NUTRIENT STUDIES
of
TWO CENTRAL AUSTRALIAN GRASSES.

A thesis submitted by

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to the

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in partial fulfilment of the requirements of the
Degree of Bachelor of Science with Honours.

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DECLARATION.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University.

To the best of my knowledge and belief this thesis contains no material previously published or written by another person, except where due reference is made in the text.

Kym Nicolson.

ACKNOWLEDGEMENTS.

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I am particularly indebted to Mr. C. Lendon and all the members of C.S.I.R.O., L.R.M. Alice Springs for their hospitality and assistance while working in Central Australia.

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CONTENTS

SUMMARY.

The grazing of domestic herbivores under rangeland conditions has important economic implications, but the ecological implications must also be considered if the rangelands are to remain a viable resource. As such a large area of Australia is maintained as rangelands, serious study is required to evaluate the effects of grazing.

It has long been recognized that grazing can cause marked changes in the botanical composition of a vegetation unit, however the effects of grazing on the soil are less well documented. In the Central Australian context, "increaser" and "decreaser" species (terminology of Dyksterhuis, 1949) can be recognized within three major ecounits in varying range condition (range condition classes). It has previously been shown that there are marked soil nutrient differences across range condition classes.

This project was an attempt to determine if nutrients may be affecting the behaviour of species as either "increaser" or "decreaser" species. This was achieved through the addition of nutrients under a factorial design, to different range condition soils. From this it could then be determined if there were nutrient limitations restricting growth, and how these limitations were related to range condition soils.

From this it was found that for the "increaser" species on Mitchell grass, namely *Eragrostis setifolia*, there were limitations of growth produced by deficiencies of N P and S. The N and P deficiencies appeared closely related to range condition, where poor range condition soil appears to be depleted of available P. From this it was concluded that a loss of range condition implied a loss of available soil P. This then gave *Eragrostis setifolia* an increase in growth potential relative to *Astrebla pectinata* (the decreaser species).

The second experiment tested the response of the "decreaser" species, *Enneapogon polyphyllus*, from the Mulga ecounit to added nutrients. It was found that there were marked responses to the addition of N and P, however these responses were not dependent on the range condition soil. From this it was concluded that the Mulga soil is very low in the major nutrients, but that the effect of grazing does not alter the soil nutrients to the extent that differences in species growth can be observed. It is more likely that in this case grazing influences the species relative competitive abilities or the ability of the species to survive after germination.

It is concluded that grazing plays an important role in the determination of vegetation types under grazing, through changes in the nutrient status of the soil. However, a number of other possible effects of grazing should be considered.

CHAPTER 1.

INTRODUCTION AND AIMS.

1.1 INTRODUCTION.

The pastoral lands of Australia are taken as to include the arid and semi arid regions of this continent. These areas are used for pastoralism as they are unsuitable for intensive agricultural purposes, chiefly due to the erratic rainfall characteristic of these areas. The rangelands cover an area of 5,700,000 square kilometres, this being 74% of the continent. (Box and Perry, 1971) This large area supports about one third of Australia's grazing animals yet is only inhabited by 3% of the population (Box and Perry, 1971). Although these areas are sparsely populated, they cannot be regarded as pristine or virgin communities, as man has had an extensive influence on them, often producing marked shifts in the botanical composition. Man's influence chiefly been exerted through increased fire frequency and the introduction of non-native herbivores.

As the world population increases there will be an increased demand for pastoral products (Box, 1974). This increased demand will place pressure on the pastoral industry to increase production. This industry relies on production from a fixed resource area, so for increased total production from these areas there must be an increased efficiency of use of the fixed vegetation and soil resource. Increased efficiency will come mainly through the adoption of management policies based on a sound scientific understanding of the interaction between grazing animals and the communities.

Before such management policies can be proposed we must define the aims of rangeland management. It appears that there are two principal attitudes towards the rangelands. The first of these regards the arid lands as a renewable resource (Heathcote, 1969); the second considers that the pastoral industry should be

treated as a slow mining proposition (Cambell, 1968) in which case the resource is regarded as non renewable. From an ecological point of view, the first of these attitudes is more acceptable (Williams, 1974) and so, much of the input into rangeland research is orientated towards conserving vegetation and soil resource, ad infinitum. This conservation must be balanced with the desirability of maintaining the pastoral industry as an economically viable proposition.

Before any management policies can be formulated a sound scientific knowledge of community dynamics is required. These dynamics must be understood in relation to the effects of grazing animals as the causative factor producing change.

1.2 SUCCESSION.

A brief resume of succession is required because secondary succession as proposed by Clements (1916) relies on community change induced by a disturbance. The community gradually resumes the structure and composition of the surrounding undisturbed area by an orderly sequence of species replacements. In this situation, grazing is the disturbance to the community. The effect of grazing on the vegetation is often referred to as retrogression rather than succession. The retrogression of the plant cover under grazing does not follow in the reverse order to the succession that gave rise to it. Because retrogression is usually of the vegetation and not of the soil, since the soil is much less damaged than the vegetation, soil retrogression usually lags far behind the vegetation retrogression. Therefore most changes in vegetation, especially short term changes, can be attributed to the effects of livestock. (Stoddard, Smith and Box, 1975). However over long periods of grazing there may be a weakening of the soil-protecting vegetation which can then lead to soil deterioration.

Grazing is highly species specific (Leigh, 1974) and for this reason there is a continuous pressure on some species, whereas others may be relatively unaffected by grazing. If classical successional theories are accepted, then it is conceivable that

the change in community composition may cause a change through environmental modification by the major species present. This then may also influence the botanical composition of the community. The change in the botanical composition under grazing is often referred to as change in the range condition, where -
"Range condition is the state of health or productivity of both soil and forage of a given range, in terms of what it could be or should be under normal climate and best practical management". (From Society of American Foresters, 1944).

This definition of range condition is usually quoted as the most acceptable for the needs of management. This emphasizes the point made in section 1.1 where it was stated that the rangelands can be regarded as a renewable resource. In classifying range condition the most commonly used categories are excellent, good, fair and poor. There are a number of methods of assessing range condition, for example Humphrey, (1947); Parker, (1954); Demming, (1957); Chippendale, (1963) and Condon, (1968). The first attempt to apply ecological principles to range condition assessment was that of Dyksterhuis, (1948, 1949) who recognized different species behaviour in response to grazing. These species were designated as either "Increaser", "Decreaser" or "Invader" species. The first two types of species behaviour are considered in this project.

1.3 INCREASER AND DECREASER SPECIES.

As has previously been mentioned (Section 1.2) some species are disadvantaged by grazing. These species usually decrease in abundance under grazing and hence the term "Decreaser" applied by Dyksterhuis (1949). "Increasers" are the species favoured by grazing and so increasing in abundance. This behaviour is shown in Figure 1.1.

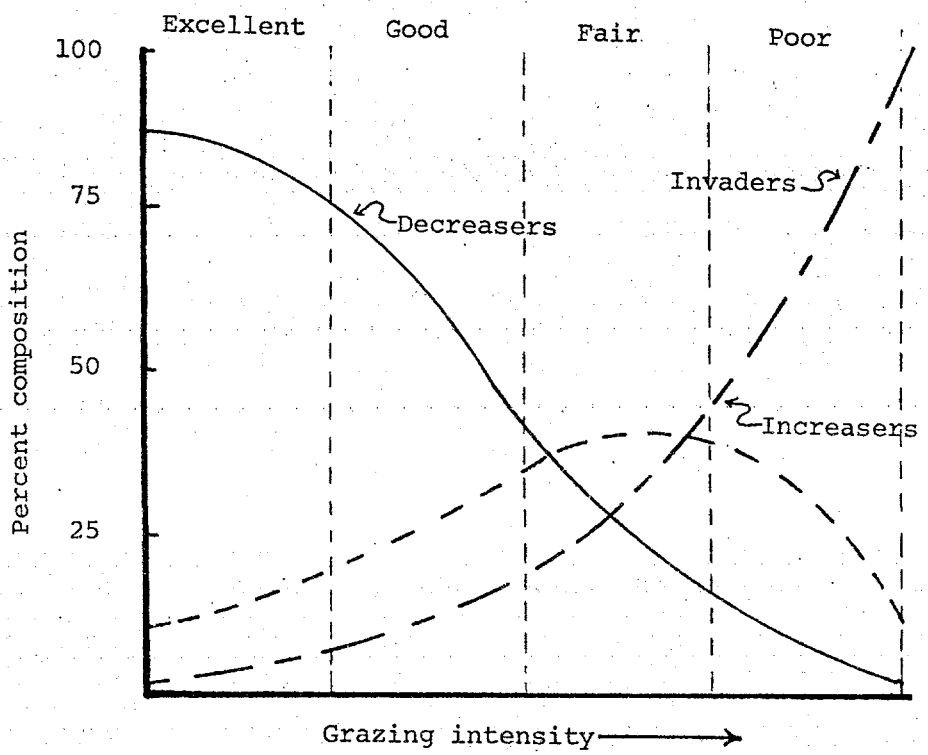
The range condition assessment study of Lendon and Lamacraft (1976) on the Alice Springs study area showed that certain species displayed a similar behaviour to that described by Dyksterhuis (1949) in relation to range condition classes.

1.4 AIMS.

The aim of this project was to study the nutrient response of two of the species identified by Lendon and Lamacraft (1976) as either increaser or decreaser species. Soil nutrient analysis by Dr.Friedel (unpublished data) had indicated that there were significant nutrient differences across range condition classes. Charley and Cowling (1968) had shown that grazing may markedly influence the soil nutrient status, in particular, significant nutrient losses were shown. The experiment was designed to test the effect of a number of nutrients on the growth of the species when grown in their field soils. The intention was to determine if there were nutrient changes across range condition classes which may be influencing the species behaviour as an increaser or decreaser species. With grazing there may be reduction of some important nutrients which give some species an advantage over other species. If grazing is shown to reduce nutrient levels then it could be expected that the increaser species may be adapted to lower level of some nutrients. This adaptation to low levels (Billings, 1957) is particularly important in the Australian arid zone context as these soils have been shown to have low nutrient levels (Charley and Cowling, 1968).

Other sections of this work include a study of the germination characteristics of the major increaser species . (Chapter 6). This was deemed necessary for the success of the pot trial as well as being an important factor in determination of seasonal floras. (Mott, 1972).

FIGURE 1.1



From Stoddard et al (1975).

CHAPTER 2.

BACKGROUND AND SPECIES STUDIED.

2.1 INTRODUCTION.

The research conducted in this project is principally a physiological investigation, however it relies on ecological observations made previously by members of C.S.I.R.O. L.R.M.* Alice Springs. This chapter deals with the field areas from which species were taken for pot trials.

2.2 C.S.I.R.O. BURT PLAIN STUDY AREA.

The C.S.I.R.O., Division of Land Resource Management in Alice Springs, have a major study programme on the Burt Plain principally involved with rangeland management. The Burt Plain, 35 Km north of Alice Springs, extends westwards along the Mac Donnell Ranges and the study area involves four stations, Hamilton Downs, Milton Park, Amburla and Narwietooma. The location of these is indicated on Map 2.1. and 2.2.

2.3 VEGETATION.

On the Burt Plain ecosystem four vegetation types or ecounits have been selected as the major grazing vegetation types. There are -

(a) Mitchell grass *(Astrebla pectinata)* plains.
(b) Open woodland.
(c) Mulga *(Acacia aneura)* shrubland with annual grass understorey.
(d) Mulga shrubland with perennial grass understorey.

Enclosures had been erected in the first three of the above ecounits. The sites were chosen as representing different range condition classes, namely excellent, good, fair, and poor condition areas. These sites had been selected to minimize site differences so

* C.S.I.R.O., Division of Land Resource Management, Alice Springs.

that the differences could be attributed to grazing effects. (C.Lendon,* pers. com.).

The Mulga shrubland and the Mitchell grass plains will be discussed, as species from these ecounits were used in pot trials.

2.3.1 MULGA *(Acacia aneura)* ECOUNIT.

The Mulga shrubland consists of regions of trees, *Acacic aneura* referred to as groves and the regions between the groves called the intergroves. The intergrove regions are covered with low shrubs and grasses and it is some of these intergrove species which are sensitive to grazing. The groves may vary from 20 - 400 m long while the intergrove region may be 5 - 50 m wide (Perry and Lazarides, 1960).

In the intergroves the principal species were *Enneapogon polyphyllus, E. avenaceus, Aristida species, Digitaria brownii and Bassis cornishiana,* however this botanical composition varies across range condition classes, as well as there being a large number of less important species.

2.3.2 MITCHELL GRASS *(Astrebla pectinata)* ECOUNIT.

The Mitchell grass regions usually occur without an upper tree storey. The communities may vary from a uniform stand of *A. pectinata* to a community in which *Eragrostis species* may predominate over the *A. pectinata.* There are three *Eragrostis* which occur in these areas namely *E. setifolia, E. xerophila* and *E. falcata.* In areas of poor condition there may be increase of other species such as *Aristida latifolia.*

The tussocks of *A. pectinata* are usually about 20 - 30 cm in diameter and 30 - 120 cm high (Lazarides, 1970) although commonly less than 60 cm high. The tussock spacing varies but is about 60 cm (Perry and Lazarides, 1960). These spaces may be bare, but often in good seasons they abound with small forbs and grasses.

* C.Lendon, C.S.I.R.O. L.R.M. Alice Springs.

The growth of *A. pectinata* is limited to the summer season as for most of the grasses (Davies et al, 1938; Roe and Allen, 1945). These areas are also reported to be sensitive to heavy stocking (Roe and Allen, 1945) with *A. pectinata* being the first perennial which is reduced in vigour. As the *A. pectinata* decreases there is a concomitant increase in the other grasses (Roe and Allen, 1945). However the pastures are not affected by light to medium stocking.

2.4 BURT PLAIN INCREASER AND DECREASER SPECIES.

Part of the work of C.S.I.R.O. L.R.M. Alice Springs was to derive a range assessment scheme which was based on a number of variable factors within the ecosystem. This system of assessment was described by Lendon and Lamacraft (1976). This assess- study was the background to the work of this project. The work of Lendon and Lamacraft (1976) indicated that across range condition classes there was a change in the botanical composition of the grasslands. It was shown that this species behaviour was similar to that proposed by Dyksterhuis (1949). See chapter 1. Not all species change in response to grazing pressure. The behaviour of the major species is indicated on graphs 2.1 - 2.3. (From Lendon and Lamacraft, 1976).

Graph 2.1 shows the vegetation changes that occur when the Mitchell grass plains are heavily grazed causing a loss in range condition. As range condition declines, so does the percentage biomass contribution of *A. pectinata*, the decreaser species. The species which are increasers are the three *Eragrostis* species namely *E. setifolia*, *E. xerophila* and *E. falcata*.

Graph 2.2 shows the vegetation changes in Mulga annual ecounit (From Lendon and Lamacraft, 1976). The main decreaser species are the grasses *Digitaria brownii*, *Aristida contorta* and *Enneapogon polphyllus*. The decreaser species chosen for the second pot trial was *E. polyphyllus*. The increaser species is the chenopod shrub *Bassia cornishiana*.

Graph 2.3 indicates the major increaser and decreaser species for the open woodland ecounit. The decreaser species are the *Enneapogon* species *(E. polyphyllus* and *E. avenaceus)* and the increaser species is *Aristida contorta.* The species of this ecounit, although not mentioned in section 2.3 are included as it is interesting to notice that the decreaser species is the same as for the Mulga shrubland ecounit. The other interesting point is that *Aristida contorta* acts as a decreaser species in the Mulga ecounit, but acts as an increaser species in the open woodland ecounit.

The increaser and decreaser species for the different ecounits are -

DECREASER.

MITCHELL GRASS	MULGA SHRUBLAND	OPEN WOODLAND.
Astrebla pectinata	*Digitaria brownii*	*Enneapogon polyphyllus*
	Aristida contorta	*Enneapogon avenaceus*
	Enneapogon polyphyllus	

INCREASER.

MITCHELL GRASS	MULGA SHRUBLAND	OPEN WOODLAND.
Eragrostis setifolia	*Bassia cornishiana*	*Aristida contorta*
Eragrostis falcata		
Eragrostis xerophila		

Dr.Friedel has completed the pot trials for *E. polyphyllus* on open woodland soil and *A. pectinata* for the Mitchell grass soil. In this project the nutrient responses of *E. setifolia* from the Mitchell grass plains and *E. polyphyllus* from the Mulga shrubland will be studied.

MAP 2.1

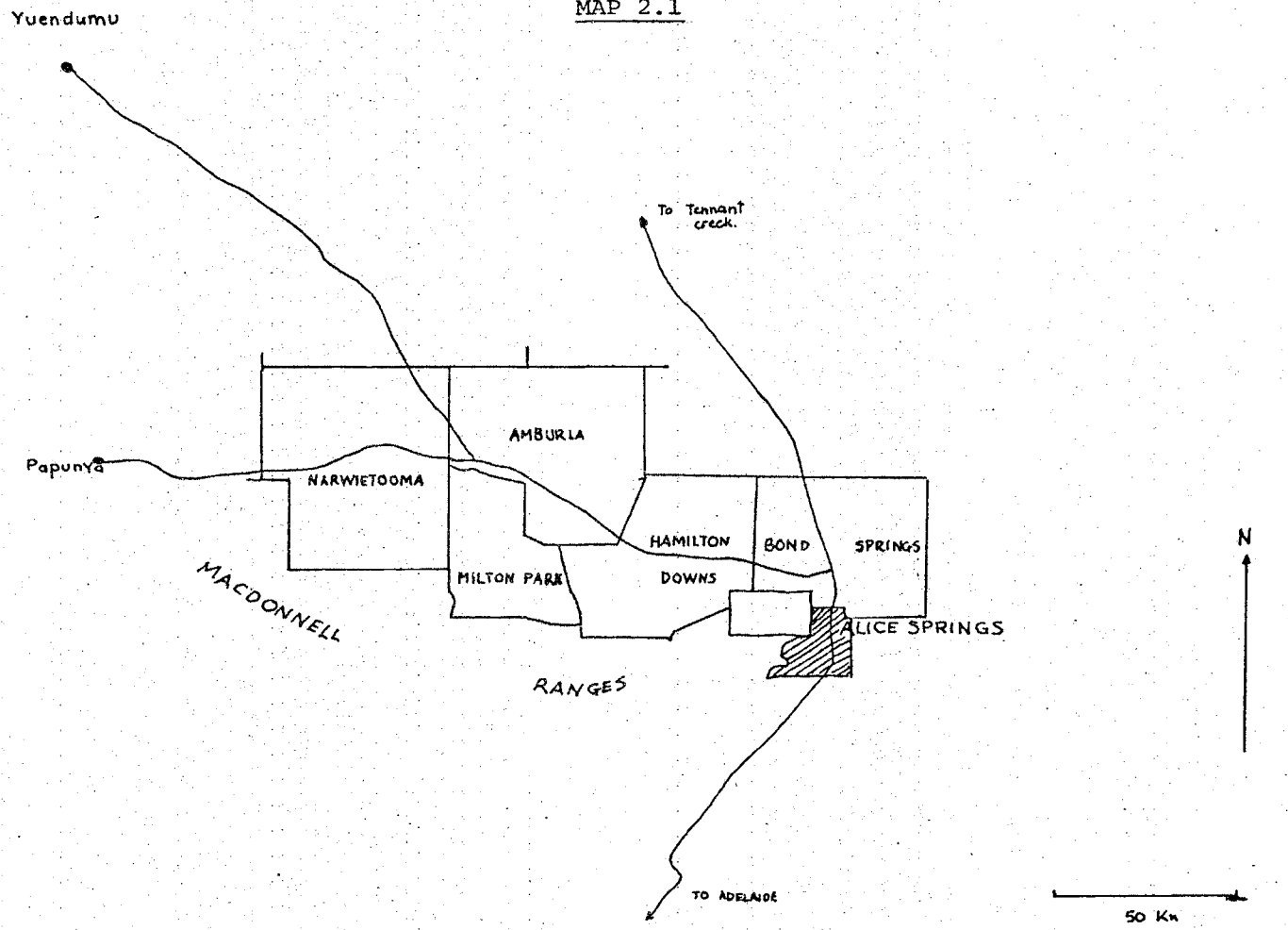
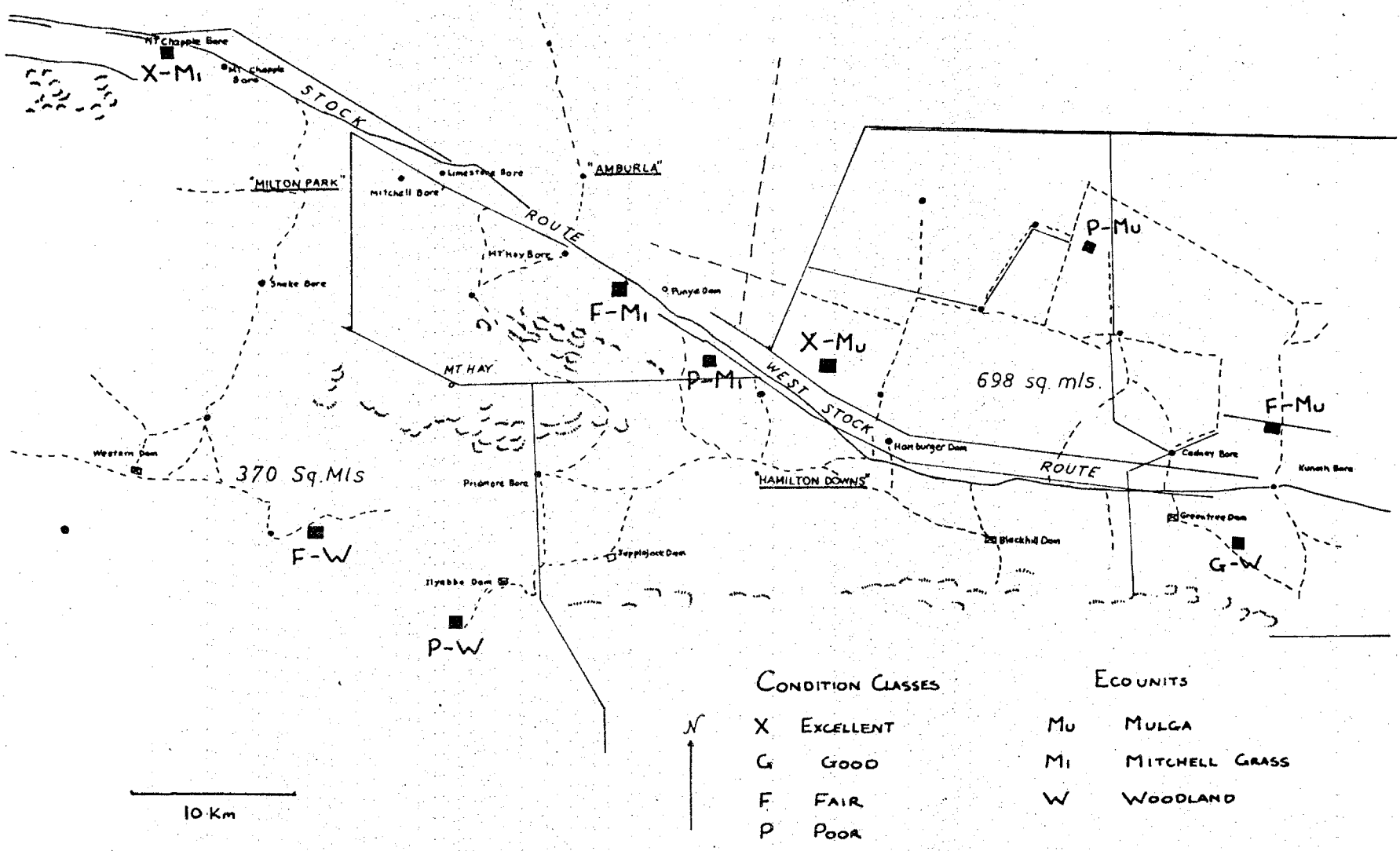
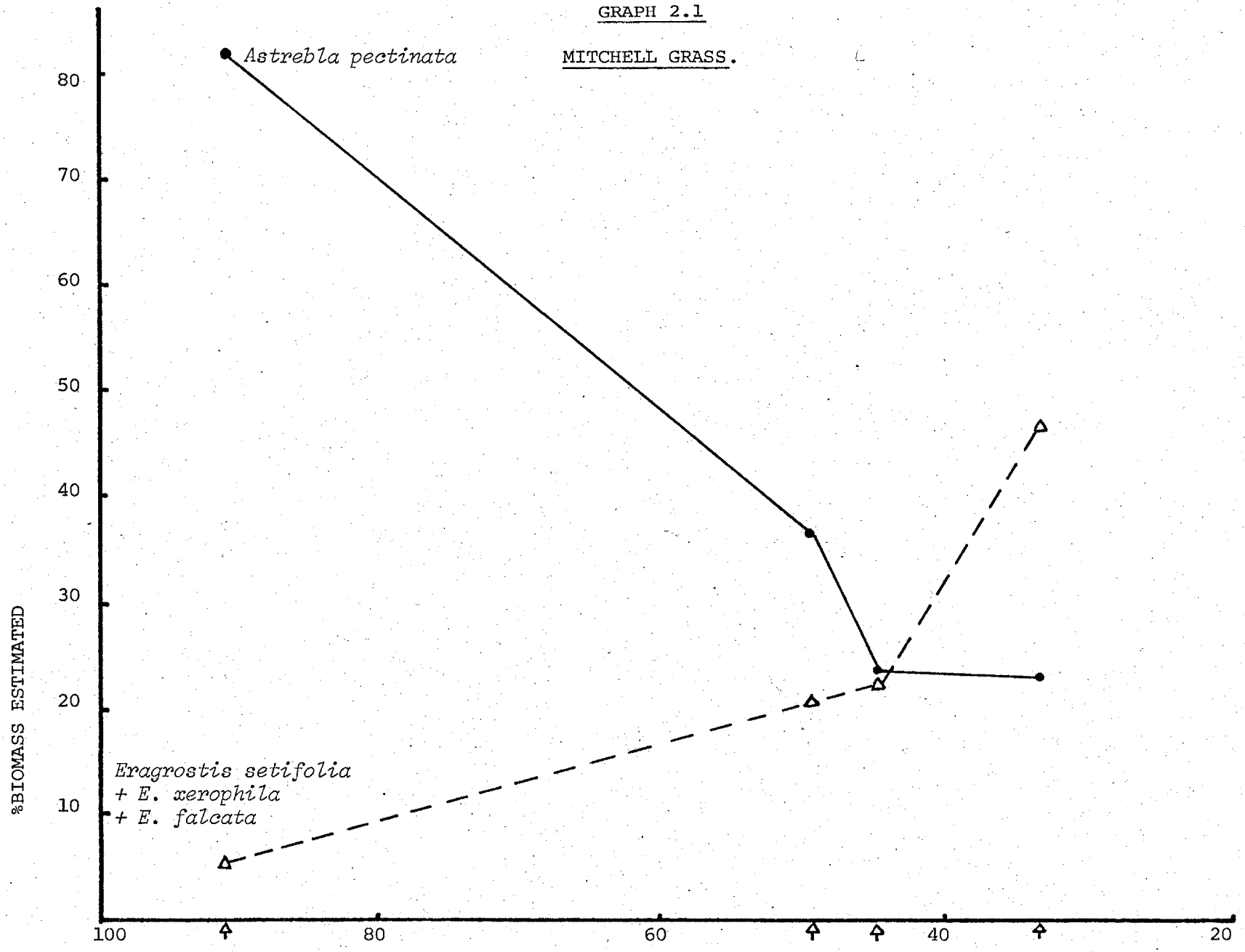

Yuendumu
To Tennant creek.
Papunya
AMBURLA
NARWIETOOMA
HAMILTON DOWNS
BOND SPRINGS
MILTON PARK
MACDONNELL RANGES
ALICE SPRINGS
TO ADELAIDE
N
50 Km
24°S
132°E
135°E

FIGURE 2.2


Mt Chapple Bore
X-Mi
Mt Chapple Bore
STOCK
ROUTE
"MILTON PARK"
Mitchell Bore
Limestone Bore
"AMBURLA"
Mt Hay Bore
Smoke Bore
F-Mi
Punya Dam
P-Mi
MT HAY
X-Mu
P-Mu
698 sq. mls.
WEST STOCK
ROUTE
Hamburger Dam
Cadney Bore
F-Mu
Kunoth Bore
Western Dam
370 Sq.Mls
Primrose Bore
"HAMILTON DOWNS"
Greentree Dam
Blackhill Dam
F-W
Tepplejack Dam
G-W
Ilyabbe Dam
P-W
10 Km
N
CONDITION CLASSES
X EXCELLENT
G GOOD
F FAIR
P POOR
ECOUNITS
Mu MULGA
Mi MITCHELL GRASS
W WOODLAND

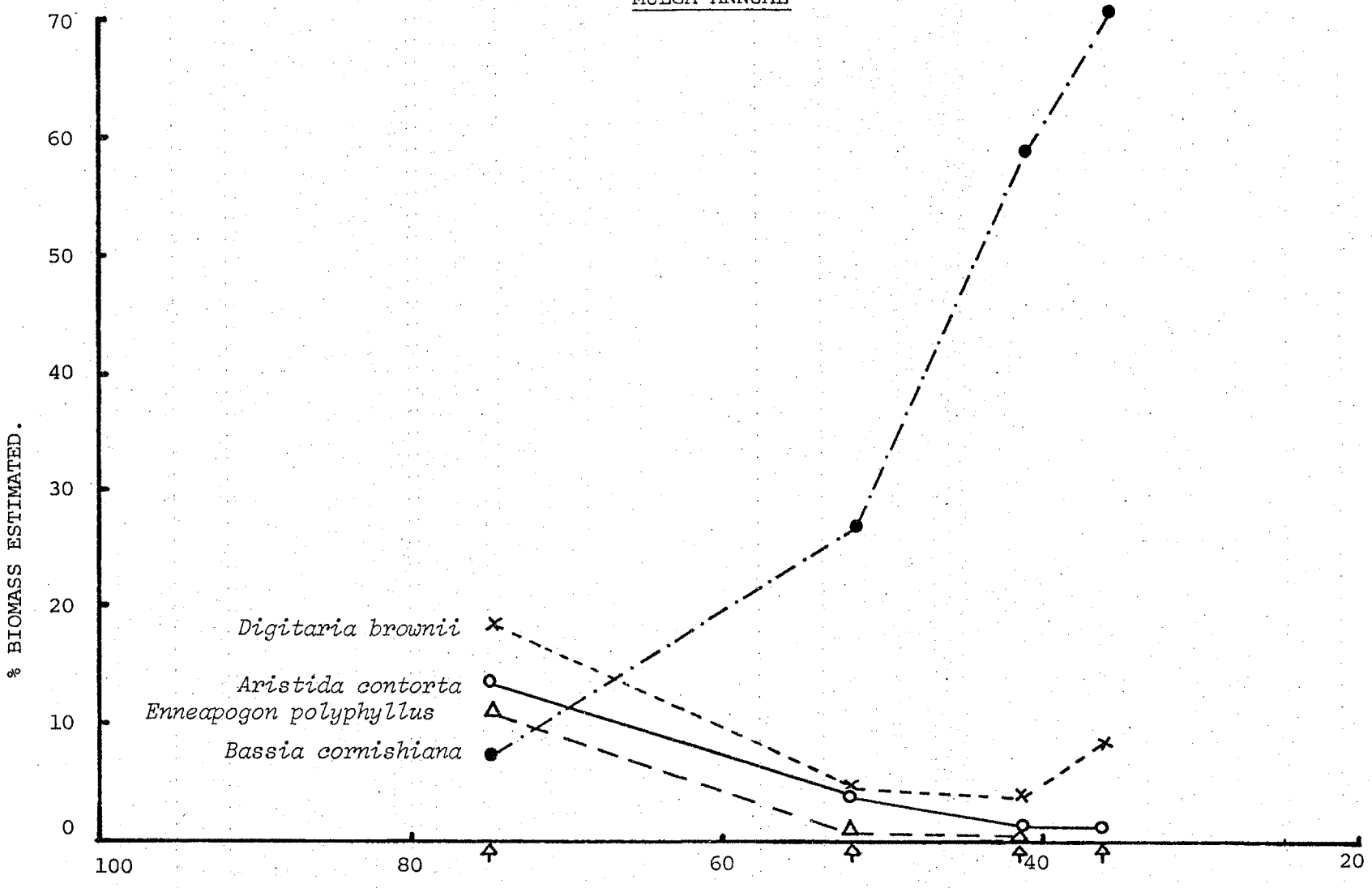
GRAPH 2.1

MITCHELL GRASS.



GRAPH 2.2

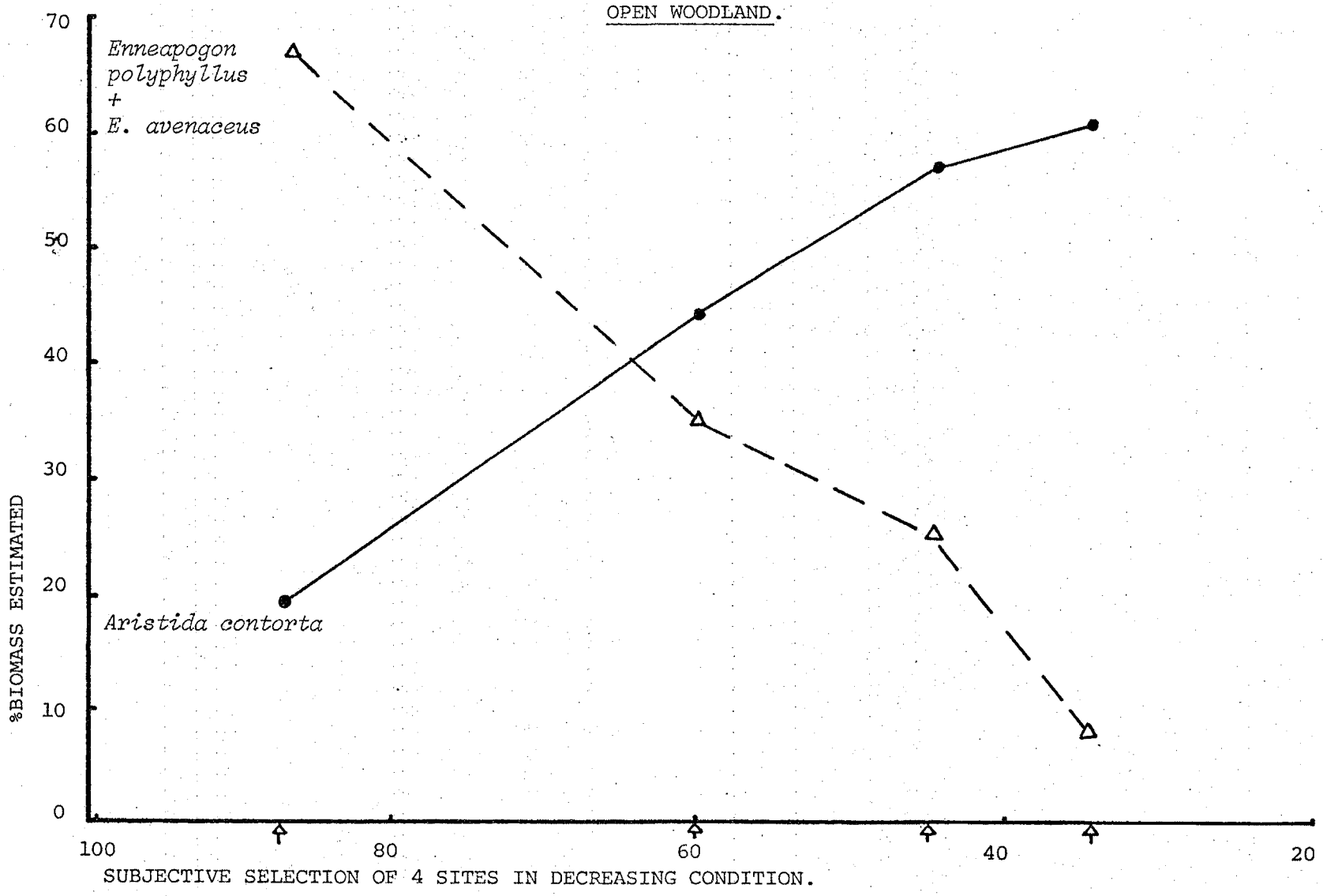
MULGA ANNUAL



SUBJECTIVE SELECTION OF 4 SITES IN DECREASING CONDITION.

GRAPH 2.3

OPEN WOODLAND.



CHAPTER 3.

EXPERIMENTAL DESIGN AND METHODS.

3.1 EXPERIMENTAL DESIGN.

Factorial experiment.

To determine if there are nutrient limitations which may be affecting the field distribution of the species mentioned in chapter 2 an experiment is required which will test a number of different nutrients and interactions between these nutrients. In this situation there were the effects of range condition and twelve nutrients to be tested. To accommodate these requirements an incomplete factorial experiment was designed by K.Cellier*, which would test all the major effects and selected interactions. To test all the interactions between range condition and the twelve nutrients would take a complete factorial of 2^{13} (13 factors at two levels). This would involve 8912 pots, which would be impossible to set up for this project. In a complete factorial of this size statistical accuracy would be greater than required. This may be best explained by mentioning that for a 2^{13} factorial, each major effect would be replicated 4456 times. A complete factorial would also consider all the combinations and interactions between the factors. This is unnecessary as the experiment is aimed at determining which are the major nutrients which may be limiting, and the major interactions between these nutrients.

The experiment designed by K.Cellier was an incomplete factorial namely a 2^{7} of a 2^{13} factorial. This experiment involves 128 pots which is a size that can be handled with ease. The 2^{7} incomplete factorial allows the effects of all the 13 factors to be estimated as well as the two-factor interactions between Range condition and nutrient. There are a number of two-factor interactions which cannot be estimated and these are shown on the following page.

*K.Cellier, C.S.I.R.O., Division of Mathematical Statistics, Adelaide.

The mathematics behind the design of the factorial are beyond the scope of this work, however an explanation of factorial experiments is given in Cochran and Cox (1957).

Zn x Cu	B x Zn
Zn x Mg	B x Mo
Co x Ca	Cu x Mn
Co x Mg	Cu x Mo
Ca x Mg	Mn x Mo
B x Cu	Zn x Co

The experiment is arranged as a randomized block design which negates the need for moving the pots for randomization. (table 3.2)

3.2 ANALYSIS.

The analysis of the data involves an analysis of variance to detect significant effects and interactions. The analysis of the data was carried out by K.Cellier.

In some cases it appeared that there may have been significant higher order interactions which would not be detected by the analysis. In these cases a restricted analysis of variance was carried out on the major nutrient effects. This restricted analysis only detects significant three-factor interactions.

In the analysis the residual mean square, which is composed of higher order non-significant effects, is used as the error variance. For the case of the restricted analysis the residual mean square was used from the original, full analysis. (K.Cellier pers. com.) This is explained more fully in chapter 5 when restricted analysis results are discussed.

Once the significant effects had been detected, tables of mean dry weights (per pot) for each treatment were compiled. The significance of differences between values in these tables is determined by using a Least Standard Difference (L.S.D.) value, where -

$$L.S.D._{(5\%)} = t_{(0.05,\ 42df)} \times S.E.D.^{*}$$

$t_{(0.05)} = 2.021$
$t_{(0.01)} = 2.704$
$t_{(0.001)} = 3.551$

3.3 METHODS.

The methods outlined in this section apply to both pot trials discussed in later chapters.

The 13 factors or nutrients tested were -

(1) Range condition
(2) Nitrogen
(3) Phosphorus
(4) Sulphur
(5) Potassium
(6) Calcium
(7) Magnesium
(8) Cobalt
(9) Zinc
(10) Manganese
(11) Boron
(12) Molybdenum
(13) Copper

Throughout the remainder of this work the nutrients will be referred to by their recognized symbols.

Each of the above nutrients was tested at two levels of application. The upper level of application consisted of additions as shown in table 3.1, the lower level consisted of no application. The upper level of nutrient application had previously been determined by communications betweeen Dr.Friedel and other workers in Australia. In other words they are largely based on the experience and findings of a number of different people. The levels of application are given as $gm.m^{-2}$. These have been recalculated as ppm of addition. It should be emphasized that these levels do not indicate what is available, but give a value for the addition which can be compared to the soil analysis data. (Appendix C)**. In the case of Range condition the two levels refer to the condition class soils, the lower level being poor range condition soil, and the upper being excellent range condition soil.

The nutrient solutions were made up as 1 litre solutions using the salts shown in table 3.1. The nutrients were then added to the

* S.E.D. = Standard Error of Difference.

** Data obtained by Dr.Friedel.

soil as 10 ml aliquots in the combinations shown on the factorial sheet (table 3.2). In the case of N two additions were made, the first being of 4 ml and the second of 6 ml. The first addition was made before the planting, while the second was made when the plants were past the initial seedling stage. The reason for this was that addition of N in large quantities can cause seedling death of some native grass species (M.Friedel pers. com.). The effect of N is discussed more fully in later sections.

3.4 SOILS.

The soils from the range condition classes were taken from the C.S.I.R.O. field enclosures shown on map 2.2 in chapter 2. Soils collected from both poor and excellent condition classes, were taken only from the top 10 cm. The soils were sieved, air dried, and then weighed (2500 gm) in plastic bags ready for nutrient additions. The nutrients were added and each bag shaken to ensure that the nutrients were mixed thoroughly through the soil. The soils were added to pots, and watered to field capacity ready for planting of seeds or seedlings. The containers used as pots were 1 litre plastic ice-cream containers. The pots were then placed in the glasshouse in the randomized block design (table 3.2). The pots were watered to weight with distilled water every 2 - 3 days, depending on rate of water loss. The pots were watered to slightly over field capacity at each watering.

During the summer period the glasshouse was covered with Sarlon cloth to reduce the temperature, and an air-conditioner was used to ensure that the glasshouse did not reach a temperature which would kill the seedlings. During winter radiators were placed in the glasshouse at night to prevent the chance of frost killing the plants.

3.5 DURATION OF THE TRIALS AND HARVESTING.

The pot trials were run for 10 weeks in the case of *Eragrostis setifolia* and 7 weeks for *Enneapogon polyphyllus*, the difference being due to the different growth rates. *Enneapogon polyphyllus*

being an annual species grew faster than *Eragrostis setifolia*, a perennial species.

At the end of the trial the plants were clipped at the base, and oven dried at 60°C for 24 hours. The plants were then weighed on a Satorius electronic balance to give a weight per pot, which was the sum of the 10 plants in that pot. All weights were given as per pot, not per plant. At the time of harvesting, the total number of tillers per pot was also counted. (Appendix A)

Attempts were made to estimate plant growth using a number of parameters such as height or tiller number as well as a visual estimate of the growth. These met with varying degree of success, but the limited amount of time available made these methods unsuitable. For this reason the results for this section are presented in Appendix A.

TABLE 3.1

NUTRIENTS.

CONCENTRATIONS ADDED.

Nutrient	Level 1 g/m^2	Level 2 g/m^2	Salt used	Amount g/litre	ppm added.
N	0	2+3	NH_4NO_3	24.14	33
P	0	5	$NaH_2PO_4.2H_2O$	37.77	30
K	0	5	KCl	16.11	34
Mg	0	1	$MgCl_2.6H_2O$	14.13	6.7
Ca	0	5	$CaCl_2.2H_2O$	31.00	33.8
S	0	0.3	Na_2SO_4	2.246	2.02
B	0	0.05	H_3BO_3	0.4858	0.34
Cu	0	0.1	$CuCl_2.2H_2O$	0.4534	0.68
Mn	0	0.2	$MnCl_2.4H_2O$	1.2178	1.35
Mo	0	0.03	$(NH_4)_6Mo_7O_{24}.4H_2O$	0.1042	0.22
Zn	0	0.1	$ZnCl_2$	0.3523	0.676
Co	0	0.005	$CoCl_2.6H_2O$	0.0343	0.034

TABLE 3.2

FACTORIAL DESIGN.

Allotment of treatments to letters in design.

a	b	c	d	e	f	g	h	j	k	l	m	n
B	Cu	Mn	Mo	R.C.	N	Zn	Co	Ca	Mg	P	K	S

BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4
abcdefgh	abhklmn	bdjkl	bchjmn
abcdegjlm	abgjlmn	acfjklmn	adehk
fmn	cdfjkn	acghl	bcefjklm
abcdghjk	abeghjkn	acegkm	bcgkmn
abcdfhjlm	cdfgjl	acefghjkl	bcghjklm
abcd	cdfghn	acfhkm	bcefhkmn
efgh	cdhklmn	bdegkm	adefjklm
ghjk	cdefhjlmn	bdgjn	adgkmn
abcdejkmn	cden	acehjm	adlm
ejkmn	abehjl	bdfhkm	adfln
abcdhjln	cdgjlmn	acefgkn	adegj
efjk	abjkm	bdelmn	adhjmn
(i)	cdefgklmn	bdefghjkl	bcejkln
efhkln	cdfhkl	aceghjklmn	bcfghjkln
abcdgkln	cdefghjkm	acfghlmn	bcegj
abcdefhkln	cdehjl	bdfgjm	bceghln
abcdeghmn	abegkl	bdfjklmn	bcfgk
fhjlm	abfgjl	acefhjn	bcfhj
abcdfgklm	abefm	achkn	bclm
gkln	abfghn	bdefgkn	adfhj
abcdehklm	cdefm	bdehjm	bcefgjmn
hjln	abfhkl	bdeghjklmn	adefghlm
abcdefgjln	abefghjkm	bdefl	adefhkmn
eghmn	cdegkl	acefl	bcfln
fgklm	abghm	bdfghlmn	adejkln
efgjln	abefhjlmn	bdefhjn	adfgk
fghjkmn	aben	acjkl	adefgjmn
egjlm	abfjkn	bdghl	bcefghlm
abcdefjk	abefgklmn	acfgjm	adghjklm
abcdfmn	cdeghjkn	acelmn	adeghln
ehklm	cdghm	acgjn	bcehk
abcdfghjkmn	cdjkm	bdhkn	adfghjkln

CHAPTER 4.

ERAGROSTIS SETIFOLIA POT TRIAL.

4.1 INTRODUCTION.

Eragrostis setifolia is a tufted perennial 22 - 45cm high, (Lazarides, 1970) which occurs in the Mitchell grass areas. This species, as indicated in chapter 2.3 is the increaser species in the ecounit. Although the generally accepted opinion is that most increaser species are unpalatable, (Stoddard et al, 1975) it is found at certain times of the year *E. setifolia* is highly preferred (Squires,* pers. com.). This may be due to the fact that this species remains green for longer than other perennials.

In this chapter, the nutrient responses of *E. setifolia* are studied. These responses are assumed to be indicative of the responses of all three *Eragrostis* species (namely *Eragrostis setifolia, E. xerophila, E. falcata)* which occur in the Mitchell grass area. The *Eragrostis* species are usually considered as a group due to the difficulty in separating the species on the basis of vegetative habit.

4.2 METHODS.

The methods for this pot trial were as set out in chapter 3. *E. setifolia*, due to its small size and low viability, was germinated in trays of washed river sand in the growth cabinets at 30°C. The seedlings were transplanted into the pots approximately one week after germination. Seedlings which died in the pots were replaced thus maintaining 10 plants per pot.

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4.3 RESULTS.

Table 4.1 shows the significant primary responses and two factor interactions detected by the *E. setifolia* pot trial. It shows clearly that the nutrients most likely to be limiting the growth of *E. setifolia* are N P and S as well as certain combinations of these nutrients. Table 4.1 summarizes the initial analysis of variance which shows the significant primary responses and two-factor interactions. To determine if there were any significant three-factor interactions present in the residual variation which were undetected, a restricted analysis of variance using only N P and S was run. These results are summarized in table 4.2.

N and P show highly significant primary effects (***,$p < 0.001$) and contribute 70.2% to the total variance which suggests that these two nutrients may be the most important in *E. setifolia* nutrition. Range condition shows a highly significant effect (***, $p < 0.001$) as do the range condition x N, range condition x P and N x P interactions. The effect of S was also significant (**, $p < 0.01$) as was the N x S and range condition x S interaction (*,$p < 0.05$). It is interesting to notice that all S effects are of a lower significance than the P and N effects, supporting the view that these two nutrients are of major importance.

In the restricted analysis of variance it should be mentioned that the residual mean square which is used as the error variance is taken from the initial, full analysis of variance for the trial. If the residual mean square from the restricted analysis was used then this would tend to unnaturally elevate the F ratios. (K.Cellier, pers. com.)

The restricted analysis of variance shows that there were three significant three-factor interactions which remained undetected by the original analysis. These significant interactions were range condition x N x S (**,$p < 0.01$), range condition x P x S (*,$p < 0.05$) and range condition x N x P (*,$p < 0.05$).

From both analyses it can be seen that all interactions except the two-factor interaction P x S and the three-factor interaction N x P x S are significant. This emphasizes the importance of these nutrients in *E. setifolia* nutrition.

Although tables 4.1 and 4.2 indicate which nutrients have significant effects, the actual effects of the nutrients can not be interpreted until the tables of means are studied (tables 4.3 - 4.5). In all these tables the values represent the mean dry weight per pot for the different treatment. To determine if the difference between the means is significant a Least Significant Difference (L.S.D.) value is used. (See chapter 3.2).

Table 4.3 shows the means for the significant major effects. The values for the range condition response (Table 4.3a) indicate that *E. setifolia* appears to grow more vigorously on poor range condition soil (RC_o) than on excellent range condition soil (RC_1). This supports the argument put forward in chapter 2 that there is a soil nutrient difference which plays an important role in determining species behaviour as increaser or decreaser species. In this case the increaser species appears better suited to growth on poor range condition soil. Table 4.3 (b) and 4.3 (c) give the means for the addition of P and N, respectively. For both these nutrients there is a very marked increase in the growth of *E. setifolia* with these additions. This is not an unexpected result as it is well reported that most Australian soils are low in nutrients (Williams and Andrew, 1970) especially in some semi-arid and arid regions which are usually low in N and P (Winkworth, 1967; Charley and Cowling, 1968). There are many pieces of work reported in the literature which indicates plant responses to addition of N and P (Charley and Cowling, 1968; Williams and Andrew , 1970; Christie, 1975 b). The effect of the addition of S (Table 4.3d) was not as pronounced, although still significant (**,$p < 0.01$). These primary responses indicate that there is an inherent soil differences which affects *E. setifolia* growth, and that the growth of *E. setifolia* can be stimulated by the addition of P, N and to a lesser extent S. These nutrients can therefore be proposed as the most likely factors controlling the distribution

of *E. setifolia*, however a more comprehensive understanding of the nutrient differences across the range condition classes can be obtained from studying the interaction tables (Table 4.4). These two-factor interactions can be divided into two distinct groups. The first group consists of range condition x nutrient interactions where as the second group consists of the nutrient x nutrient interactions.

Table 4.4a shows the range condition x P interaction. There is a significant effect from P addition on soils of both range condition classes, but the effect is of a larger magnitude on poor range class soil. This would suggest that there is a P limitation of *E. setifolia* growth on poor range class soil. As phosphorus does not produce an effect of the same magnitude on excellent range class soil, this indicates that some other nutrient(s) may be reponsible for a secondary limitation of growth on excellent range class soil.

Table 4.4b gives the relationships between N responses and range condition classes. On both range class soils N has a significant effect, however the effect is much larger on excellent range class soil than on poor range class soil. The final values for the addition of N to both range class soils is very similar. This would indicate that any deficiency which may have been present on excellent range class soil has been aleviated and so producing equal growth on both range condition class soils. From this it could be proposed that N is the main nutrient which is affecting or controlling *E. setifolia* behaviour in relation to the grazing pressure and range condition classes. These results would suggest that there is a N limitation on excellent range condition soil, but not on poor range condition soil. Although the N limitation appears range condition specific, the growth of *E. setifolia* increased on both range condition class with N addition. This suggests that *E. setifolia* has a prime N requirement for growth.

The interaction table, 4.4c, indicates that S effects are localized on excellent range condition soil. The S effects do not appear as important as the N and P responses. This is more

clearly shown in the three-factor interactions. The S effect may be of greater importance when the N limitation has been overcome.

The next interactions discussed are the nutrient x nutrient two-factor interactions. Table 4.4d gives the N x P interaction. This table indicates that N addition produces a marked increase in growth of *E. setifolia* as does the addition of P. The addition of P and N produces a very marked increase in growth which is highly significant (***,$p < 0.001$). This response is larger than the response to N plus the response to P. This would indicate that the uptake of the two nutrients may somehow be associated. This response to the addition of N and P can be interpreted as indicating that the productivity of the natural grassland is below it potential, (Tupper, 1978). This effect of N and P can best be understood by studying the three-factor interactions which are discussed later in this section.

Table 4.4e gives the values for the interaction between N and S. This indicates that the S effect appears to be dependent on the presence of N. This interaction is unusal in that from the previous interactions it may have been expected that S would have an effect in the absence of N. The range condition x S interaction indicated that S had the greatest effect on excellent range class soil which has been shown to be deficient in N (also see appendix C) This can possibly be explained through a reported close relationship between N and S (Dijkshoorn and Van Wijk, 1967) where it appears that S uptake depends on N levels. This explains the S effect in the presence of N but does explain why S has a greater effect on excellent range condition soil. The two principal possibilities here are that the S is promoting uptake of N on excellent range condition soil but not on poor range condition soil. This may be due to the already higher N on poor range soil than on excellent range condition soil. The other possibility is that the S effect on excellent range condition soil is related to the P levels on the range condition classes. This will be considered later when the range condition x P x S interaction is discussed.

The three-factor interactions are summarized in Table 4.5.

Table 4.5a gives the relationship between range condition, N and P. In the absence of N and P range condition has a highly significant effect (***,$p < 0.001$). It can also be seen that in the absence of N, the P effects appear localized on poor range condition soil. In the absence of P, the N effects are localized on excellent range condition soil. This supports the view put forward in the previous section in that N appears limiting on excellent range condition and P is limiting on poor range condition soil. There is a highly significant N x P interaction on both condition class soils. The magnitude of the responses is larger on poor range condition soil than on excellent range condition soil. This can be attributed to the higher N in the poor condition soil (Appendix C) increasing the effectiveness of the added P. (This interaction is also shown on Figure 4.1

Table 4.5b summarizes the Range condition x N x S relationships. The interesting value on this table is for the addition of S in the presence of N. As previously stated this interaction between N and S appears restricted to excellent range condition soil. The interpretation of this could be that the S deficiency is masked by the N deficiency. On poor range condition the P deficiency masks the S effect. This needs to be compared to the next table (4.5c), which indicates that S has an effect only when added to excellent range condition soil in combination with P. These responses to S can be used to explain the differences in the N x P interaction on the different condition class soils. The interaction is of a smaller magnitude on excellent range condition soil due to the S limitation which appears when P and N have been added. This can be interpreted as indicating that S does not seriously limit the growth of *E. setifolia*, unless the P and N limitations are alleviated. Thus S appears of limited importance when discussing the behaviour of *E. setifolia*.

4.4 DISCUSSION.

It was shown in chapter 2 that there is a difference in growth of *E. setifolia* across range condition classes. The results presented here indicate that there is an inherent soil difference

across these condition classes which markedly affects the growth response of *E. setifolia*. This supports the view that grazing produces changes in the soil (Charley and Cowling, 1968) similar to those that occur in a secondry successional situation (Rice et al, 1960; Roux and Warren, 1963). The field behaviour of *E. setifolia* appears related to responses to changes in the soil nutrient status, the nutrients implicated by this experiment being N and P. It has been reported that many species have adaptations to low levels of some nutrients (Billings, 1957) and more specifically, many Australian species appear adapted to low levels of P (Bishop, 1977). In this case it appears that *E. setifolia* has adapted to grow on soils which are low in available P. This species does not appear to have adapted in the same way to low N levels. The implication of N P and to a lesser extent S, is not unexpected as most Australian soils particularly arid zone soils (Perry, 1960; Charley and Cowling, 1968) are low in these nutrients. These nutrients have also been implicated in changes of the botanical composition of an area (Cook et al, 1978).

E. setifolia, the increaser species on the Mitchell grass areas, appears to grow better on poor range condition soil than on excellent range condition soil. The reduced growth on excellent range condition soil appears to be due to a reduced level of available N in the soil. This is also indicated by the data from the soil nutrient analysis (M.Friedel, pers. com.). These analyses are shown in Appendix C. The increased growth on poor range condition soil is due to the increased level of available N (Appendix C) which was also indicated by the pot trial. The P levels appear to be of less importance than the N levels. Although P addition produces an increase in growth, *E. setifolia* does not appear to be disadvantaged by the low P levels in the poor range condition soil. The results also suggest that there may be a deficiency of S on excellent range condition soil. This cannot be checked as there are no nutrient analyses for S.

Up to this point the results of the *E. setifolia* pot trials have been considered in isolation from other species within the ecounit. This is very artificial as the responses of one species

may influence the nutrient responses of other species. At this point it becomes necessary to introduce some data obtained by Dr. Friedel for a pot trial on *Astrebla pectinata*. *A.pectinata* is the decreaser species for the Mitchell grass areas (chapter 2). By comparing the results of this pot trial with the one previously discussed, hopefully, some overall conclusions can be drawn concerning nutrient changes in the Mitchell grass areas.

With *A. pectinata*, Dr.Friedel found that N, P and S were the principal nutrients involved with nutrition of this species. This is similar to what was found with *Eragrostis setifolia*. *A. pectinata* showed the expected response to range condition in that it grew better on good range condition soil than on poor range condition soil. There appears to be a marked increase in growth in response to P addition on poor range condition soil. The N response is localized on excellent range condition soil. This can be interpreted as suggesting that the P limitation on poor range condition soil is important in *A. pectinata* nutrition. The *E. setifolia* pot trial also showed similar trends, but in that particular case *E. setifolia* was not greatly disadvantaged by the low P levels, however, *A. pectinata* appears to be sensitive to the P level in the soil. These results are included in Appendix B for comparison.

Summarizing this, it appears that with declining range condition there is a decline in available P accompanied by an increase in available N levels. This indicates that *A. pectinata* distribution appears dependent on the P levels rather than the N levels. This P requirement for *A. pectinata* growth has been shown previously. (Christie and Moorby, 1975). The pot trial indicated that *E. setifolia* was dependent on the N levels.

Placing this in field context it appears that heavy grazing reduces the available P level which disadvantages *A. pectinata*. Accompanying this is an increase in the available N status of the soil which is favourable for the growth of *E. setifolia* and hence its behaviour as an increaser species. From this it can be concluded that nutrient changes are implicated in changes in

the botanical composition of the grassland in response to grazing. The effects of nutrients have previously been implicated in control of vegetation types (Beadle and Tchan, 1955; Bland, 1968; Charley and Cowling, 1968; Reuss and Innis, 1977). In this system changes in soil nutrients contribute significantly to changes in the vegetation. For this reason it is of importance to consider how these nutrient changes may occur.

Possibly the most widely accepted view of soil changes in response to grazing, is that grazing promotes erosion (Stoddard et al, 1975). This appears particularly important as most of the nutrients appear localized in the top centimetres of soil (Charley and Cowling, 1968; Stoddard et al, 1975). In this case the available nutrients appear localized in the top four centimetres (Appendix C) as shown by nutrient analysis (M.Friedel, pers.com.). The theory is that the combined effect of grazing reducing the vegetative cover and animals trampling the soil crust increases the susceptibility to erosion. It appears unlikely that erosion plays a major role in the Mitchell grass areas. Perry and Lazarides (1960) report that these areas are soil stable. Due to the dense covering of tussocks it is unlikely that either wind or water erosion would significantly affect the soil surface. The other reason why erosion is unlikely to be the cause of the soil nutrient changes is, that with a loss of range condition it could be expected that there would be a loss of N and P in the top soil. However this has been shown not to occur. It appears that only P declines with range condition and N increases. N levels are sensitive to erosion (Beadle and Tchan, 1955) so this increase in N levels in the soil would indicate that erosion is not occurring.

From the above discussion it is reasonable to assume that grazing does not appear to have a direct effect on soil properties, and that the soil nutrient changes may be a vegetation mediated effect, possibly due to a change in the rates of nutrient cycling. Cycling may be important because such a small proportion of the total nutrients are in the available form for biological cycling (Bokari and Singh, 1975).

If the decreaser species, in this case *A. pectinata*, is heavily grazed, then it may be that there is a marked reduction in one or more of the important nutrients. In this case there appears to be a significant loss of P through the vegetation and little return by the grazing animals to the system. This may be important as it has been shown that plants can take up P faster than it can be supplied (Bieleski, 1973) and under grazing there is reduced nutrient return due to reduced litter cycling. The situation may eventually be reached where the soil has been depleted of available P to an extent that the growth of *A. pectinata* is limited. This reduction in growth may lead to a reduced uptake of N thus allowing a build up of available N in the soil. In the system under study this increase in available N appears to suit the growth of *E. setifolia*. The reduced level of available P does not disadvantage *E. setifolia* as severely as it does *A. pectinata*. This advantage of *E. setifolia* over *A. pectinata* does not occur on excellent range condition soil. The advantage which has been mentioned is probably a competitive advantage in the utilization of the soil nutrient levels. This may be important on the Mitchell grass soils as both species discussed appear adapted to low levels of either N or P. *E. setifolia* may have a competitive advantage for the utilization of available P whereas *A. pectinata* may have the competitive advantage for the utilization of low soil N levels. There have been a number of investigations studying competions as a factor determining patterns within arid zone plant communities (Greig-Smith and Chadwick, 1965; Beals, 1968; Woodell, Mooney and Hill, 1969; Anderson, Jacobs and Malik, 1969; Barbour, 1969; Yeaton, Travis and Glinsky, 1977). This may be particularly important in arid zone soils where the effectiveness of P decreases rapidly as temperature rises (Barrow, 1974; Barrow and Shaw, 1975) and so the species with the greatest ability to extract P may be advantaged. This supports the view of the importance of P in range condition vegetation differences.

Other possibilities for explaining the differences in species responses to N and P may be due to differences in the internal properties of the plants. This may be important in the case of P (Barrow, 1975) where the P is important in photosynthate production.

This would be a property inherent in the plant and unlikely to be affected by soil properties (Barrow, 1975). Another plant property which should be considered is root size and volume. It has been found that low levels of P may reduce the length of roots and the branching of roots for *A. pectinata* (Christie, 1975 b). This may be related to the competition factor mentioned above. This root reduction may reduce the plant's ability to lower the P level at the root surface and so reduce its ability to extract P from the soil (Barrow, 1975).

It appears that there are a number of investigations which support the view that competition for nutrients may be playing an important role in species' abilities to survive. The work presented in this chapter does not give direct evidence to indicate that competition does occur. From the results, however, it appears that the difference in the species' adaptation to nutrient levels may give sufficient grounds for suspecting nutrient competition as an important factor.

One factor not tested in the pot trial and not considered in the discussion was the effect of pH. The soil analysis data (Appendix C) obtained from Dr.Friedel, indicates that there are significant differences in pH across range condition classes. The pH of the excellent range condition soil is 6.62 whereas that from the poor range condition soil is 7.82 (for 0-4cm depth). The effects of pH on the availability of some soil nutrients is very important (Wiklander, 1965) although the effects of pH are poorly documented for non-leguminous native species. A more complete discussion of the possible effects of pH have been included in chapter 5.

FIGURE 4.1

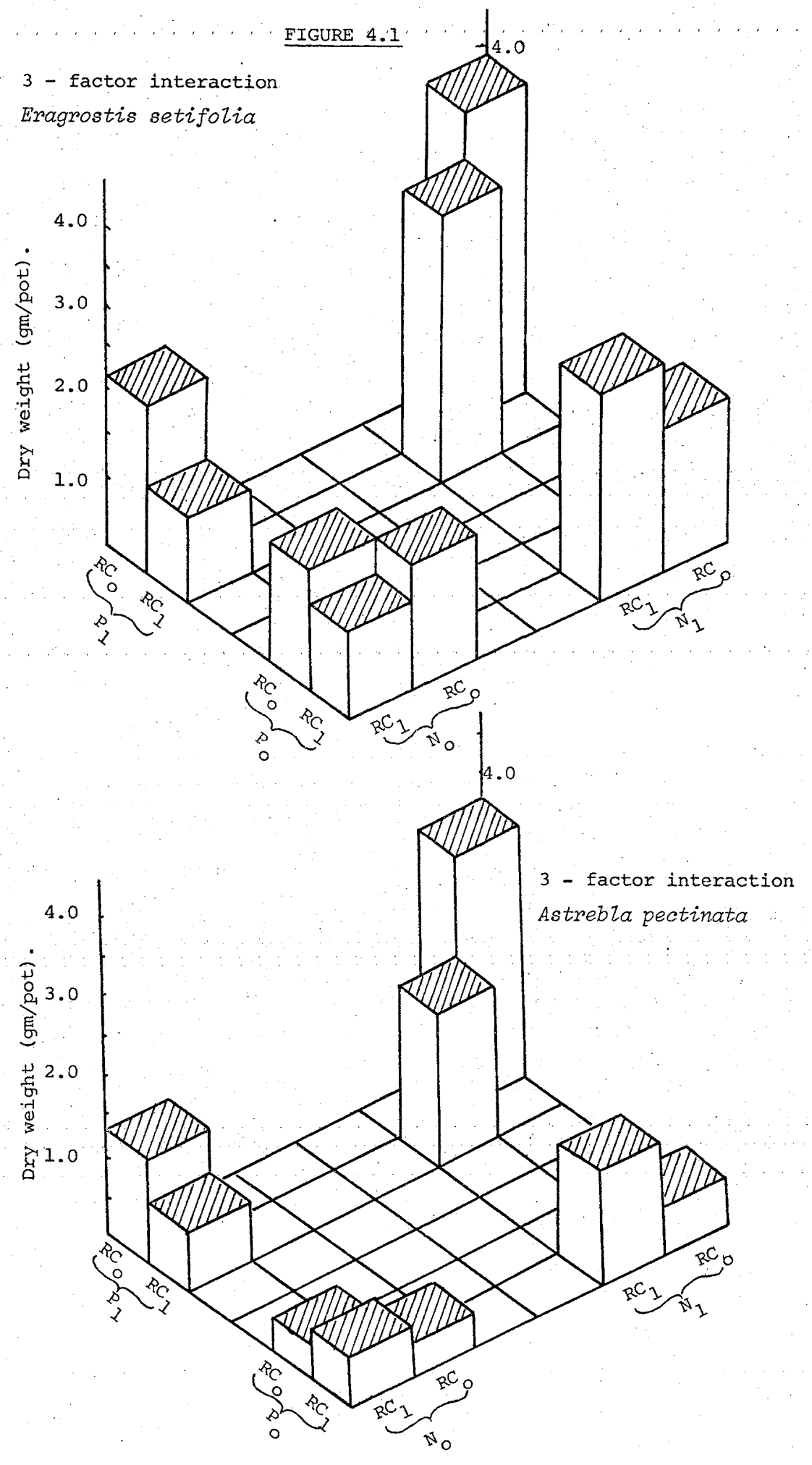
3 - factor interaction
Eragrostis setifolia
Dry weight (gm/pot).
4.0
3.0
2.0
1.0
RC0
RC1
P1
P0
N1
N0
3 - factor interaction
Astrebla pectinata

TABLE 4.1

ERAGROSTIS SETIFOLIA: Analysis of variance.

Source of variation.	df.	SS.	SS%	MS	V.R.	
Blocks	3	0.8224	0.59	0.2741	2.213	ns
RC	1	4.4030	3.18	4.4030	35.543	***
N	1	73.0538	52.71	73.0538	589.715	***
P	1	24.2730	17.51	24.2730	195.940	***
S	1	1.8050	1.30	1.8050	14.571	**
RC.N	1	5.3220	3.84	5.3320	42.961	***
RC.P	1	6.0118	4.34	6.0118	48.529	***
RC.S	1	0.8911	0.64	0.8911	7.193	*
N.P	1	8.9359	6.45	8.9359	72.133	***
N.S	1	1.0585	0.76	1.0585	8.545	*
Non sig. effects	73	6.8064	4.93			
Residual	42	5.2030	3.75	0.1239		
Total	124	137.7635	99.41	1.1110		
Grand total	127	138.5859	100			

TABLE 4.2

ERAGROSTIS SETIFOLIA: Restricted analysis of variance.

Source of variation.	df.	SS.	SS%	MS	V.R.	
RC	1	4.4030	3.18	4.4030	35.543	***
N	1	73.0538	52.71	73.0538	589.715	***
P	1	24.2730	17.51	24.2730	195.940	***
S	1	1.8050	1.30	1.8050	14.571	**
RC.N	1	5.3219	3.84	5.3219	42.961	***
RC.P	1	6.0117	4.34	6.0117	48.529	***
N.P	1	8.9358	6.45	8.9358	72.133	***
RC.S	1	0.8911	0.64	0.8911	7.193	*
N.S	1	1.0585	0.76	1.0585	8.545	*
RC.N.P	1	0.7230	0.52	0.7230	5.835	*
RC.N.S	1	1.5931	1.15	1.5931	12.857	**
RC.P.S.	1	0.8385	0.61	0.8385	6.76	*
Residual	110	8.710	6.29	0.0791		
Total	124	137.7635	99.41	1.1110		

TABLE 4.3

ERAGROSTIS SETIFOLIA: Primary responses.

(a) Range condition.

RC_o	RC_1	
2.41	2.04	L.S.D.$_{(5\%)}$ = 0.10

(b) Phosphorus.

P_o	P_1	
1.78	2.66	L.S.D.$_{(5\%)}$ = 0.10

(c) Nitrogen.

N_o	N_1	
1.46	2.98	L.S.D.$_{(5\%)}$ = 0.10

(d) Sulphur.

S_o	S_1	
2.11	2.34	L.S.D.$_{(5\%)}$ = 0.10

Subscripts refer to the level of application, see Appendix

In the case of Range Condition,

RC_o = Poor range condition soil.

RC_1 = Excellent range condition soil.

All values as mean dry wt, gm/pot.

TABLE 4.4

ERAGROSTIS SETIFOLIA: two - factor interaction.

(a) Range condition x Phosphorus.

	P_o	P_1	
RC_o	1.76	3.06	
RC_1	1.81	2.25	L.S.D.$_{(5\%)}$ = 0.14

(b) Range condition x Nitrogen.

	N_o	N_1	
RC_o	1.86	2.96	
	1.08	3.00	L.S.D.$_{(5\%)}$ = 0.14

(c) Range condition x Sulphur.

	S_o	S_1	
RC_o	2.37	2.44	
RC_1	1.84	2.24	L.S.D.$_{(5\%)}$ = 0.14

(d) Nitrogen x Phosphorus.

	P_o	P_1	
N_o	1.29	1.64	
N_1	2.28	3.68	L.S.D.$_{(5\%)}$ = 0.14

(e) Nitrogen x Sulphur.

	S_o	S_1	
N_o	1.44	1.49	
N_1	2.77	3.19	L.S.D.$_{(5\%)}$ = 0.14

TABLE 4.5

ERAGROSTIS SETIFOLIA: three - factor interactions.

Range condition x Nitrogen x Phosphorus.

(a)

	N_o		N_1	
	P_o	P_1	P_o	P_1
RC_o	1.54	2.17	1.97	3.95
RC_1	1.05	1.11	2.59	3.40

$L.S.D._{(5\%)} = 0.20.$

(b)

	N_o		N_1	
	S_o	S_1	S_o	S_1
RC_o	1.80	1.91	2.94	2.97
RC_1	1.08	1.08	2.59	3.40

$L.S.D._{(5\%)} = 0.20.$

(c)

	P_o		P_1	
	S_o	S_1	S_o	S_1
RC_o	1.66	1.85	3.08	3.04
RC_1	1.72	1.91	1.95	2.56

$L.S.D._{(5\%)} = 0.20.$

CHAPTER 5.

ENNEAPOGON POLYPHYLLUS POT TRIAL.

5.1 INTRODUCTION.

Enneapogon polyphyllus was shown to be the decreaser species on the Mulga shrubland and open woodland ecounits (chapter 2). The pot trial testing the response of *E. polyphyllus* on open woodland soil has previously been completed by Dr.Friedel. This chapter discusses the pot trial of *E. polyphyllus* on Mulga shrubland soil. These results will then be compared with those obtained for the trial completed by Dr.Friedel.

E. polyphyllus, although a highly preferred species (Squires pers. com.) and thus an important dietary component, does not contribute a large percentage to the standing biomass of the shrubland. This is shown by the graphs 2.1 - 2.3 in chapter 2. *E. polyphyllus* is an important forage species due to its response to rainfall. This species is usually an annual or short lived perennial. It will respond to rainfall within four or five days (Lazarides, 1970), and may show successive regenerations throughout the year. This behaviour explains its palatability and forage importance. As this species shows similar behaviour in two different ecounits, it is necessary to have a more complete understanding of its behaviour, and what may be producing the changes which result from the initial grazing disturbance.

5.2 METHODS.

The methods of the pot trial were outlined in chapter 3. The only difference in method from the previously trial was the way in which seedlings were placed in the pots. In the previous trial seedlings were transplanted into the pots. In this trial seed was placed directly into the pots. This was possible, due to the size of the seed (see chapter 6) and the high viability of the seed. Soils were taken only intergrove regions as there appear to be marked nutrient differences between grove and intergrove regions. (M.Friedel, pers. com.)

5.3 RESULTS.

Table 5.1 gives the significant responses detected by the analysis of variance for the species *E. polyphyllus* growing on Mulga soil. The significant single nutrient effects are those of P and N (***p < 0.001), Ca, Mg (**p < 0.01) and Mn (*p < 0.05). The effect of range condition soils was also significant (**p < 0.01). There were three significant two-factor interactions, these being N x P (**p < 0.01), Zn x N and Co x K (*p < 0.05).

As with the previous pot trial a restricted analysis of variance was conducted, the factors used being range condition, N, P, S and Ca. This restricted analysis detected only one significant three-factor interaction, namely the P x Ca x S interaction (*p < 0.05) see table 5.2. From the analysis of variance it can be seen that the most important responses are those of N and P which together contribute one third of the total variance. No other effect or interaction contributes more than 5% of the total variance. From this it could be proposed that these two nutrients are those most likely to be involved in nutrition of *E. polyphyllus*.

Table 5.3 gives the mean dry weight (gm/pot) for the primary effects. This table indicates that there is a negative response to range condition (table 5.3a). As a decreaser species, it would be expected that *E. polyphyllus* would show a greater growth response on excellent range condition soil than on poor range condition soil. This does not appear to be the case. Table 5.3 indicates that *E. polyphyllus* appears to grow marginally better on poor range condition soil than on excellent range condition soil. This would suggest that there may be other factors besides nutrients which are controlling growth. This will be discussed more fully in a later section.

Table 5.3b shows the effect of added N on the growth of *E. polyphyllus*. This indicates that there is a highly significant and large increase in growth with N addition. Table 5.3c gives

responses to added P. As for the previous figures (5.3b) the addition of P produces a large increase in growth. This is expected due to the relatively low levels of these nutrients in Australian soils (Beadle, 1962; Winkworth, 1964; Charley and Cowling, 1968; Christian and Barnard, 1964).

The other significant primary responses, Ca, Mg and Mn all produce a reduction in growth when added to *E. polyphyllus* on Mulga soil (tables 5.3c - e). The effects of Ca and Mg have already been noted by Dr.Friedel for the pot trial of *E. polyphyllus* on open woodland (M.Friedel pers. com. Appendix B) however in that particular trial there was no Mn response.

The next results considered are the two-factor interactions (table 5.4). Table 5.4a shows the relationships between N and P addition. This indicates that the addition of P produces a marked increase in growth and the addition of N also produces a marked increase in growth. The response to the addition of N and P in combination was markedly larger than the single additions. This marked response to N and P may indicate that the productivity of the grassland is well below its potential (Tupper, 1978). It would therefore be concluded that N and P are limiting growth.

The next interaction is that between Zn and N (table 5.4b). This indicates that in the absence of N, Zn inhibits the growth of *E. polyphyllus*, but the addition of N with Zn produces a marked increase in growth. This would suggest that the inhibitory effect of Zn is important only in the absence of N. The addition of N will alleviate the growth inhibition produced by Zn.

The other two-factor interaction is the Co x K interaction (table 5.4c). The addition of K produces a decrease in growth as does the single addition of Co. The interesting point about this table is the response of *E. polyphyllus* to the addition of both nutrients. The addition of both nutrients to the soil does not produce a significant growth response over and above

the single additions. This would indicate that although both nutrients will inhibit growth the effects are not additive. It could possibly be that the two nutrients act in similar manner to restrict the uptake of some other important nutrient. As few workers report Co effects for higher plants, this particular interaction will be discussed more fully in section 5.4.

Table 5.5a gives the means for the significant three-factor interaction P x S x Ca. This table indicates that Ca has a significant depressant effect on the growth of *E. polyphyllus* in the presence of P and the absence of S. From this result it could be suggested that Ca is influencing the uptake of P and this effect of Ca may be alleviated by the addition of S.

5.4 DISCUSSION.

This pot trial for *E. polyphyllus* shows some interesting results in comparison to the other pot trials already completed. The experiment relies on the fact that there are differences between range condition classes. The primary response to range condition (table 5.3) indicates that this is so. However, in all the results there were no range condition specific interactions. This could be an indication that the nutrient deficiencies detected by the pot trial may not be directly influencing the distribution of *E. polyphyllus*. This does not mean that the nutrient responses mentioned in the previous section should be ignored and treated as unimportant. These nutrients may still be important in species - species interactions or specifically competition effects.

The responses obtained for nutrient additions in this pot trial were similar to the responses obtained by Dr.Friedel for *E. polyphyllus* on open woodland soil. Dr.Friedel showed that N and P produced large increases in growth while additions of Ca and Mg depressed growth (M.Friedel, pers. com.). These results have been included in Appendix B for comparison.

The response to N and P in both cases was not unexpected,

due to the low levels of these nutrients in Australian arid zone soils (Winkworth, 1964; Charley and Cowling, 1968; Williams and Andrew, 1970). In work by Silcock et al (1976) it was found that Mulga soils were highly deficient in N and P, and the native species appear to have adaptations to low levels of P (Rorison, 1968). Not only are the available levels of these nutrients low, but also the total levels are low (Dawson and Ahern, 1973; Silcock et al, 1976). To overcome these deficiencies, particularly of P, it is thought that native grasses can adjust their uptake to suit their requirements. P is possibly of major importance because the seedlings respond initially to P and then as the plants mature the response to N increases (Silcock et al, 1976). This also explains the highly significant interactions of P x N which were encountered in the trials.

The significant interactions were unusual in that Zn, K and Co all showed interaction effects, but did not show major responses (see table 5.1 and 5.2). Zn has been reported to be deficient in some Australian soils (Teitzel and Bruce, 1971; Winter and Jones, 1977). From the results it would be assumed that in this case Zn is not deficient, but is related to P uptake. Zn may be reducing the N and P utilization by the plant (Saeed, 1977). It has been reported that at low P levels there is a high adsorption of Zn (Saeed, 1977). This experiment did not indicate that there was a significant Zn x P interaction, so it is possible that there may be some relationship between N x P x Zn although this would not be detected by the analysis.

The interaction between Co and K is unusual in that Co has not been implicated in nutritional studies, although low plant concentrations of this nutrient have been reported (Ozanne, Greenwood and Shaw, 1963; Hallsworth, Wilson and Adams, 1965; Winter and Jones, 1977). Gerloff (1963) reports that Co is not essential for the growth of higher plants although the effect of Co on plants relying directly on nitrogen fixation for a source of N seems to be firmly established (Ahmed and Evans, 1960; Reisenauer, 1960; Ahmed and Evans, 1961; Delwiche et al, 1961).

The K influence on nutrition has previously been found, especially in relation to competition between plants (Blaser, 1950; Gray et al, 1953; Hall, 1971). Hall (1971) suggested that for legume species the dependence on K was related to the species' abilities to extract this nutrient at the expense of other species. It has also been shown that K can influence P uptake (Siddiqi, 1978), however this was not supported by this work as there was not a significant K x P interaction. As both K and Co inhibited the growth of *E. polyphyllus*, but yet the effects of the nutrients were not additive, it suggests that both these nutrients influence the uptake of other nutrients, rather than having direct metabolic effects to reduce the growth of this species.

In the pot trial of *E. polyphyllus* grown on open woodland soil, previously completed by Dr.Friedel, similar nutrient responses were found namely N, P, Mg and Ca, however in this trial there were no range condition specific interactions as were found by Dr.Friedel. From this it could be concluded that the above nutrient effects may not be playing a major role in determining the growth of *E. polyphyllus* on the different range condition classes. For this reason other possibilities must be considered as to what may control growth of this species.

Competition between species for the different nutrients is one important factor not considered by the design of the experiment. In the field situation there may be important relationships between the growth of a species and the arrangement of the various species present. It is possible that the increaser species may be adapted to extracting nutrients at the expense of the decreaser species. This may be of importance as N and P have been implicated in competition (Groves et al,1973) as has also K (Blaser and Brady, 1950; Hall, 1971).

When soil analysis data for these areas is studied (Appendix C M.Friedel pers. com.) it can be seen that there are significant nutrient differences across the range condition classes. The difference which is often overlooked is the effect of pH. It has been reported that pH can have marked effect on growth,

particularly in relation to N and P nutrition (Arnon et al, 1942). There may also be a relationship between pH, water stress and N utilization (Havill et al, 1977).

Most of the work relating pH effects to nutrition of plants appears to be associated with the study of legume species and their nodulation (Loneragan and Dowling, 1968; Munns, 1965a, 1965b, 1970; Lee and Wilson, 1972; Andrew and Johnson, 1976; Andrew, 1976). Although pH has marked effects on legume nutrition, these results cannot be easily extrapolated to non-legume species. One of the major effects of pH appears to be to alter the adsorption of the nutrients by the soil (Winklander, 1965); this is especially the case for P (Epstein and Leggett, 1954). Little can be extrapolated concerning pH and nutrition as the effects of pH are very dependent on the minerals of which the soil is composed, and the percentages of these minerals.

The physical properties of the soil may play an important role in species distribution. It was noted that there were marked soil differences between the poor condition class soil and excellent condition class soil, particularly in their water retention. It was noticed that after the pots had been watered the surface of the poor condition class soil dried very rapidly and formed a very hard crust approximately 1 cm thick. The surface of the excellent condition class soil did not show this to the same extent. This behaviour of the soil had a marked effect on seed germination and seedling survival. This is important as seedling survival in arid and semi-arid regions is dependent on the ability to withstand dry periods, or to establish rapidly and so avoid desiccation (Bokhari, Singh and Smith, 1975; Christie, 1975). This may be an erosion effect altering the soil surface, as in the Mulga shrubland in poor condition areas the appearance of scald areas is common. In this ecounit grazing may promote erosion as has been proposed for other ecosystems. (Stoddard et al, 1975). The difference in species survival may be directly related to germination requirements. There may also be inportant nutrient requirements within a few days of germination. (Mc William et al, 1970). Some workers have shown that N is

absorbed in greater amounts than P, but both these nutrients and others such as K, Ca and Mg have been shown to be essential for seedling developement. (Ozanne and Asher, 1965; Bouma and Dowling, 1966a, 1966b; Asher and Loneragan, 1967; Kriegel, 1967; Edwards, 1968). In addition it appears that N is particularly important in seedling establishment. (Cambell, 1968).

The interesting point to notice is that the nutrients mentioned above were all shown to have effects on the growth of *E. polyphyllus*. It could therefore be that the differences between range condition do not produce large differences in the size of mature plants, but play an important role in the establishment and survival of *E. polyphyllus* seedlings.

The responses to Ca and Mg, which produced marked reductions in growth, should be treated with care in that addition of these nutrients may produce artificially high levels and may be unrelated to range condition. At this stage it should be mentioned that the differences observed in vegetation by Lendon and Lamacraft (1976) and attributed by them to represent range condition, may in fact, be due to an inherent site difference.

TABLE 5.1

ENNEAPOGON POLYPHYLLUS: Analysis of variance.

Source of variation.	df.	SS.	SS%	MS	V.R.	
Blocks	3	0.4607	2.09	0.1535	1.603	
RC	1	0.7457	3.38	0.7457	7.785	**
N	1	3.6822	16.68	3.6822	38.442	***
P	1	3.6147	16.37	3.6147	37.737	***
Mg	1	0.9367	4.24	0.9367	9.770	**
Ca	1	0.8272	3.75	0.8272	8.636	**
Mn	1	0.4477	2.03	0.4477	4.674	*
N.P.	1	0.8112	3.67	0.8112	8.469	**
Zn.N	1	0.5927	2.68	0.5927	6.188	*
Co.K	1	0.4501	2.04	0.4501	4.699	*
Non sig. effects	73	5.7588	26.08	0.0788		
Residual	42	4.02306	18.22	0.0957		
Total	127	22.0808	100.00			

TABLE 5.2

ENNEAPOGON POLYPHYLLUS: Restricted analysis of variance.

Source of variation.	df.	SS.	SS%	MS	V.R.	
RC	1	0.7457	3.38	0.7457	7.939	**
N	1	3.6822	16.68	3.6822	39.200	***
P	1	3.6147	16.37	3.6147	38.481	***
Ca	1	0.8272	3.75	0.8272	8.806	**
N.P.	1	0.8112	3.67	0.8112	8.636	**
P.S.Ca	1	0.7488	3.39	0.7488	7.971	**
Residual	99	9.2995	42.12			
Total	127	22.08083	100.00			

TABLE 5.3

ENNEAPOGON POLYPHYLLUS: Primary responses.

(a) Range condition.

RC_o	RC_1	
0.733	0.581	L.S.D.$_{(5\%)}$ = 0.11

(b) Nitrogen.

N_o	N_1	
0.487	0.827	L.S.D.$_{(5\%)}$ = 0.11

(c) Phosphorus.

P_o	P_1	
0.489	0.825	L.S.D.$_{(5\%)}$ = 0.11

(d) Magnesium.

Mg_o	Mg_1	
0.743	0.572	L.S.D.$_{(5\%)}$ = 0.11

(e) Calcium.

Ca_o	Ca_1	
0.737	0.577	L.S.D.$_{(5\%)}$ = 0.11

(f) Manganese.

Mn_o	Mn_1	
0.716	0.598	L.S.D.$_{(5\%)}$ = 0.11

Subscripts refer to the level of application, see Appendix

In the case of Range Condition,

RC_o = Poor range condition soil.

RC_1 = Excellent range condition soil.

All values as mean dry wt, gm/pot.

TABLE 5.4

ENNEAPOGON POLYPHYLLUS: two - factor interactions.

(a) Nitrogen x Phosphorus.

	P_o	P_1	
N_o	0.399	0.576	
N_1	0.579	1.074	$L.S.D_{(5\%)} = 0.156.$

(b) Zinc x Nitrogen.

	N_o	N_1	
Zn_o	0.542	0.745	
Zn_1	0.433	0.909	$L.S.D._{(5\%)} = 0.156.$

(c) Cobalt x Potassium.

	K_o	K_1	
Co_o	0.807	0.587	
Co_1	0.608	0.626	$L.S.D._{(5\%)} = 0.156.$

TABLE 5.5

ENNEAPOGON POLYPHYLLUS: three factor interactions.

Phosphorus x Sulphur x Calcium.

	S_o		S_1	
	Ca_o	Ca_1	Ca_o	Ca_1
P_o	0.495	0.459	0.568	0.434
P_1	1.089	0.596	0.797	0.817

$L.S.D_{(5\%)} = 0.219$

CHAPTER 6.

GERMINATION.

6.1 INTRODUCTION.

For success of the pot trial it was necessary to determine the optimum germination requirements for the species involved. As germination plays an important role in the establishment and subsequent survival of many arid zone plants, this study has been extended to cover the major increaser and decreaser species, including those for which pot trials had not yet been completed.

In the arid regions much of the flora is composed of annual and biennial floras, which are dependent on climatic conditions. (Mott,1972) This is analogous to the situation in North America as reported by Went (1948, 1949), Tevis (1958) and Beatley (1967), where much of the difference in seasonal floras can be attributed to varying germination requirements.

6.1.1 GERMINATION.

Germination plays an important role in successful establishment and survival of desert plants. This arises from the specificity of conditions which are required for the germination of seeds (Wareing, 1963; Mayer and Poljakoff - Mayber, 1963). This specificity of conditions controls the time of year at which the seeds germinate and so ensures their survival to a reproductive age (Koller, 1964). Most seeds and particularly those of arid zone species, exist in a state of dehydration, (Wareing, 1963) this enables the seeds to resist damage by such factors as high temperature. Therefore, before the seeds can germinate there is a primary requirement for moisture. The other principal factor which controls germination is the temperature (Mayer and Poljakoff - Mayber, 1963). Most seeds have a specific range of temperature within which germination can occur. The optimum

temperature need not necessarily be the mid - point of the range as was shown by Ross (1976). This moisture and temperature requirement will often only be satisfied during one season of any year. This is especially the case in arid climatic regions where periods of moisture availability are limited.

There are a number of other factors which are important in controlling germination of seeds of some species. These include light requirements, pH and seed bed characteristics (Mayer and Poljakoff - Mayber, 1963), however they are not as widely found in arid zone plants as are the moisture and temperature requirements. For this reason these additional factors have not been considered in detail.

The lack of germination due to adverse environmental conditions is often referred to as "imposed dormancy". This should not be confused with the dormancy, inherent in the seed, which is discussed in the next section.

6.1.2 DORMANCY.

Much of the interest in the germination of arid zone plants is centered around the dormancy mechanisms inherent in the seeds. (Mott, 1972). The dormancy referred to here is the inability of the seed to germinate even if given the optimum environmental conditions required for germination. Evenari, (1965), defined seed dormancy as

"The cessation of growth in the embryo, without the latter losing its viability, for a prolonged period of time".

The degree of dormancy for seed of any particular species can be measured by the specificity of conditions required to bring about germination. (Evenari, 1961).

Dormancy mechanisms primarily fulfil two functions. The first is that the seed or dispersal unit is able to survive prolonged adverse environmental conditions without a loss of viability. This is due to the dormancy mechanism increasing the resistance to desiccation and damage. (Mayer and

Poljakoff - Mayber, 1975). The second function of dormancy is to restrict germination. This only permits germination under a predetermined set of environmental conditions which may involve factors such as soil type, light conditions,or frosting to name a few. It can be seen that dormancy mechanisms are geared towards a similar set of factors as may produce an imposed dormancy.

Dormancy mechanisms appear to be an adaptation to harsh environments, particularly arid environments. (Hammouda and Bakr, 1969). These adaptations are often orientated towards negating the effects of light and sporadic falls of rain. Rainfalls such as these may otherwise induce germination under conditions which would not last long enough to ensure seedling survival. This is particularly important, as immediately after germination young seedlings are very sensitive to adverse conditions even if they are exposed to them for only a short period of time.

Dormancy mechanisms can take a number of different forms. Crocker (1916) recognized six different forms of dormancy.

(1) Immaturity of the embryo.
(2) Hard seed coats.
(3) Need for after-ripening in dry storage.
(4) Requirements for light and dark.
(5) Requirement for chilling.
(6) Interference of seed coats with oxygen uptake.

Although these factors are listed separately, some seeds may show more than one form of dormancy. (Evenari, 1965; Mott, 1974; Mayer and Poljakoff - Mayber, 1975; Hagon, 1976; Hagon and Simmons, 1978). Mott (1972) reports on one Australian arid zone species, *Aristida contorta*, which shows two distinct dormancies, these being an after ripening requirement of the embryo and a seed coat suppression of germination.

Dormancies can often be described as Primary or Secondary dormancy. Primary dormancy describes the dormancy of the ripe

dispersal unit at the time of dispersal or harvest. Secondary dormancy describes the dormancy appearing in the mature dispersal unit when imbibed under conditions favourable for germination. (Koller et al, 1962). Secondary dormancy can also be described as a long term dormancy. (Mott, 1974).

6.2 AIMS.

In this chapter the germination characteristics of five arid zone species have been studied. These are *Eragrostis setifolia, Enneapogon polyphyllus, Aristida contorta, Astrebla pectinata and Bassia cornishiana.*

The requirements of all species are reported, although most of the discussion is centered around *B. cornishiana* as this species appears to show a dormancy mechanism. *A. contorta* also shows dormancy mechanism, however the germination of this species has been comprehensively investigated by Mott (1972, 1974a, 1974b, 1976).

The discussion of germination will be orientated towards an interpretation of their field behaviour, rather than elucidating or proposing what the biochemical basis of the dormancy may be. There are excellent reviews which cover this topic, namely Mayer and Shain (1974) and Taylorson & Hendricks (1977).

6.3 METHODS.

The range of temperature, within which germination occurs, was determined by use of a germination plate. This consists of a metal plate along which a continuous temperature gradient is set up. The seeds are placed on a felt mat soaked in distilled water, this mat then rests on top of the metal plate. The seed is placed in parallel rows along the mat. The positions at which germination occurs are noted and this is converted to a temperature measurement by means of a standard curve (Appendix D).

Standard germination trials* were used in all cases to determine the germination percentages. This consisted of placing 25 seeds on a 12.5 cm, Number 1 Whatman filter paper. This was supported on an inverted watchglass in a 10 cm petri dish. The filter paper was moistened by placing 30 mls of distilled water in the petri dish. This arrangement ensured that the seeds were kept moist for the duration of the trial but were not submerged in water. (Mott, 1972). All trials for the grass species were run for 7 days. For the *Bassia*, 14 days was used as the standard time, due to slower germination. Germination was assumed to have taken place when the length of the radicle exceeded the diameter of the seed. (Mott, 1972).

Germination percentages were expressed as a percentage of the viable seed, where viability was determined with Tetrazolium staining using the method of Porter et al. (1947). The condition found most suitable was to stain a subsample of 100 seeds in 0.2% Tetrazolium for 12 hours. The seeds were individually studied under a low power binocular microscope to determine if staining had occurred.

Standard germination trials were carried out at 30°C for *Aristida contorta, Astrebla pectinata, Eragrostis setifolia* and *Enneapogon polyphyllus* and at 15°C for *Bassia cornishiana*. The effects of alternating temperature were also tested, but only for *B. cornishiana*. This was tested due to the success Auld (1976) had in germinating *B. birchii* with alternating temperature. *B. birchii* is thought to be closely related to *B. cornishiana*. The temperature regime tested was 20°C for 8 hours and 8°C for 16 hours. These conditions approximated the winter conditions under which it was observed that *B. cornishiana* was germinating in the field. In Central Australia, severe frosts occur during the winter months and for this reason, frosting the seed was tested to determine whether frosts were important under field conditions.

The effect of 10µg/ml of gibberellic acid (GA_3) was tested on the germination of *B. cornishiana*. There have been a number

*Temperatures for trials being defined from the germination plate experiments.

of reports that gibberellic acid will break dormancy of seeds. (Mott,1974; Hagon, 1976; Tothill, 1977). The gibberellic acid was prepared by initially dissolving the salt in a small quantity of ethanol and then making to the required volume with distilled water. The effects of the gibberellic acid were tested by replacing the water used in the standard germination trial with 30 ml of gibberellic acid.

As previously mentioned (section 6.1.2) some seeds show dormancy mechanisms which are dependent on their seed coats. Of the species studied, the seeds of *A. contorta* and *B. cornishiana* had hard seed coats. For this reason trials were run on the intact dispersal unit as well as on seed with the hard coat removed. The seed coat or hull (Mott, 1974) of *A. contorta* could be removed with the aid of jeweller's forceps, without damaging the caryopsis. This hull consists of the tightly adhering glumes. *B. cornishiana* has a hard dispersal unit or fruiting perianth which encloses the seed. It was found that this fruiting perianth could be removed with the aid of a sharp scalpel. Care was taken not to damage the seed. Two ages of seed were tested for this species, these are referred to as fresh (less than one year old) and old seed (greater than one year old). These seed types had very distinctive appearances and the fruiting perianth varied in hardness.

A number of different seed lots (previously collected by Dr.Friedel) were tested for *A. contorta*. These are identified by the site(s) they came from, namely,

Amburla	1972.
Bond Springs	1976.
Woodland sites.	1977.
Kunoth Paddock.	1978.

All these localities are shown on the location map. chapter 2.

6.4 RESULTS.

For convenience, the germination characteristics will be treated individually for each species.

6.4.1 *ERAGROSTIS SETIFOLIA*. (tables 6.1 and 6.2)

E. setifolia will germinate within the temperature range 15 - 33°C. This is a large range which most likely approximates to summer conditions. Germination may occur outside this range however it is uncommon. The germination percentage indicates that there is a high percentage of the viable seed which germinates if given optimum environmental conditions. This would indicate that there are no dormancies inherent in the seed.

It will be noticed that the viability of the seed is low, but the germination percentage of viable seed is high, in this case only 40% of the seed is viable. This may be of little significance for *E. setifolia* due to the large amount of seed produced. The small size and large quantity of seed may be important in the species behaviour as an increaser species.

6.4.2 *ASTREBLA PECTINATA*. (tables 6.1 and 6.2)

This species also shows a large temperature range within which germination occurs. (table 6.1). This seed was not collected immediately prior to germination and so no conclusions could be drawn as to the presence of dormancy mechanisms. The seed had a high viability and a high germination percentage. The seed of *A. pectinata* is much larger than that of *E. setifolia*.

6.4.3 *ENNEAPOGON POLYPHYLLUS*. (tables 6.1 and 6.2)

As with the other species mentioned above, *E. polyphyllus* also germinates within a large temperature range (table 6.1). This species is also a summer germinating and summer growing plant. Table 6.2 indicates that *E. polyphyllus* has a high germination percentage and a high viability. This species does not appear to show any dormancy mechanism to restrict germination.

6.4.4 *ARISTIDA CONTORTA*. (table 6.3)

Mott (1972) suggests that *A. contorta* has two dormancy mechanisms, the first being a primary dormancy which is a property of the embryo. This dormancy can be broken by storage at ambient temperature for a period of approximately 6 months, or by shorter storage at a higher temperature. This dormancy mechanism appears to be an after ripening requirement. The secondary dormancy is thought to be imposed on the embryo by attributes of the seed coat. The results found here were not identical to those indicated above from Mott (1972). It was found that seed stored for over two years was non viable and hence the lack of germination indicated by the results. The Kunoth, 1978, seed was found to be dormant. (Friedel, pers. com.). A quantity of this seed was sent to J. Mott* who tested it and found the seed would germinate if the seed coat was removed. (table 6.3) His suggestion was to place the seed in an oven at 60°C for three months, which would hopefully break any dormancy that may still be present. After three months of heat treatment it was found that there was no germination. It was concluded that the heat treatment had either killed the seed or the seed had been forced back into a primary dormancy state.

The seed from the woodland sites, which were collected in September of 1977, were found to be viable and would germinate intact or dehulled. This seed had therefore been left for sufficient time for the after-ripening process to occur. Also this seed had not been heat treated.

From these results it appears that if the seed is exposed to high temperature after the primary dormancy has been removed, then the seed may suffer damage so that no germination occurs. This supports the view that in dormant state seed is more resistant to damage and desiccation than it is in the non dormant state.

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6.4.5 *BASSIA CORNISHIANA*. (tables 6. 1 and 6.4)

The results from the germination plate indicate that *B. cornishiana* would most likely germinate during the winter months. This is supported by the observation of seedling emergence in the field during the winter months. *B. cornishiana* is very similar in morphology to *B. birchii*. The main difference the orientation of the embryo within the hard spiny perianth. In *B. birchii* the growing tip of the embryo is orientated at right angles to the spines, whereas in *B. cornishiana* the growing tip is orientated parallel to the spines and emerges between them. It has been reported that *B. birchii* does not germinate in great numbers through the hard perianth. However, if the apex of this hardened perianth is removed to expose the growing tip then germination occurs. (Auld, 1976). Due to the orientation of the embryo in *B. cornishiana* (figure 6.1) a dissection to expose the growing tip is difficult without damaging the seed.

Auld (1976) reports that dissected seeds of *B. birchii* can be induced to germinate with alternating temperature. For this reason its effect on *B. cornishiana* was tested. The results indicate that there was very little effect on the germination. As *B cornishiana* appeared to be a winter germinating species it was proposed that frost may play a role in triggering germination. The results for chilling the seed (table 6.4) for 12 hours show that there is a very marked increase in the germination. This increase is similar to the result obtained if the seed is treated with 10µg/ml of gibberellic acid. (Mott, 1974a, 1974b; Mayer and Poljakoff - Mayber, 1975; Totthill,1977).

From this it can be concluded that *B. cornishiana* has a dormancy mechanism which may be an after-ripening requirement which can be broken by a cold snap or frost. This dormancy mechanism may be particularly important in restricting germination until the seed has actually fallen to the ground. The hard perianth, in which the seeds are enclosed, is firmly attached to the stem of the bush. It appears to take more than one year

for the bush to break down and for the seed to reach the ground. During this time of bush decay there would be a parallel decay of the hard perianths so that by the time the seed reaches the ground the perianth would have decayed sufficiently to allow germination to occur. It can be proposed that the dormancy mechanism would ensure that seed on the bush does not germinate. Once the seed reaches the ground, a frost then triggers germination of the seed.

6.5 DISCUSSION.

In view of the lack of published material, the role of germination in the behaviour of species in changing communities, particularly in the pastoral regions, does not appear to have been considered of major importance. Roux and Warren (1963), and Rice et al,(1960), have shown that germination plays an important role in succession on abandoned fields. It is therefore possible that germination and seed dispersal may play a major role in determining the vegetation changes that occur in response to grazing, as seeds are the major method of propagation of many species. In the Mitchell grass areas the principal species are *Astrebla pectinata*, and the three *Eragrostis* species (chapter 2). (Only *E. setifolia* is considered here). There are large differences in the seeds of the following two species. *E. setifolia* has small seeds which may be easily transported, whereas *A. pectinata* has much larger and heavier seeds. The small seeds of *E. setifolia* may assist in its behaviour as an increaser species. It has been reported that there is a correlation between seed size and the ability of a species to colonize areas. (Rice et al, 1960; Roux and Warren, 1963). Where there is a disturbance to a community which exposes bare areas the plants which produce the largest quantity of small transportable seed will have the best chance of producing the greatest number of seedlings.

This view can be extrapolated to the Mitchell grass areas. Heavy grazing of *A. pectinata* may cause a reduction in the soil vegetation cover, this may allow the small seed of *E. setifolia* to find areas conducive to germination and establishment. These

bare areas may be particularly important in seedling establishment, because there will be a reduced competition for light. In an ungrazed stand of *A. pectinata* the tussocks develop to a large size so that they spread sideways, effectively shading the inter-tussock regions. This may produce conditions which are unfavourable for seedling establishment and so tend to suppress any change in the botanical composition.

Another advantage which may assist *E. setifolia* as an increaser species is its rapid growth rate. *E. setifolia* is reported to be a perennial species (Black, 1960), although it can appear as an annual species (Lazarides, 1970). This behaviour means that *E. setifolia* reaches reproductive maturity much more rapidly than *A. pectinata*, so enhancing its ability to produce larger quantities of seed.

In other ecounits, germination may also be of importance in determining species behaviour. The example discussed here will be *Enneapogon polyphyllus* on Mulga shrubland soil. *E. polyphyllus* does not show any dormancy mechanism and germinates during the summer months. It appears that the behaviour of *E. polyphyllus* may be related to soil characteristics. This was supported by observations of its germination in the pot trial. The soil from the different range condition classes appears to show a marked difference in water retention under alternating periods of wetting and drying. The soil from the poor condition class showed a tendency to produce a hard crust which was not conducive to seedling establishment. Often it appeared that the seeds imbibed and germination commenced before the soil surface dried to a crust (often in one day). This dehydration then causes damage to the germinating seed (Collis - George and Sands, 1962; Koller, 1967; McWilliam et al, 1970; Tapia and Schmutz, 1971; Feddes, 1972; Bokhari, Singh and Smith, 1975). This soil behaviour was not as pronounced for the excellent range condition soil. The increaser species, *B. cornishiana*, may be advantaged in that it is a winter germinating species and so may not suffer the effects of soil crusting until the seedlings have reached a size which can

withstand drying of the soil surface.

B. cornishiana may be influenced by the physical effect of trampling by grazing animals, especially under heavy grazing. The effect of trampling is to accelerate the breakdown of the bushes, which in turn will accelerate the decomposition of the hard dispersal unit, or perianth parts, which surround the seed. It appears that the restriction imposed by the hard perianth may be a mechanical effect. The influence of the breaking down of the dispersal unit may be to reduce any dormancy mechanisms inherent in the seed.

The other ecounit from which seeds were collected was open woodland. It appears that there may be a similarity between the responses of the plants in this area and those of Mitchell grass area, although the species differ *E. polyphyllus* will remain palatable while flowering and seeding, and therefore at these times grazing may markedly reduce the seed store which would normally be available to produce a new generation of plants. The increaser species in this area, *A contorta* may be advantaged by its unpalatability while seeding, and also by its specific dormancy mechanisms. (Mott, 1972, 1974a, 1974b). This dormancy may ensure that a greater percentage of seedlings will survive due to germination under a highly specific set of environmental conditions.

This chapter has been involved mainly in the discussion of the germination characteristics of some of the possible indicator species for range condition. It can be seen that species behaviour will be largely controlled by the conditions under which germination occurs. This suggests that there may be a potentially important need for the study of field germination percentages and seedling survival percentages. In conclusion it can be stated that we have only a limited knowledge of the autecology of the species studied in these pot trials.

TABLE 6.1

RESULTS.

Temperature range within which germination will occur.

Species.	Minimum Temperature	Maximum Temperature
Enneapogon polyphyllus.	15°C	33°C
Eragrostis setifolia.	21°C	37°C
Aristida contorta.	20°C	35°C (Mott, 1972).
Astrebla pectinata.	20°C	33°C
Bassia cornishiana.	17°C	25°C

TABLE 6.2

RESULTS.

Germination percentages.

Eragrostis setifolia	70%	(40)
Astrebla pectinata	67%	(86)
Enneapogon polyphyllus	73%	(90)

The figures for germination are expressed as a percentage of the viable seed.

The figures in brackets were the viabilities as a percentage.

TABLE 6.3

Germination percentages.

ARISTIDA CONTORTA.

Location.	Intact	Dehulled	Viability
Amburla, 1972.	0	0	0
Bond Springs, 1976.	0	0	0
Woodland sites, 1977.	79%	100%	86%
Kunoth, 1978.			
Kunoth (Heat treated).	0	0	

TABLE 6.4

Germination percentages.

BASSIA CORNISHIANA.

	Intact	Dissected out	Viability
Fresh seed (Taken from the bush).	0	24%	90%
Old seed (approx. 2 seasons old).	47%	71%	34%

Alternating temperature (20°C for 8 hours, 8°C for 16 hours).

	Intact	Dissected out	Viability
Fresh seed	0	28%	90%
Old seed	50%	70%	34%
Chilled seed			
Fresh seed	0	66%	90%
GA_3 10µg/ml			
Fresh seed	0	52%	90%

CHAPTER 7.

DISCUSSION AND CONCLUSIONS.

7.1 DISCUSSION AND CONCLUSIONS.

The results and discussions of the pot trials given in previous chapters, allow a number of conclusions to be drawn. The major conclusion is that across range condition classes there is a a difference in the growth potential in both increaser and decreaser species, and that this appears to be related to soil nutrient changes. In the case of *Erogrostis setifolia* this growth difference is very marked, however the results obtained for *Enneapogon polyphyllus* is less conclusive. It was also shown that Central Australian soils are very low in the major nutrients N, P and S. This has also been shown by Winkworth, (1967) and Charley and Cowling, (1968). The severe limitation of growth observed may be important, as many species may be sensitive to small changes in the available levels of these nutrients. The severe growth limitations, and the response of the species to added nutrients was also shown by Dr.Friedel (unpublished data) in two pot trials completed by her, and by soil nutrient analyses. (Unpublished data).

In the case of *E. setifolia*, there were marked nutrient responses which were range condition linked. (chapter 4). Extrapolating this to the field situation, it could be suggested that there are marked soil nutrient changes on the Mitchell grass plains in response to grazing. It appears that there may be a complex relationship between grazing, vegetation and soil nutrient changes. Grazing will specifically advantage or disadvantage different species, so producing a change in botanical composition. Grazing also appears to influence the soil nutrient status by removal of nutrients through the vegetation. This soil nutrient change will also influence the botanical composition of the vegetation. It could also be suggested that the vegetation influences the soil nutrient levels

and any change in botanical composition may alter the relative amounts of the available nutrients.

The situation in the Mulga shrublands appears to be different from that mentioned above. *E. polyphyllus* showed marked responses to a number of nutrients, some causing an increase in growth, others a decrease. Of major importance was the difference between the pot trials in the range condition interactions. (Chapters 4 and 5). In the Mulga shrubland, rather than large nutrient effects on the different range condition, there may be important species - species interactions. Competition between the different species may be affected by grazing, such that the increaser species become more competitive for the available nutrients when the palatable decreaser species are selectively grazed, thus reducing their competitive ability. Germination and seedling survival may also play an important role in species survival in this ecounit. Differences in soil physical properties may be markedly reducing survival of *E. polyphyllus* at the seedling stage. (Chapter 6). The germination characteristics of *Bassia cornishiana* may also play an important role in the behaviour of this species as an increaser species. The effect of trampling may increase the seed dispersal as well as accelerate the breakdown of the hard perianth surrounding the seed.

From the above it appears that any generalizations concerning different ecounits may be difficult to justify. In one case, the grazing effect appears to be manifested by soil nutrient changes where there is a relationship between stocking intensity and nutrient loss. In the Mulga shrubland the changes in botanical composition may be related to species - species competition for nutrients and different germination characteristics of the species. This difference would suggest that the effect of grazing may be very dependent on the species characteristics, and generalizations from one vegetation type to another should not be made at this stage.

These experiments were conducted in an attempt to determine which nutrients are the most likely to be implicated in the field

distribution of the species. Extrapolations from a controlled glasshouse experiment should be made only with the realization that true field nutrient effects may differ from those mentioned (Rorison, 1969) and for this reason the next step in work would be to run a limited factorial in the field, using those nutrients shown to be limiting growth. Another experiment which could be of use in understanding the relative abilities of species to extract the nutrients, would be to run a limited factorial experiment in which the increaser and decreaser species were grown in the one pot. It would then be possible to determine if one species was extracting nutrients at the expense of the other.

It can be seen that there are large gaps in our knowledge of the effects of grazing on plant communities. Hopefully, this small piece of work contributes to the collective knowledge, such that in the future a greater understanding of grazing - vegetation interactions may lead to the proposal of sensible management policies. This would allow the retention of the pastoral lands as a large tract of native vegetation from which pastoral products can be obtained on a permanent basis.

APPENDIX A

The factorial experiment relies on the assumption that at the termination of the pot trials, the growth of the plants in the pots will be limited by a particular nutrient in the pot. At this stage the biomass of the plants should reach a maximum value while the growth rate tends to zero. Another alternative, however, is that a nutrient may inhibit growth and so slow the growth rate of the plants throughout the experiment. If the growth rate of the plants in the individual pots were known then this could be equated with the results from the factorial experiment. Also if growth rates were being monitored, then it would possible to terminated the experiment in the knowledge that there were nutrient limitations.

To follow growth rates of potted plants a non-destructive method of biomass estimation is required. With grass species a number of parameters could be measured which may possibly be equated to the biomass. Due to the time limitations it was found that it was not possible to take readings throughout the experiment, and so it was decided to test the parameters against the final biomass when the plants were harvested.

The first pot trial involved the perennial grass *Eragrostis setifolia*. This grass produces tillers from the base, therefore it was proposed that the number of these tillers may be representative of the biomass of the plants. Another parameter which was thought to be indicative of biomass, was plant height.

The two methods mentioned above were time consuming to read values for 128 pots of 10 plants each. For this reason a simpler estimation technique was attempted. One pot was chosen as the standard pot and all other pots were estimated against this standard. It was not possible to use a continuous scale for estimation so that size classes of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 were used.

The results for these three methods plotted against the final

dry weight of the plants (grams/pot) are graphed. Regressions were also calculated each graph.

RESULTS.

Graph 1 shows that there was a good correlation between the tiller number and the dry weight of the plants. (r^2 = It appears from this that tiller number could be used as an estimate of the dry weight and the growth rate thus followed. The main problem with this method is that in the vicinity of 19,000 tillers were counted in 138 pots. The time required to take this measurement prohibits the use of this method as a continuous reading throughout the experiment.

Graph 2 shows the regression for plant height and dry weight. This correlation is poor (r^2 = and so it appears that this parameter cannot be used. It will be noticed that there are only 32 values for this regression. This is due to the time taken to measure the plants. This principally comes from the risk of damaging the plants, and also, as each value is an average of five tiller lengths for each plant. This result, of a poor correlation between plant height and dry weight could be expected due to the growth form of the grass. Its growth mainly takes the form of tillering, rather than extension of a principal axis. For this reason it could be expected that the tillers would rapidly reach a maximum value for length, and then most of the biomass increment would be in the production of new tillers from the base of the plant.

The final method of biomass estimation against a standard pot, showed the greatest potential as a feasible method for estimating biomass. However, when the regression is computed for this data it is found that there is a poor correlation. (r^2 =). This appears to be due to observer error, that is, the difficulty in detecting differences in the pots. This is compounded by the difference in the sizes of plants within the one pot.

A possible solutiom to the problem of inaccuracy would be to use two standards of different size, to which the pots are compared. However, this then reduces the advantage of the method for estimation as it becomes time consuming and suffers the same problem as the first method. That is it would take so long to obtain a set of data that not enough sets could be obtained during the total period of the experiment to give an indication of growth.

From the results of the first section of Appendix A it was decided that the visual estimate method was not sufficiently accurate as a biomass estimate, so that this was not attempted for *Enneapogon polyphyllus*. In addition the height measurements were not taken as it is reported that height, or tiller extension does not give a good correlation with biomass. (Friedel, pers. com.)

For these reasons the only measurement taken was that of tiller number. The results for this regression are graphed.

The regression equation is

$$A = 27.75\ B + 21.40$$

where A = tiller number.
B = dry weight.

The $r^2 = 0.507$.

These results indicate that it is only a fair regression between tiller number and dry weight.

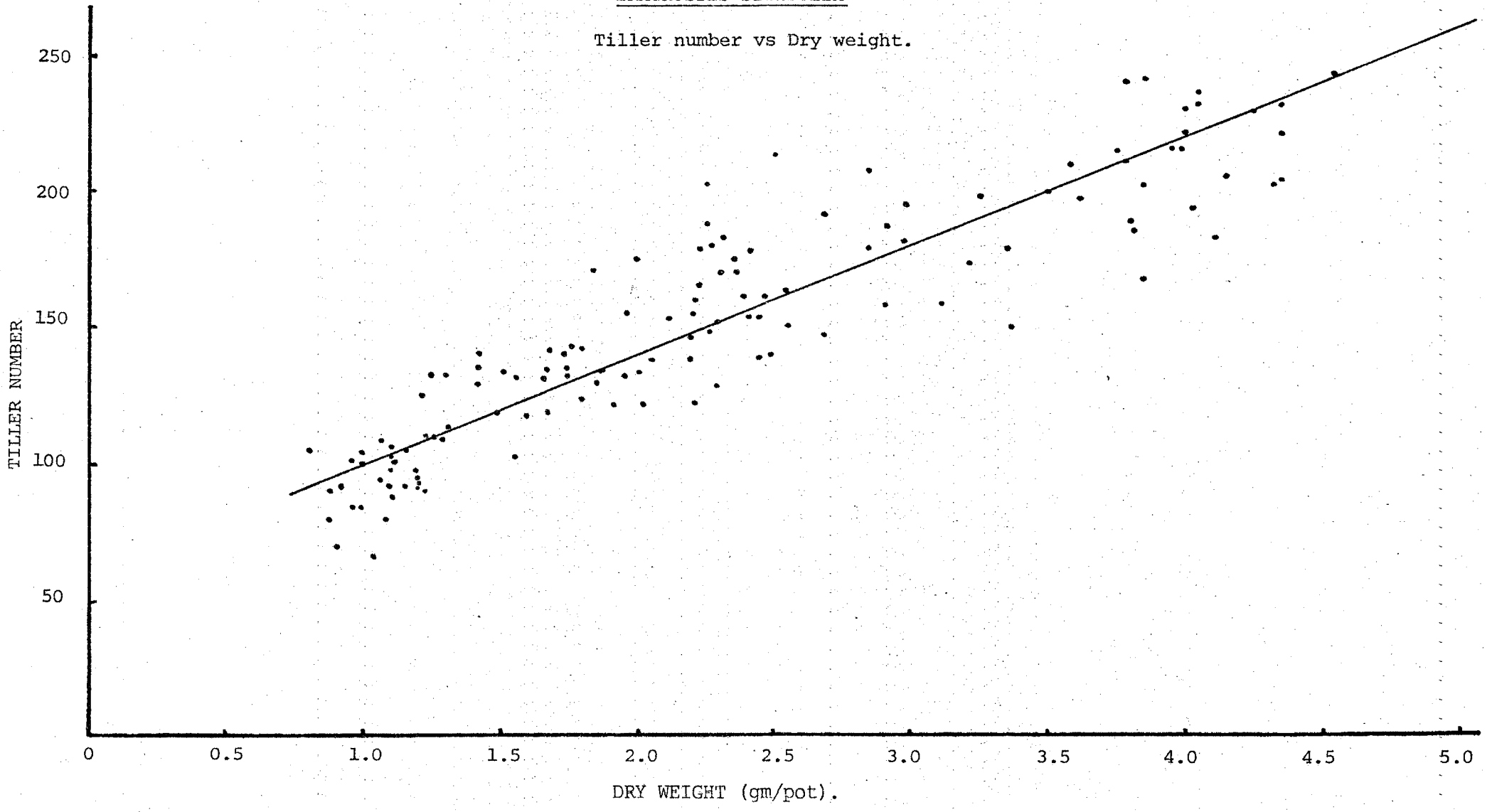
This section of the work indicates that tiller number, height or a visual estimate can be used for estimation of biomass of the species discussed. However, for the work here the accuracy was not quite to the level desired and most methods were extremely time consuming. Possibly these methods would be more applicable where the differences between the pots were greater. For the estimation technique, the small biomass of the pots made estimations relative to other pots difficult.

APPENDIX A.

GRAPH 1.

ERAGROSTIS SETIFOLIA

Tiller number vs Dry weight.

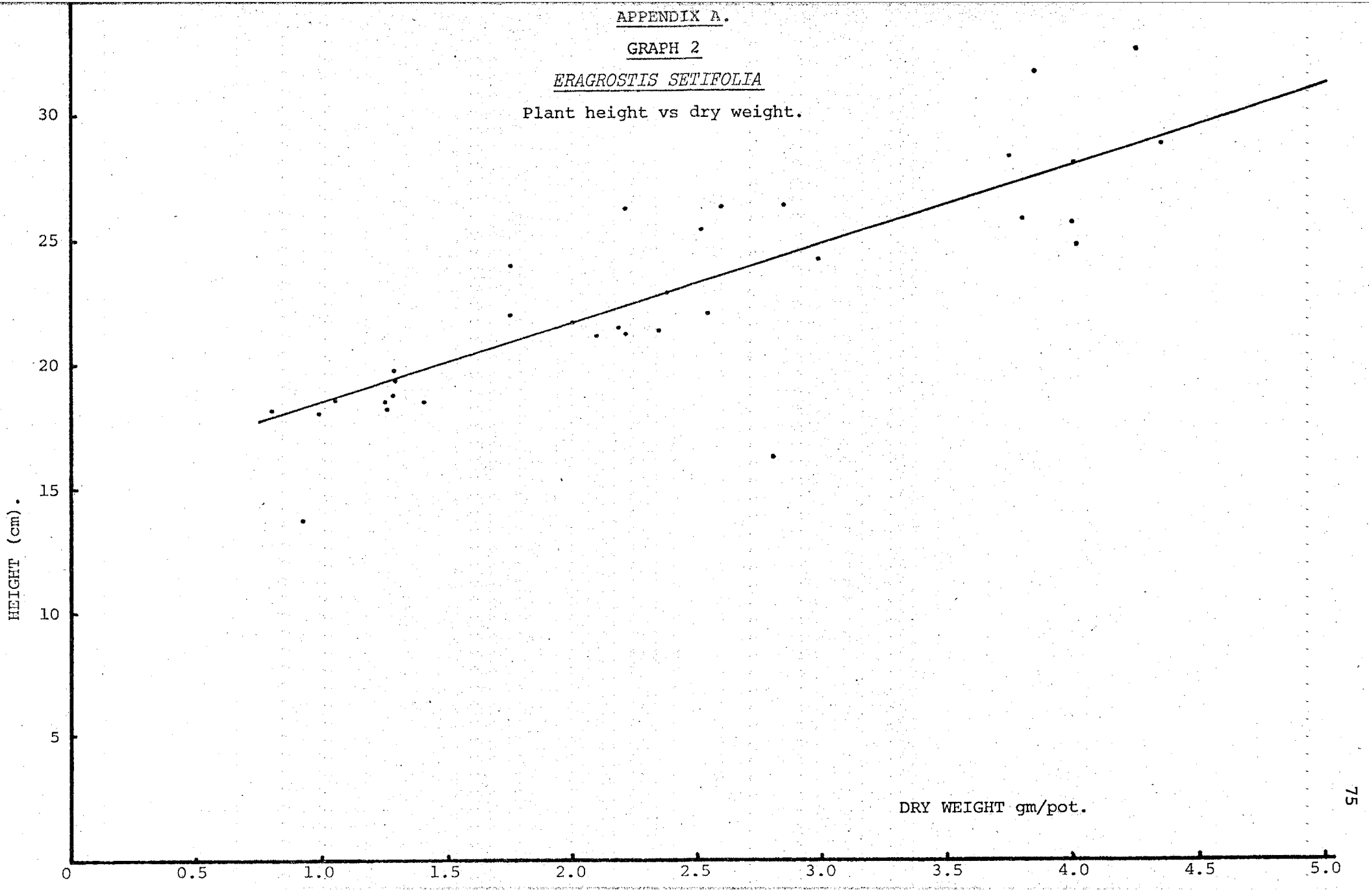


APPENDIX A.

GRAPH 2

ERAGROSTIS SETIFOLIA

Plant height vs dry weight.

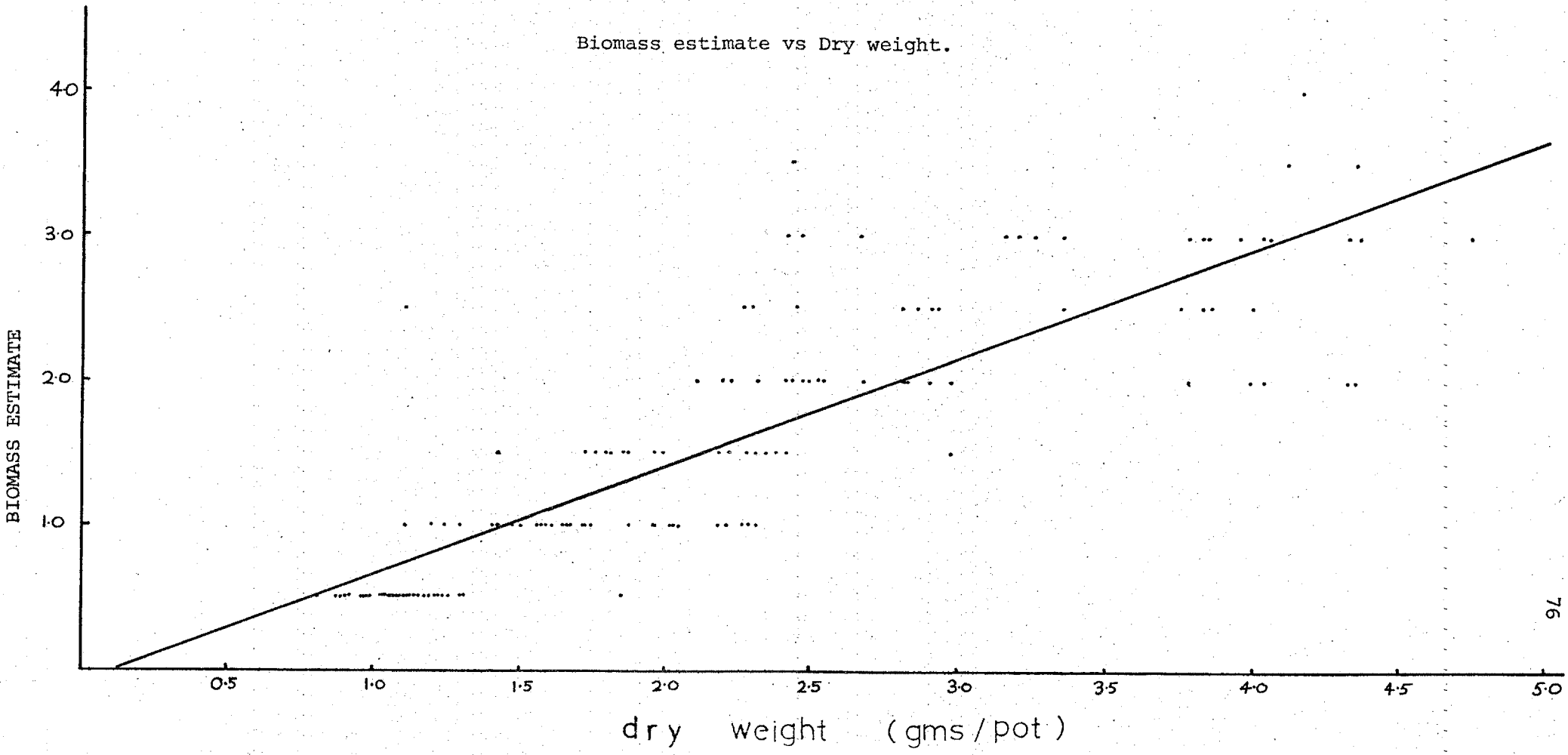


APPENDIX A.

GRAPH 3.

ERAGROSTIS SETIFOLIA

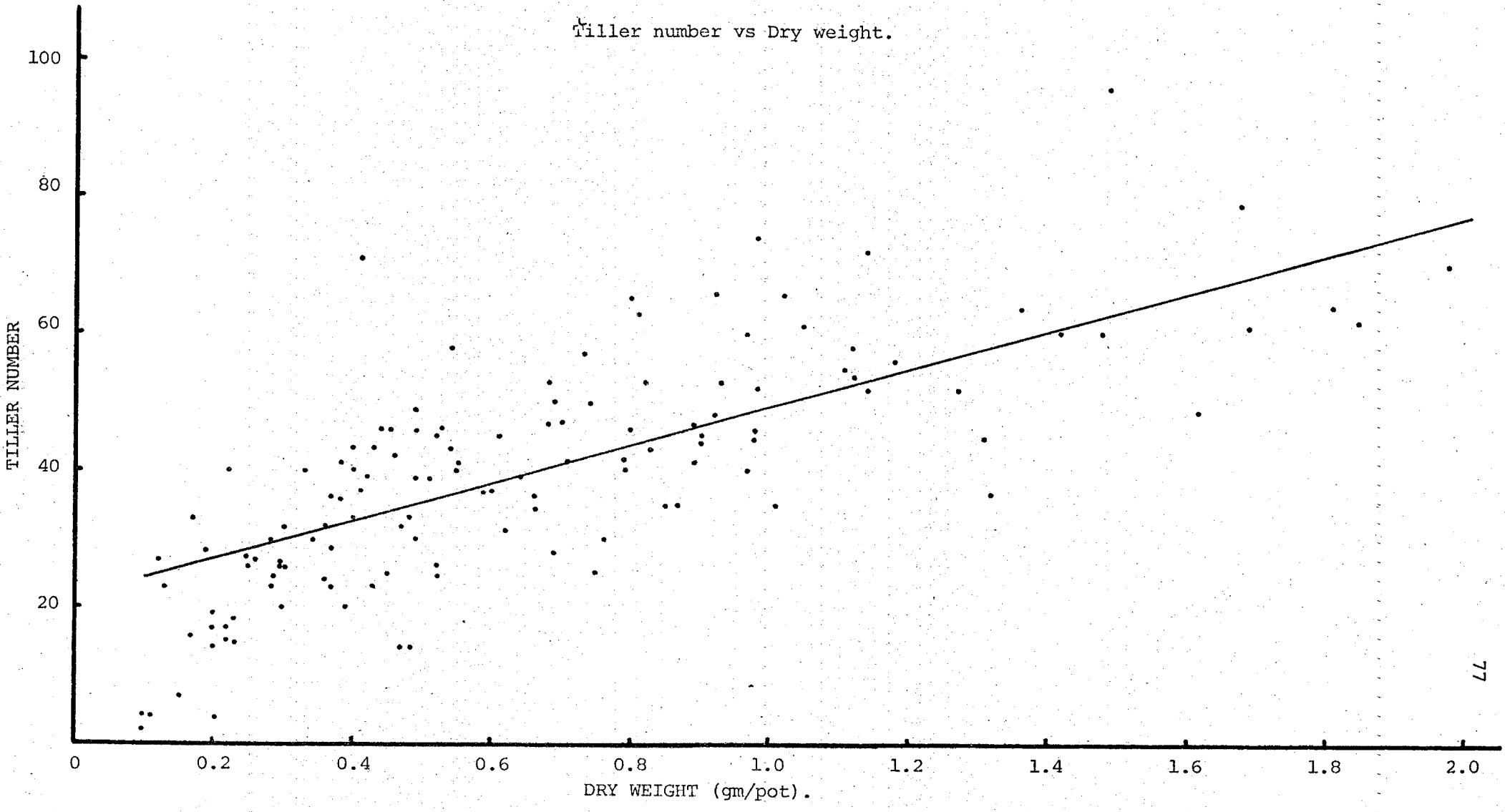
Biomass estimate vs Dry weight.



GRAPH 4.

ENNEAPOGON POLYPHYLLUS

Tiller number vs Dry weight.



APPENDIX B.

Astrebla pectinata :- pot trial on Mitchell grass soil.

Results (M.Friedel pers com.)

Primary responses - mean dry wt, gm/pot.

Range condition.

RC_o	RC_1	
1.376	1.182	L.S.D.$_{(5\%)}$ = 0.17

Nitrogen.

N_o	N_1	
0.791	1.767	L.S.D.$_{(5\%)}$ = 0.17

Phosphorus.

P_o	P_1	
0.795	1.763	L.S.D.$_{(5\%)}$ = 0.17

Sulphur.

S_o	S_1	
1.164	1.394	L.S.D.$_{(5\%)}$ = 0.17

The subscripts refer to the levels of application, see Appendix

RC_o = Poor range condition soil.

RC_1 = Excellent range condition soil.

APPENDIX B.

Astrebla pectinata :-

Results (M.Friedel pers. com.)

Primary interactions.

Range condition x Phosphorus

	P_o	P_1
RC_o	0.518	2.233
RC_1	1.072	1.292

Nitrogen x Phosphorus.

	P_o	P_1
N_o	0.558	1.025
N_1	1.033	2.500

Range condition x Sulphur.

	S_o	S_1
RC_o	1.377	1.375
RC_1	0.951	1.414

Nitrogen x Sulphur.

	S_o	S_1
N_o	0.803	0.780
N_1	1.525	2.009

APPENDIX B.

Astrebla pectinata :- three factor interactions.

Results (pers. com. M.Friedel).

Range condition x Phosphorus x Nitrogen. *** ($p < 0.001$).

	N_o		N_1	
	P_o	P_1	P_o	P_1
RC_o	0.428	1.337	0.608	3.129
RC_1	0.687	0.712	1.458	1.871

$L.S.D._{(5\%)} = 0.2449.$

APPENDIX B.

Enneapogon polyphyllus :- pot trials on open woodland soil.

Results (M.Friedel pers. com.)

Primary responses - mean dry wt, gm/pot.

Range condition.

RC_o	RC_1	
2.929	3.377	L.S.D.$_{(5\%)}$ = 0.23

Nitrogen.

N_o	N_1	
2.426	3.881	L.S.D.$_{(5\%)}$ = 0.23

Phosphorus.

P_o	P_1	
2.832	3.474	L.S.D.$_{(5\%)}$ = 0.23

Sulphur.

S_o	S_1	
2.467	3.840	L.S.D.$_{(5\%)}$ = 0.23

Calcium.

Ca_o	Ca_1	
3.380	2.927	L.S.D.$_{(5\%)}$ = 0.23

Magnesium.

Mg_0	Mg_1	
		L.S.D.$_{(5\%)}$ = 0.23

APPENDIX B.

Enneapogon polyphyllus: - two factor interactions

Results continued (pers. com. M.Friedel).

Mean dry wt/pot.

Range condition x Nitrogen.

	N_o	N_1	
RC_o	2.345	3.514	
RC_1	2.507	4.248	L.S.D.$_{(5\%)}$ = 0.32.

Range condition x Phosphorus.

	P_o	P_1	
RC_o	2.423	3.436	
RC_1	3.242	3.513	L.S.D.$_{(5\%)}$ = 0.32.

Nitrogen x Sulphur.

	S_o	S_1	
N_o	2.338	2.513	
N_1	2.596	5.166	L.S.D.$_{(5\%)}$ = 0.32.

APPENDIX B.

Enneapogon polyphyllus : three - factor interactions.

Results continued.

Mean dry wt/pot.

Range condition x Phosphorus x Sulphur.

	P_o		P_1	
	S_o	S_1	S_o	S_1
RC_o	1.919	2.926	2.606	4.266
RC_1	2.409	4.075	2.934	4.092

$$L.S.D_{(5\%)} = 0.457$$

Soil										
Fair Range Soil	0.054	0.039	21.3	0.2	7.1	1.0	7.50	7.74	0.54	0.40
Excellent Range Soil	0.057	0.044	22.4	0.2	10.5	1.6	6.62	6.90	0.59	0.39
Significance * p<0.05 ** p<0.01 *** p<0.001	NS	*	*	NS	**	NS	***	***	*	*
L.S.D.$_{(5\%)}$	-	0.003	8.5	-	2.6	-	0.14	0.16	0.08	0.05

APPENDIX C. (data of M.Friedel, pers. com.)

NUTRIENT ANALYSIS - MULGA SHRUBLAND

	Total N (%)		Incubated NH_4 ppm		Available P ppm		pH		Organic C (%)	
Depth (cm)	0-4	4-10	0-4	4-10	0-4	4-10	0-4	4-10	0-4	4-10
Poor Range Soil	0.074	0.037	23.9	17.3	7.7	3.4	5.19	4.87	0.88	0.50
Fair Range Soil	0.057	0.030	27.2	18.1	12.4	6.1	6.09	6.07	0.82	0.53
Excellent Range Soil	0.053	0.025	31.8	17.8	8.5	3.9	5.87	5.87	0.69	0.67
Significance * p<0.05 ** p<0.01 *** p<0.001	NS	NS	NS	NS	**	**	***	***	NS	NS
$L.S.D_{(5\%)}$	-	-	-	-	2.9	1.6	0.37	0.53	-	-

APPENDIX C. (data of M.Friedel, pers. com.)

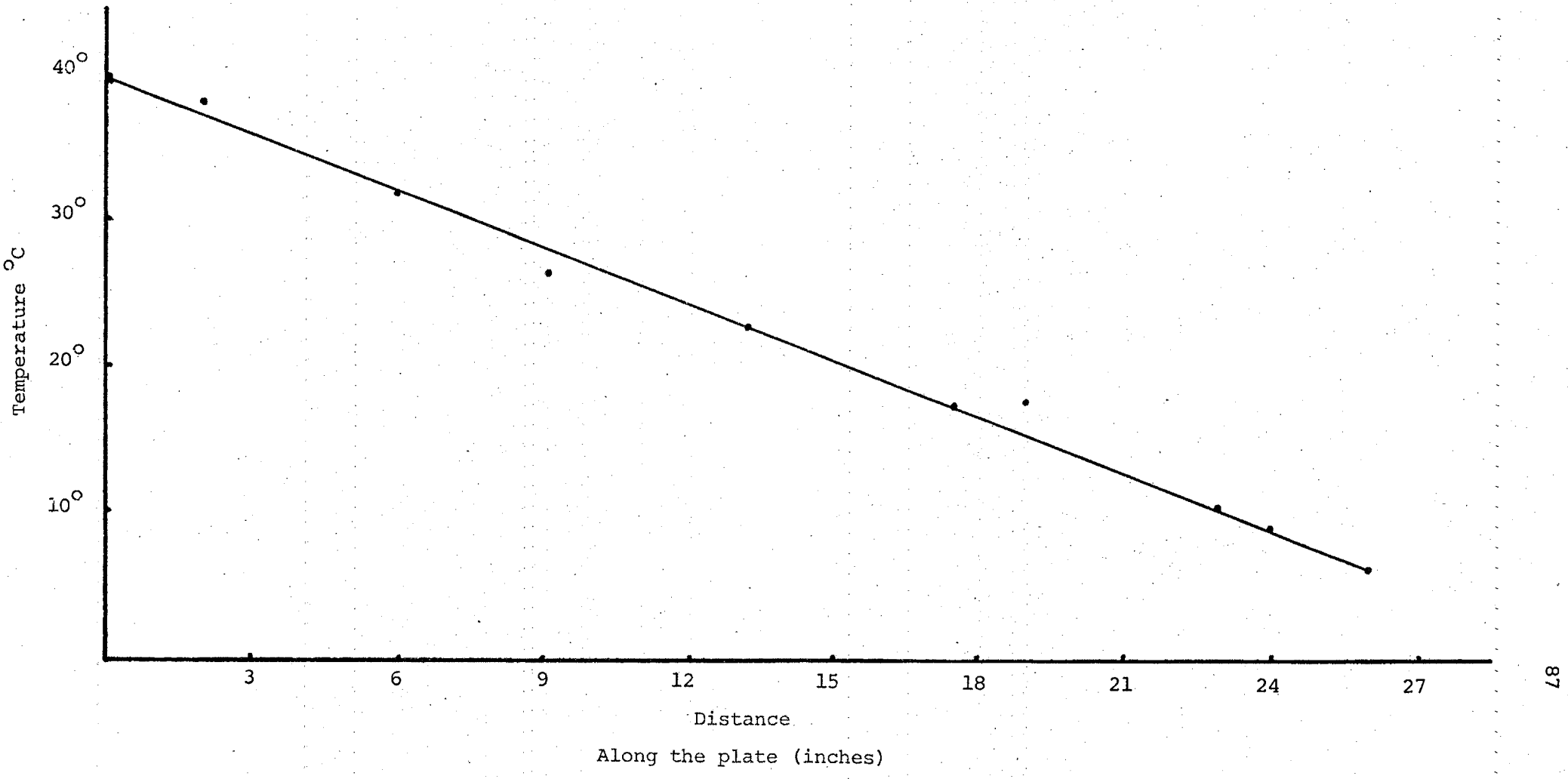
NUTRIENT ANALYSIS - OPEN WOODLAND.

	Total N (%)		Incubated NH_4 ppm		Available P ppm		pH		Organic C (%)	
Depth (cm)	0-4	4-10	0-4	4-10	0-4	4-10	0-4	4-10	0-4	4-10
Poor Range Soil	0.027	0.014	13.6	0.1	11.8	7.3	6.02	6.15	0.47	0.30
Fair Range Soil	0.045	0.021	21.2	3.0	19.0	11.4	6.10	6.09	0.68	0.43
Excellent Range Soil	0.030	0.014	11.1	0.2	15.3	11.9	6.07	6.20	0.64	0.50
Significance * p<0.05 ** p<0.01 *** p<0.001	**	*	**	*	**	**	NS	NS	*	***
L.S.D (5%)	0.011	0.005	5.4	2.5	4.3	2.4	-	-	0.15	0.07

APPENDIX.D.

STANDARD CURVE

Germination Plate



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