11, 20/12 excluded from analysis.

Data transformed to $\sqrt{x + \frac{1}{2}}$

FIGURE 10

THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL ON BARE GROUND.

Each curve shows the changes in seedling numbers from 243 viable seed sown (81 on each of three plots) in any one month. The number at the foot of each curve indicates week of sowing. Discrepancy between this number and the horizontal week and date scale was caused by time required for germination and seedling appearance.

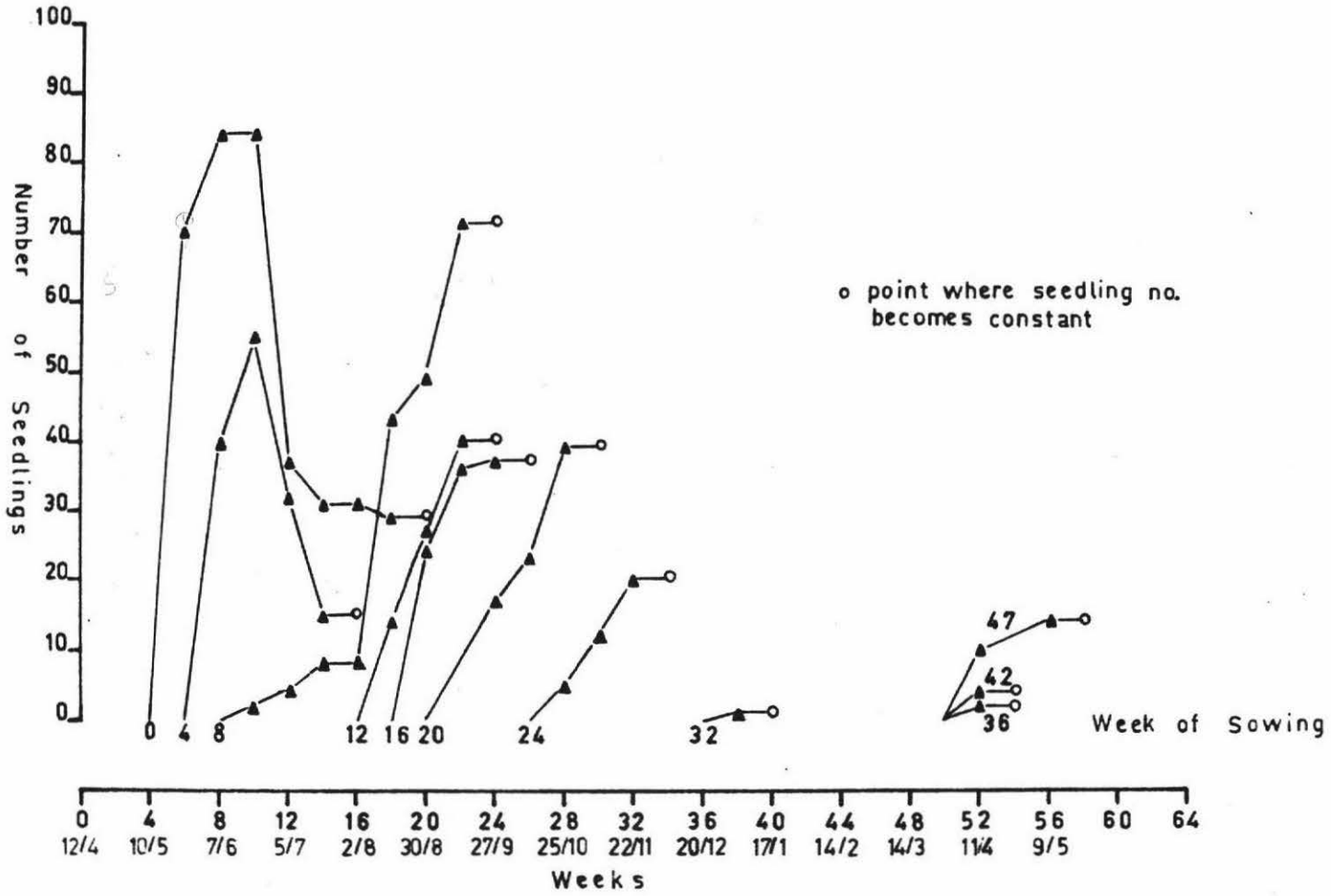

Number of Seedlings
100
90
80
70
60
50
40
30
20
10
0
o point where seedling no. becomes constant
0
4
8
12
16
20
24
32
47
42
36
Week of Sowing
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
12/4 10/5 7/6 5/7 2/8 30/8 27/9 25/10 22/11 20/12 17/1 14/2 14/3 1/4 9/5
Weeks

FIGURE 10

11.2 RESULTS

Seed germination and seedling survival on bare ground is subject to considerable seasonal influence (Table 8 and Figure 10). In the year under study germination was most rapid and complete in autumn and early spring. Germination was delayed in winter (June and July) and delayed and often zero or very low over the late spring and summer (October, November, December, January and February). Following frequent rain in April germination occurred on three sets of plots, one set of which had been sown 14 weeks earlier. Although the greatest number of germinations for any one time of sowing occurred in the autumn sowing, the number of seedlings surviving from this sowing was lower than in the winter or early spring months due to the effect of frost lift. Seedling survival was greatest from seed sown in early June. Few or no seedlings established from seed sown in October, November or December. (Original data, analysis of variance: Appendices 6.1, 6.2).

11.3 DISCUSSION

The ability to germinate and survive on bare ground from seed sown in eleven months of the year indicates great physiological plasticity. This could explain why the species can grow in so many diverse environments and has such a high invasion potential. Although the number of seeds germinating and surviving in any one month must be greatly influenced by the environment at the time of sowing and shortly after, there seems to be a definite trend in Fig. 10 which suggests overall seasonal influences rather than day to day variations in environment may have played the more important part in controlling numbers. It is presumed that the major factor influencing germination

and seedling survival on bare ground was frost in winter and desiccation in summer. However, Harper (1956) demonstrated that under low temperatures many germinating seeds have increased susceptibility to pathogen attack. Also at low temperatures increasing soil moisture content increased the susceptibility of germinating seeds to pathogen attack. (Harper, Landragin and Ludwig, 1955).

Differences in plot microtopography between months could have influenced germination. Harper, Williams and Sagar (1965) found the optimum germination of Chenopodium album (fathen) and Brassica oleracea acephala (green marrow-stemmed kale) occurred under different surface conditions, coinciding in each case with maximum water absorption by the seeds. They concluded that the type of contact between seed and soil determined the rate of uptake of water necessary for germination. Consequently the type of contact could be critical in determining whether or not a seed germinates and this contact may be affected by the interaction of size and shape of the seed with topographical variations.

Climatic variations from district to district could be expected to have a major effect. Where summer rainfall is higher there may be a high level of germination and establishment over this period.

Also the topographic variations of hill country under similar climatic conditions may have provided many sheltered moist situations more suited to germination and survival of seedlings on bare ground.

12. THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL IN PASTURE

To determine the seasonal pattern of germination and seedling survival under pasture the following observations were made.

12.1 METHOD

Three quadrats 1 x $\frac{1}{2}$ m. within two meters of the Tiritea *L. scoparium* stand were permanently pegged. These areas were selected because of the large numbers of *L. scoparium* seedlings present. Location of the chart quadrat sites is given in Fig. 1.

At monthly intervals from late summer 1965 to autumn 1966 a quadrat frame divided into one decimeter squares (Fig. 16) was placed over each area and seedling locations with associated vegetation, charted on graph paper (based on the technique given in Weaver and Clements, 1938). The areas covered per quadrat were:

quadrat	A	30 sq. dm.
"	B	15 sq. dm.
"	C	25 sq. dm.

Surface unevenness, causing parallax errors, prevented the whole of each quadrat from being recorded. Charts from each quadrat were later compared to provide information on numbers of new seedlings and their associated vegetation,and seedling mortality. However, confusion resulted from the difficulty of recording seedlings in identical positions from month to month. This was overcome by drawing the charts on transparent PVA sheeting, overlaying successive months charts to ensure seedlings were noted down in the same position.

Once new seedlings ceased to appear the chart method was abandoned and replaced by a simple count, note being made of whether the

seedlings were this season's, or older.

To estimate if the numbers of seedlings recorded on the three quadrats were typical of a greater area a transect (not shown in Fig. 1) was run across the open ridge down the middle of the paddock.

On the initial quadrat charts (charted on 22/3/65, see Figs. 6, 7, 8) all vegetation was recorded, providing an indication of the structure and composition of the pasture communities involved.

12.2 RESULTS

Because of the major differences in aspect and pasture type, and areas recorded in the three quadrats data was generally impossible to analyse statistically. Changes in total seedling numbers, trends in seedling ingress and mortality, and association between seedling appearance and some habitat features are presented in Figs. 11, 12, 13.

It is apparent that there is a definite seasonal influence on germination and seedling survival. However, much of the variation in seedling appearance would be caused by seasonal variation in seed fall. Seedlings appeared in the pasture from late autumn through to December with a very pronounced peak on all quadrats (Fig. 12b) in October and November, at the same time, or slightly later than the peak in seed fall. At this time current seasons numbers were at a maximum. Fig. 14 indicates seedling size at this stage, and relationship to pasture components. From early December pasture growth exceeded the demands of set-stocked ewes and lambs and by January grass height (extended foliage height) had increased from the winter - early spring level of

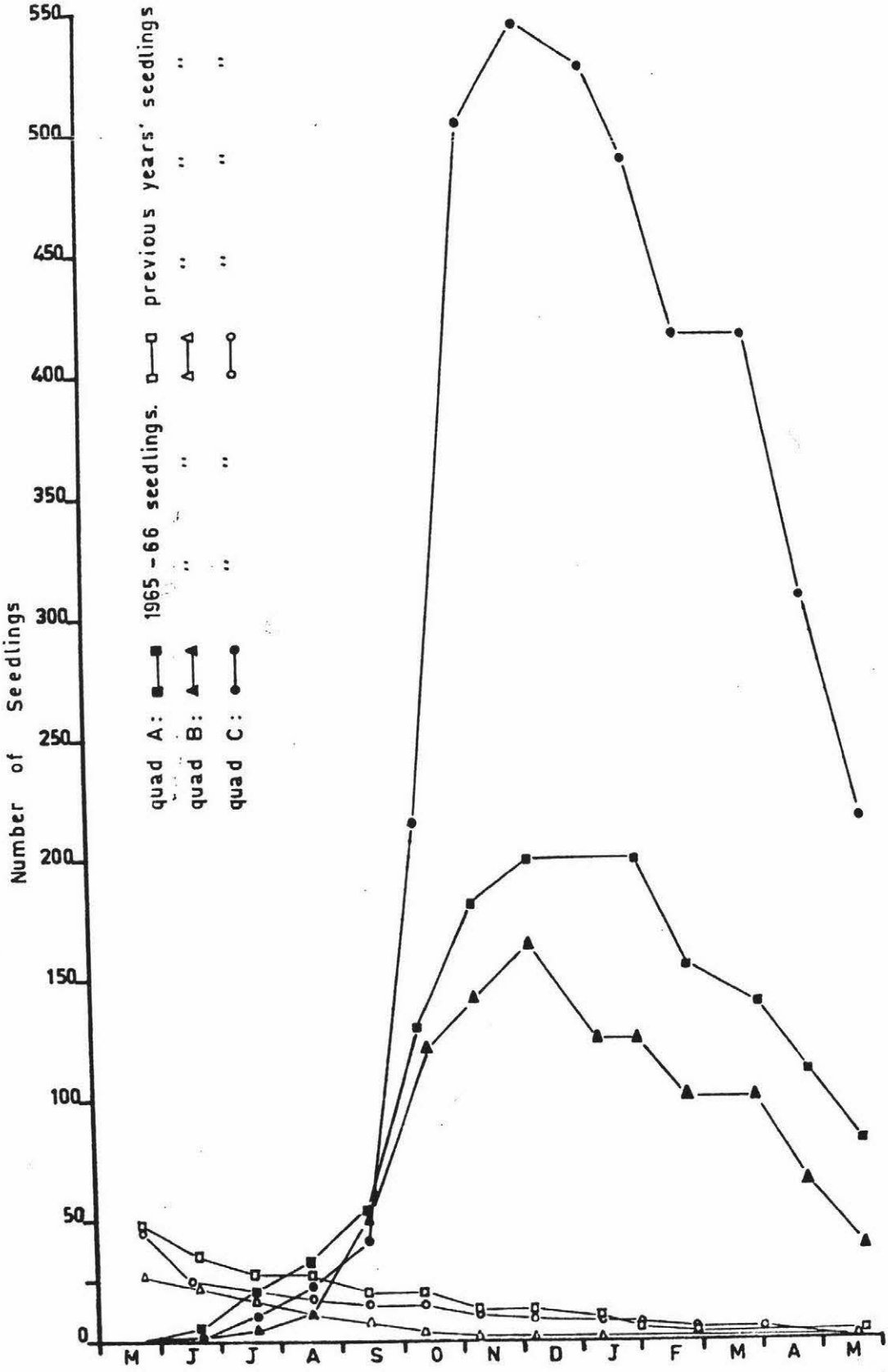


FIGURE 11: CHANGES IN TOTAL SEEDLING NUMBERS IN PASTURE WITH SEASON

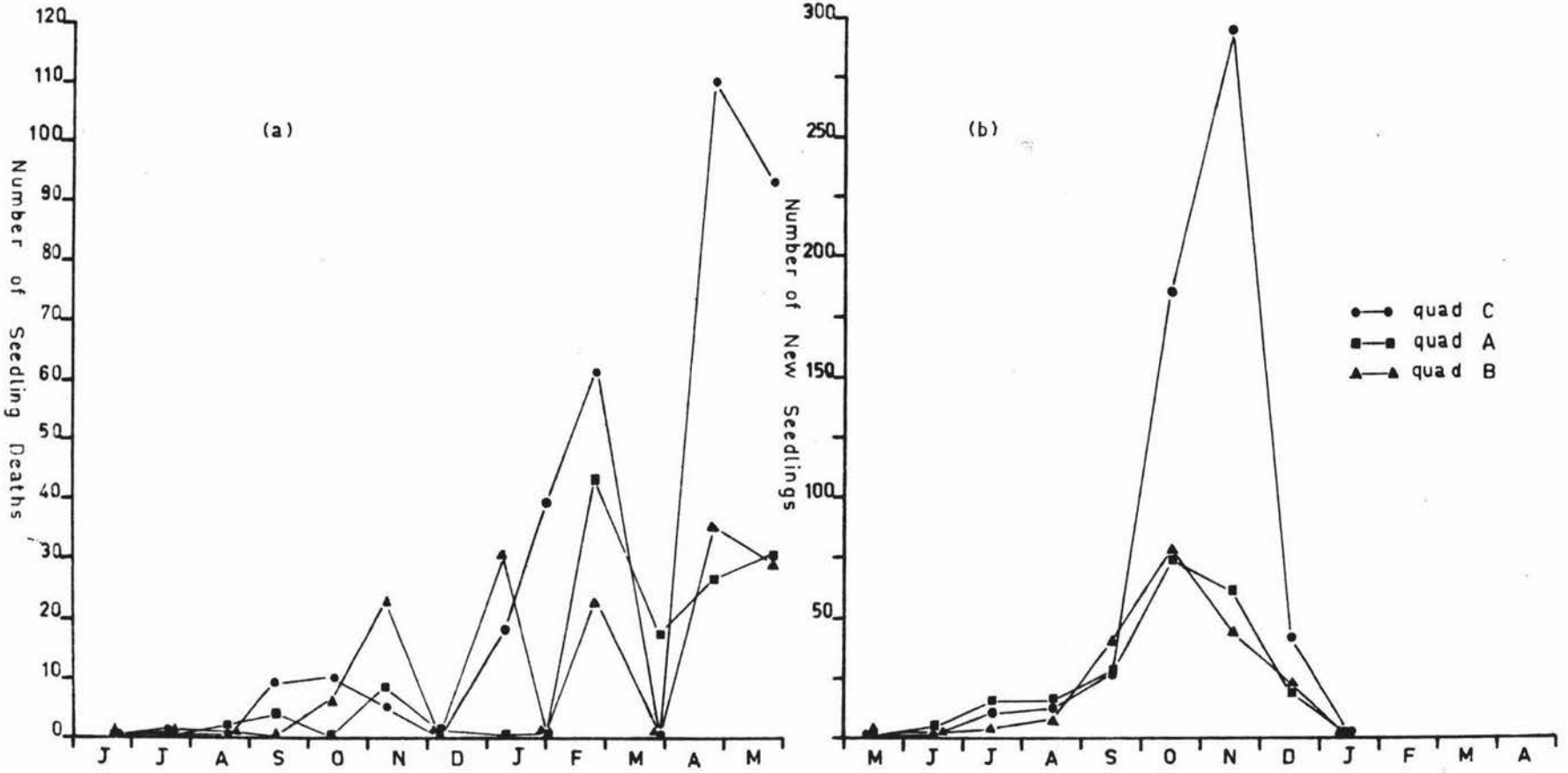


FIGURE 12: THE EFFECT OF SEASON (a) ON SEEDLING MORTALITY IN PASTURE
(b) ON SEEDLING APPEARANCE IN PASTURE

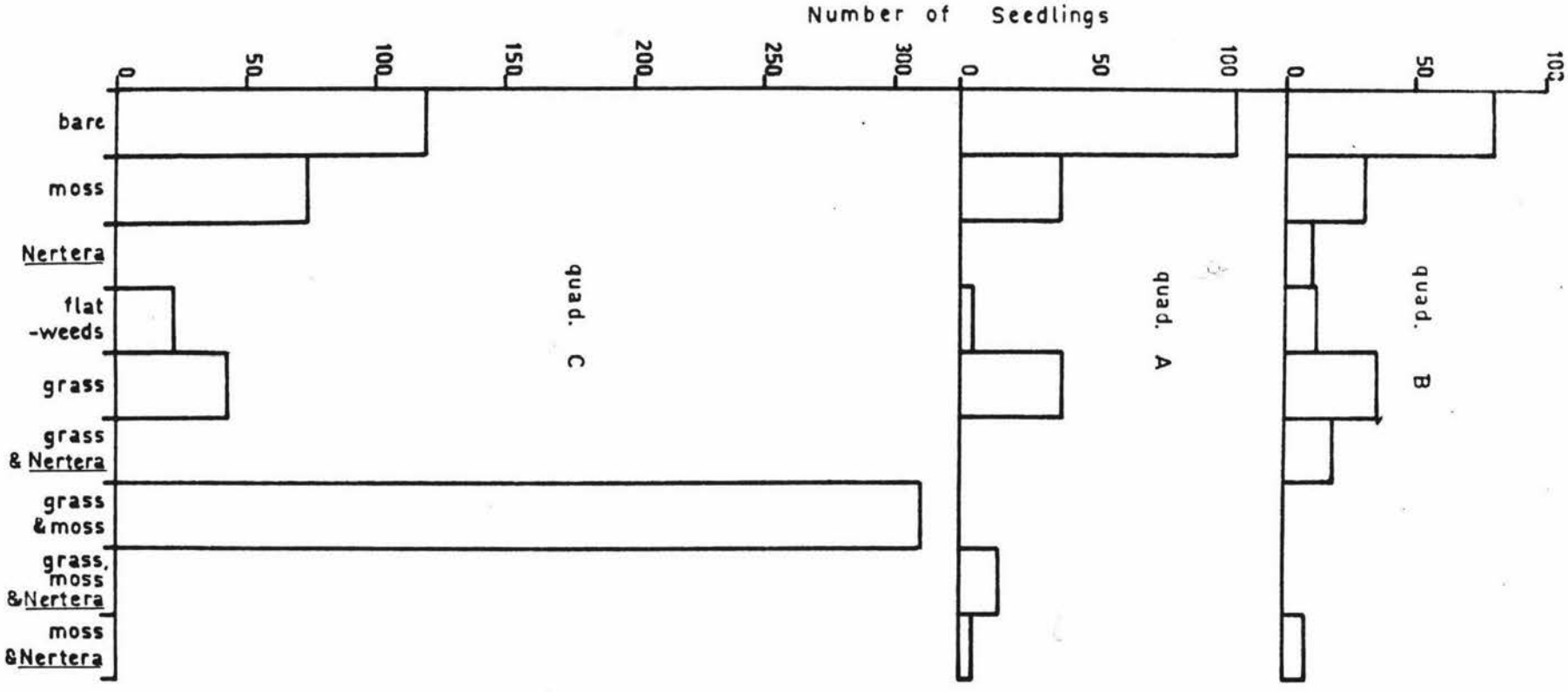


FIGURE 13: THE EFFECT OF SOME HABITAT FEATURES ON GERMINATION AND SEEDLING SURVIVAL IN PASTURE

1.5 - 2.5 cm. up to a maximum of 10 cm. depending on site and grazing pattern. During late January or early February all stock were removed from the paddock for two months and grass growth continued unchecked. Etiolation occurred in many L. scoparium seedlings from early December. It is also apparent from Fig. 11 that seedling numbers began to decline rapidly on two of the three quadrats from this time. Quadrat A was on steeper ground with a more scattered cover than the other two (Figs, 6, 7, 8) so presumably factors affecting mortality did not come into force until later.

Following the initial rapid fall the decline of seedling numbers appeared to ease over late February - early March (Fig. 12a) even though pasture at this stage had an extended height of 15 cm. in some places. L. scoparium seedlings surviving to this stage were often 5 cm. high with 16 leaves (Fig. 15). Others were only 1.5 cm. high and very suppressed, or etiolated with relatively few leaves. Previous seasons seedlings were 15 - 30 cm. high (Fig. 16). Mob stocked ewes began grazing the paddock during April and the sharp increase in mortality rate at this time (Figs. 11, 12a) was due to the effect of stock grazing. On quadrat C especially dead seedlings were found lying on the ground after having been pulled free of the soil. Others were nipped back, some to below the lowest leaves. During 1965 observations were carried out through the winter and it was obvious that even greater damage was done to seedlings when cattle were introduced in June. The effect of heavy grazing was twofold however. Although seedling mortality was high as a result, the stock greatly reduced the pasture cover exposing much moss, Nertera and bare ground. The hoof action of cattle was particularly effective in baring the soil.

FIGURE 14: L. SCOPARIUM SEEDLINGS IN PASTURE, NOVEMBER 1965, QUAD. C

The seedlings are shown ringed in white. The habitat in which they appear corresponds to the grass and moss category in Figure 13 or the intimate species mixture mapped in Figure 8.

FIGURE 15: L. SCOPARIUM SEEDLINGS IN PASTURE, MARCH 1966, QUAD. C

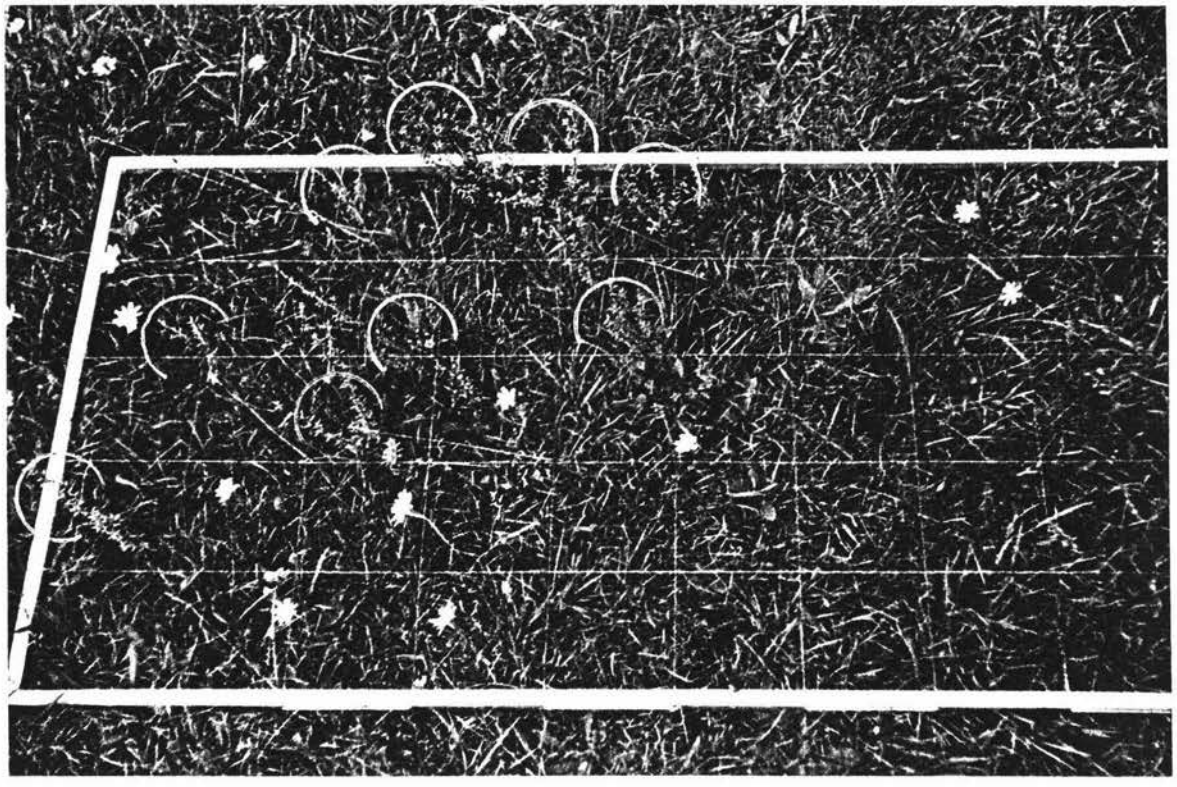


FIGURE 16: QUADRAT FRAME, 1 x $\frac{1}{2}$ METER, ON QUAD. C, FEBRUARY 1965
Previous season's seedlings (15 - 20 cm. high) showing.

This bare state persisted until October by which time seed shed was at a maximum and germination and seedling growth could occur with little competition from pasture plants.

The number of seedlings surviving one season was small and almost none survived two seasons. However, the survival of one seedling per quadrat over the whole area would be sufficient to form a dense stand.

An indication of the nature of the pasture on each quadrat can be gained from Figs. 6, 7, 8. It is obvious that major differences exist in structure and composition but that all represent poor hill pastures of various types.

Fig. 13 shows that there is no consistent pattern for the three quadrats in the association between seedling appearance and habitat features. To determine whether the associations shown represent a departure from random, the area covered by the repective habitat features in each quadrat would have to be determined. The charts presented in Figs. 6, 7, 8 were drawn on 22/3/65 and species cover would have altered considerably, due to grazing and trampling, by the time of seedling appearance. Analysis of these charts would therefore provide little information.

The results of the transect across the bare ridge indicated that only in gaps in the stand edge and within a meter or two of the edge did seedlings appear to be as numerous as in the quadrats. Beyond 12 m. from either side of the ridge it was impossible to find one seedling within a 1 x $\frac{1}{2}$ m. quadrat. The age of the marginal L. scoparium plants in the stand is 5 - 8 years (Fig. 2). Thus, even although

there is a large seedling ingress into the surrounding pasture each year the stand has ceased to enlarge. Presumably this is due to the present management policy as outlined previously although there may be some unobserved limiting environmental factor.

Major sources of error in the chart quadrat method were double recording of seedlings along decimeter boundaries due to parallax caused by the quadrat frame not sitting hard down on the uneven surface, the physical discomfort and tedium involved in the method, and the difficulty of relocating many seedlings due to their small size. (Original data: Appendices 7, 8, 9, 10).

12.3 DISCUSSION

It is apparent that although seedlings appear over seven months of the year, the majority appear in the spring, when seed fall is highest. The results of the transect also suggest that seedling ingress occurs in great numbers only where much seed falls i.e. around the margin of the stand. This fact emphasizes the importance of removing all L. scoparium when clearing reverted land, and in clearing from the windward side so that marginal infection from adjacent stands is also at a minimum.

Possibly the most important observation is that even under poor hill country pasture conditions suitable stock and pasture management can prevent the establishment of a large number of seedlings which appear in the pasture each year. Removal of all stock from a paddock for a period sufficient to allow a greater cover of herbage than normal to develop, followed by heavy mob stocking appear to be effective in control. Because most seedlings appear in spring a similar policy

in late spring may prevent seedling ingress altogether. Equally important is the demonstration that heavy grazing may result in large amounts of bare ground, favourable for seedling establishment.

13. THE EFFECT OF COVER, APPLIED FERTILIZER, AND CUTTING FREQUENCY ON GERMINATION AND SEEDLING SURVIVAL IN GRASSED AND BARE PLOTS

These factors were examined under semi-controlled conditions to obtain information on their influence on germination and seedling survival.

13.1 METHOD

A plot experiment arranged in a factorial design replicated four times contained the following treatments:

presence or absence of Browntop

3 rates of applied fertilizer (none)
(low)
(high)

3 cutting frequencies (no cutting)
(fortnightly cutting)
(monthly cutting)

Black (1958) has discussed the use of boxes to obtain a high degree of control without loss of application to field conditions. In this case the extra cost and effort required to set up a full scale box experiment necessitated a compromise using wooden frames set on the ground and filled with soil. This enabled the experiment to be conducted on a flat relatively homogeneous area with a monospecific sward and known fertility differences, thus simplifying and reducing the number of variables and interactions.

13.1.1 PLOT CONSTRUCTION AND SWARD ESTABLISHMENT

The experiment was laid out using 61 x 61 cm. plots delimited by wooden frames 10 cm. deep set 15 cm. apart on the plot sub soil. To ensure a sufficiently low level of fertility on the appropriate plots, all the frames were filled with a soil similar to Raumai sandy loam hill soil (see Table 1 for chemical analyses) which had been mixed and sieved through a 1.3 cm. mesh prior to being placed in the frames. Care was taken to compact all plots to the same degree so that effects on root penetration and soil water relations would be similar. Pure Browntop seed of 90% viability was sown on the grass treatment plots during the summer of 1964-65 at the rate of 1.62 gm./plot. Irrigation using a soak hose spray system was carried out when necessary.

Black (1961) demonstrated that a 2 in (5.1 cm.) border where no edge restrictions on roots or shoots were applied, was sufficient to give homogeneity of Trifolium subterraneum plants. Although a 3 in. (7.6 cm.) border around the inside of each frame had been allowed for, with the growth of the grass it was obvious that there was considerable edge effect, although not often extending further than 3 in. (7.6 cm.) into the plots. To reduce edge effect soil between the frames was excavated to 8 in. (20.3 cm.) and replaced with sawdust topped with shingle. No shades to prevent lateral illumination were erected.

The presence of a fungus disease, tentatively identified in the field as Rhizoctonia brownspot by Dr. Latch of D.S.I.R., on the Browntop necessitated spraying with Thiram at a rate equivalent to $1\frac{1}{2}$ - 2 lb/100 gal. water at ten days intervals during danger periods. These coincided with warm moist autumn and spring conditions. Unfort-

unately, control was difficult and considerable damage was done to some plots, resulting in an uneven tiller distribution and unthrifty growth.

D.D.T. was also sprayed on the plots ($\frac{1}{2}$ - 1 lb/100 gal. water) in the autumn and spring to control macro-organisms which may have damaged the grass or the L. scoparium seedlings.

Applications of fertilizer to give the desired fertility levels were based on recommendations by Levy (1949) for bowling greens. Nitrate of soda, superphosphate, and potassium chloride combined to give an N:P:K ratio of 3:2:3 were applied as a split dressing in April and August at the rate of 65.0 gm. per plot for the high fertilizer application rate treatment and 32.5 gm. per plot for the low fertilizer application rate treatment.

Cutting with hand shears 1.5 - 2.5 cm. above ground was carried out from mid winter as dictated by treatment. Clippings were discarded.

Oven dry herbage weights, inside the 7.6 cm. buffer strip, were recorded from the time the L. scoparium seed was sown until the experiment finished.

The appearance of plots prior to the autumn sowing is shown in Fig. 17.

13.1.2 SOWING THE L. SCOPARIUM SEED

Field observations indicated greatest ingress of seedlings in spring and sowing was carried out accordingly. On each plot at the beginning of September 196 selected viable seeds were sown. Four seeds were sown at each of 49 points spaced 7.6 cm. apart leaving a

7.6 cm. buffer around the plot edge. Sowing was carried out using a small funnel and a sheet of hardboard with holes drilled at suitable intervals to mark the spacing (Fig. 19). On the grassed plots the grass under the holes was parted and the L. scoparium seed sown on the ground. On the bare plots the seed was sown at each point into a small depression made on the soil surface with a pencil. All bare plots were surface hoed, raked and firmed prior to sowing. Sowing points were marked by coloured headed pins in the cut grass plots, by lengths of fine wire in the uncut grass plots (Fig. 20), and not at all on the bare plots.

Sowing was followed by irrigation (as described in Section 13.1.1) whenever the bare plots appeared likely to dry out on the surface. Sufficient water was applied to keep the soil surface moist for 24 hours. The irrigation was designed to remove any differential water stress effects from the experiment as a whole and from between grassed and ungrassed plots.

Spraying the grassed plots with Thiram for control of Rhizoctonia brownspot resulted in the failure of this seed sowing. (Appendix 25). The plots were resown between 22/3/66 and 24/3/66. Treatment fertility differences were re-established by adding Nitrate of Soda at the rate of 9.2 and 4.65 gm. per plot to the high and low fertilizer application rate treatments respectively, at monthly intervals for three months prior to sowing. After the last application the plots were well watered before sowing to ensure that the fertilizer could have no direct effect on germination. Grass growth was also stimulated by irrigation. Thiram spraying was ceased one month before seed sowing.

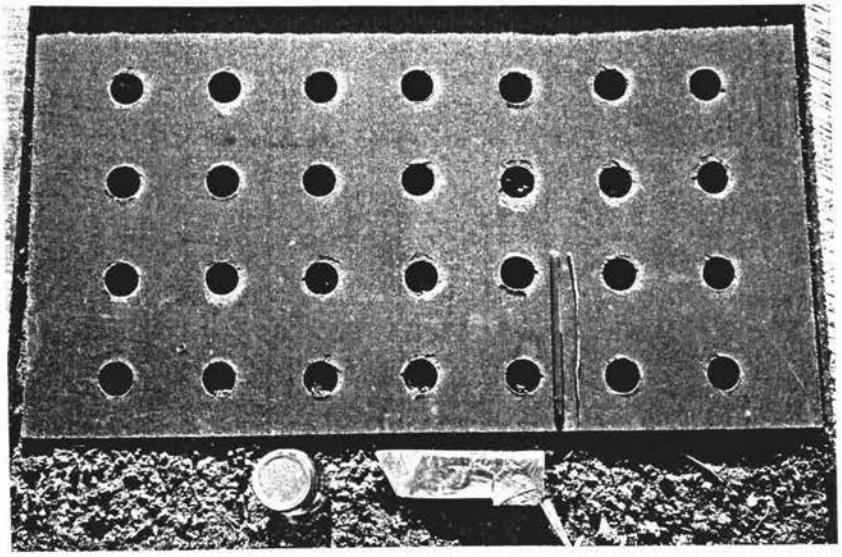


FIGURE 19: TEMPLATE AND FUNNEL FOR SEED SOWING

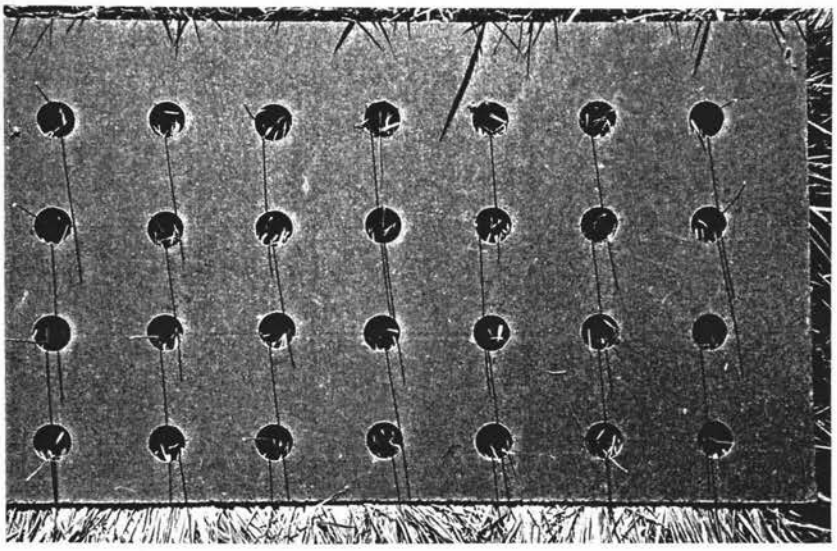


FIGURE 20: MARKING WIRES INSERTED IN UNCUT GRASS PLOTS

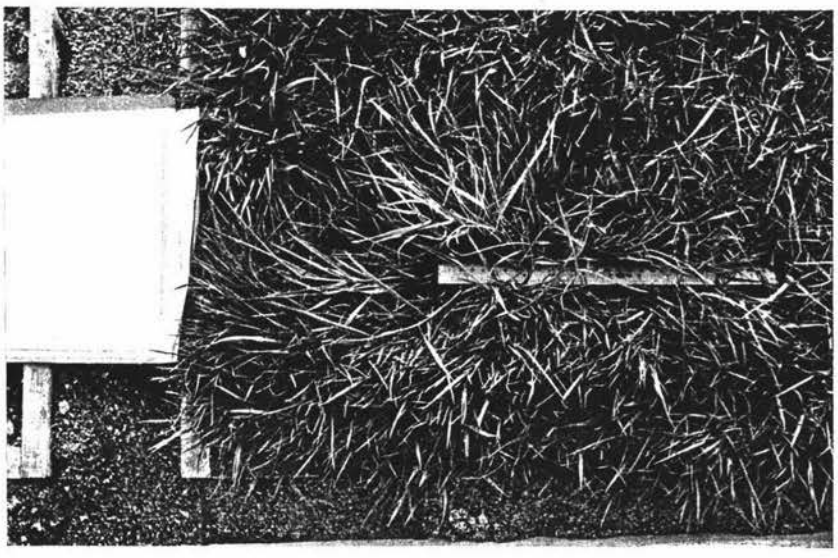


FIGURE 21: TRANSECT DELINIATION FOR GRASS PLOT PROFILE DIAGRAMS

Germination and seedling survival were recorded by seedling counts made every fortnight. The first full count was made on the 7/4/66 and the last count a month later on the 4/5/66. When making counts the outer row of seedlings in each plot was recorded separately in case edge effects were present. Counts give no indication of differences in growth or etiolation between seedlings in different treatments but growth was followed for too short a period to warrant measuring dry weights, stem length, and leaf numbers.

13.1.3 RELATIVE ILLUMINANCE

In this experiment

$$R.I. = \frac{\text{light value 0.63 cm. above ground under Browntop}}{\text{light value in the open}}$$

L. scoparium requires light for germination and a relatively high illuminance for seedling survival. In this experiment it was presumed that treatments would influence germination and seedling survival through soil surface shading.

To determine inter-treatment differences in relative illuminance near ground level a light meter causing minimum disturbance in short pasture and sensitive to radiation 400 - 700 mμ in wavelength was constructed (Appendix 26). Using this meter light values were recorded during the second week of March, just prior to the cutting of the fortnightly and monthly cut grass plots and before the autumn sowing of L. scoparium seed. Six readings 15 cm. apart were taken per plot on a systematic pattern in a manner such that personal bias was minimized. Another set of 20 readings per plot at 7.5 cm. spacings was taken at the end of the experiment during the second week of May, just prior to applying all cutting treatments. Readings on both days were taken in early afternoon under sunny conditions with some scattered

cloud. Light values in the open were checked after every two or three readings.

Relative illuminance differences between the grass plots must have been caused by differences in community structure resulting from the fertilizer and cutting treatments. Pasture features normally measured to provide information on structure involve destructive sampling. Incorporation of sufficient area to allow destructive sampling would have made the experiment impractical. To overcome the problem profile diagrams were drawn. Tiller numbers and Leaf Area Indices were determined for all plots at the end of the experiment.

13.1.4 PROFILE DIAGRAMS

For each grassed plot a drawing was made on graph paper of the side view of a 30 x 0.5 cm. band in the middle of the plot, at right angles to the edge. A 30 cm. ruler with pins 0.5 cm. long projecting from its edge at 2 cm. intervals was used to delimit the band at ground level (Fig. 21). All tillers and leaves coming from this band were drawn as accurately as possible. Leaf width half way from the tip was measured or estimated. Time involved varied from one-quarter hour for frequently cut plots to one-half hour for uncut plots. By counting the number of tillers recorded and by calculating the area of the leaves shown (length x width) estimates of tiller density and leaf area indic (L.A.I.) were derived.

Profile diagrams were drawn for each plot a fortnight before the autumn sowing of L. scoparium seed (3 - 5 days before all the plots in the cutting treatments were cut) and again at the end of the

experiment, nine days after the previous fortnightly cut.

13.1.5 PERCENTAGE BARE GROUND

Percentage bare ground in the cut grass treatments was determined at the end of the experiment by point analysis. On each plot 117 - 132 points were taken, first hit only being recorded. Cover points included hits on stem as well as leaf. Points were taken at 5 cm. spacings with the plot being resampled at right angles to give the desired number of points.

13.1.6 LEAF AREA INDEX

Leaf area was taken as the product of width half way from the tip, and length. Because of the regular taper of Browntop leaves this was considered to be sufficiently accurate. The plots were finally harvested during the period 18 - 25/5/66, one replicate at a time. Leaf area indices were determined only for plots in reps. C and D. From a sub-sample divided into leaf and stem, 40 leaves were taken at random and measured. All material was dried in an oven for 36 hours at 80°C (176°F) and then weighed. The proportion of leaf to stem ratio from which leaf weight of the total plot herbage could be determined.

$$LAI = \frac{(W)(A)}{P}$$

W = total leaf weight

A = leaf area/unit weight determined from measured leaves

P = plot area

13.1.7 TILLER NUMBERS

Tiller counts were made on ten 5 cm. diameter cores taken

systematically from each grassed plot after all other measures had been made. A further ten samples from each of the high rate of applied fertilizer frequently cut grassed plots in reps. A and D, and each of the low rate of applied fertilizer monthly cut plots in all reps., were later taken.

13.2 RESULTS

(Bracketed figures in the text are true mean treatment values per plot.)

13.2.1 GERMINATION AND SURVIVAL OF L. SCOPARIUM

Seedlings were observed in fortnightly cut grass plots on 28/3/66, less than a week after seed sowing. By 31/3/66 seedlings were appearing on the bare plots.

Preliminary analysis showed no difference between results from outer row seedlings and the remainder so these counts were combined.

Analysis of the final seedling count gave the following results (Table 9, Fig. 28):

(1) Seedling numbers differed significantly between the three cutting treatments, most seedlings occurring on fortnightly cut plots (55) and least on uncut plots (17).

(2) Seedling numbers were significantly greater on plots without applied fertilizer (60) than on plots with low or high rates of applied fertilizer (28 and 19 respectively).

(3) Uncut grass plots had few or no seedlings, monthly cut-grass plots did not differ significantly from bare plots but fortnightly cut-grass plots had significantly more seedlings (83) than bare plots (26).

TABLE 9

THE EFFECT OF COVER, APPLIED FERTILIZER, AND CUTTING FREQUENCY ON GERMINATION AND SEEDLING SURVIVAL IN GRASSED AND BARE PLOTS

Mean seedling number/treatment

Initial Count 7/4/66

Fertilizer	Cover	Mean	Fortnightly Cut	Monthly Cut	Uncut
0	grass	7.56 (67)	12.17 (148)	10.35 (109)	3.54 (12)
	bare		5.63 (36)	6.40 (44)	7.29 (54)
L	grass	5.88 (39)	9.54 (93)	5.28 (31)	3.63 (13)
	bare		5.99 (36)	5.52 (32)	5.32 (32)
H	grass	5.20 (33)	9.88 (100)	5.18 (29)	3.44 (12)
	bare		3.53 (13)	4.82 (23)	4.38 (23)
S.E. ±		0.35	0.85		
d.05(.01)		0.99(1.32)	2.42(3.24)		
Mean cutting frequency effect			7.79 (71)	6.25 (45)	4.60 (24)
S.E. ±			0.35		
d.05(.01)			0.99(1.32)		
	grass	7.00 (61)			
	bare	5.43 (32)			
S.E. ±		0.28			
d.05(.01)		0.81(1.08)			

Final Count 4/5/66

Fertilizer	Cover	Mean	Fortnightly Cut	Monthly Cut	Uncut
0	grass	6.88 (60)	11.70 (137)	8.82 (84)	1.37 (2)
	bare		5.93 (40)	6.17 (44)	7.28 (52)
L	grass	4.72 (28)	7.12 (57)	4.32 (20)	0.84 (0)
	bare		5.40 (29)	5.54 (35)	5.1 (29)
H	grass	3.71 (19)	7.12 (56)	3.20 (12)	0.84 (0)
	bare		3.00 (9)	4.30 (18)	3.82 (18)
S.E. ±		0.39	0.96		
d.05(.01)		1.13(1.51)	2.76(3.68)		
Mean cutting frequency effect			6.71 (55)	5.39 (36)	3.20 (17)
S.E. ±			0.39		
d.05(.01)			1.13(1.51)		
	grass	5.04 (41)			
	bare	5.17 (30)			
S.E. ±		0.32			
d.05(.01)		0.93(1.24)			

Note: 0 = no applied fertilizer
L = low fertilizer application rate
H = high fertilizer application rate
Data transformed to $\sqrt{x + \frac{1}{2}}$
Bracketed figures in main body of tables represent true means.

FIGURE 22

THE EFFECT OF COVER, APPLIED FERTILIZER, AND CUTTING FREQUENCY ON GERMINATION AND SEEDLING SURVIVAL IN GRASSED AND BARE PLOTS

(a) Mean treatment numbers from initial count

(b) " " " " final count

0 = no applied fertilizer

L = low rate of applied fertilizer

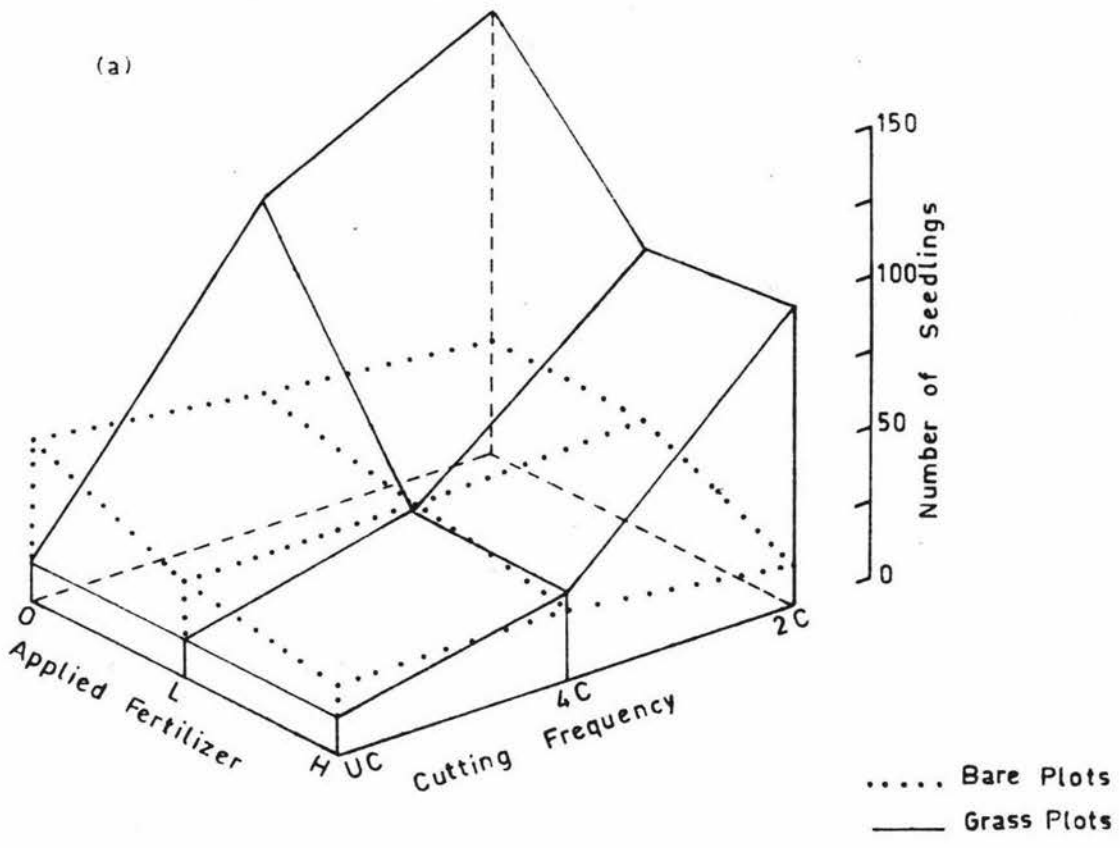
H = high rate of applied fertilizer

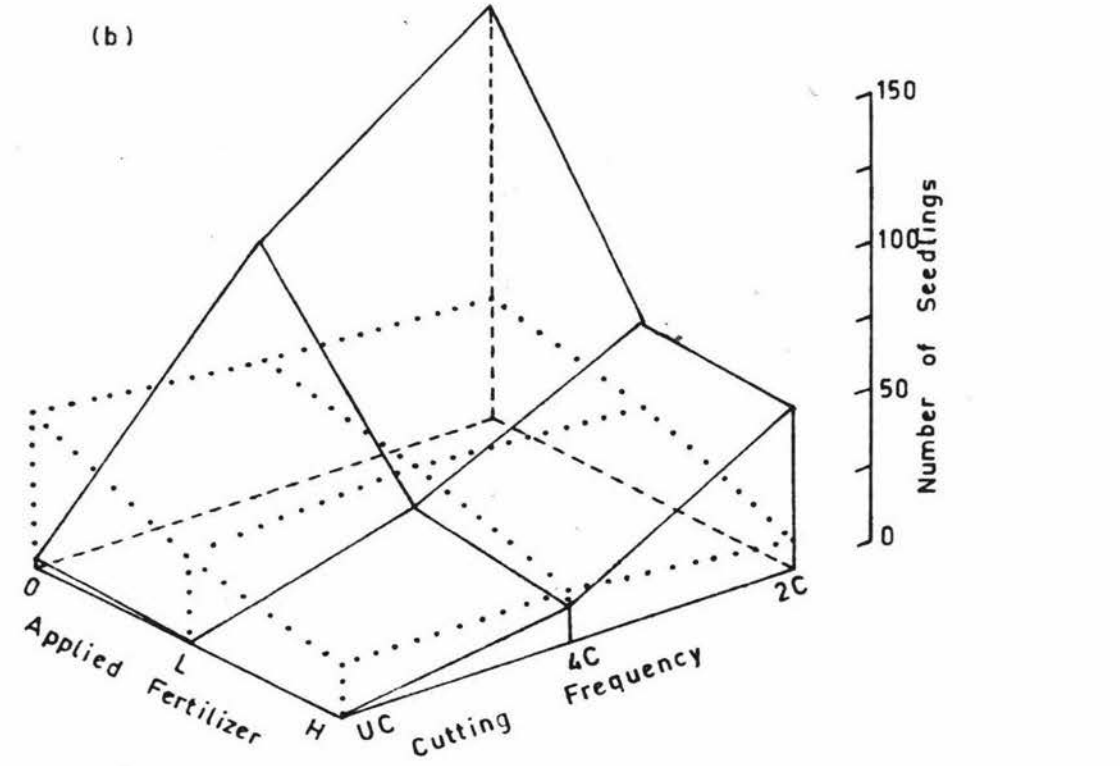
UC = uncut

4C = monthly cut

2C = fortnightly cut

FIGURE 22


(a)
150
100
50
0
Number of Seedlings
0
L
H
UC
4C
2C
Applied Fertilizer
Cutting Frequency
..... Bare Plots
—— Grass Plots


(b)
150
100
50
0
Number of Seedlings
0
L
H
UC
4C
2C
Applied Fertilizer
Cutting Frequency

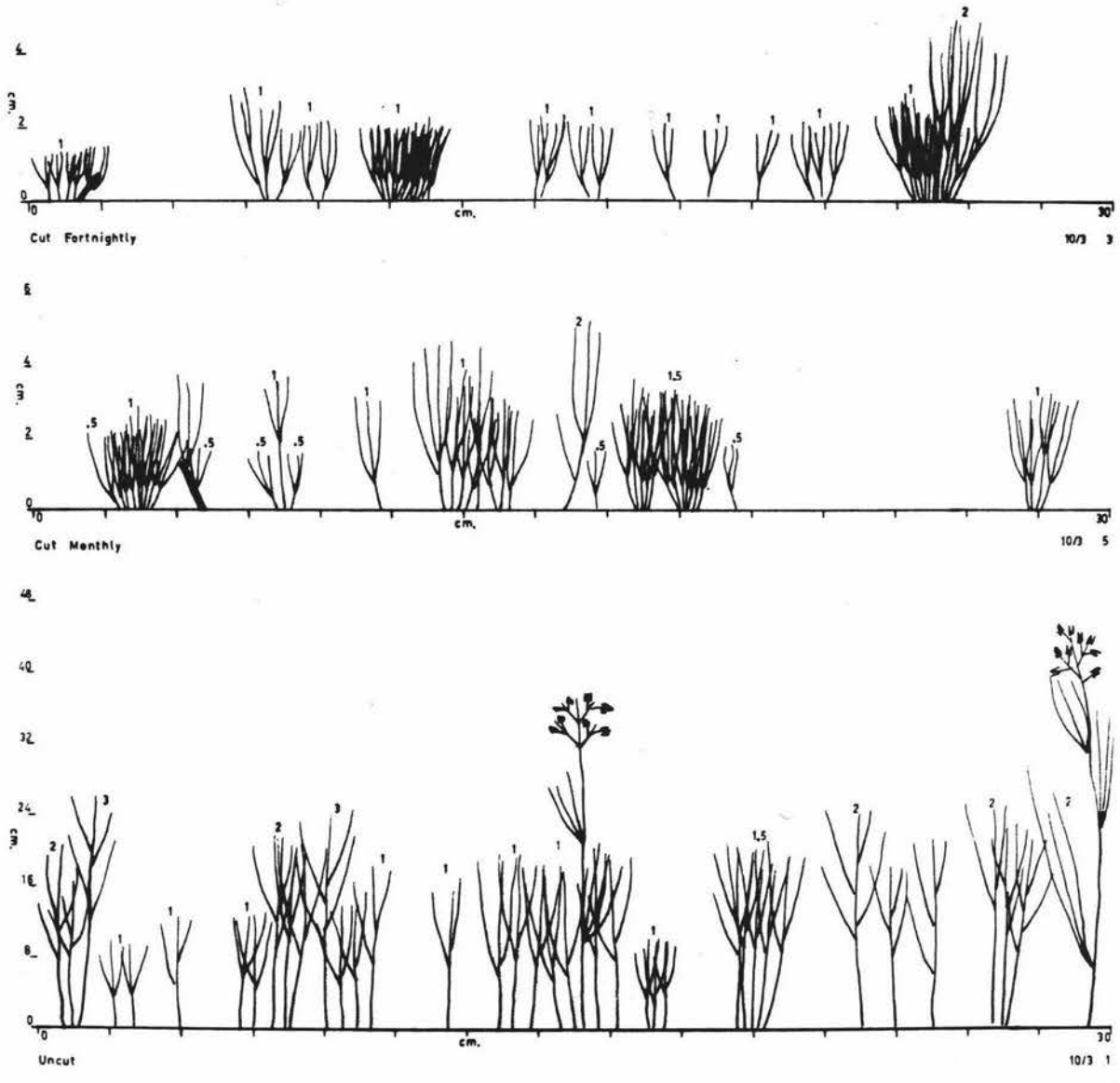


FIGURE 23: GRASS PLOT PROFILE DIAGRAMS

No applied fertilizer treatment 10/3/66.
Numbers in the profiles are leaf widths (mm.)

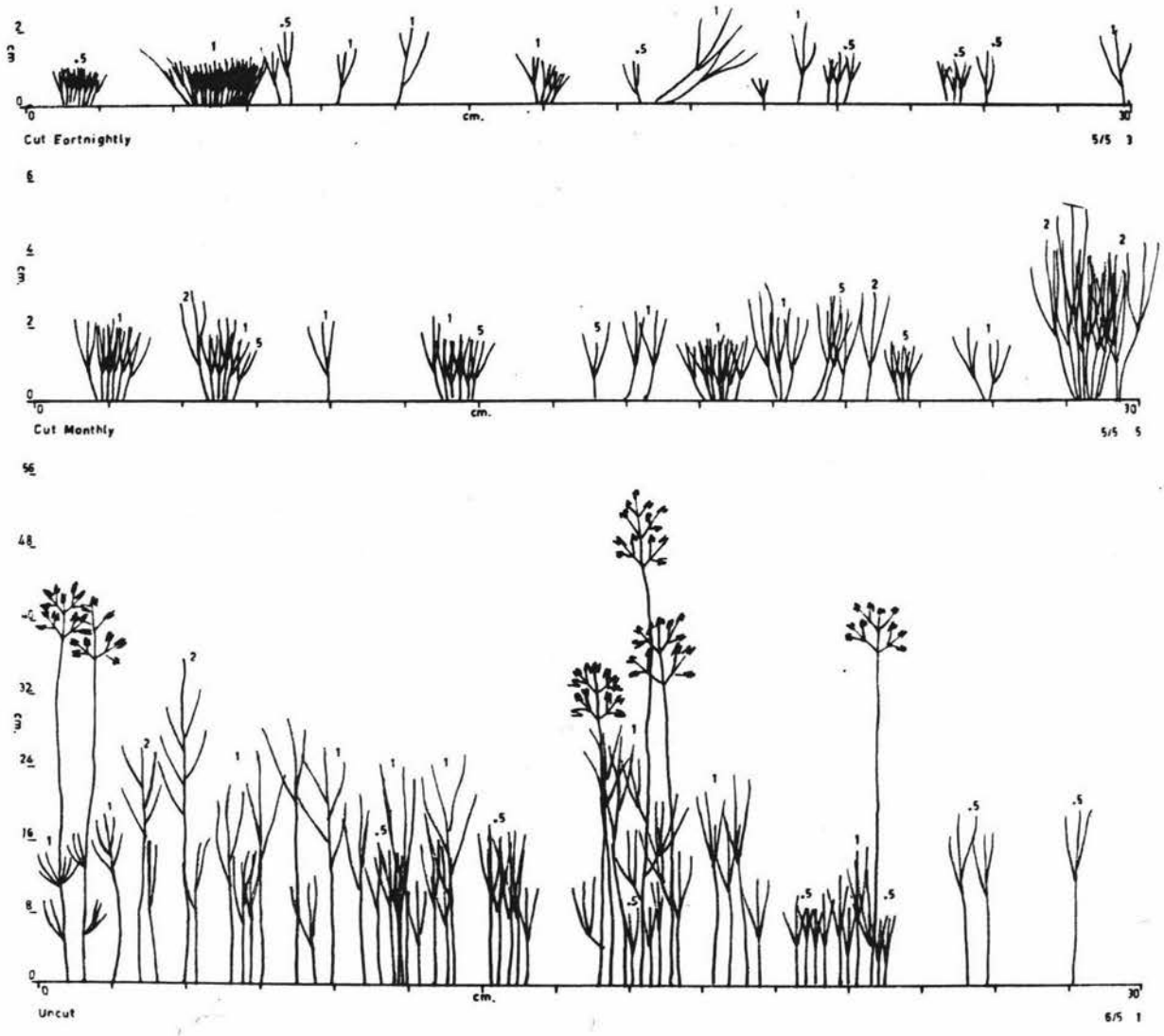


FIGURE 24: GRASS PLOT PROFILE DIAGRAMS

No applied fertilizer treatment 5 and 6/5/66.

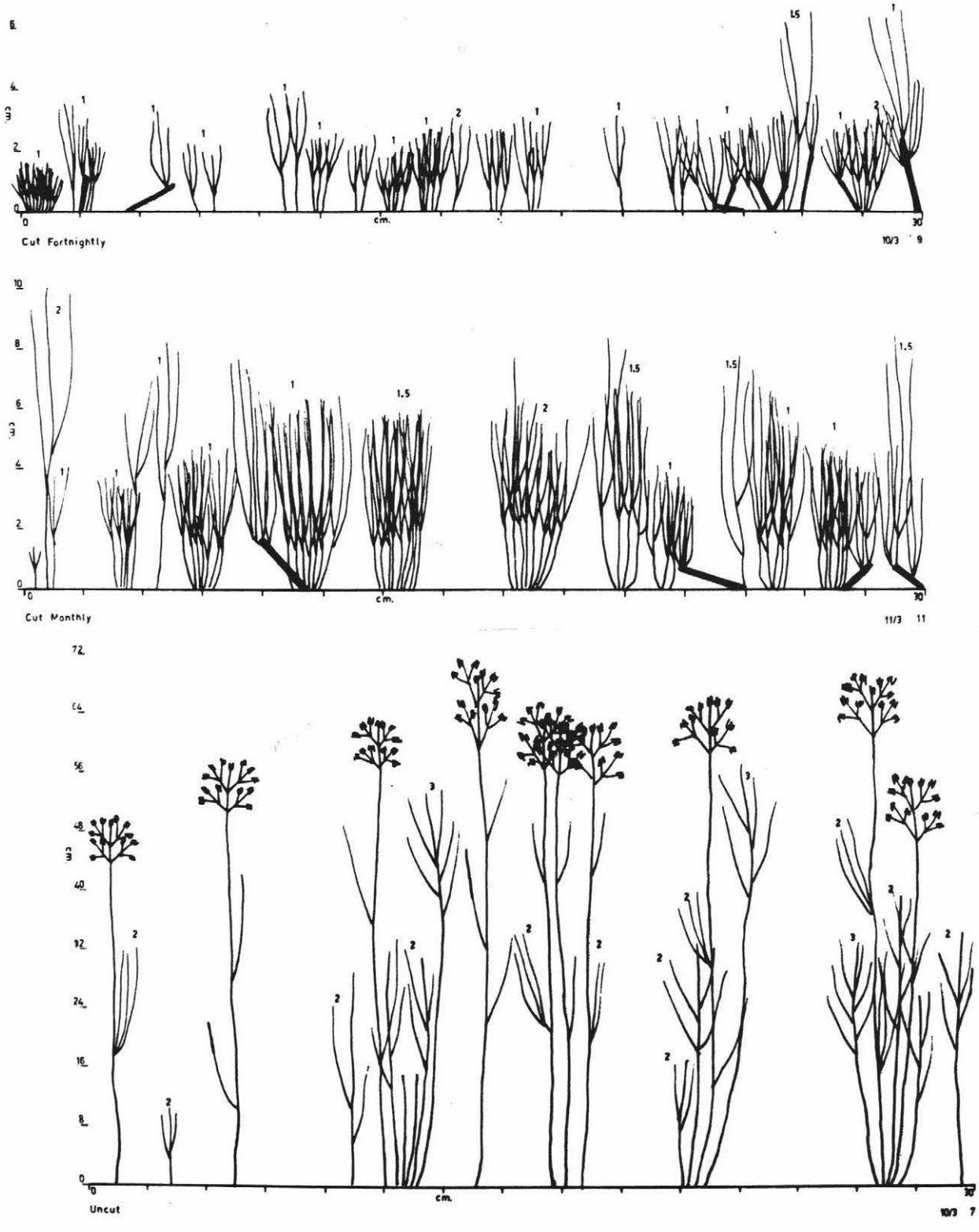


FIGURE 25: GRASS PLOT PROFILE DIAGRAMS

Low rate of applied fertilizer treatment
10 and 11/3/66.

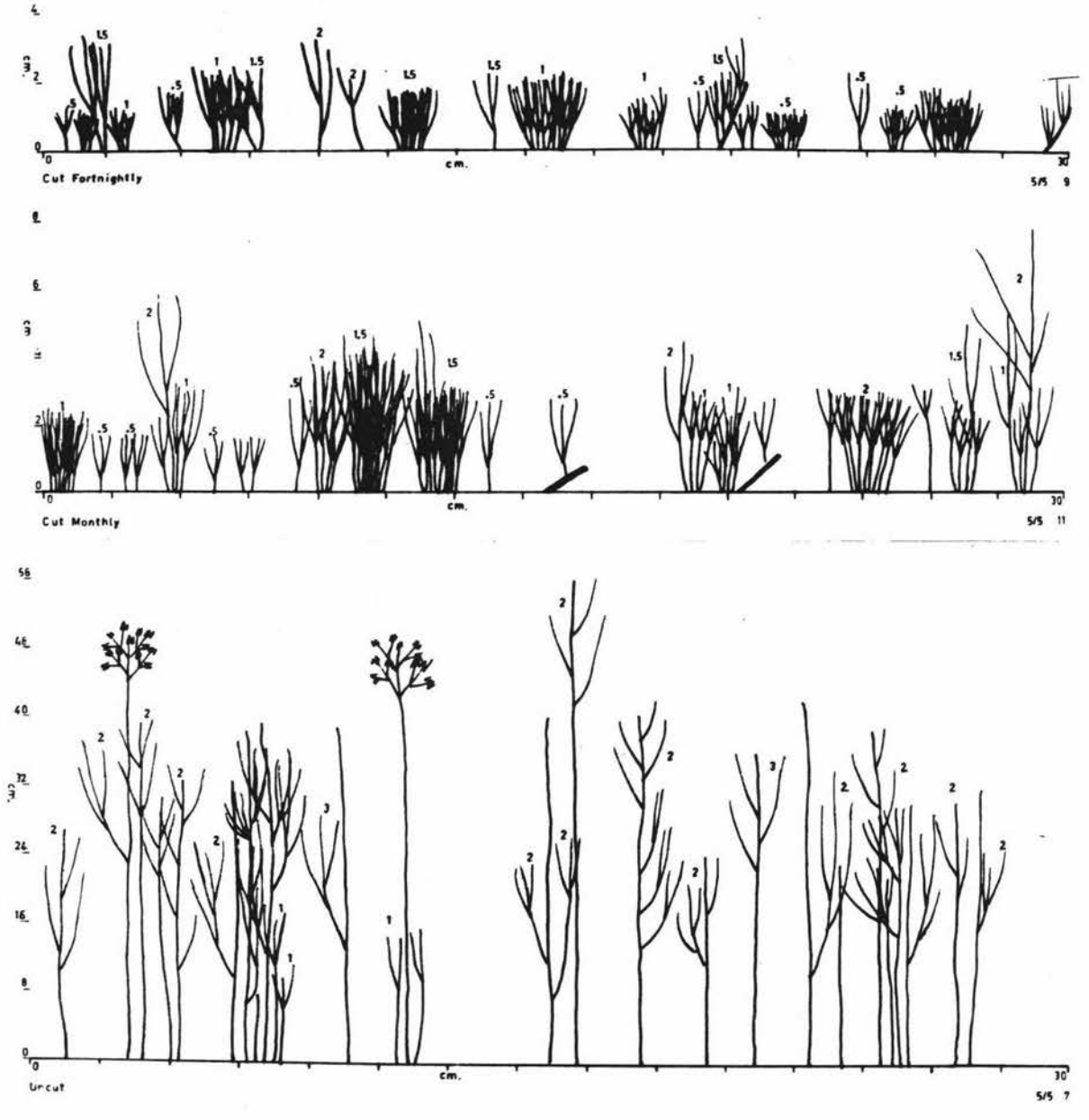


FIGURE 26: GRASS PLOT PROFILE DIAGRAMS

Low rate of applied fertilizer treatment 5/5/66.

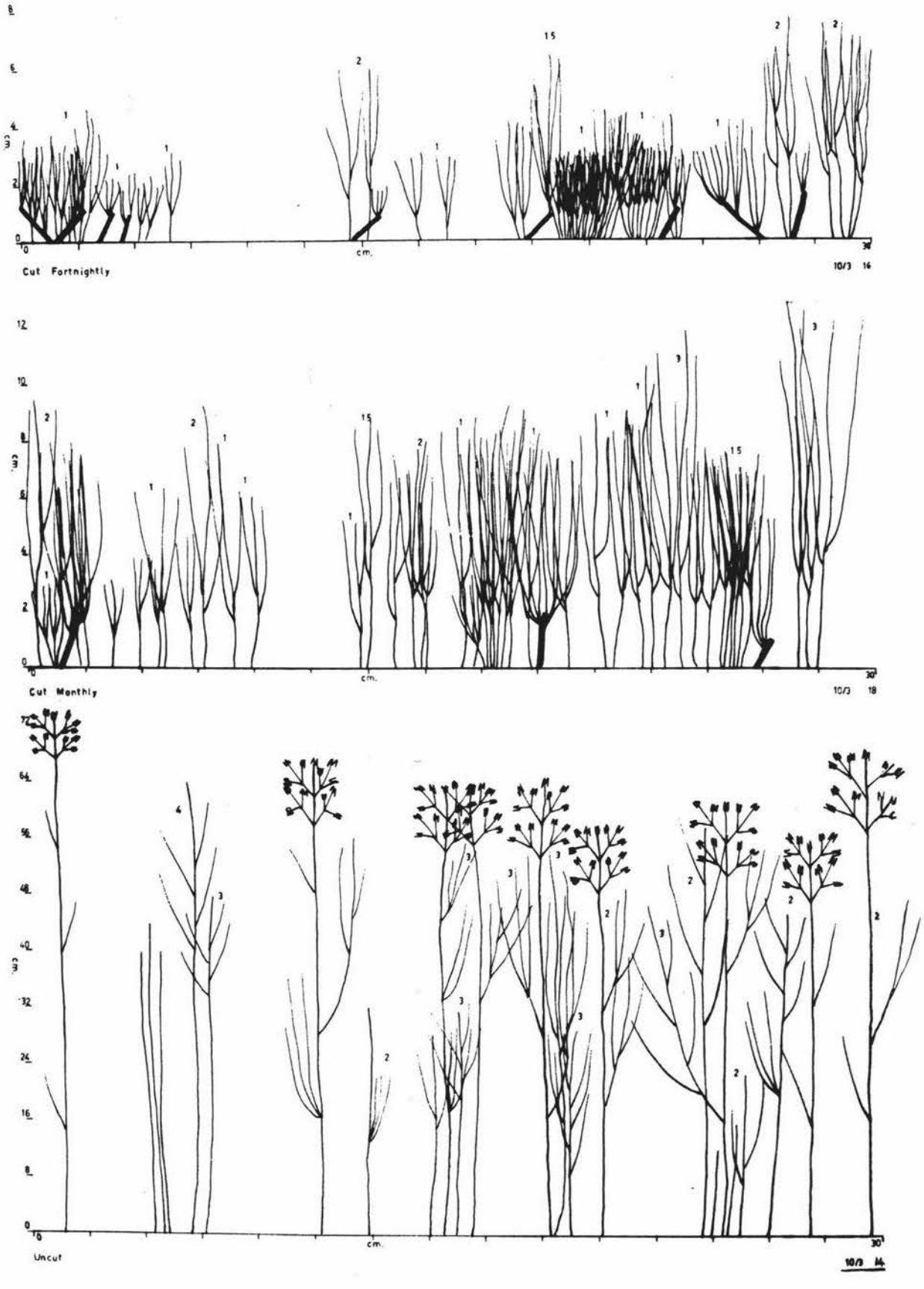


FIGURE 27: GRASS PLOT PROFILE DIAGRAMS

High rate of applied fertilizer treatment 10/3/66.

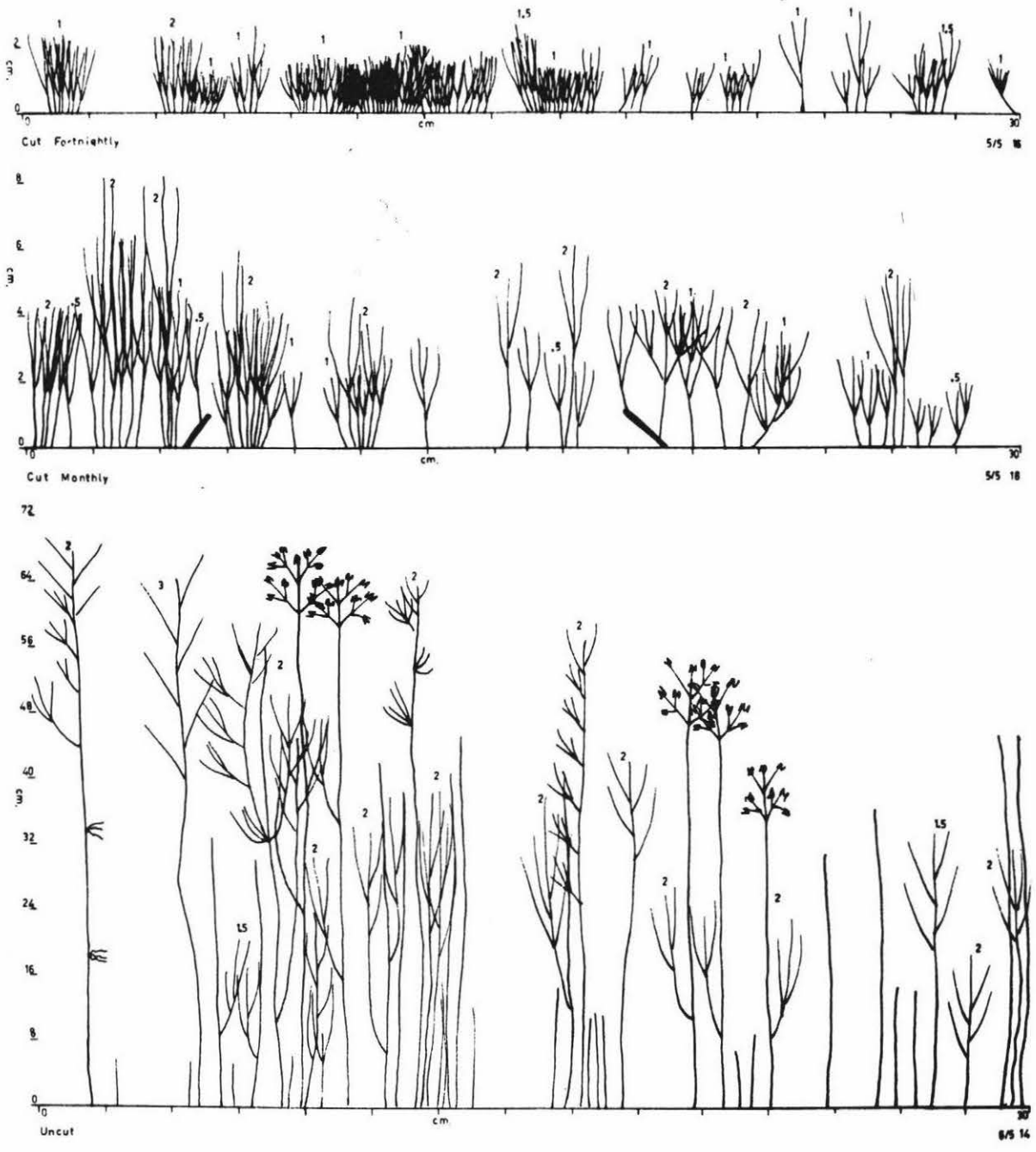


FIGURE 28: GRASS PLOT PROFILE DIAGRAMS

High rate of applied fertilizer treatment
5 and 6/5/66.

The initial count differed from the final one in that seedling numbers were higher on low and high rate of applied fertility grassed plots. (Original data, analyses of variance: Appendices 11.1, 11.2).

13.2.2 RELATIVE ILLUMINANCE

Results of the analysis of variance of R.I. values determined on 9/5/66 (Table 10) show that:

(1) R.I. was significantly greater within fortnightly cut swards (10%) than in monthly cut swards (5%). Little or no light penetrated uncut swards.

(2) R.I. was significantly greater within unfertilized swards (14%) than in those fertilized at low or high rates (5% and 4% respectively).

Values determined on 14/3/66 differed in that the R.I. within fortnightly cut swards was much lower (6%), not differing significantly from the value in monthly cut swards. R.I. under low and high rates of applied fertilizer was also lower than the equivalent 9/5/66 values. (Original data, analyses of variance: Appendices 12.1, 12.2).

13.2.3 PROFILE DIAGRAMS

Differences in community structure between treatments for rep. C are shown in Figs. 23 - 28.

It is apparent that:

(1) Uncut plots had long rank herbage and fewer tillers. For clarity the stems and leaves are shown erect. In fact these formed a tangled mat up to 25 cm. thick.

TABLE 10

RELATIVE ILLUMINANCE

Mean % R.I./treatment.

14/3/66

Applied Fertilizer		
O	L	H
19.39 (11.60)	7.61 (2.32)	6.16 (1.20)
S.E. = ± 1.35 d.05(.01) = 4.07(5.63)		
Cutting frequency: fortnightly monthly		12.69 (6.00) 9.41 (4.08)
S.E. ± d.05(.01)		1.13 3.32 (4.60)

9/5/66

Applied Fertilizer		
O	L	H
21.24 (13.71)	12.25 (4.86)	10.92 (3.96)
S.E. = ± 1.11 d.05(.01) = 3.34 (4.63)		
Cutting Frequency: fortnightly monthly		17.38 (9.78) 12.23 (5.24)
S.E. = ± 0.90 d.05(.01) = 2.71 (3.75)		

Note: Data transformed to arc sine $\sqrt{\%}$
Bracketed figures in main body of the tables represent true means.

(2) Fortnightly cut plots had the shortest herbage.

(3) The amount of herbage was reduced under all cutting treatments on plots without applied fertilizer, especially in comparison with high rate of applied fertilizer plots.

(4) The amount of herbage present on fortnightly and monthly cut plots decreased over the period 10/3/66 - 6/5/66.

Rep. C. profile diagrams were presented because these showed treatment differences most clearly.

13.2.4 LEAF AREA INDEX

Analysis of leaf area indices determined on material cut 18 - 25/5/66 gave the following results:

TABLE 11

LEAF AREA INDEX (LEAF MEASUREMENT AND DRY WEIGHT BASIS)

Mean LAI/treatment

19/5/66

Fortnightly Cut	Monthly Cut	Uncut
1.20 (0.94)	1.52 (1.81)	3.02 (8.90)
Applied Fertilizer		
0	1.74 (3.18)	
L	2.03 (4.44)	
H	1.96 (4.42)	
S.E. = ±	0.14	
d.05(.01) =	0.45 (0.65)	

Note: Data transformed to $\sqrt{x + \frac{1}{2}}$
Bracketed figures in the main body of the table represent true means.

(1) L.A.I. was significantly higher on uncut plots (8.90) than on fortnightly or monthly cut plots (0.9 and 1.8 respectively).

(2) Fertility treatments did not significantly affect leaf area.

Although the actual values differ, L.A.I.'s determined from profile diagrams drawn on 10/3/66 and 5/5/66 present a similar

TABLE 12

LEAF AREA INDEX (PROFILE DIAGRAM BASIS)

Mean LAI/treatment

9/3/66

Fortnightly Cut	Monthly Cut	Uncut
1.62 (2.17)	2.18 (4.60)	3.30 (10.75)
Applied Fertilizer		
0	1.91 (3.63)	
L	2.50 (6.50)	
H	2.70 (7.38)	
S.E. =	0.11	
d.05(.01) =	0.31 (0.42)	

4/5/66

Fortnightly Cut	Monthly Cut	Uncut
1.45 (1.65)	1.58 (2.08)	2.68 (6.89)
Applied Fertilizer		
0	1.58 (2.30)	
L	2.07 (4.21)	
H	2.06 (4.12)	
S.E. = ±	0.067	
d.05(.01) =	0.196 (0.27)	

Note: Data transformed to $\sqrt{x + \frac{1}{2}}$

Bracketed figures in main body of the tables represent true means.

pattern (Table 12) except for a significant decrease in L.A.I. on plots with no applied fertilizer. Also L.A.I. determined from 9/3/66 profile diagrams was significantly higher on monthly cut plots, but still lower than on uncut plots. L.A.I. decreased on all plots between 10/3/66 and 5/5/66 except on those without applied fertilizer. (Original data, analyses of variance: Appendices 13.1, 13.2, 14.1, 14.2).

13.2.5 TILLER NUMBERS

The results of analysis of tiller numbers determined from plugs taken on 6/6/66 show that:

TABLE 13

TILLER NUMBERS (CORE BASIS)

Mean core number/treatment.
Core area 20.3 sq.cm.

6/6/66

Fortnightly Cut	Monthly cut	Uncut
89.95 (450)	80.13 (401)	24.29 (121)
Applied Fertilizer		
0	62.91 (315)	
L	70.85 (354)	
H	60.62 (303)	
S.E. = ±	4.90	
d.05(.01) =	14.30 (19.43)	

Note: Data not transformed.
Bracketed figures in main body of table represent tillers/sq.dm.
x 10 gives approximate number of tillers/sq.ft.

(1) Tiller numbers were significantly lower on uncut plots (121/dm.^{2}) than on fortnightly or monthly cut plots (450 and 401/dm.^{2} respectively).

(2) Tiller numbers did not differ significantly with different fertilizer treatments.

An identical pattern of results with similar values was shown

TABLE 14

TILLER NUMBERS (PROFILE DIAGRAM BASIS)

Mean transect number per treatment.
Transect area 15 sq. cm.

9/3/66

Fortnightly Cut	Monthly Cut	Uncut
56.67 (378)	59.08 (394)	29.00 (193)
Applied Fertilizer		
0	48.50 (323)	
L	50.92 (339)	
H	45.33 (302)	
S.E. = ±	3.26	
d.05(.01) =	9.48 (12.88)	

4/5/66

Fortnightly Cut	Monthly Cut	Uncut
72.25 (482)	52.58 (350)	27.00 (180)
Applied Fertilizer		
0	45.25 (302)	
L	60.17 (401)	
H	46.42 (309)	
S.E. = ±	4.32	
d.05(.01) =	12.61 (17.14)	

Note: Data not transformed.
Bracketed figures in main body of table represent tillers/sq.dm.
x 10 gives approximate number of tillers/sq.ft.

by tiller number determined from 10/3/66 profile diagrams (Table 14). However, tiller numbers determined from 5/5/66 profile diagrams (Table 14) were significantly greater on fortnightly cut plots and on low rates of applied fertilizer plots. (Original data, analyses of variance: Appendices 15.1, 15.2, 16.1, 16.2).

13.2.6 PERCENTAGE BARE GROUND

The results of analysis of percentage bare ground values (Table 15) show that:

TABLE 15

% BARE GROUND IN GRASSED PLOTS AS DETERMINED BY POINT ANALYSIS

Mean % / treatment.

9/5/66

Applied Fertilizer		
0	L	H
47.42 (54.22)	40.69 (42.64)	38.54 (38.94)
S.E. = ± 1.32 d.05(.01) = 3.96(5.49)		
Cutting Frequency fortnightly cut monthly cut	43.30 (47.15) 41.14 (43.38)	
S.E. = ± 1.07 d.05(.01) = 3.24 (4.48)		

Note: Data transformed to arc sine $\sqrt{\%}$
Bracketed figures in main body of table represent true means.

(1) The % bare ground did not differ significantly between fortnightly and monthly cut plots (47% and 43%) respectively. Uncut plots were assumed to have complete cover (Fig. 17).

(2) Plots with no applied fertilizer had significantly more bare ground (54%) than plots with low or high rates of applied fertilizer (43% and 39% respectively).

(Original data, analysis of variance: Appendices 17.1, 17.2).

TABLE 16

HERBAGE YIELDS

Mean gm. dry weight/treatment

13/4/66

	Applied Fertilizer			
	O	L	H	Mean
fortnightly cut	0.9989 (10.05)	1.2335 (17.31)	1.2883 (19.50)	1.17 (15.62)
monthly cut	0.9726 (9.80)	1.3138 (20.69)	1.4118 (25.96)	1.23 (18.82)
S.E. =	± .033			0.019
d.05(.01)	= 0.1 (0.139)			0.057(0.08)
Mean	0.9860 (9.93)	1.2740 (19.00)	1.3500 (22.74)	
S.E. =	± .024			
d.05(.01)	= 0.071 (0.097)			

20/5/66

Applied Fertilizer		
O	L	H
1.0435 (11.24)	1.1717 (14.95)	1.1789 (15.19)
S.E. = ± 0.016		
d.05(.01) = 0.049 (0.068)		
Cutting freq.		
fortnightly cut	1.1037 (12.89)	
monthly cut	1.1590 (14.70)	
S.E. = ± 0.013		
d.05(.01) = 0.04 (0.056)		

Note: Data transformed to logs.
Bracketed figures in main body of tables represent true means.

13.2.7 HERBAGE YIELDS

The results of analysis of herbage yields from plots cut between 18 - 25/5/66 (Table 16) show that :

(1) Fortnightly cut plots yield significantly less (12.9 gm.) than monthly cut plots (14.7 gm.).

(2) Plots with no applied fertilizer had a significantly lower yield (11.2 gm.) than plots with low or high rates of fertilizer application (14.9 gm. and 15.2 gm. respectively).

With the exception of plots without applied fertilizer the yield on all plots decreased between 13/4/66 and 18 - 25/5/66. (Original data, analyses of variance: Appendices 18.1, 18.2).

Comparison of the results shows that R.I. values varied between treatments in exactly the same fashion as seedling numbers. For example, both R.I. values and seedling numbers are highest on plots without applied fertilizer and lowest on uncut plots. Thus germination and seedling survival appear to be dependent on R.I. or some closely correlated factor, supporting the hypothesis put forward in Section 13.1.3.

The differences in R.I. between treatments must have resulted from differences in the amount of herbage shading the ground. Of the pasture features measured to indicate the structure of the plot communities, herbage yield was the only one showing an identical relationship to R.I. under all treatments. It was thought that L.A.I. and % bare ground would have given accurate estimates of the amount of herbage shading the ground but neither measure differentiated significantly between fortnightly and monthly cutting treatments

(except for L.A.I. determined from 10/3/66 profile diagrams). Tiller numbers were not influenced by the treatments except under no cutting conditions (discounting the results of analysis of tiller numbers determined from 5/5/66 profile diagrams).

The increase in R.I. between 14/3/66 and 9/5/66 was paralleled by decreasing L.A.I. and herbage yields.

In comparison with conventional methods of measuring tiller numbers and L.A.I., the estimates of these features from profile diagrams showed identical trends in most cases although the actual values differed. Differences are also obvious visually. Considering the errors inherent in measuring or estimating leaf width and length under field conditions and the difficulty in accurately delimiting the 30 x 0.5 cm. band from which the profile diagram was drawn, these results suggest that the profile diagram method may have application in recording differences in pasture structure.

13.3 DISCUSSION

The most significant features of this experiment were the demonstration that:

(1) Few or no seedlings would germinate and survive in uncut grass.
(2) Germination and seedling survival was highest on grass plots without applied fertilizer than on any other, including bare plots.
(3) Where large numbers of seedlings did appear mortality was greatest under low and high fertility conditions.

In all cases low seedling numbers were coupled with low illumination values.

These results fully support the hypothesis of Levy (Section 4.6) that maintenance of a complete ground cover by use of fertilizer and sound stock management is essential for control of L. scoparium. The results of other workers (Lazenby, 1953; Harper and Chancellor, 1959) also indicate that weed seedling numbers are normally reduced in the presence of grass especially under conditions of high fertility.

In this experiment seedling numbers were higher and germination was faster on fortnightly cut grass treatments than on bare ground. Also, relative germination and seedling survival on bare ground was lower than on bare ground in some sowing months of the experiment described in Section 11. Because of warm temperatures at the time of the experiment moisture stress may have occurred on bare plots in spite of irrigation. Lazenby (1955) found that establishment of Juncus effusus was greater under patchy grass than on bare ground because of the adverse effect direct exposure to sunlight had on germination.

Except on uncut grass plots it is doubtful that the direct influence of shading was responsible for the pattern of seedling numbers recorded in this experiment. Only under uncut plots was there insufficient light for germination. Consequently initial seedling counts should have been higher under all other grass treatments. After a period of time it could be expected that seedling survival would be less in plots with lower relative illuminance where light values were possibly below compensation point. However, as decapitated seedlings were observed it was considered possible that low seedling numbers in the more shaded treatments may have resulted from mortality caused by greater populations of macro- and micro-organisms.

Favouring the presence of pests and diseases was regarded by Harper (1964) as a competive interaction capable of influencing plant survival.

Unfortunately the fate of seedlings in this experiment was not followed for a longer period. It is conceivable that at the end of two or three months only cut plots without applied fertilizer would contain L. scoparium seedlings. Even so the results show that seedling ingress can be reduced, in some circumstances to zero, by pasture manipulation. As suggested by Levy the vital factor is shading at the ground surface. Once seedlings have emerged above the pasture canopy they cannot be controlled without grazing. At a still later stage they would have to be cut.

14. VARIATION IN L. SCOPARIUM

There is great morphological variation in L. scoparium (Section 2). The basis of this variation has not been determined but Burrell suggested that most is a plastic response to environmental influences. The amount and form of physiological variation within the species is unknown.

Establishment of plants within pasture must be partly dependent on seedling growth rate. Seedlings with a high rate of growth could have a greater chance of escaping pasture shade. To determine whether establishment of L. scoparium in some districts may be favoured by individuals genetically capable of faster growth, variation in growth rate was studied in a uniform environment. To provide supplementary information on the degree of genetic differentiation between plants from different areas studies were made on variation in some leaf features. A preliminary study had shown that these leaf features

differed significantly between some Australian species of Leptospermum (Appendices 19.1, 19.2, 19.3, Fig. 31). Records of phenological variation were also made.

14.1 METHOD

Seeds were collected from one or two bushes in each of eleven districts (Fig. 29). Seedlings from this seed were potted, and after six months in a cold frame, transplanted into open ground in May 1965. Plants were spaced two feet apart in a randomized block design replicated nine times.

In May 1966 accumulated differences in growth rate between the even aged seedlings were assessed by height and crown width measures (based on the average of two measures made at right angles).

Leaf features measured on these plants were:

(1) density (i.e. the number of leaves per cm. of branch).

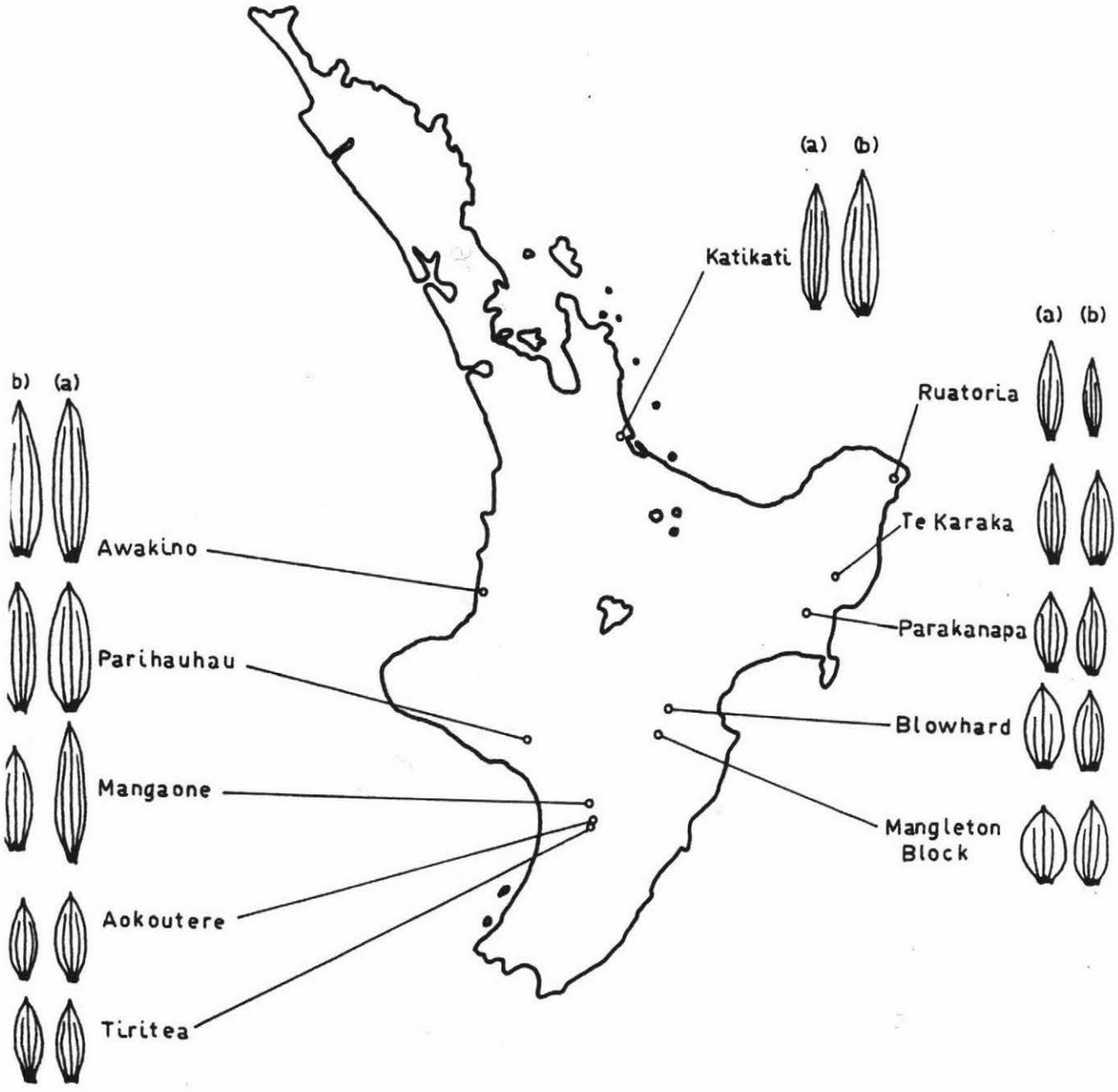
(2) width mid-way along the leaf, and length.

These measures were used to derive indices of leaf shape, (L)(W) and $\frac{(L)}{(W)}$.

Leaf features were also measured on herbarium specimens collected in the eleven areas where seed was gathered (Fig. 29), and on samples collected from 40 shrubs in the Tiritea field area (a plan of the sampling traverse is shown in Fig. 1). Measures were made on a subsiduary branch about 20 cm. long. Shoots up to 7.5 cm. long were carried in the axils of the lower leaves. Leaf density was determined on three of these shoots and the other features were derived from measures made on four mature leaves attached to the branch. Records of bud break and flowering were made from fortnightly observations of

FIGURE 29

SOURCES OF MATERIAL USED IN THE VARIATION EXPERIMENT, AND LEAVES (x 2)
(a) FROM HERBARIUM SPECIMENS
(b) FROM EXPERIMENTAL GARDEN SPECIMENS



the experimental garden plants.

14.2 RESULTS

Analysis of crown width and height measures shows that (Table 17, Fig. 30) significant differences between some districts occur in these cumulative indicators of growth rate. The district means of each measure can be divided into three significantly different groups with indistinct boundaries. There is no apparent correlation between the measures. The graph of mean crown width against height for each area produces a moderately compact cluster (Fig. 30). Although it is apparent that the environment was not completely uniform (Appendix 23.2) most of these differences must have been genetic in origin.

(Original data, analyses of variance: Appendices 23.1, 23.2.).

The results of analysis of leaf feature measurements -

(1) on experimental garden plants (Appendix 21.3) show that mean values of leaf features when arranged in order of size can be broken into three or four significantly different groups. Some boundaries between groups are wide, covering up to five district means not differing significantly from either group. The hierachical analyses of variance show that significant differences between plants from the same area occur. As for the above section most of these differences must have been genetic in origin.

(2) on herbarium specimens (Appendix 20.3) show that, as for experimental garden specimens significant differences do occur between areas in the features measured although these could be

TABLE 17

GROWTH RATE INDICATORS IN L. SCOPARIUM

(EXPERIMENTAL GARDEN SPECIMENS)

Mean Height and Crown Width

	Crown Width (cm)	Height (cm)
	(5) 79.89	(4) 126.44
	(2) 79.11	(6) 124.89
	(8) 78.55	(8) 123.55
	(9) 70.67	(5) 120.30
	(4) 69.11	(7) 117.67
	(3) 68.78	(2) 113.11
	(7) 65.44	(1) 110.45
	(1) 58.78	(10) 110.00
	(6) 58.44	(3) 109.11
	(11) 57.78	(11) 99.55
	(10) 52.22	(9) 96.78
S.E.	± 3.51	± 3.14
d.05(.01)	9.92 (13.19)	8.88 (11.81)

Note: Data not transformed.

Bracketed figures in main body of table represent area code (see Fig. 29).

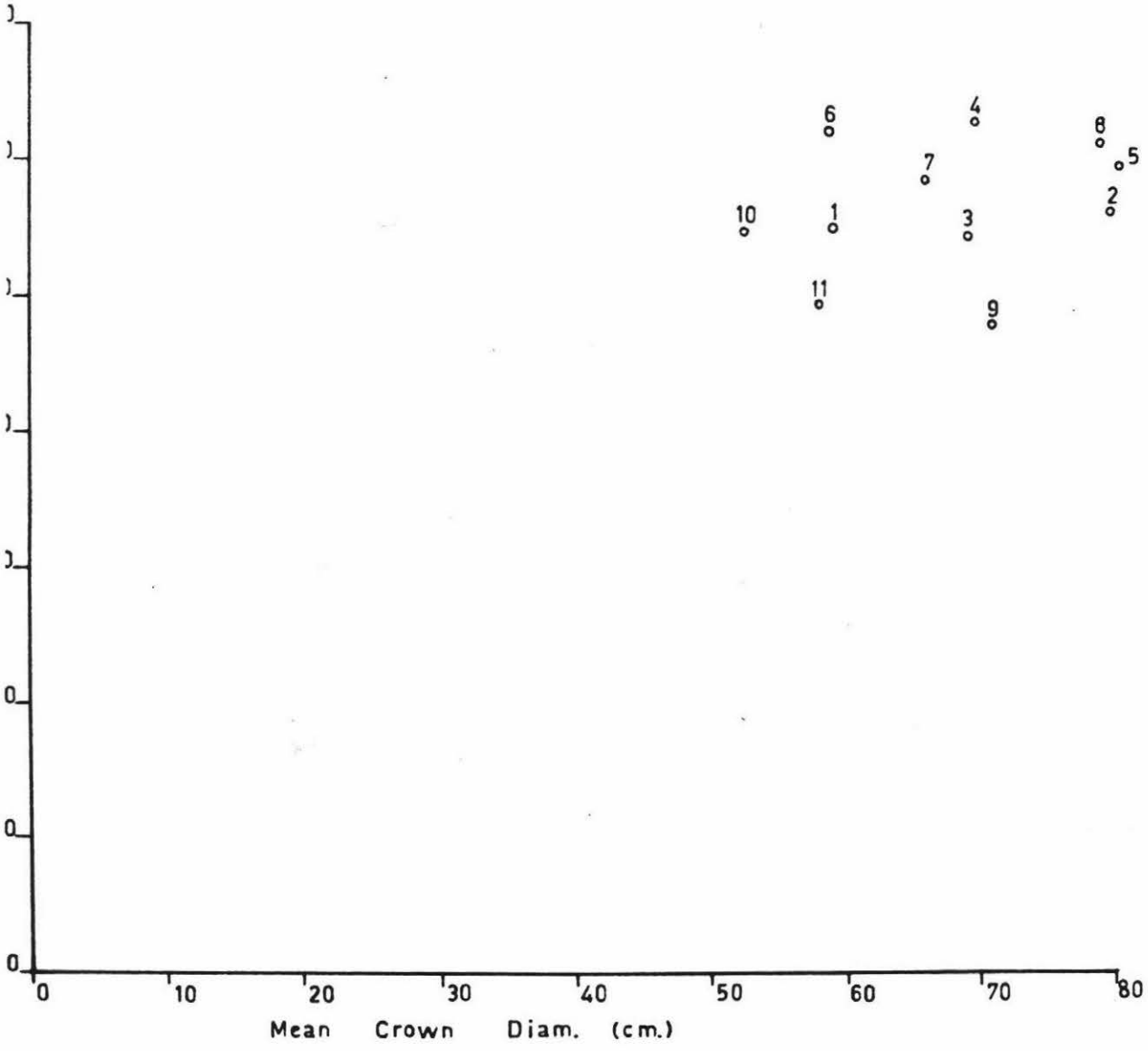


FIGURE 30: RELATIONSHIP BETWEEN L. SCOPARIUM FROM DIFFERENT AREAS FOR GROWTH RATE INDICATORS

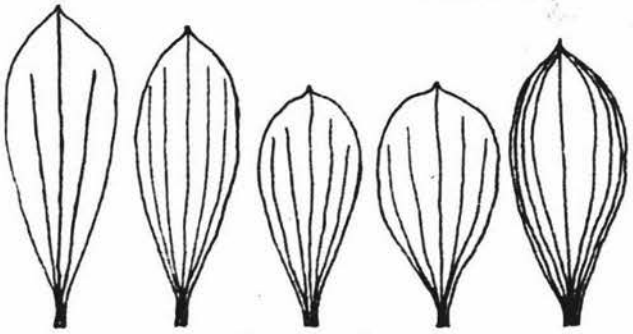
Data from experimental garden specimens

Area Code:

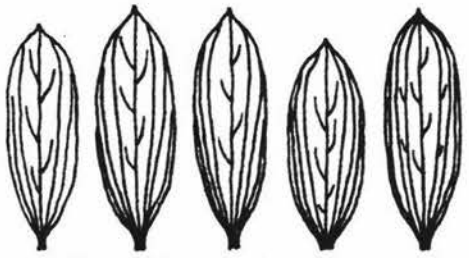
1. Ruatoria
2. Parihauhau
3. Parakanapa
4. Te Karaka
5. Katikati
6. Mangleton Block
7. Aokautere
8. Mangaone
9. Awakino
10. Tiritea
11. Blowhard

LEAVES OF SOME AUSTRALIAN SPECIES
OF LEPTOSPERMUM. x 2

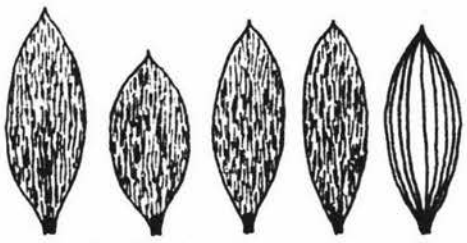
Lower surface appearance. Leaf on right in each group shows venation apparent on dissection.



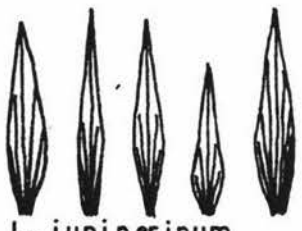
L. laevigatum
Victoria Harbour, S.A.



L. attenuatum
west of Kiama, N.S.W.

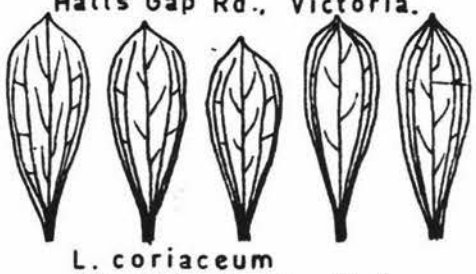


L. lanigerum
west of Kiama, N.S.W.

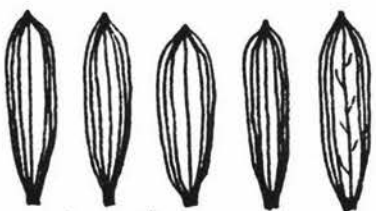


L. juniperinum
Halls Gap Rd., Victoria.

L. juniperinum
Sale, Victoria.



L. coriaceum
Monarto South, S.A.

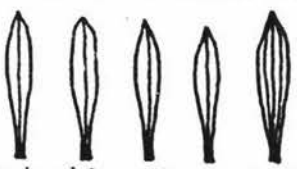


L. sericeum
Sister Hills, N.W. Tasmania

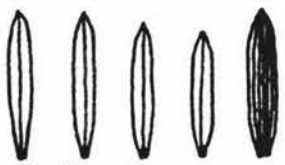
L. squarrosum
Sydney, N.S.W.

L. myrtifolium
Mt. Kosciusko, N.S.W.

L. lanigerum
Christmas Hills, N.W.Tasmania.



L. ericoides (Kunzea peduncularis)
Fernbank, Victoria.



L. flavescens
Brisbane, Queensland.

FIGURE 32

LEAVES OF LEPTOSPERMUM SCOPARIUM
FROM HERBARIUM COLLECTION. x2

Lower surface appearance. Leaf (leaves) on right in each group shows venation on dissection.

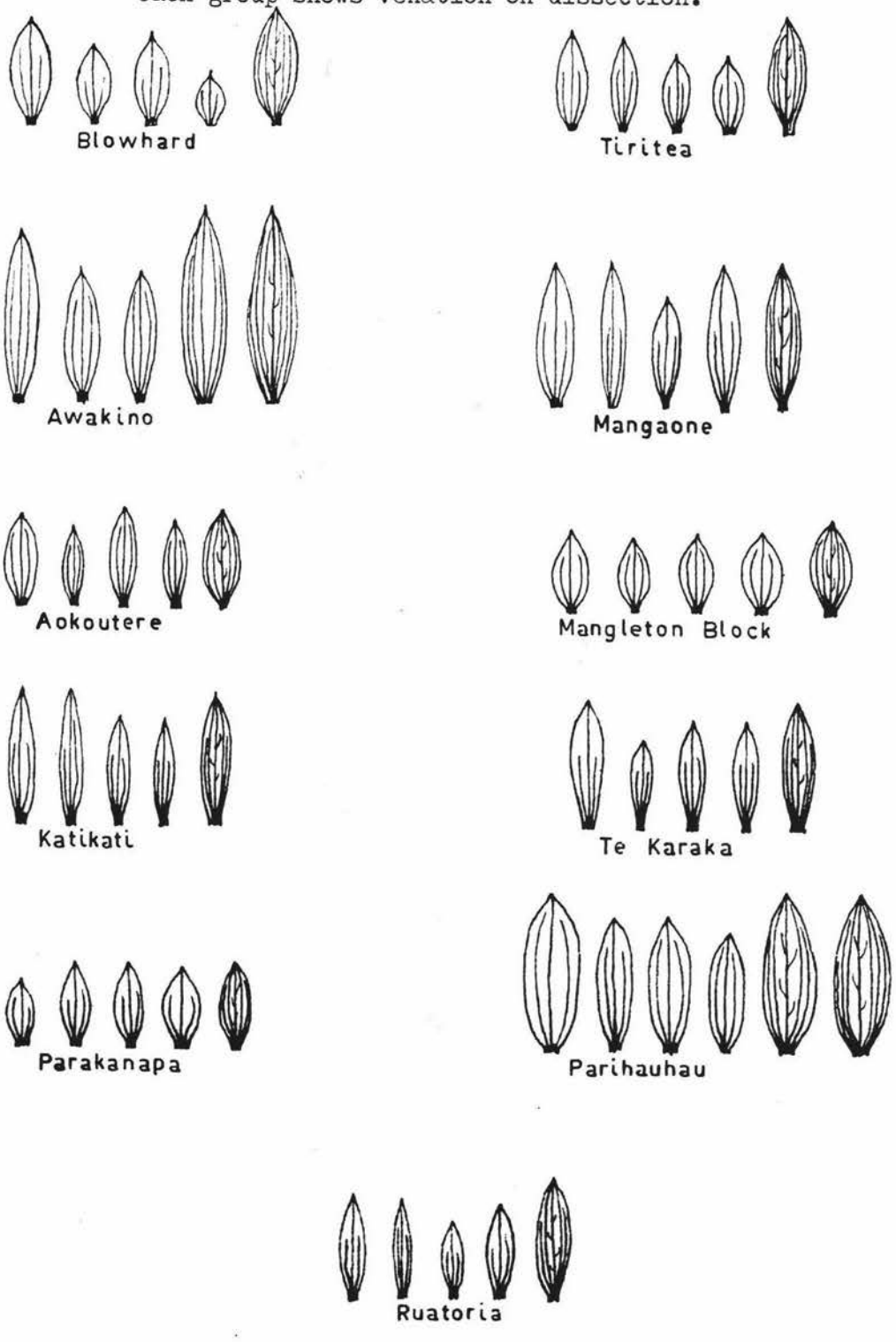
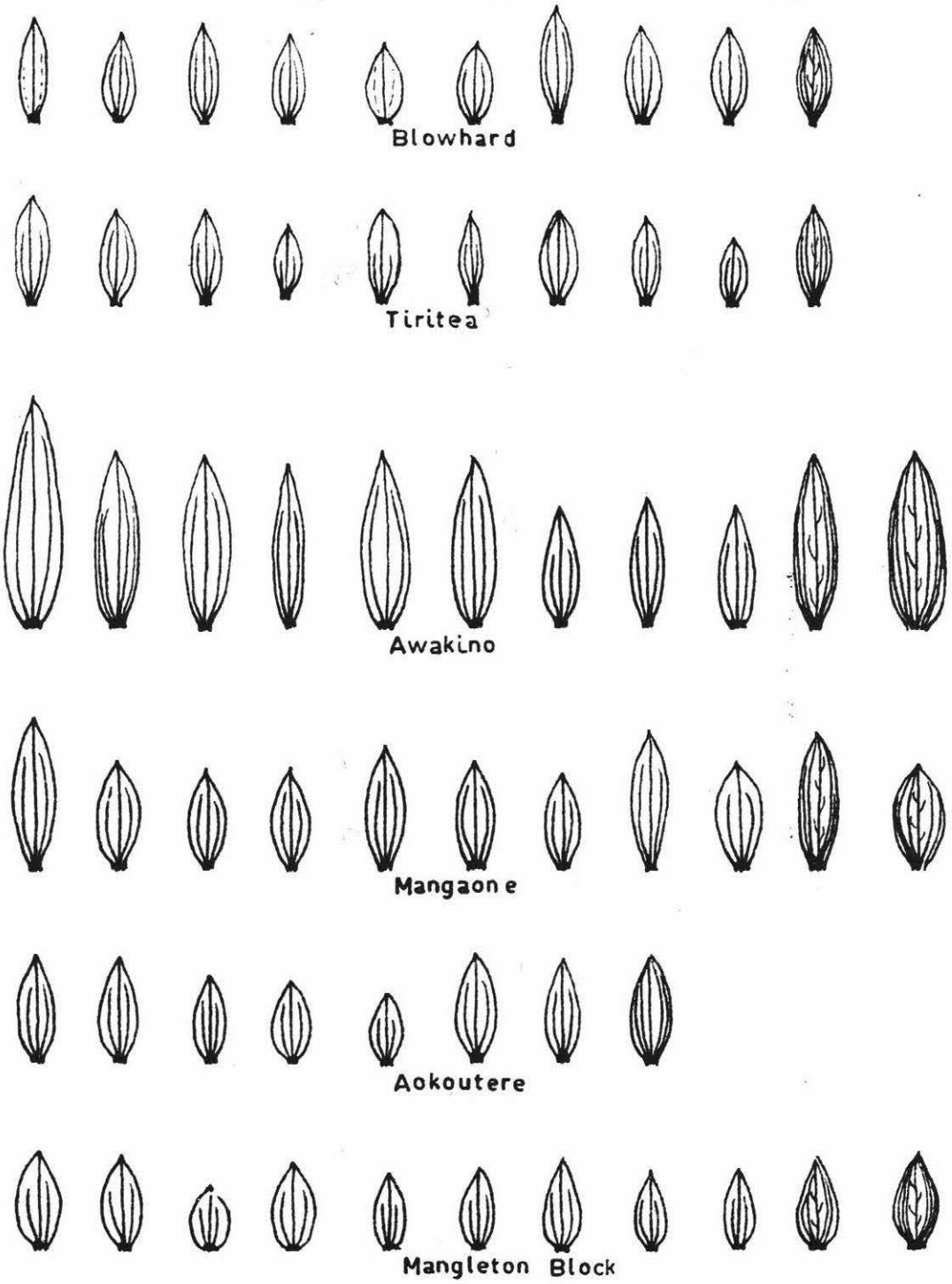


FIGURE 33

LEAVES OF LEPTOSPERMUM SCOPARIUM
FROM EXPERIMENTAL GARDEN. x2

Lower surface appearance of an average leaf from 9 reps (7 for Aokautere) of each area. Leaf/leaves on right shows venation apparent on dissection.



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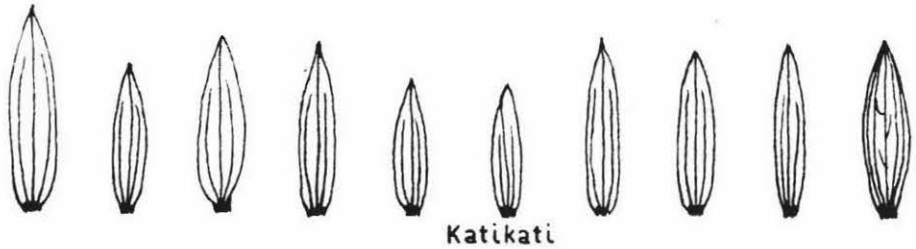
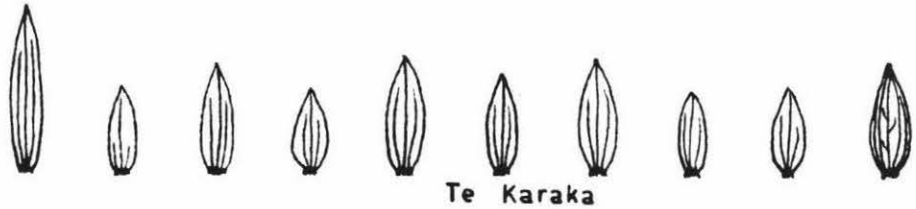
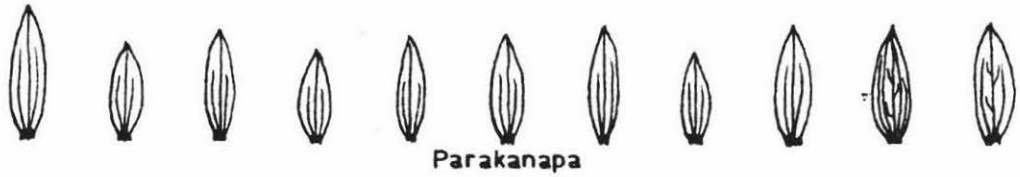


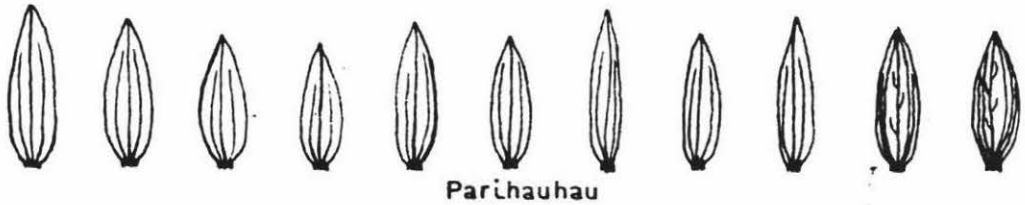
Katikati



Te Karaka



Parakanapa



Parihauhau

Ruatoria

due to environmental influence. The boundaries between significantly different groups are indistinct. In many cases where several samples from each area were included in the analyses these lie in significantly different groups.

(3) on Tiritea field area specimens (Appendix 22.3) show that a similar pattern is presented as in (1) and (2). In this case boundaries between significantly differing groups are even less distinct. The range of values in each feature is almost as great as the total range of values in each feature for plants from the eleven districts. As in (2) much of the significant variation must be due to variable environmental influence.

The drawings of leaves from herbarium specimens and experimental garden specimens in Figs. 29, 32, 33 indicate the visible differences in leaf features between areas, and the influence of transfer to a different environment.

(Original data, analyses of variance: Appendices 20 - 22).

Timing of bud break and the age at first flowering and flowering season also varies between districts (Appendix 24).

14.3 DISCUSSION

This experiment has shown that a degree of genetic differentiation exists between plants from different areas in growth rate leaf features, and phenology. There are no sharp boundaries.

Differences in leaf features present in the field are retained to a considerable degree under uniform environmental conditions. Although the great range in leaf features present in the Tiritea

samples may be due to environmental influence significant differences in leaf features also occur between plants from the same area when grown in a uniform environment. Thus variation in growth rate between districts may be little greater than the total variation in growth rate present in one area. It could be expected that an apparently cross pollinated species with wide dispersal of seed, and growing in a large range of habitats in any one district would be highly variable.

The apparently faster growth in some areas is probably insufficient to increase the likelihood of establishment in that area. However, this experiment was carried out in one environment only and plants from some areas may have possessed physiological adaptions which could have benefited them relative to others in another environment. Ideally a reciprocal transplant experiment would have to be carried out over a wide range of environments and the plants observed for differential fitness. Also, material from the various areas was collected in the form of seed from a limited number of plants. Thus the samples used may not express the typical form of the species in that district, or they may include off-types which normally would not have survived the seedling stages.

15. SUMMARY AND CONCLUSIONS

This study has shown that intrinsic factors favouring the establishment of L. scoparium include:

(1) The production of large numbers of extremely light seed.

(2) Year-round shedding of seed with greatest numbers being shed in spring.

(3) The ability to germinate rapidly.

(4) The ability to germinate over a wide range of temperatures.

(5) The ability to remain viable for some months in dark conditions which are otherwise favourable to germination.

(6) The ability to germinate and survive when sown on bare ground, over eleven months of the year.

The high invasion potential of the species must result from these factors allowing germination with the occurrence of isolated opportunities at almost any time of the year.

There is no evidence that establishment in some districts may be favoured by the existence of genotypes capable of much faster growth.

As stated by Silvester, probably the major factor limiting establishment of the species is its requirement of light for germination, and relatively high illuminance for seedling growth. It was demonstrated quantitatively that decreasing the amount of light penetrating to ground level in Browntop plots, by increasing the level of fertility and decreasing the frequency of defoliation progressively reduced seedling survival. The necessity for continuous cover is emphasized by these results, but in practice it is impossible to maintain a complete cover on steep hill country because of slips and steep banks, and droughts, etc.

Observations showed that seedling numbers can be greatly reduced by heavy non-selective grazing. Very heavy grazing during winter, however, can favour germination of L. scoparium in the spring by baring the ground. Because the majority of seedlings appear in

pasture over a moderately short period, control by pasture spelling to increase shading, followed by heavy non-selective grazing is possible. Observation also showed that two-year-old seedlings up to 30 cm. high can be effectively controlled by grazing. Re-infection of cleared areas can only be from adjacent stands or isolated plants as the seed, once shed, has a limited life.

SECTION IV

APPENDICES
BIBLIOGRAPHY

APPENDIX 1.1 THE EFFECT OF SEASON ON SEED SHED

Seed numbers per tin per month

	Tin Number					
	1	2	3	4	5	6
23/12	1	54	89	130	22	0
26/1	0	260	305	226	178	0
22/2	9	93	195	85	35	3
22/3	8	80	449	129	93	2
27/4	23	607	770	555	318	52
24/5	23	409	570	622	191	16
21/6	7	300	576	515	157	52
19/7	20	192	560	312	134	38
16/8	334	574	1410	1196	613	207
13/9	188	1032	1071	1456	755	182
13/10	59	1487	1153	2346	783	225
8/11	77	705	620	749	362	110
8/12	45	483	371	339	229	52

APPENDIX 1.2 ANALYSIS OF VARIANCE OF THE EFFECT OF SEASON ON SEED SHED

Data transformed to $\sqrt{x}$

Source of variation	d.f.	M.S. and F test
Tins	5	817.82 **
Month	12	323.37 **
Residual	60	13.98
Total	77	
V%		23

APPENDIX 2 THE EFFECT OF LIGHT ON GERMINATION

% germination per sample (a,b) per exposure level

Time After Setting Out		Exposure Time (min.)				
		0	1	2	3	5
9 days	a	0	15.00	15.00	15.00	19.50
	b	0	15.75	13.75	17.50	17.50
16 days	a	1.0	21.25	17.00	16.75	19.50
	b	0.25	18.25	15.00	18.00	17.50

APPENDIX 3 THE EFFECT OF TEMPERATURE ON GERMINATION

% germination per sample (a,b) per temperature level

Time After Setting Out		Temperature (°F)			
		40	60	65	90
9 days	a	0	0	19.25	18.75
	b	0	0	19.50	19.25
16 days	a	0	15.75	19.25	18.75
	b	0	13.50	19.50	19.25
43 days	a	14.50	15.75	19.25	18.75
	b	12.75	13.50	19.50	19.25

APPENDIX 4.1 THE EFFECT OF SEED AGE ON GERMINATION

% germination per sample per month

Date	Sample a	b	c	d
16/10	15.0	16.5	19.5	18.0
17/11	15.0	16.0	20.0	14.0
18/12	21.5	19.5	19.0	20.5
18/1	22.5	21.0	17.5	18.5
18/2	21.0	16.5	21.5	17.5
24/3	17.5	17.0	17.0	22.0
21/4	13.0	17.0	20.0	12.0
20/5	14.0	22.0	20.5	16.0
18/6	19.0	21.0	16.5	19.0
19/7	18.5	16.5	22.5	22.5
18/8	17.5	16.0	20.5	13.5
18/9	15.0	22.0	20.5	20.5
18/11	20.5	23.0	24.0	18.5
17/1	19.5	17.0	17.5	19.0
14/2	24.5	17.5	16.5	20.0
14/3	19.0	20.5	17.5	22.5
11/4	20.0	23.5	17.5	17.0
18/5	13.5	14.0	19.0	17.5

APPENDIX 4.2 ANALYSIS OF VARIANCE OF THE EFFECT OF SEED AGE ON GERMINATION

Data transformed to arc sine $\sqrt{\%}$

Source of variation	d.f.	M.S. and F test
Month	17	6.12 N.S.
Residual	54	3.92
Total	71	
V%		8

APPENDIX 5 THE EFFECT OF EXPOSURE ON AND BELOW THE GROUND SURFACE ON GERMINATION

% normal germination, % abnormal germination and % underground germination per sample (a,b,c) per fortnight

Time After Setting Out		Seeds on Ground		Seeds Underground	
		Normal	Abnormal	Normal	Underground
2 weeks	a	52	16	92	
	b	56	4	84	
	c	44	6	86	
4 weeks	a	0	0	86	
	b	24	8	96	
	c	18	4	42	
6 weeks	a	2	0	76	
	b	2	0	80	
	c	2	0	76	
8 weeks	a	2	0	76	2
	b	4	0	80	4
	c	0	0	80	4
10 weeks	a	0	0	84	4
	b	0	0	68	4
	c	0	0	72	4
12 weeks	a	0	0	84	4
	b	0	0	68	4
	c	0	0	64	2

APPENDIX 6.1

THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL ON BARE GROUND

Seedling numbers per rep (a,b,c) per treatment

	Sowing Time											
	1	2	3	4	5	6	7	8	9	10	11	12
	a b c	a b c	a b c	a b c	a b c	a b c	a b c	a b c	a b c	a b c	a b c	a b c
12/4	sown											
26/4	0 0 0											
10/5	0 0 0	sown										
24/5	30 20 20	0 0 0										
7/6	33 28 23	21 8 10	sown									
21/6	33 28 23	30 15 10	2 0 0									
5/7	13 11 13	20 7 5	2 2 0	sown								
19/7	10 11 10	10 3 2	3 3 2	0 0 0								
2/8	10 11 10	10 3 2	3 3 2	0 0 0	sown							
16/8	8 11 10		13 15 15	0 6 8	0 0 0							
30/8	8 11 10		13 18 18	12 7 8	10 7 7	sown						
13/9			13 28 30	14 15 11	13 12 11	0 0 0						
27/9			13 28 30	14 15 11	11 15 11	8 5 4	sown					
11/10					11 15 11	8 5 10	0 0 0					
25/10						11 10 18	2 1 2	sown				
8/11						11 10 18	8 0 4	0 0 0				
22/11							10 3 7	0 0 0	sown			
6/12							10 3 7	0 0 0	0 0 0			
20/12								0 0 0	0 0 0	sown		
3/1									0 1 0			
17/1									0 1 0			
31/1												
14/2											sown	
28/2												
14/3												sown
28/3												
11/4												
25/4										2 0 0	0 3 1	3 5 2
Final no./plot 9/5	8 11 10	10 3 2	13 28 30	14 15 11	11 15 11	11 10 18	10 3 7	0 0 0	0 1 0	2 0 0	0 3 1	5 7 2

APPENDIX 6.2 ANALYSIS OF VARIANCE OF THE EFFECT OF SEASON ON GERMINATION AND SEEDLING SURVIVAL ON BARE GROUND

Only final results analysed
Treatments 8, 9, 10 excluded from analysis
Data transformed to $\sqrt{x + \frac{1}{2}}$

Source of Variation	d.f.	M.S. and F Test	
Replicates	2	0.135	N.S.
Sowing Time	8	3.720	* *
Residual	16	0.499	
Total	26		
V %		24	

APPENDIX 7 THE EFFECT OF SEASON ON SEEDLING APPEARANCE IN PASTURE

Number of seedlings per month per quadrat (A, B, C)

	24/5	21/6	19/7	16/8	13/9	11/10	8/11	6/12	10/1
A	0	4	15	15	27	74	61	19	0
B	0	1	4	7	41	77	44	22	0
C	0	1	10	12	27	185	293	42	0

APPENDIX 8 THE EFFECT OF SEASON ON SEEDLING MORTALITY IN PASTURE

Number of deaths per month per quadrat (A,B,C)
1965-66 season's seedlings

	A	B	C
24/5	0	0	0
21/6	0	0	0
19/7	0	1	1
16/8	2	1	0
13/9	4	0	9
11/10	0	6	10
8/11	8	23	5
6/12	1	0	0
10/1	0	39	18
31/1	0	1	39
26/2	43	23	61
28/3	17	0	0
25/4	26	35	109
23/5	30	29	92

Note: area: quad A 30 $dm.^2$
quad B 15 $dm.^2$
quad C 25 $dm.^2$

APPENDIX 9 CHANGES IN TOTAL SEEDLING NUMBERS IN PASTURE WITH SEASON

Number of seedlings per month per quadrat (A,B,C)

	Current Season's Seedlings			Previous Season's Seedlings		
	A	B	C	A	B	C
24/5	0	0	0	48	26	45
21/6	4	1	1	35	22	23
19/7	19	4	10	32	17	21
16/8	32	10	22	32	11	17
13/9	55	51	40	20	7	15
11/10	129	122	215	20	3	15
8/11	182	143	503	13	1	11
6/12	200	165	545	13	1	9
10/1	200	126	527	11	1	9
31/1	200	125	488	5	1	7
26/2	157	102	417	4	1	5
28/3	140	102	417	4	1	5
25/4	114	67	308	4	1	1
23/5	84	38	216	4	1	1

Note: area: quad A 30 $dm.^2$
quad B 15 $dm.^2$
quad C 25 $dm.^2$

APPENDIX 10 THE EFFECT OF SOME HABITAT FEATURES ON SEEDLING GERMINATION AND SURVIVAL IN PASTURE

Number of seedlings per habitat feature per quadrat (A,B,C)

	A	B	C
Bare ground	112 (52.09)	80 (40.82)	119 (20.88)
Moss	38 (17.67)	31 (15.82)	74 (12.98)
Nertera	0 (0)	11 (5.61)	0 (0)
Flatweeds	5 (2.33)	12 (6.12)	23 (4.03)
Grass	39 (18.14)	36 (18.37)	43 (7.54)
Grass and Nertera	0 (0)	18 (9.18)	0 (0)
Grass and moss	0 (0)	0 (0)	311 (54.56)
Grass, moss and Nertera	16 (7.44)	0 (0)	0 (0)
Moss and Nertera	5 (2.33)	8 (4.08)	0 (0)

Note: Bracketed figures represent % of quadrat total

area: quad A 30 $dm.^2$
quad B 15 $dm.^2$
quad C 25 $dm.^2$

APPENDIX 11.1 THE EFFECT OF COVER, APPLIED FERTILIZER AND CUTTING FREQUENCY ON GERMINATION AND SEEDLING SURVIVAL IN GRASSED AND BARE PLOTS

Total seedling number per rep. (A,B,C,D) per treatment.

Initial Count 7/4/66

	Browntop Plots								
	fortnightly cut			monthly cut			uncut		
	0	L	H	0	L	H	0	L	H
A	160	45	49	65	8	21	9	10	13
B	125	98	138	144	29	8	18	8	7
C	154	115	106	135	19	48	12	17	13
D	153	115	107	93	69	38	10	17	13
	Bare Plots								
A	36	53	12	72	58	25	36	40	41
B	79	30	19	45	14	20	55	60	13
C	8	29	18	52	22	25	46	19	38
D	21	31	3	9	34	21	78	7	1

Final Count 4/5/66

	Browntop Plots								
	fortnightly cut			monthly cut			uncut		
	0	L	H	0	L	H	0	L	H
A	136	9	8	28	5	5	1	0	0
B	127	56	83	153	19	4	5	1	0
C	162	108	59	95	17	33	0	0	1
D	123	55	75	60	40	6	1	0	0
	Bare Plots								
A	53	37	7	89	68	19	36	28	38
B	80	25	17	38	5	16	52	60	12
C	8	33	7	44	30	18	50	23	23
D	20	21	5	5	36	19	72	5	0

O = no fertilizer applied

L = low fertilizer application rate

H = high fertilizer application rate

APPENDIX 11.2 ANALYSES OF VARIANCE OF THE EFFECT OF COVER, APPLIED FERTILIZER AND CUTTING FREQUENCY ON GERMINATION AND SEEDLING SURVIVAL IN GRASSED AND BARE PLOTS

Data transformed to $\sqrt{x + \frac{1}{2}}$

Initial Count 7/4/66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	1.04	N.S.
Cover	1	44.48	* *
Time of Cutting	2	60.89	* *
Fertilizer	2	35.48	* *
C x T	2	87.22	* *
C x F	2	4.90	N.S.
F x T	4	2.86	N.S.
C x T x F	4	7.73	*
Residual	51	2.88	
Total	71		
V %		27	

Final Count 4/5/66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	4.37	N.S.
Cover	1	0.32	N.S.
Time of Cutting	2	75.31	* *
Fertilizer	2	62.83	* *
C x T	2	102.25	* *
C x F	2	6.62	N.S.
F x T	4	2.15	N.S.
C x T x F	4	7.83	N.S.
Residual	51	3.73	
Total	71		
V %		38	

APPENDIX 12.1

RELATIVE ILLUMINANCE
6.3 mm. ABOVE GROUND

Mean % R.I. per rep (A,B,C,D) per treatment

14/3/66 (based on 6 readings/plot)

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
A	18.78	0.60	1.18	16.33	0.18	1.13	0.08	0	0
B	8.52	6.55	1.33	10.47	1.12	0.50	0.78	0	0
C	14.73	5.83	1.13	13.12	0.98	1.08	0.05	0	0
D	8.22	2.85	2.32	2.70	0.45	0.95	0.25	0	0

9/5/66 (based on 24 readings/plot)

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
A	19.56	3.04	2.59	15.12	1.99	1.59	0.02	0	0
B	19.45	7.12	9.99	15.75	4.20	5.05	0.04	0	0
C	17.06	9.65	5.80	4.81	3.11	2.42	0.01	0	0
D	12.89	7.49	2.76	5.07	2.25	1.49	0.04	0	0

O = no fertilizer applied

L = low fertilizer application rate

H = high fertilizer application rate

APPENDIX 12.2

ANALYSIS OF VARIANCE OF RELATIVE ILLUMINANCE

Data transformed to arc sine $\sqrt{\%}$

Data from uncut treatments excluded from analysis

14.3.66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	13.49	N.S.
Time of cutting	1	64.55	N.S.
Fertilizer	2	421.47	* *
T x F	2	13.27	N.S.
Residual	15	14.64	
Total	23		
V %		35	

9.5.66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	32.59	*
Time of Cutting	1	159.03	* *
Fertilizer	2	251.66	* *
T x F	2	3.60	N.S.
Residual	15	9.85	
Total	23		
V %		21	

APPENDIX 13.1 LEAF AREA INDEX (LEAF MEASUREMENT AND DRY WEIGHT BASIS)

L.A.I. per rep (C,D) per treatment

19/5/66

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
C	0.68	0.76	0.72	1.20	2.04	1.90	3.01	8.19	9.33
D	0.97	1.33	1.21	1.90	2.12	1.68	11.31	12.17	9.41

Note: L.A.I. determined by this method only for reps. C and D.

APPENDIX 13.2 ANALYSIS OF VARIANCE OF LEAF AREA INDEX (LEAF MEASUREMENT AND DRY WEIGHT BASIS)

Data transformed to $\sqrt{x + \frac{1}{2}}$

19/5/66

Source of Variation	d.f.	M.S. and F test	
Replicates	1	0.48	N.S.
Time of Cutting	2	5.68	* *
Fertility	2	0.13	N.S.
T x F	4	0.05	N.S.
Residual	8	0.13	
Total	17		
V %		17	

APPENDIX 14.1 LEAF AREA INDEX (PROFILE DIAGRAM BASIS)

L.A.I. per rep. (A,B,C,D) per treatment

9/3/66

	Fortnightly Cut			Monthly Cut			Uncut		
	0	L	H	0	L	H	0	L	H
A	0.98	2.20	3.40	1.15	4.10	10.80	9.96	14.44	14.50
B	1.76	2.82	1.45	2.40	4.10	6.35	3.28	17.00	10.82
C	1.33	2.30	3.57	2.00	6.90	6.35	10.30	8.50	12.30
D	2.16	1.92	2.16	1.74	3.35	5.92	6.55	10.35	11.00

4/5/66

	Fortnightly Cut			Monthly Cut			Uncut		
	0	L	H	0	L	H	0	L	H
A	1.24	1.79	1.45	0.69	1.95	2.07	4.05	5.28	7.25
B	1.54	2.22	1.18	0.81	2.44	2.51	2.48	9.83	8.05
C	0.73	1.52	2.32	1.75	2.45	3.11	5.00	7.20	8.65
D	0.65	2.48	2.66	1.36	3.08	2.76	7.27	10.28	7.38

0 = no applied fertilizer

L = low fertilizer application rate

H = high fertilizer application rate

APPENDIX 14.2 ANALYSIS OF VARIANCE OF LEAF AREA INDEX

(PROFILE DIAGRAM BASIS)

Data transformed to $\sqrt{x + \frac{1}{2}}$

9/3/66

Source of Variation	d.f.	M.S. and F Tests	
Replicates	3	0.13	N.S.
Time of Cutting	2	8.85	* *
Fertility	2	2.02	* *
T x F	4	0.27	N.S.
Residual	24	0.13	
Total	35		
V %		15	

4/5/66

Source of Variation	d.f.	M.S. and F Tests	
Replicates	3	0.15	N.S.
Time of Cutting	2	5.51	* *
Fertility	2	0.94	* *
T x F	4	0.01	N.S.
Residual	24	0.054	
Total	35		
V %		12	

APPENDIX 15.1 TILLER NUMBERS (CORE BASIS)

Mean number per core per rep. (A,B,C,D,) per treatment
Core area 20.3 sq. cm.

6/6/66

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
A	78.8	130.5	92.4	89.5	80.3	83.6	24.4	19.4	23.9
B	107.2	108.1	33.7	74.6	77.8	46.9	16.6	29.1	25.0
C	72.5	83.1	86.8	72.3	82.6	114.2	41.2	21.5	32.7
D	94.8	118.1	73.4	61.2	77.2	101.4	21.8	22.5	13.4

APPENDIX 15.2 ANALYSIS OF VARIANCE OF TILLER NUMBERS (CORE BASIS)

6/6/66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	231.55	N.S.
Time of Cutting	2	15,051.35	* *
Fertility	2	346.08	N.S.
T x F	4	645.97	N.S.
Residual	24	288.88	
Total	35		
V %		26	

APPENDIX 16.1 TILLER NUMBERS (PROFILE DIAGRAM BASIS)

Number per transect per rep. (A,B,C,D) per treatment

Transect area 15 sq. cm.

9/3/66

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
A	49	48	70	58	65	83	56	33	30
B	57	57	54	60	63	45	18	37	15
C	45	63	58	42	64	51	39	22	20
D	80	60	39	43	77	58	35	22	21

4/5/66

	Fortnightly Cut			Monthly Cut			Uncut		
	O	L	H	O	L	H	O	L	H
A	64	81	54	45	53	33	16	23	14
B	84	78	48	62	79	33	12	41	28
C	50	66	98	51	69	51	55	27	24
D	47	101	96	33	75	47	24	29	31

o = no applied fertilizer

L = low fertilizer application rate

H = high fertilizer application rate

APPENDIX 16.2 ANALYSIS OF VARIANCE OF TILLER NUMBERS (PROFILE DIAGRAM BASIS)

9/3/66

Source of Variation	d.f.	M.S. and F Tests	
Replicates	3	186.99	N.S.
Cutting Time	2	3,352.58	* *
Fertility	2	94.08	N.S.
T x F	4	213.17	N.S.
Residual	24	127.24	
Total	35		
V %		23	

4/5/66

Source of Variation	d.f.	M.S. and F Tests	
Replicates	3	272.70	N.S.
Cutting Time	2	6,177.69	* *
Fertility	2	825.86	*
T x F	4	240.36	N.S.
Residual	24	224.33	
Total	35		
V %		30	

APPENDIX 17.1 % BARE GROUND IN GRASSED PLOTS AS DETERMINED BY POINT ANALYSIS

% bare ground per rep. (A,B,C,D) per treatment

9/5/66

	Fortnightly Cut			Monthly Cut		
	0	L	H	0	L	H
A	53.04	29.55	29.55	51.52	30.31	46.21
B	58.34	46.98	49.25	53.79	46.22	38.65
C	58.98	56.42	39.33	53.00	43.60	42.74
D	57.20	51.30	35.90	47.86	36.76	29.92

Note: uncut plots assumed to have complete cover

APPENDIX 17.2 ANALYSIS OF VARIANCE OF THE % BARE GROUND IN GRASSED PLOTS AS DETERMINED BY POINT ANALYSIS

Data transformed to arc sine $\sqrt{\%}$

9/5/66

Source of Variation	d.f.	M.S. and F Tests	
Replicates	3	40.82	N.S.
Time of Cutting	1	28.15	N.S.
Fertility	2	171.77	* *
T x F	2	11.14	
Residual	15	13.84	
Total	23		
V%		9	

APPENDIX 18.1 HERBAGE YIELD

Monthly total gm. dry weight per rep (A,B,C,D) per treatment

13/4/66

	Fortnightly Cut			Monthly Cut		
	0	L	H	0	L	H
A	9.98	20.53	16.68	7.59	22.69	21.94
B	9.43	16.14	19.88	6.64	17.64	29.84
C	8.68	13.88	20.08	11.14	21.79	26.14
D	12.13	18.68	21.38	13.84	20.64	25.94

20/5/66

	Fortnightly Cut			Monthly Cut		
	0	L	H	0	L	H
A	10.09	14.23	13.08	10.06	13.46	13.92
B	10.74	13.51	13.69	9.65	15.32	16.32
C	8.74	12.21	14.46	12.29	16.52	17.87
D	12.27	16.90	14.73	16.10	17.46	17.44

0 = no applied fertilizer

L = low fertilizer application rate

H = high fertilizer application rate

APPENDIX 18.2 ANALYSIS OF VARIANCE OF HERBAGE YIELDS

Data transformed to logs

13/4/66

Source of Variation	d.f.	M.S. and F Test	
Replicates	3	0.0091	N.S.
Cutting Time	1	0.0210	*
Fertility	2	0.2953	* *
T x F	2	0.0219	*
Residual	15	0.0045	
Total	23		
V%		5.6	

20/5/66

Source of Variance	d.f.	M.S. and F Test	
Replicates	3	0.0122	* *
Cutting Time	1	0.0184	*
Fertility	2	0.0464	* *
T x F	2	0.0003	N.S.
Residual	15	0.0021	
Total	23		
V%		3.5	

APPENDIX 19.1 LEAF FEATURES OF SOME AUSTRALIAN SPECIES OF LEPTOSPERMUM

Density of leaves and measurements of leaf length and midwidth

(1)		(2)		(3)		(4)		(5)		(6)	
D		D		D		D		D		D	
1.5		1.5		1.8		2.1		2.2		2.0	
2.0		1.4		1.9		2.4		2.3		1.2	
1.6		1.4		1.6		2.2		2.3		1.5	
L	W	L	W	L	W	L	W	L	W	L	W
21.5	7.0	16.0	4.5	15.5	5.0	12.8	2.2	10.0	2.8	15.0	5.0
20.0	6.5	14.5	4.5	12.0	5.0	13.5	1.5	11.0	2.8	15.0	4.5
16.0	6.5	16.0	4.8	14.0	4.5	13.0	2.0	9.5	2.8	14.5	5.0
16.5	7.5	14.0	4.8	14.0	4.0	10.0	1.8	11.5	2.8	13.5	4.8

(7)		(8)		(9)		(10)		(11)		(12)	
D		D		D		D		D		D	
1.6		2.0		1.2		4.0		2.3		2.0	
1.3		2.1		2.0		4.0		1.5		4.0	
2.0		1.8		1.7		3.8		2.0		2.5	
L	W	L	W	L	W	L	W	L	W	L	W
13.0	3.0	12.0	2.5	9.5	3.5	6.0	2.5	9.5	1.5	10.0	1.5
13.0	3.0	11.0	2.5	9.5	3.5	6.0	2.5	9.2	1.5	10.0	1.5
12.0	3.5	12.5	2.5	9.0	3.2	6.0	2.5	10.0	1.5	9.0	1.5
12.5	2.8	12.5	2.8	6.5	3.2	6.0	3.0	9.0	1.2	8.5	1.2

D = leaf density/cm. of branch
L = leaf length (mm.)
W = leaf midwidth (mm.)

(1) = L. laevigatum (Soland. ex Gaert) F.v.M.
(2) = L. attenuatum J. Sm..
(3) = L. lanigerum J. Sm.. (Kiama, N.S.W.)
(4) = L. juniperinum J. Sm. (Hall's Gap Rd., Victoria)
(5) = L. juniperinum (Sale, Victoria)
(6) = L. coriaceum (F.v.M.) Cheel.
(7) = L. sericeum Labill.
(8) = L. squarrosum Gaertn.
(9) = L. murtifolium Sieb. ex DC.
(10) = L. lanigerum (Tasmania)
(11) = Kunzea peduncularis F.v.M. = L. ericoides A. Rich.
(12) = L. flavescens J. Sm.

APPENDIX 19.2 ANALYSIS OF VARIANCE OF LEAF FEATURES OF SOME AUSTRALIAN SPECIES OF LEPTOSPERMUM

Leaf Density

Source of Variation	d.f.	M.S. and F Test
Species	11	1.478 * *
Residual	24	0.15
Total	35	
V %		19

Leaf (length) (midwidth) Ratio

Source of Variation	d.f.	M.S. and F Test
Species	11	4,254.11 * *
Residual	36	193.37
Total	47	
V %		34.08

Leaf $\frac{\text{(length)}}{\text{(midwidth)}}$ Ratio

Source of Variation	d.f.	M.S. and F Test
Species	11	11.42 * *
Residual	36	0.396
Total	47	
V %		15.21

APPENDIX 19.3 LEAF FEATURES OF SOME AUSTRALIAN SPECIES OF LEPTOSPERMUM

Mean species values

Mean Leaf Density (leaves/cm.)

(10)	(12)	(5)	(4)	(8)	(11)	(3)	(1)	(7)	(9)	(6)	(2)
3.93	2.83	2.26	2.23	1.96	1.93	1.76	1.70	1.63	1.63	1.56	1.43
S.E. = ± 0.22 d.05(.01) = 0.66 (0.89)											

Mean Leaf $\frac{(\text{length})}{(\text{midwidth})}$ Ratio

(4)	(11)	(12)	(8)	(7)	(5)	(2)	(3)	(6)	(1)	(9)	(10)
6.72	6.71	6.60	4.98	4.14	3.75	3.25	3.03	3.01	2.70	2.56	2.30
S.E. = ± 0.31 d.05(.01) = 0.90 (1.21)											

Mean Leaf (length) (midwidth) Ratio

(1)	(6)	(3)	(7)	(2)	(5)	(8)	(9)	(4)	(10)	(11)	(12)
127.06	69.95	64.12	38.75	36.00	29.40	29.37	29.02	23.10	15.75	13.46	13.42
S.E. = ± 6.95 d.05(.01) = 20.05 (27.03)											

Note: Species code (bracketed figures) as in Appendix 19.1

APPENDIX 20.1 LEAF FEATURES OF L. SCOPARIUM (HERBARIUM SPECIMENS)

Density of leaves and measurements of leaf length and midwidth

(11.1)		(11.2)		(11.3)		(11.4)		(10.1)		(10.2)	
D		D		D		D		D		D	
3.7		1.7		1.8		2.3		3.0		2.2	
3.0		3.0		2.2		1.6		1.8		3.5	
3.4		2.3		3.8		1.1		2.4		2.0	
L	W	L	W	L	W	L	W	L	W	L	W
6.5	2.5	7.0	2.5	4.0	2.2	7.0	2.2	7.0	2.1	7.0	2.2
6.0	2.2	8.0	3.0	5.0	2.0	8.5	2.5	6.0	2.0	6.8	1.8
5.0	2.0	6.0	2.0	5.0	2.0	7.0	2.5	6.0	2.0	6.5	2.2
5.0	2.0	6.0	2.2	5.0	2.2	5.5	3.0	7.0	2.0	7.5	2.2

(9.1)		(9.2)		(9.3)		(6.1)		(5.1)		(5.2)	
D		D		D		D		D		D	
3.5		2.1		1.3		2.0		2.2		3.4	
2.2		2.4		1.2		2.0		1.9		2.3	
2.0		1.9		1.2		3.2		2.0		2.8	
L	W	L	W	L	W	L	W	L	W	L	W
16.5	3.0	9.5	2.5	10.0	3.0	6.0	2.8	8.0	1.5	10.0	1.5
16.0	3.0	10.0	2.2	13.0	2.8	5.5	2.2	8.0	1.5	10.0	1.5
13.0	2.5	9.5	2.2	10.5	3.0	6.0	2.5	8.0	1.2	10.0	1.5
14.0	2.5	9.5	2.5	11.5	3.0	6.0	3.2	8.5	1.8	9.0	1.5

(4.1)		(4.2)		(3.1)		(3.2)		(2.1)		(2.2)	
D 2.8 3.1 2.6		D 2.7 1.9 2.4		D 2.8 3.0 2.7		D 2.7 2.3 2.7		D 1.2 2.2 1.3		D 1.4 2.0 3.2	
L	W	L	W	L	W	L	W	L	W	L	W
6.5	1.8	9.5	2.0	5.0	2.0	5.5	2.5	11.2	3.2	12.0	3.2
8.0	2.2	8.0	2.0	6.5	2.0	6.5	3.5	9.0	2.5	12.0	4.0
7.5	2.0	8.5	2.0	6.5	2.0	6.5	2.5	9.5	2.5	11.0	3.0
6.8	1.5	8.0	2.0	6.0	2.0	6.5	2.5	9.5	2.5	10.0	3.0

(1.1)		(1.2)		(1.3)		(8.1)		(7.1)	
D 3.8 17.0 20.0		D 9.4 13.0 14.6		D 18.0 15.0 15.1		D 1.4 1.7 1.5		D 3.5 3.0 3.1	
L	W	L	W	L	W	L	W	L	W
7.0	1.5	6.5	1.8	8.0	1.8	11.0	2.5	6.5	1.8
6.0	1.8	7.0	2.0	7.5	1.5	11.0	1.8	7.5	2.0
8.0	2.0	7.0	2.0	7.5	2.0	11.0	2.2	7.0	2.0
7.5	1.8	6.0	1.8	7.0	1.8	8.5	1.8	6.0	1.5

D = leaf density/cm. of branch
L = leaf length (m.m.)
W = leaf midwidth (m.m.)

(1.) = Ruatoria
(2.) = Parihauhau
(3.) = Parakanapa
(4.) = Te Karaka
(5.) = Katikati
(6.) = Mangleton Block
(7.) = Aokautere
(8.) = Mangaone
(9.) = Awakino
(10.) = Tiritea
(11.) = Blowhard

(.1), (.2) etc. gives sample identification within areas.

APPENDIX 20.2 ANALYSES OF VARIANCE OF LEAF FEATURES OF L. SCOPARIUM (HERBARIUM SPECIMENS)

Leaf Density

Source of Variation	d.f.	M.S. and F Test
Area	22	49.75 * *
Residual	46	3.93
Total	68	
V %		51

Leaf $\frac{(\text{length})}{(\text{width})}$ Ratio

Source of Variation	d.f.	M.S. and F Test
Area	22	4.79 * *
Residual	69	0.21
Total	91	
V %		12

Leaf (length) (width) Ratio

Source of Variation	d.f.	M.S. and F Test
Area	27	285.75 * *
Residual	69	14.98
Total	91	
V %		21

APPENDIX 20.3 LEAF FEATURES OF L. SCOPARIUM (HERBARIUM SPECIMENS)

Mean values

D		L/W		(L)(W)	
(1.3)	16.00	(5.2)	6.50	(9.1)	41.25
(1.1)	13.00	(5.1)	5.51	(2.2)	37.35
(1.2)	12.33	(9.1)	5.41	(9.3)	32.72
(11.1)	3.36	(8.1)	5.06	(2.1)	26.46
(7.1)	3.20	(4.2)	4.31	(8.1)	21.70
(5.2)	2.83	(1.3)	4.27	(9.2)	20.35
(4.1)	2.83	(9.2)	4.11	(11.4)	17.66
(3.1)	2.83	(1.1)	4.04	(3.2)	17.25
(11.3)	2.60	(4.1)	3.88	(4.2)	17.00
(10.2)	2.57	(9.3)	3.78	(11.2)	16.67
(9.1)	2.57	(7.1)	3.71	(6.1)	15.77
(3.2)	2.56	(2.1)	3.67	(5.2)	14.62
(10.1)	2.40	(1.2)	3.48	(10.2)	14.61
(6.1)	2.40	(2.2)	3.44	(4.1)	13.62
(11.2)	2.33	(10.2)	3.33	(1.3)	13.31
(4.2)	2.33	(10.1)	3.21	(10.1)	13.17
(2.2)	2.20	(3.1)	3.00	(1.1)	12.70
(9.2)	2.13	(11.2)	2.81	(1.2)	12.62
(5.1)	2.03	(11.4)	2.80	(7.1)	12.42
(11.4)	1.67	(11.1)	2.58	(11.1)	12.36
(2.1)	1.56	(3.2)	2.31	(5.1)	12.22
(8.1)	1.53	(11.3)	2.27	(3.1)	12.00
(9.3)	1.23	(6.1)	2.22	(11.3)	9.95
S.E. = ±	1.14		0.23		1.93
d.05(.01) =	3.45(4.62)		0.64(0.85)		5.48(7.29)

Note: Area code (bracketed figures) as in Appendix 20.1

APPENDIX 21.1 LEAF FEATURES OF L. SCOPARIUM

(EXPERIMENTAL GARDEN SPECIMENS)

Density of leaves and measurements of leaf length and midwidth

(1)

D		D		D		D		D		D		D		D		D	
10.0 12.0 14.0		14.0 16.0 15.0		10.0 11.0 10.0		10.0 9.0 11.0		7.0 10.0 8.0		12.0 10.0 12.0		14.0 11.0 15.0		10.0 12.0 12.0		10.0 11.0 8.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
8.5	1.5	4.5	1.3	8.5	1.3	6.5	1.5	5.0	1.0	7.5	1.5	6.0	1.5	6.0	1.5	7.0	1.8
8.0	1.5	5.0	1.3	6.5	1.1	7.0	1.5	4.0	0.8	7.5	1.8	6.5	1.5	8.0	1.8	7.5	1.8
8.0	1.5	5.5	1.5	8.5	1.5	6.0	1.5	4.0	1.0	8.0	1.5	6.0	1.5	7.2	1.8	7.0	1.8
8.5	1.5	6.0	1.5	7.0	1.2	6.5	1.5	4.0	1.0	7.5	1.5	6.0	1.5	6.5	1.5	7.0	1.8

(2)

D		D		D		D		D		D		D		D		D	
5.3 4.3 4.6		4.0 3.3 4.6		4.6 4.0 2.2		2.4 3.0 2.0		3.6 3.5 2.4		7.0 5.5 5.0		3.2 2.8 3.5		2.0 1.4 1.2		5.0 4.0 5.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
10.0	3.0	11.0	3.0	9.0	3.0	8.5	2.5	10.0	2.5	9.2	3.0	11.0	2.5	10.0	2.8	10.5	2.8
9.5	3.0	11.0	3.0	9.0	3.0	8.5	2.5	10.0	2.8	10.5	3.2	10.5	2.5	9.5	2.5	10.5	2.8
10.0	3.0	11.0	3.0	9.0	2.8	8.5	2.5	8.5	2.8	9.0	2.6	11.0	2.0	9.5	2.5	10.0	2.5
10.0	2.8	11.0	3.0	9.0	3.0	8.5	2.5	8.5	3.0	8.5	2.5	11.0	2.2	11.0	2.8	10.5	2.5

(3)

D		D		D		D		D		D		D		D		D	
6.0 4.5 5.0		6.5 4.6 7.0		4.0 3.6 3.5		3.2 2.4 2.6		5.0 8.0 6.0		5.0 5.5 5.3		4.5 3.4 4.0		3.5 3.0 4.0		3.3 3.6 5.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
7.0	2.0	8.0	1.5	6.2	2.0	6.2	1.8	7.5	2.2	7.5	2.0	8.5	2.0	6.0	2.2	8.0	5.8
7.0	2.0	7.5	1.5	7.0	2.2	7.0	1.8	6.5	2.0	8.0	2.0	8.5	2.2	6.0	2.0	8.0	2.5
6.5	2.0	7.5	1.8	7.0	2.5	7.0	1.8	7.0	2.5	8.0	2.0	9.0	2.2	6.5	2.5	8.5	2.2
6.5	2.0	7.5	1.5	6.0	2.0	6.0	1.8	6.0	1.8	7.0	1.8	8.5	2.2	6.0	2.0	8.0	2.5

(4)

D		D		D		D		D		D		D		D		D	
4.0 2.8 2.2		5.0 6.0 6.0		6.0 8.0 6.0		3.6 3.6 6.0		6.0 3.4 5.3		6.6 6.0 7.3		3.2 4.0 5.3		4.6 4.0 5.0		6.0 5.0 5.3	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
6.0	2.0	7.0	2.0	6.0	2.0	8.0	2.8	7.5	2.0	11.0	2.0	8.0	2.2	7.5	2.2	5.5	2.5
6.0	1.8	8.0	2.2	6.0	2.2	7.5	2.2	7.5	2.2	12.0	2.0	8.5	2.5	5.5	1.8	5.0	2.0
6.0	2.0	7.0	2.0	6.0	2.2	8.0	2.2	7.0	2.0	10.5	1.8	7.0	2.0	7.0	2.2	6.0	2.2
6.5	2.0	8.5	2.5	5.5	2.0	8.0	2.5	6.2	2.0	12.0	2.0	8.0	2.5	5.0	2.0	6.0	2.5

(5)

D		D		D		D		D		D		D		D		D	
6.0 5.5 6.0		3.6 4.0 4.0		4.0 4.5 4.0		3.8 4.5 4.0		3.0 3.3 4.0		3.0 4.0 3.3		2.8 3.2 5.3		3.3 4.0 4.0		2.6 2.4 3.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
10.0	1.8	11.5	3.0	12.0	2.0	15.0	3.0	9.0	2.5	8.8	2.2	12.0	2.2	11.0	2.5	13.5	2.5
11.5	2.2	12.0	2.8	11.5	2.2	13.0	2.2	9.5	2.2	10.0	2.5	12.0	2.2	11.0	2.5	10.0	1.8
10.0	2.0	12.0	3.5	11.5	2.5	14.0	2.8	9.0	2.2	9.0	2.0	11.0	2.0	11.0	2.5	11.5	1.8
10.0	2.0	12.0	3.0	13.0	2.0	13.0	2.2	9.0	2.2	9.0	2.0	12.0	2.2	10.0	2.2	12.0	2.0

(6)

D		D		D		D		D		D		D		D		D	
2.4 2.4 2.4		2.8 3.2 3.4		4.0 3.0 4.0		2.8 3.6 3.2		2.8 3.6 4.6		2.4 3.6 4.0		2.2 2.2 2.0		2.4 3.2 2.2		2.0 3.2 3.6	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
6.0	2.2	5.0	2.5	6.5	3.0	5.5	2.2	6.2	2.2	7.5	3.0	7.0	3.0	6.0	2.0	6.0	2.0
6.5	3.0	4.5	2.5	6.8	3.0	5.5	2.2	6.0	2.2	6.5	2.0	7.0	3.0	6.0	2.2	6.0	2.0
6.5	3.0	6.0	3.0	5.8	2.5	5.5	2.5	6.0	2.2	7.0	3.0	6.5	2.5	6.0	2.2	6.0	2.0
6.0	3.0	6.0	3.0	6.0	3.0	5.5	2.2	6.0	2.2	6.5	2.0	6.5	2.8	6.0	2.2	6.0	2.0

(7)

D		D		D		D		D		D		D		D		D	
4.6 2.2 3.0		7.5 8.0 7.0		2.8 4.8 4.4		4.8 5.0 3.0		3.6 3.2 4.6		4.0 7.0 8.0		2.8 2.6 2.8		3.5 3.5 3.5		4.8 4.8 4.8	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
8.0	2.2	8.0	3.0	7.0	2.8	5.5	2.5	5.5	2.2	7.0	2.8	8.0	2.8				
7.0	2.2	8.0	2.8	6.5	2.2	6.0	2.5	7.0	2.2	8.0	3.0	7.5	2.5				
8.0	2.2	8.0	2.8	6.5	2.2	6.0	2.8	6.0	2.5	8.0	2.5	7.5	2.5				
8.0	2.5	7.0	2.5	7.0	2.2	6.5	3.0	5.0	2.5	8.5	3.0	7.0	2.5				

(8)

D		D		D		D		D		D		D		D		D	
2.2 2.0 1.6		8.0 7.0 6.0		2.4 3.0 2.4		3.2 2.4 3.0		4.0 3.5 5.0		2.4 4.0 3.8		1.6 3.2 2.2		2.2 1.4 2.6		4.0 2.8 2.8	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
8.0	3.0	8.5	2.5	9.0	3.2	8.0	2.5	10.0	3.0	8.0	3.0	7.0	3.0	10.5	2.8	8.0	3.0
8.0	3.0	10.0	3.0	8.0	2.8	8.5	2.2	11.0	3.0	7.5	2.8	7.5	3.2	10.5	2.8	6.5	2.5
7.5	3.0	8.0	3.0	8.0	2.5	9.0	2.5	10.8	3.0	8.0	2.8	7.0	2.5	9.0	2.2	8.0	3.0
9.0	3.5	7.5	2.5	8.0	3.5	8.0	2.2	11.0	3.0	8.0	2.5	8.5	3.2	9.5	2.5	7.5	3.0

(9)

D		D		D		D		D		D		D		D		D	
5.0 4.6 3.2		2.0 2.0 4.0		4.5 5.0 4.7		2.0 2.2 2.2		4.0 5.0 5.0		6.0 6.0 6.0		2.0 2.0 1.8		5.0 4.6 4.0		4.0 5.0 3.5	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
9.0	2.5	10.5	2.8	9.0	2.5	10.5	3.0	13.0	3.0	13.0	3.0	15.0	3.5	13.0	3.0	17.0	3.8
9.0	2.5	9.5	2.0	9.0	2.5	11.0	3.0	13.0	3.0	12.0	2.5	15.0	3.5	14.0	3.0	16.0	3.5
9.0	2.8	11.0	2.8	9.5	2.5	11.0	3.0	11.0	2.5	12.5	3.0	13.0	3.0	13.0	3.0	17.0	4.0
9.0	2.5	10.0	2.5	9.0	2.5	11.0	3.0	11.5	2.5	11.5	2.5	13.0	3.0	13.5	3.0	15.0	3.0

Note: Numbers underlined are replacements for missing items.

(10)

D		D		D		D		D		D		D		D		D	
5.0 7.0 8.0		7.0 9.0 7.0		6.0 6.0 5.3		2.5 3.2 5.0		3.2 3.2 3.5		6.0 7.0 6.0		4.0 4.0 4.0		2.8 2.4 3.0		7.0 9.0 8.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
7.5	2.8	6.0	1.8	8.5	2.5	7.0	1.8	7.0	2.0	5.5	2.0	6.0	2.2	7.0	2.2	7.0	2.5
6.5	2.0	7.0	2.0	7.0	2.5	6.5	1.5	6.0	2.0	6.0	2.0	8.0	2.5	8.0	2.5	7.0	2.5
7.0	2.5	5.5	1.8	7.0	2.5	7.5	2.2	6.0	1.8	6.0	2.0	6.8	2.2	6.0	2.2	7.5	2.8
5.0	2.0	6.5	1.8	7.0	2.0	5.0	1.5	7.5	2.0	6.0	2.0	7.0	2.2	6.5	2.2	7.5	2.5

(11)

D		D		D		D		D		D		D		D		D	
8.0 9.0 8.0		6.0 7.2 7.0		2.8 2.8 5.0		2.4 3.6 4.1		2.2 3.2 2.0		3.2 3.2 3.4		10.0 9.0 3.2		2.8 3.0 3.0		8.0 9.0 8.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
8.0	2.0	7.0	2.5	7.0	2.2	6.0	2.5	6.0	2.2	6.2	2.8	10.0	2.5	7.0	2.8	7.0	2.8
8.0	2.0	7.0	2.5	7.5	2.0	6.5	2.5	6.0	2.5	6.0	2.8	8.5	2.0	7.0	2.8	8.0	2.5
8.0	2.0	6.5	2.0	7.5	2.0	8.0	3.0	6.0	2.5	5.5	2.8	8.0	2.2	7.0	2.8	7.0	2.5
8.0	2.0	7.0	2.0	6.5	2.5	6.0	2.5	6.0	2.2	8.0	3.0	6.0	2.0	7.0	2.5	8.0	2.5

(1) = Ruatoria
(2) = Parihauhau
(3) = Parakanapa
(4) = Te Karaka
(5) = Katikati
(6) = Mangleton Block
(7) = Aokautere
(8) = Mangaone
(9) = Awakino
(10) = Tiritea
(11) = Blowhard

D = leaf density/cm. of branch

L = leaf length (mm.)

W = leaf width (mm.)

APPENDIX 21.2 ANALYSES OF VARIANCE OF LEAF FEATURES OF L. SCOPARIUM (EXPERIMENTAL GARDEN SPECIMENS)

Leaf Density

Source of Variation	d.f.	M.S. and F Tests
Replicates	8	20.81 * *
Between areas	10	136.81 * *
Within area	78	5.98 * *
Residual	194	0.87
Total	290	
V %		50

Leaf $\frac{(\text{length})}{(\text{midwidth})}$ Ratio

Source of Variation	d.f.	M.S. and F Tests
Replicates	8	0.43 N.S.
Between areas	10	19.91 * *
Within areas	78	1.47 * *
Residual	291	0.081
Total	387	
V %		47

Leaf (length) (midwidth) Ratio

Source of Variation	d.f.	M.S. and F Tests
Replicates	8	101.48 N.S.
Between areas	10	1931.10 * *
Within areas	78	87.85 * *
Residual	291	10.33
Total	387	
V %		34

APPENDIX 21.3 LEAF FEATURES OF L. SCOPARIUM (EXPERIMENTAL GARDEN SPECIMENS)

Mean values

Leaf Density	L/W	(L)(W)
(1) 8.44	(5) 4.90	(9) 35.14
(10) 4.00	(1) 4.55	(2) 26.66
(11) 3.86	(9) 4.12	(5) 25.78
(4) 3.78	(2) 3.61	(8) 24.12
(3) 3.40	(3) 3.57	(7) 18.57
(7) 3.35	(4) 3.44	(11) 17.02
(9) 2.92	(10) 3.17	(4) 15.66
(5) 2.92	(8) 3.06	(6) 15.30
(2) 2.76	(11) 2.99	(3) 14.79
(8) 2.46	(7) 2.78	(10) 14.38
(6) 2.26	(6) 2.51	(1) 9.87
SE = ± 0.47	0.2	1.56
d.05(.01) = 1.33(1.77)	0.56(0.74)	4.42(5.88)

Note: Area code (bracketed figures) as in Appendix 21.1

APPENDIX 22.1 LEAF FEATURES OF L. SCOPARIUM (TIRITEA SPECIMENS)

Density of leaves and measurements of leaf length and midwidth

(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
D		D		D		D		D		D		D		D	
5.0		4.0		5.0		10.0		4.5		8.0		9.0		7.0	
4.0		8.0		4.0		3.0		4.0		7.0		3.0		10.0	
4.0		8.0		5.0		8.0		4.0		7.0		7.0		4.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
9.0	1.7	8.5	1.8	8.0	2.0	7.0	2.0	6.8	2.2	8.5	1.8	5.5	2.0	8.0	2.8
7.0	1.7	8.0	2.0	8.0	2.0	7.5	2.0	5.0	2.0	9.0	1.8	5.0	2.2	9.0	3.0
7.0	1.5	8.0	1.8	8.0	2.8	7.5	2.0	6.0	2.1	7.5	2.1	7.0	2.5	9.0	3.1
9.0	2.0	9.0	1.8	7.0	1.7	7.0	2.0	6.5	2.0	7.0	2.1	6.0	2.2	9.0	2.0

(9)		(10)		(11)		(12)		(13)		(14)		(15)		(16)	
D		D		D		D		D		D		D		D	
7.0		5.0		6.0		8.0		8.0		9.0		9.0		6.0	
4.0		4.0		4.0		9.0		8.0		5.0		6.0		8.0	
6.0		3.0		7.0		9.0		6.0		7.0		8.0		6.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
7.0	1.8	5.0	2.8	7.0	3.1	6.5	1.8	7.5	1.5	7.0	1.5	8.5	2.0	7.0	1.9
6.0	1.8	5.0	2.5	6.5	2.8	5.0	2.0	8.0	2.0	6.0	1.8	7.0	2.0	8.0	2.2
6.0	1.8	4.5	1.7	7.0	3.5	6.5	1.8	8.0	1.8	6.0	1.5	8.2	1.8	7.0	1.9
6.5	2.0	4.5	1.8	7.0	3.2	5.5	2.0	8.5	1.8	6.8	1.8	9.0	2.2	6.5	1.5

(17)		(18)		(19)		(20)		(21)		(22)		(23)		(24)	
D		D		D		D		D		D		D		D	
7.0		5.0		7.0		7.0		3.0		9.0		9.0		12.0	
5.0		5.0		9.0		4.0		3.0		4.0		8.0		7.0	
6.0		3.0		7.0		6.0		4.0		4.0		5.0		10.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
6.0	2.1	7.0	2.4	7.0	1.8	6.0	2.1	7.0	2.2	8.0	2.5	4.5	1.8	6.4	2.0
6.8	2.1	7.2	2.4	8.0	1.8	7.0	1.8	7.0	2.2	7.0	2.2	4.5	1.8	6.2	2.0
5.8	1.8	6.8	2.4	8.0	2.2	6.5	2.0	7.5	2.0	8.0	2.5	5.0	2.2	5.2	2.2
6.0	2.0	6.0	2.2	8.2	1.8	6.0	2.0	7.0	2.5	7.5	2.8	6.5	2.0	6.2	2.0

(25)		(26)		(27)		(28)		(29)		(30)		(31)		(32)	
D		D		D		D		D		D		D		D	
11.0		5.0		9.0		3.0		8.0		6.0		6.0		8.0	
12.0		4.0		3.0		4.0		9.0		8.0		7.0		12.0	
4.0		6.0		8.0		6.0		7.0		7.0		5.0		10.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
6.5	1.8	5.5	1.5	7.0	2.0	5.1	2.0	5.2	2.1	9.0	2.0	8.0	2.0	7.8	2.5
6.0	1.8	6.5	2.0	7.5	2.0	4.1	2.0	6.0	2.5	7.0	1.8	9.0	2.2	5.0	2.0
6.0	1.8	5.2	1.5	7.0	2.0	6.0	2.0	5.8	2.2	8.5	2.0	7.5	2.0	6.2	1.8
6.8	2.0	5.2	1.5	6.0	1.8	4.8	2.0	5.0	1.8	8.0	2.0	8.0	2.0	6.5	1.8

(33)		(34)		(35)		(36)		(37)		(38)		(39)		(40)	
D		D		D		D		D		D		D		D	
9.0		10.0		7.0		3.0		7.0		4.0		6.0		6.0	
10.0		8.0		3.0		6.0		8.0		6.0		5.0		6.0	
12.0		9.0		5.0		8.0		5.0		5.0		4.0		6.0	
L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
8.0	2.5	8.5	2.2	7.0	2.1	7.0	2.0	6.0	1.8	7.6	2.1	6.0	2.1	7.0	2.0
8.5	2.5	9.0	2.0	7.0	2.5	6.2	2.0	6.0	1.8	6.5	2.0	7.5	1.8	6.5	2.5
8.5	2.5	8.5	2.5	6.0	2.6	6.0	2.5	5.2	1.8	7.8	2.4	6.0	2.0	8.0	2.0
7.5	2.0	8.0	2.0	6.0	2.8	7.0	2.5	6.0	1.5	7.2	2.2	7.5	2.0	8.3	2.0

Note: Bracketed figures represent sample identification number.

D = leaf density/cm. of branch

L = leaf length (mm.)

W = leaf midwidth (mm.)

APPENDIX 22.2 ANALYSES OF VARIANCE OF LEAF FEATURES OF L. SCOPARIUM (TIRITEA SPECIMENS)

Leaf Density

Source of Variation	d.f.	M.S. and F Tests
Samples	39	8.57 * *
Residual	80	3.47
Total	119	
V %		29

Leaf $\frac{\text{(length)}}{\text{(width)}}$ Ratio

Source of Variation	d.f.	M.S. and F Tests
Samples	39	2.56 * *
Residual	120	0.15
Total	159	
V %		11

Leaf (length) (width) Ratio

Source of Variation	d.f.	M.S. and F Tests
Samples	39	41.30 * *
Residual	120	5.24
Total	159	
V %		16

APPENDIX 22.3 LEAF FEATURES OF L. SCOPARIUM (TIRITEA SPECIMENS)

Mean values

Leaf Density		L/W		(L)(W)	
(33)	10.33	(1)	4.71	(8)	23.82
(32)	10.00	(2)	4.54	(11)	21.70
(24)	9.67	(13)	4.54	(33)	19.37
(25)	9.00	(30)	4.16	(22)	19.10
(34)	9.00	(6)	4.13	(34)	18.49
(29)	8.00	(19)	4.13	(31)	16.70
(12)	8.00	(15)	4.10	(3)	16.57
(15)	7.67	(31)	3.96	(15)	16.39
(19)	7.67	(34)	3.94	(35)	16.15
(13)	7.33	(14)	3.94	(18)	15.90
(2)	7.33	(16)	3.76	(30)	15.90
(6)	7.33	(3)	3.74	(38)	15.88
(4)	7.00	(4)	3.62	(21)	15.82
(8)	7.00	(40)	3.56	(40)	15.71
(14)	7.00	(29)	3.52	(6)	15.49
(30)	7.00	(26)	3.46	(2)	15.47
(16)	6.67	(9)	3.45	(19)	14.84
(23)	6.67	(33)	3.44	(36)	14.72
(27)	6.67	(25)	3.42	(4)	14.50
(37)	6.67	(37)	3.39	(13)	14.24
(7)	6.33	(38)	3.38	(1)	13.92
(17)	6.00	(39)	3.38	(16)	13.49
(40)	6.00	(8)	3.31	(27)	13.45
(31)	6.00	(20)	3.25	(7)	13.17
(36)	5.67	(32)	3.17	(32)	13.09
(22)	5.67	(12)	3.12	(39)	13.02
(20)	5.67	(21)	3.10	(5)	12.64
(11)	5.67	(22)	3.08	(20)	12.55
(9)	5.67	(17)	3.08	(17)	12.33
(26)	5.00	(36)	2.95	(24)	12.26
(35)	5.00	(24)	2.94	(29)	11.92
(38)	5.00	(5)	2.92	(9)	11.80
(39)	5.00	(18)	2.87	(25)	11.72
(3)	4.67	(19)	2.75	(12)	11.10
(1)	4.33	(7)	2.64	(14)	10.63
(5)	4.33	(35)	2.64	(10)	10.56
(18)	4.33	(23)	2.63	(23)	10.05
(28)	4.33	(28)	2.50	(28)	10.00
(10)	4.00	(10)	2.73	(37)	9.99
(21)	3.33	(11)	2.19	(26)	9.21
SE = ±	1.08		0.19		1.14
d.05(.01) =	3.04(4.04)		0.53(0.71)		3.21(4.24)

Bracketed figures represent sample identification number.

APPENDIX 23.1 GROWTH RATE INDICATORS IN L. SCOPARIUM
(EXPERIMENTAL GARDEN SPECIMENS)

Crown width (cm.) 26/5/66
Average of 2 measurements taken at right angles at the widest point

Rep Area	a	b	c	d	e	f	g	h	i
1	90	58	65	50	48	48	55	62	53
2	90	72	84	78	73	70	75	90	80
3	90	58	73	55	80	63	65	75	60
4	83	70	43	60	65	73	75	75	78
5	83	82	98	65	65	75	87	72	92
6	88	61	60	60	40	48	67	50	52
7	64	77	60	60	85	52	60	64	60
8	90	93	75	63	93	63	75	85	70
9	70	77	80	83	73	80	70	58	45
10	43	48	58	59	45	52	60	55	50
11	63	72	63	63	62	58	47	47	45

Height (cm.) 26/5/66

Rep Area	a	b	c	d	e	f	g	h	i
1	112	106	122	120	90	114	103	116	111
2	99	100	107	130	103	123	124	120	112
3	102	99	99	117	110	111	130	114	100
4	130	121	133	130	114	113	126	126	145
5	104	120	130	103	129	128	123	112	134
6	121	100	133	139	120	131	105	135	140
7	110	117	130	111	115	125	116	119	124
8	128	121	135	133	124	121	121	109	120
9	86	101	100	106	98	101	90	80	109
10	103	111	113	113	88	118	110	123	111
11	102	90	99	98	103	101	93	104	106

Note: Numbers underlined are replacements for missing items.
Area code as in Appendix 21.1

APPENDIX 23.2 ANALYSES OF VARIANCE OF GROWTH RATE INDICATORS IN L. SCOPARIUM (EXPERIMENTAL GARDEN SPECIMEN)

Crown width (cm.)

Source of Variation	d.f.	M.S. and F Tests
Replicates	8	257.05 *
Areas	10	825.30 * *
Residual	78	110.79
Total	96	
V %		16

Height (cm.)

Source of Variation	d.f.	M.S. and F Tests
Replicates	8	232.00 *
Areas	10	885.60 * *
Residual	78	88.79
Total	96	
V %		8

APPENDIX 24 PHENOLOGICAL OBSERVATIONS IN L. SCOPARIUM (EXPERIMENTAL GARDEN SPECIMENS)

Time of Bud Break

Number of plants from each area showing bud break since previous observation

Area	1	2	3	4	5	6	7	8	9	10	11
11/8/65		1		2	1	1					
25/8/65	6	7	5	7	8	7	2	5	6	3	3
9/9/65	3	1	4	0	0	1	5	4	3	6	6

Flowering Season

Number of plants from each area flowering in spring and/or autumn

Area	1	2	3	4	5	6	7	8	9	10	11
spring	1	2	0	0	3	3	1	2	0	0	0
Autumn	0	0	1	0	0	4	0	1	0	0	1

Note: Area code as in Appendix 21.1

APPENDIX 25: FUNGICIDE TOXICITY TEST

Fungicides in sufficiently high concentration are toxic to higher plants.

Following the failure of L. scoparium seed sown into grassed plots to which Thiram was applied (Section 13.1.2), the effect of the fungicide at recommended spray concentrations was tested on germination. A preliminary test showed that germination proceeded to the stage of testa shedding but no root or shoot growth occurred.

In a more comprehensive test the effects of a range of fungicides on germination of L. scoparium were determined.

METHOD

The tests were carried out in Petri dishes each containing 50 selected viable L. scoparium seeds resting on filter paper. To each dish was added a liquid suspension of one of the fungicides under test, at recommended spray concentrations. Sufficient suspension was added to moisten the filter paper and the seed, and further suspension was added if signs of desiccation appeared. One lot of 50 seeds was also tested against the wetting agent used in plot spraying. As a control 50 seeds were moistened with water. There was no replication.

The fungicides and wetting agent tested, and the concentrations used, are listed below.

DITHANE M22	(Manganous ethylene bisdithiocarbamate)	1½ - 2 lb/100 gal
CAPTAN 50%	(N- Trichloromethyl mercapto 4 cyclo hexene 1,2 dicarboximide)	2 - 4 lb/100 gal
THIRAM	(Tetramethylthiuram disulphide)	1½ - 2 lb/100 gal
P.C.N.B.	(Pentachloronitrobenzene)	1½ - 2 lb/100 gal
AGRAL LN	(wetting agent)	1 tsp./3 gal

The Petri dishes were placed in a germination cabinet and examined one

week after setting out.

RESULTS

(a) DITHANE - Germination, 18%. Seedlings 0.22 - 0.37 cm. long. Apparently normal shoot development. Cotyledons green and normal. No root development.

(b) CAPTAN 50% - Germination, 100%. Seedlings 0.13 - 0.37 cm. long. Most shoots twisted and tinged brown. Many cotyledons colourless. No root development.

(c) THIRAM - Germination, 100%. Seedlings 0.2 - 0.34 cm. long. All but three showing no colour and no further signs of development after testa shed.

(d) P.C.N.B. - Germination, 94%. Seedlings 0.35 cm. av. length. Cotyledons green. Root elongation and root hair development apparent.

(e) AGRAL LN - Germination, 98%. Seedlings 0.19 - 0.24 cm. long. Little cotyledon colouration and no root elongation or root hair development.

(f) CONTROL - Germination, 100%. Seedlings av. 0.71 cm. long. Cotyledons green. Stems tinged red. Root elongation and profuse root hair development apparent.

The effect of the various treatments can be seen in Fig. 34.

On the evidence of these tests no further attempt was made to control Rhizoctonia brownspot.

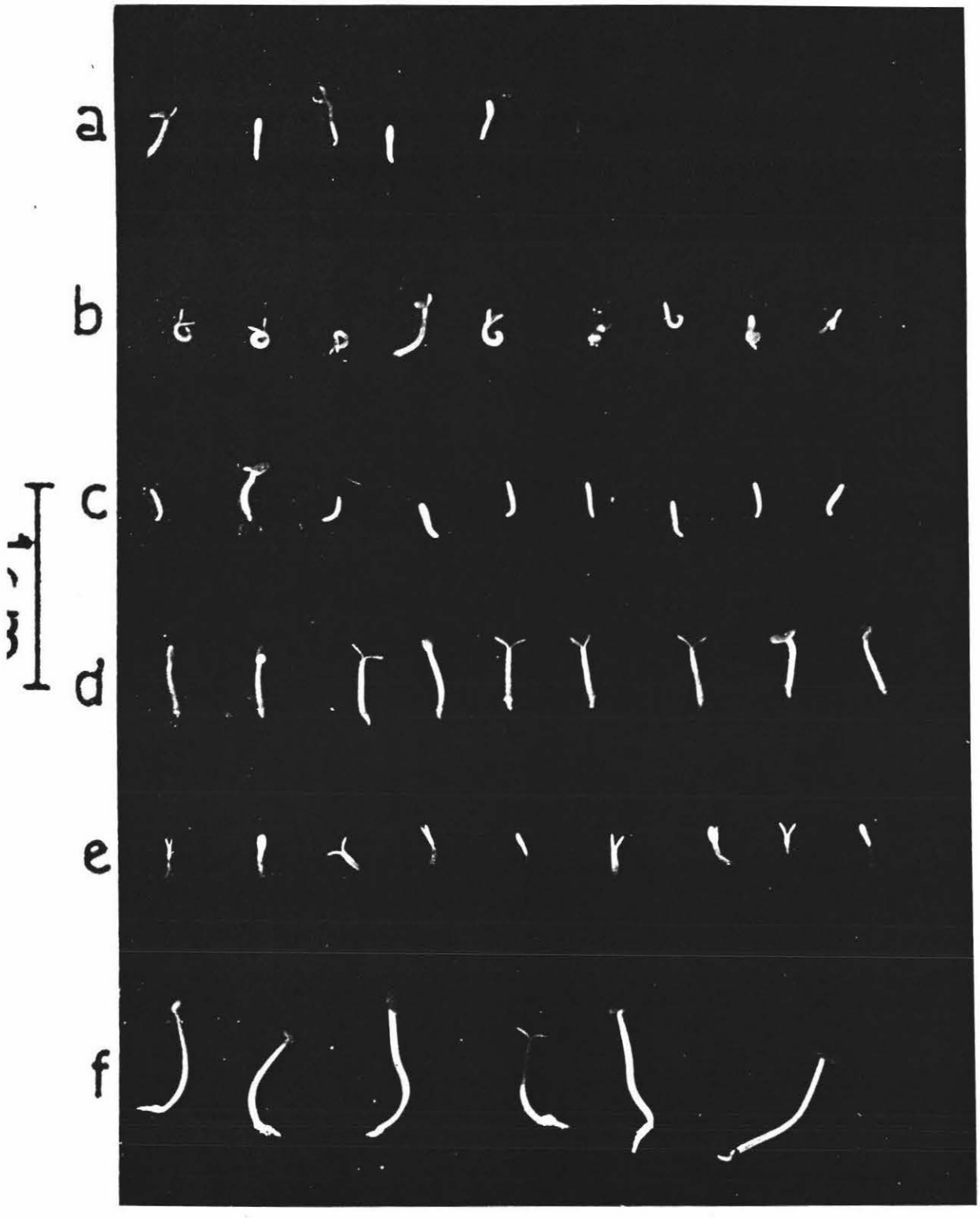


FIGURE 34: THE INFLUENCE OF FUNGICIDES ON THE GERMINATION OF L. SCOPARIUM

a. Dithane
b. Captan
c. Thiram
d. P.C.N.B.
e. Agral
f. control

APPENDIX 26: CONSTRUCTION AND CALIBRATION OF A CADMIUM SULPHIDE LIGHT METER.

GENERAL

Canopy disturbance is a major problem in measuring light values within short swards.

In the experiment described in Section 13 cut grassed plots with no applied fertilizer seldom carried herbage exceeding a height of 1 - 2 cm. and no cut grassed plots had foliage greater in height than 12 - 14 cm. (Figs. 23 - 28). Inserting the probe of a light meter, similar to that described by Barrowman (1956), into the sward of a fortnightly-cut grass plot with no applied fertilizer spread the canopy to such an extent that the probe was completely exposed. Disturbance to the canopies of other cut grass treatments occurred also. The same problem would arise using the light meters developed by Allan and McCree (1955), and Giovanelli (1953).

An investigation was made into the possibility of constructing a light meter causing minimum canopy disturbance and sensitive to radiation in the 400 - 700 mμ wavelength band. Restriction to this wavelength band is necessary because it is thought that most important photobiological processes are activated by radiation in the range 400 - 760 mμ. Also Loomis (1965) showed that vegetation intercepts 80 - 75% of blue (400 - 500 mμ), 60 - 80% of green (500 - 600 mμ), and 80 - 90% of red (600 - 700 mμ) light, and that above 700 mμ absorption by vegetation fell rapidly to about 5%, the remaining proportion being almost equally divided between reflection and transmission.

Devices commonly used in measuring solar radiation were

discussed by Anderson (1964), Stern (1962), Geiger (1965), Gates (1962), and others. Briefly these devices fall into two categories:

(a) Photometric devices consisting of semiconductors or chemical integrators. These have various spectral sensitivites and are normally calibrated in photometric units (based on the spectral sensitivity of the human eye).

(b) Radiometric devices, working on a black body principle, responding equally to all incident radiation or some portion of this as delimited by filters. Radiation received is measured in terms of energy units.

Solar radiation reaching a plant community varies in quantity and spectral quality. The transmission, absorption, and reflection of different wavelengths of this radiation by plants varies with species. Under these circumstances interpreting the readings of a device of variable sensitivity reading in photometric units is difficult. Comparison of the results of workers using different photometers would be confusing. However, because of their cheapness and availability, photometers are used. To reduce the confusion liable to arise Anderson (1964) stressed the importance of stating the spectral sensitivity of the instrument and the conditions under which measurements were made.

Within the same plant community interception of light can differ depending on numerous factors (Stern, 1962; Anderson, 1964). Ideally an integrating recorder is necessary to record "typical" light values within a community. Where treatments within an experiment are being compared a large number of spot readings could be sufficient.

LIGHT METER CONSTRUCTION AND CALIBRATION

A Phillips ORP 63 Cadmium sulphide photosemiconductor 6 x 30 mm. with high spectral sensitivity in the visible range, was used as the basis of a spot reading light meter. Full technical data on the cell are available in the Phillips Semiconductor Manual 1963.

The major disadvantage of the CdS cell was sensitivity to radiation of wavelengths greater than 700 mμ (radiation transmission by vegetation increases greatly above this point; Loomis, 1965). (Fig. 35). Selective absorptance by white PVC film used to shield the photocell reduced this effect (Fig. 35), and subsequent tests have shown that sensitivity to light transmitted by leaves is very low (Table 18).

TABLE 18

RESPONSE OF CdS LIGHT METER TO RADIATION TRANSMITTED BY LEAVES

Scale reading per additional leaf covering probe head

No. of leaves	0	1	2	3	4	5
Senecio petasites	6700	210	47	15	8	4
Hibiscus sp.	6200	180	49	21	11	7

Spectral absorptance of the white PVC film was determined on a Beckmann DU photometer (Fig. 35 and Table 19). The relative transmission of the PVC film was determined over a range of wavelengths working either way from the maximum wavelength transmission point which was taken as 100. A similar procedure was adopted without the PVC film in place i.e. using unfiltered Tungsten filament light. The difference between the resultant curves, after rescaling because the maximum transmission of PVC did not coincide with maximum wavelength

radiation of unfilter Tungsten filament light, was taken as the absorptance of PVC film. The presence of PVC film over the photocell reduced the amount of light falling on the cell to one-fifth.

Details of the probe head construction and the positioning of the photocell can be seen in Fig. 37.

The light meter circuit diagram is given in Fig. 36 and a picture of the completed instrument can be seen in Fig. 38.

The CdS photosemiconductor decreases its resistance to an applied voltage, as the amount of light falling on the sensitive surface increases. This process is non-linear (Phillips Semiconductor Manual 1963). The photocell was set in parallel with a 0-1 milli-ammeter. Light falling on the photocell lowered its resistance causing more current to flow around the photocell loop with a consequent alteration in meter reading. By varying the resistance load in various parts of the circuit and incorporating a diode, three ranges were possible each occupying over two-thirds scale reflection with a total coverage of 10,00 arbitrary units. The coverage of each range was

A	0	-	100
B	100	-	1000
C	1000	-	10,000

Basic circuitry for each range was designed by Mr. E.R. Hodgson, Senior Lecturer in Physics, Massey University. The actual resistance values to give most satisfactory scale coverage were determined by trial and error on the light bench described below.

Calibration was carried out in a dark room on a 3 m. light bench using a Phillips 250 watt P28S Tungsten filament lamp as the

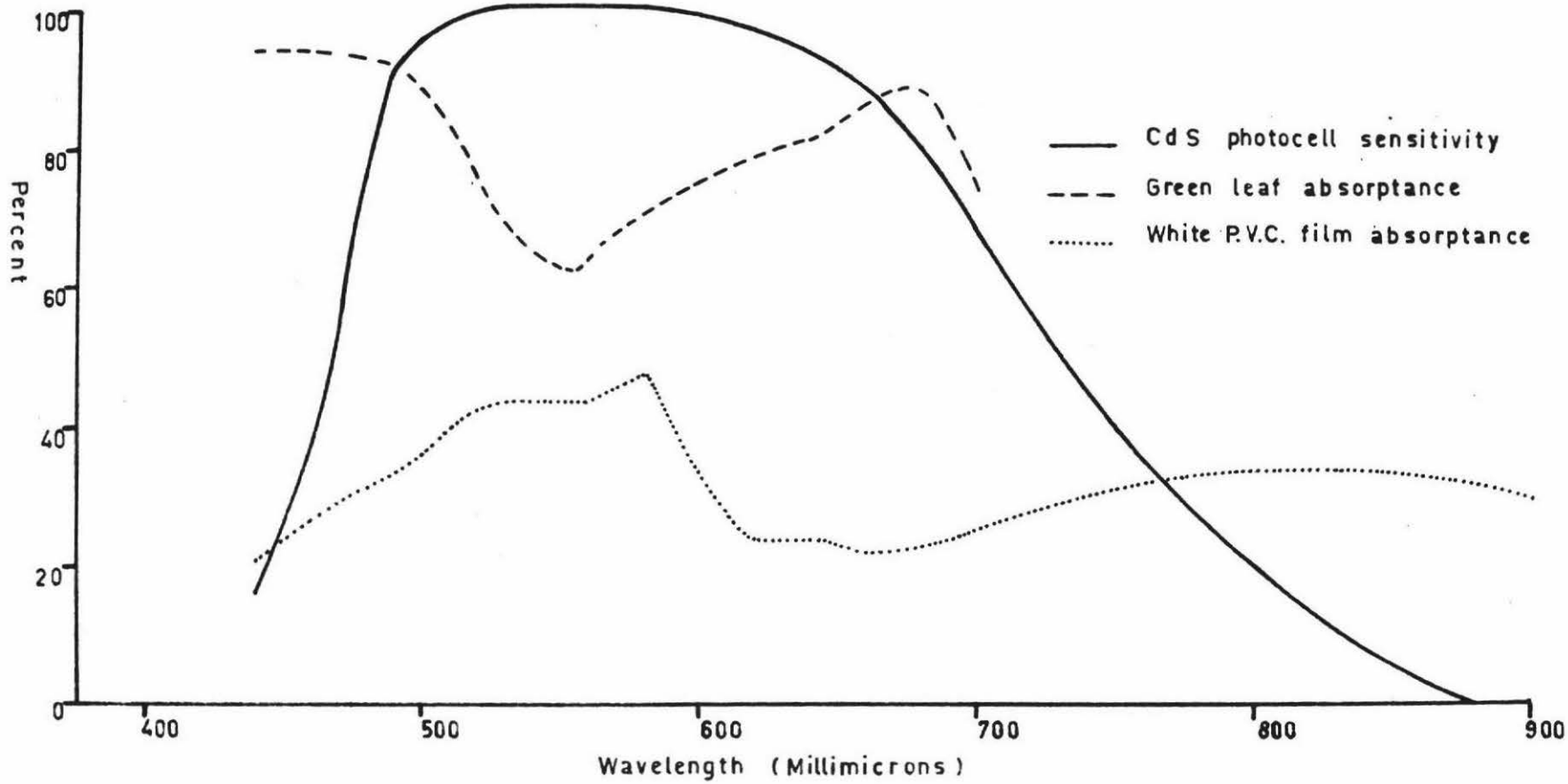


FIGURE 35: ABSORPTION AND SENSITIVITY SPECTRA

Green leaf absorption spectra. Loomis (1965)
CdS photo cell sensitivity. Phillips Semiconductor Manual 1963.
PVC film absorptance (determined on a Beckmann Photometer).

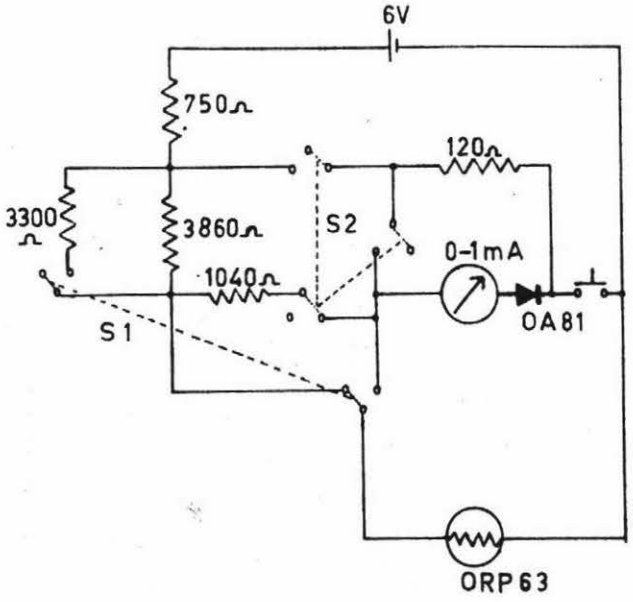


FIGURE 36: CdS LIGHT METER CIRCUIT DIAGRAM

Switches (S1, S2) are shown set for range A.
Shifting S1 sets for range B.
Shifting S1, S2 sets for range C.
750 resistance in circuit is permanent setting point for voltage regulator rheostate shown in Fig. 38.

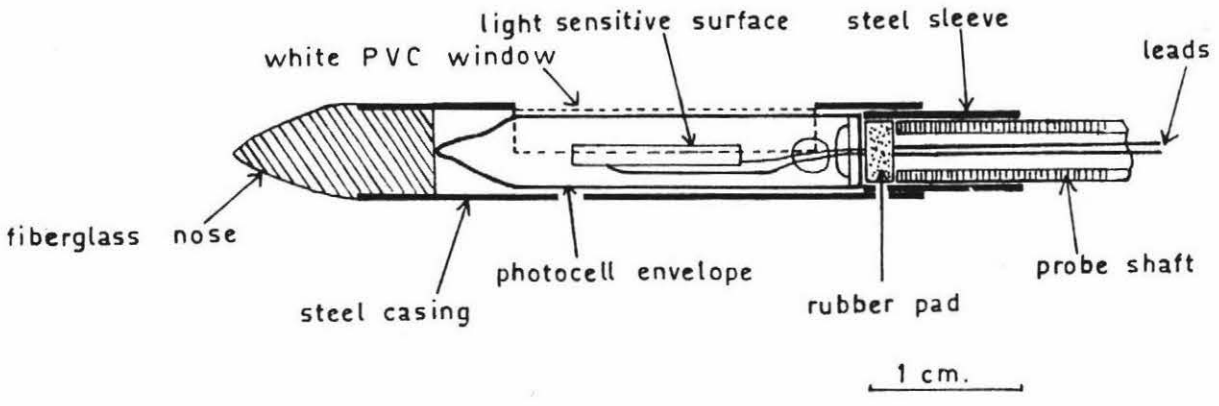


FIGURE 37: CdS LIGHT METER PROBE HEAD CONSTRUCTION

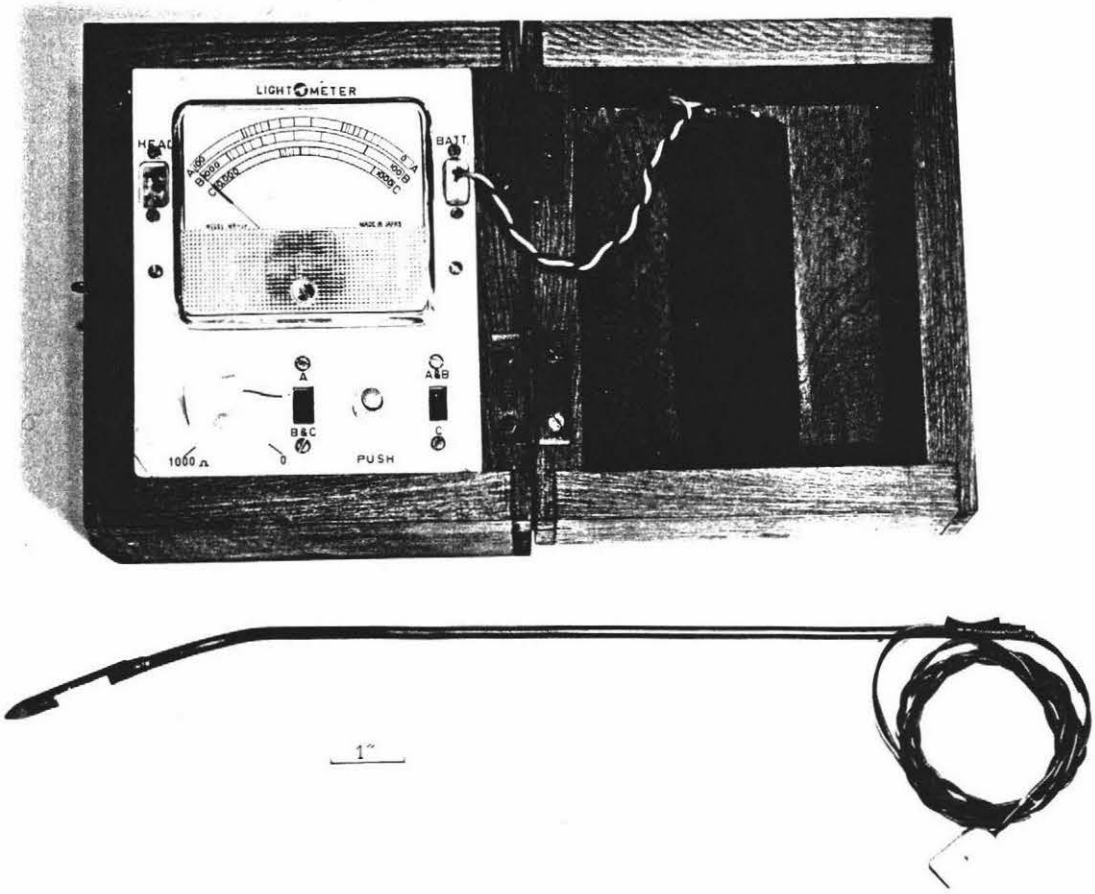


FIGURE 38: CdS LIGHT METER

Voltage supply (four heavy duty Penlite cells) housed in black box. Probe lead connects to socket on left.
Setting switches to: A, A & B gives range A (low illuminance)
B & C, A & B gives range B (medium illuminance)
B & C, C gives range C (high illuminance)
Scale reads right to left. Figures at scale ends apply to nearest division towards the centre (except for 0 where nearest division is 3). Reading taken by setting range switches appropriately and pressing push button. Voltage will influence reading. To check voltage set to range A, place head in darkness. Reading should lie to extreme right of scale. 0 - 1000 rheostat was intended as a voltage balance but shifting from the 750 position severely influences B and C scale readings.

TABLE 19

BECKMANN DU (200-2000 mμ) PHOTOMETER
DETERMINATION OF PVC ABSORPTION SPECTRUM.

% wavelength transmittance

Wavelength mμ	(a)	(b)	
400	0	5.5	
450	0.5	15	
500	3.0	30	
525	4.9	39	
550	5.9	41	
575	6.2	38	
600	5.7	30	meter blue/red sensitivity change
625	1.7	7.8	
650	2.8	11	
675	4.4	15.5	
700	6.7	21.2	
725	10.0	27.8	
750	14.0	35	
775	18.5	42	
800	24.0	49	
850	36.0	60	
900	52.5	72	
950	79.0	93	
980	--	100	
1000	98	98	
1010	100	--	
1050	89.3	75	
1100	51.5	37	
1150	20.2	11.8	
1200	5.4	2.8	
1250	0.9	0.7	

(a) light filtered through white PVC film

(b) unfiltered Tungsten filament light

light source. By variation of the distance between the light source and probe head the meter was calibrated in arbitrary units using the law:

$$\text{Illuminance} = \frac{\text{Intensity}}{(\text{Distance})^2}$$

Illuminance was taken as 10,000 units at 5 cm. from the light source. Error could result from the fact that the above formula applies to a point light source, a requirement which a Tungsten filament lamp may not meet over short distances.

Calibration data are given in Table 20 and the calibration curves in Fig. 39. The relationship between values given by the Cds meter and the readings in foot candles of an Evans Electroselenium meter as determined on the light bench can be seen in the same figure. The ratio between the two sets of readings varies from three at very low illumination to 1.6 when the Evans meter shows an illuminance of 1000 foot candles. Readings of afternoon sunlight by the Cds meter and an Eppley pyroheliometer (transformed into foot candles) correspond at about 2000 foot candles.

Conversion of the log intensity scale in Fig. 39 to an arithmetic scale as in Fig. 40 gives some idea of the accuracy of the meter within each range. In all cases response is greatest to the lowest values of illuminance covered by each scale. Inaccuracies also arise in estimating values between the marked divisions on a log scale thus accuracy is probably limited to the units into which each scale is divided (see Fig. 38).

The results of an angular response test are given in Fig. 41.

Meter performance could be improved by ensuring a constant voltage supply, and accuracy increased by recalibration using a more powerful light source to enable high illuminance positions to be determined at a greater distance from the source, and a detailed spectral response determination for the probe head.

Under field conditions the meter was easy to use and gave satisfactory results.

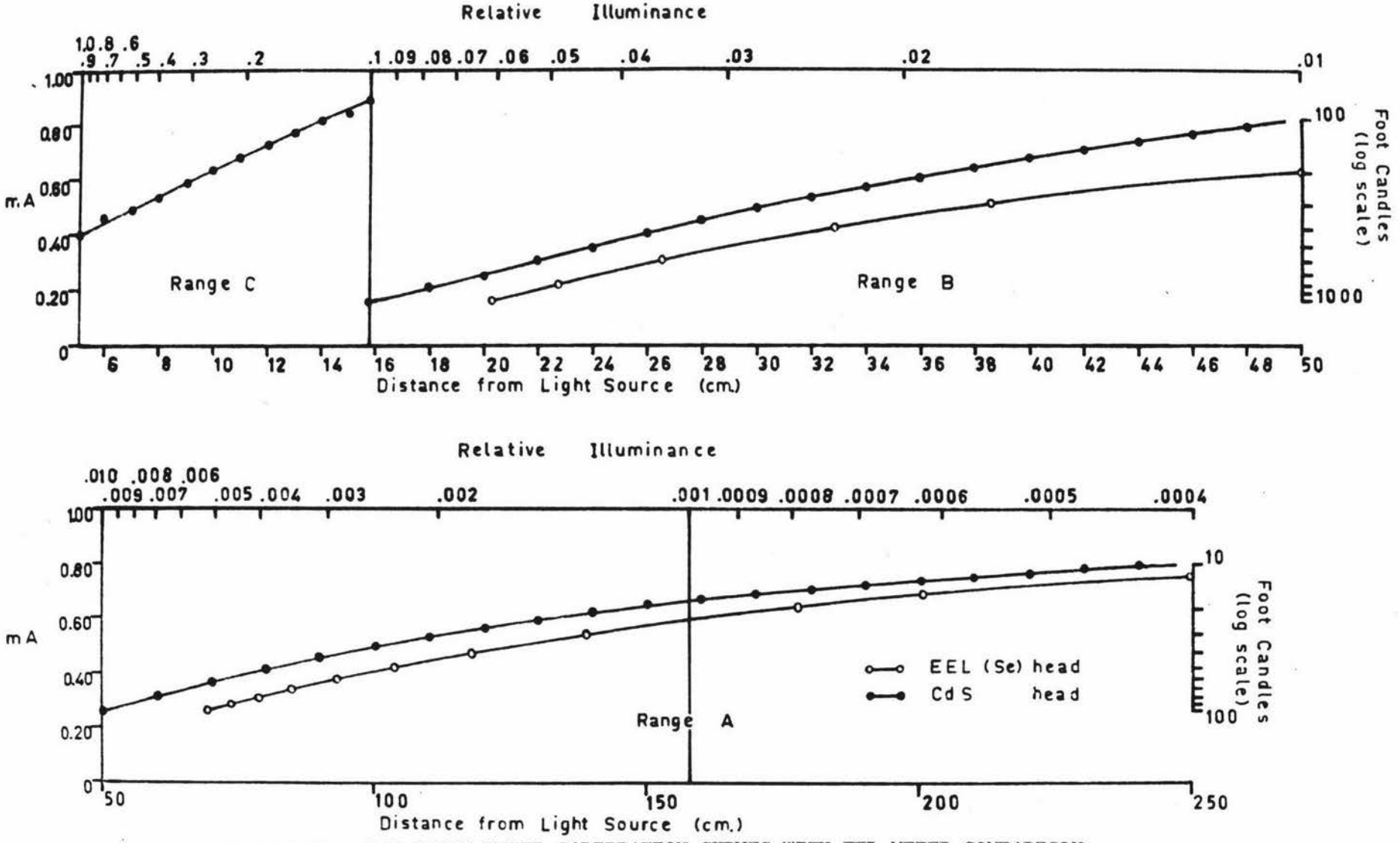


FIGURE 39: CdS LIGHT METER CALIBRATION CURVES WITH EEL METER COMPARISON

0 - 1 milli-ammeter readings of CdS meter against distance from light source. Foot candle readings of EEL meter over same light bench are shown fitted to a log scale covering the CdS meter deflection range. See text.

TABLE 20

CdS LIGHT METER CALIBRATION DATA

Readings of 0-1 milli-ammeter with distance (cm.) from Tungsten filament light source.

cm.	mA
4	.34
5	.39
6	.46
7	.49
8	.53
9	.58
10	.63
11	.68
12	.725
13	.77
14	.81
15	.84
16	.89
range change	

cm.	mA
16	.16
18	.21
20	.25
22	.30
24	.34
26	.40
28	.43
30	.49
22	.53
34	.56
36	.60
38	.64
40	.67
42	.70
44	.74
46	.77
48	.79
50	.82
range change	

cm.	mA
50	.25
60	.31
70	.36
80	.41
90	.45
100	.49
110	.53
120	.56
130	.59
140	.62
150	.65
160	.67
170	.69
180	.70
190	.72
200	.74
210	.75
220	.77
230	.78
240	.79
250	.80
260	.81
270	.82
280	.825
290	.835
300	.84

Note: A re-test gave readings within $\pm$ .005 mA.

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