RADICAL VELD IMPROVEMENT IN SOUTH AFRICA WITH SPECIAL REFERENCE TO THE HIGHLAND SOURVELD OF NATAL

by

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GENERAL INTRODUCTION

South Africa, like all developing countries, has a rapidly increasing population which is steadily increa= sing its standard of living. The inevitable result of this unavoidable trend is a continuously increasing de= mand for food. This increasing demand will soon reach the stage where it places a servere strain on the agri= cultural land and agricultural industry of South Africa to produce to potential. At this stage it will be im= portant that all available arable land produce human food as efficiently as possible. The production of food directly from plant sources is considerably more efficient than the conversion of plant crops to animal products for human consumption. Thus field crop pro= duction will in time take precedence over livestock farming for the arable areas of the country.

South Africa has relatively little land which is suited to annual cropping. It seems to be generally agreed that no more than 15% of the land surface of the country is potentially arable. It is also pro= bably true to say that much of this land is already cultivated for annual cropping. In turn much of this cultivated land is already producing at levels some= where near the potential of the land. The remaining 85% of the Republic must, due to limitations of rainfall and physiography, be retained as veld or grassland. What is the potential of this grassland and has this po= tential been fully developed and utilized? Is it not possible to meet the need for food, of the growing po= pulation, from the as yet unutilized potential of this grassland? Information on which to base answers to these questions is limited and has not been co-ordina= ted and assessed.

Radical veld improvement means the use of radical measures (cultivation, overseeding and fertilization) in an attempt to develop the full production potential of the veld areas. Tidmarsh (1966), Edwards (1966) and Davies (1968) have indicated that the production of the grassland of certain areas of this country can be improved considerably. However, as yet no surveys have been made to determine the extent of the areas which can be improved. Thus one of the aims of this study was to produce, in very general terms, a map of the grassland potential of the Republic. Such a map, if reliable, would provide some data on the nature and scale of the potential for radical veld improvement.

The Highland sourveld of Natal, which has a high rainfall, a rugged terrain and which is generally un= suited for large scale annual cropping, is a good example of grassland in which the full potential has yet to be developed. It was for this reason, and be= cause facilities for research, as well as much research data, was already available, that a detailed investiga= tion of the potential for the improvement of veld in this area was instigated. The research programme was not initiated with the specific purpose of studying radical veld improvement but developed in this direc= tion over a period of years from the time of establish= ment of the Tabamphlope Research Station in 1936. The period of research covered by this dissertation extends from 1955 to 1966, during which time the writer was ac= tively engaged in research in the area.

Thus the objects of this dissertation are fully to assess the production potential of the non-arable areas of the various ecological regions of the Repu= blic of South Africa, to consider the possibilities for increasing production to the potential of these areas and, by way of example, to study the possibili= ties for the maximization of production of Natal through radical veld improvement. Furthermore, the aim of the work reported here is to provide some in= formation on methods of achieving this objective. Finally, it is hoped that the whole will provide both a stimulus and a starting point for further work di= rected to the realization of this goal.

2. THE FUTURE FOR RADICAL VELD IMPROVEMENT IN SOUTH AFRICAN AGRICULTURE

2.1 Introduction

It is estimated that the population of the Republic of South Africa will reach 54 million at the turn of the century (Barac, 1969). This is about three times the present population. A breakdown of this figure into racial groupings gives 35.5 million Africans, 6 million Coloureds, 5 million Asiatics and 7.5 million Whites. This increase in population will be paralelled by an increased demand for food.

It must be assumed that there will also be a stea= dy increase in earnings of the non-European population. Such increased earnings will result in a demand for more food <u>per capita</u> for these 47 million people. Voster (1963) attributes the increases in the daily in= takes <u>per capita</u> of calories from 2,456 to 2,879 and of protein from 68 to 82 grams between 1947 and 1962 to rising incomes combined with rapid urbanisation in the Republic. When the increase in population is con= sidered in conjunction with the increased incomes, a four-fold increase in the demand for food by the year 2000 does not appear to be unreasonable.

At present the position regarding the supply of human food in the Republic shows a fairly even balance between exports and imports. Maize is exported (in years of plenty but imported in drought years such as 1969) as are considerable quantities of sugar, fruit and fruit products. There are no significant exports of edible grassland products inspite of periodic local seasonal surplusses. Significant imports of wheat and rice are made annually. In 1962, 72,000 and 48,000 short tons of wheat and rice respectively were imported.

Based on the present systems of farming only re=latively small increases in food production can be expected. Techniological advances in agricultural production, increased areas under cultivation and the application of improved farming practices will un=doubtedly go some way towards alleviating the problem of future food shortage. A small increase in the production of the fishing industry in local waters, which provides an important source of protein, can also be expected. Although only ten percent of the total area of the Republic was cultivated in 1963, it appears that this area is unlikely ever to exceed fifteen percent, due to physical limitations (Voster, 1963).

It would seem therefore, that if the expected de=mands for food are to be met, considerable reliance will have to be placed on the remaining 85% of the area of the Republic. The uncultivated land (veld) is stocked up to and, in some cases, over its present carrying capacity. Some improvement in production from the veld can be expected if the potential carry=ing capacity is realized by means of the application of desirable veld management practices on a nation-wide basis. Despite many repeated appeals to arrest veld deterioration and soil erosion and to implement veld management methods designed for reclamation of of the grassland vegetation to its optimum condition and restoration of the potential productive capacity, little has been done. Even if these measures are applied, as they must be if denudation is to be avoi= ded, the increase in production will be small in re= lation to the anticipated demand.

It would appear that, if the demands for increas= ed food production are to be met, some drastic chan= ges in the farming systems will be needed in the future. Pentz (1945) presented a detailed agro-ecological map of the Republic in 1945. These surveys, in which he recommended the application of farming systems deter= mined by the natural limiting factors, describe the agricultural potential of the Republic as he saw it over twenty years ago. At that stage, the possibility of altering the natural factors other than soil fer= tility, in order to alleviate limiting factors was not considered in the context of a balanced farming system. However, because of the predicted food shortages and because of technical advances these possibilities now warrant careful consideration. Pentz (1945) consi= dered the natural factors limiting the potential of an area to be soil, climate, vegetation and topography. It is, of course, not feasible to consider large scale changes in climate and topography even though local improvement can be achieved by irrigation and by con= structing terraces and contours. The soil, although it can not be changed, can be improved considerably on a practical scale by the application of fertilizers. The indigenous vegetation of our grasslands frequently has genetic limitations which prevent it from making optimum use of environmental conditions. Much re=

search work, the most recent of which is that of Ed= wards (1966) and Graven (1967), has shown that the partial or total replacement of veld by species with a greater genetic potential, when associated with fer= tilization of the soil, results in a vastly increased production in the higher rainfall areas. The advent of the aeroplane in agriculture, used for the sprea= ding of fertilizer, herbicides and seed, also makes the rapid development of large tracts of non-arable land more practicable.

For these reasons it was considered that a reas= sessment of the production potential of our grasslands was a matter of some urgency. In spite of a lack of adequate knowledge and data, an attempt is made to pre= sent such an assessment in the following section.

2.2 The production potential of the veld areas of South Africa

Pentz (1945) emphasised the need for planned farming on the basis of the type of agriculture to which the area was best suited. "This must be based in the first place on a knowledge of the vegetation, soil and climatic conditions - particularly the inci= dence and distribution of rainfall, summer and winter temperatures, altitude and topography, and in the se= cond place on a knowledge of the requirements for dif= ferent types of stock, crops, pastures and timber. Such a survey made on the broadest lines, would demo= crate first of all the areas suitable for different types of farming." (Pentz, 1945). Although the first object of this section is to delimit areas in which grassland farming systems can be considered, and not, as was Pentz's concern, to define correct land utili= zation in all agro-ecological regions, the approach to the realization of the former objective lies also in the consideration of the natural limiting factors de= scribed by Pentz.

Although the distribution of the indigenous vege= tation, as mapped in veld types, is a valuable indica= tor of the potential of the vegetation in its undi= sturbed state, it does not necessarily indicate the potential of areas for production by means of radical veld improvement. Such maps are usually based on the distribution of the climax species, but it may well be the pioneer species which determine the reaction of the sward to certain radical veld improvement prac= tices such as fertilization and introduced species may be those to be used in complete replacement. On the other hand, it may well be that the species pre= sent in a particular veld type will influence the suc= cess of overseeded species. Their growth habit, their competitive ability and possibly root exudates may act to the detriment or benefit of introduced species. However, lack of information in these direc= tions necessitates the exclusion of such considerations. It is probable that the vegetation, as classified into veld types, can serve as a useful indicator of the po= tential for radical veld improvement because it is a tangible expression of the edaphic and climatic envi= ronmental conditions. Such use of these maps must, however, await the acquisition of more field data. In a later portion of this chapter an attempt has been made to relate the proposed classification for radical veld improvement to Acocks' (1953) veld types.

Topographical considerations undoubtedly play an important role in determining the grassland potential of an area. The influence of altitude, aspect and slope on climatic conditions is well known. Topography is also important in that it may often determine the most suitable method for grassland improvement. However, because topographical changes take place within short distances, particularly in the high rainfall areas of this country, it is an almost impossible task to survey and map the country on a scale which would reflect the influence of topography on grassland potential.

Soils fall into much the same category as does topography. In fact, in many instances local variations in soils and topography are closely associated. Both the texture of the soils and their chemical composition are of importance in grassland improvement. The texture is of significance in determining the soil water regime and the erodibility of the soil. The chemical composition (although it can usually be ameliorated by the addition of lime or fertilizers) frequently determines the range of plant species and legume rhizobia which will succeed in a specific area. It may determine the production of the successful species, and in extreme cases (alkali) is related to the stability of the soil. Unfortunately, however, because of the localized nature of soil variations, and because of the possibilities of modification by amelioration and fertilization, soils are unsuitable as a mapping unit for this classification of categories of differing potential for radical veld improvement.

The parent material from which the soils are formed is, except for local intrusions such as dole= rite, usually distributed in a form suitable for map= ping. However, in many of the higher rainfall areas, climatic and thus topographic conditions override the influence of parent material in soil formation (Or= chard, 1954). Thus the parent geological formations may have little influence on the grassland potential of a region.

Climatic factors, partly because of their over= riding influence, undoubtedly play a greater role than do other environmental factors in determining the suc= cess of plants in an area. Precipitation and, to a lesser extent, the extremes of temperature are the most significant of the climatic factors.

The season of the year during which the greatest proportion of the precipitation falls, is of consequ= ence in determining the grassland potential of an area. Whether the rain falls during winter or summer not only determines the effectiveness of the rainfall due to variations in the evaporation rate, but also deter= mines the plant species best suited to the area prima= rily because of the photoperiod and temperature condi= tions prevailing during the moist season. For satis= factory growth, soil moisture, temperatures and photo= periods must be near the optimum for the plant species under consideration. Thus two regions which receive the same total amount and form of precipitation, but at different seasons, would be suited to entirely different plant species. The total amount of precipitation (as well as its distribution) is perhaps the most important single factor determining the grassland potential of an area. It is generally accepted that most plant species have certain moisture tolerance ranges outside which they can not survive. Further their production and competitive ability within these ranges is determined by the available water supply. The efficiency of the precipitation in maintaining a favourable moisture regime for plant growth is modified by evaporation. It would appear that evaporation rates are an empirical expression of the effects of altitude, temperature and incoming radiation on the moisture regime, and as such can be an aid to mapping for grassland potential. Extremes of temperature are of importance in determining the range of plant species. In the wetter (>500 mm annual rainfall) regions of the Republic the incidence of high temperatures, appears to be negetively related to the occurrence of extremes of cold (frost incidence). Thus the latter appears to be a satisfactory line of demarcation. Because of the overriding influence of climate on other environmental components, these climatic factors have been used as the basis for compiling a map of the grassland potential of the Republic.

The report published by the Weather Bureau (Anon, 1960) divides the Republic into twenty-three rainfall districts, and presents data giving the percentage of the annual rainfall which falls in the summer between October and March. The districts, when considered on this basis, fall into three fairly distinct categories:

(1) The winter rain region consists of the first

four districts all of which are situated in the Western Cape Province and receive less than 33% of their total annual rainfall in the summer.

(2) The all-year rain region includes districts five to eight which lie along the southern coast-line of the Cape Province and receive more than 43% but less than 56% of their to= tal annual rainfall in the summer.

(3) The summer rain region (districts nine to twenty-three) which comprises the rest of the country, receives more than 66% of its rainfall in the summer. In this region the incidence of summer rainfall is greatest in the north (up to 86% in the Transvaal) and least in the south (down to 66% in the Karoo).

(Note: None of the districts receive between 34-42% and between 57-65% of their rain in summer.)

These rainfall regions have been used to provide the basic division of the Republic of South Africa for the purpose of this discussion.

The Weather Bureau (Anon, 1965a), presents a map on which the coastal areas and the Transvaal lowveld are separated from the rest of the country, on the ba= sis that these areas have an average annual occurence of less than five days with minimum temperatures below 0^{0}C. This information has provided the basis for the subdivision of the summer rainfall region into "frost" and "frost free" zones. The lines demarcating the five, ten and thirty day per annum frost frequency zones lie very close to one another and so further subdivision was not warranted. It was not considered necessary to extend this division to the all year and winter rain regions because the temperate plant species, which dominate pastures in these regions, are adapted to frost conditions. A case could be made for demarcating the small portion of the all-year rainfall region between Port Elizabeth and East London on this basis. This area is suited to tropical grass and legume species, but it is small and the western boundary is at this stage uncertain. Such a subdivision would be more appropriate in a more detailed classification of the area than is undertaken here.

The total annual rainfall within each region (Anon, 1957) has been employed to sub-divide further the regions and zones in relation to their grassland use potential. In this sub-division the average annual evaporation, as recorded from the American class A tank (Anon, 1965a) has also been taken into account. (It is considered that this factor influences the effectiveness of the rainfall). Fortunately rainfall reliability and variability appear to be closely related to total rainfall. The former is positively and the latter is negatively related to total rainfall (Anon, 1960).

In an earlier publication the writer (Edwards, 1966) suggested a preliminary division of the Republic into three veld use categories based on the potential for grassland improvement. These three categories were: (a) veld suited to management only, (b) areas suited to veld reinforcement (overseeding and fertilization), and (c) areas suited to veld replacement. Veld management is achieved by making use of fencing to control stocking densities and livestock movement and by providing water facilities. Reclamation measures may be necessary. These measures may include the re-seeding of areas, but the process is distinct from that practiced in radical veld improvement, in that the original components of the sward are generally reseeded and not exotic species. Veld may be rein=forced by the addition of improved pasture plants and/or by the addition of plant nutrients by fertilizer application. Veld replacement is the complete and immediate replacement of veld on a large scale by im=proved perennial pasture plants.

Since the date of this publication the term "Radical veld improvement" has been coined. This term, Radical veld improvement, in the context of this thesis is considered to include both veld reinforcement and veld replacement. Thus each region or zone has been subdivided into rainfall and evaporation areas which correspond with one of these three potential veld use units.

In the winter rainfall region the 300 mm annual rainfall isohyet has been accepted as the lower limit to radical veld improvement, and consequently the upper limit for veld management and reclamation. This figure was decided upon somewhat arbitrarily, although at similar latitudes, with winter rainfall in Australia it has been found to be close to the practical limit to pasture improvement (Anon, 1965b; Edwards, 1968). In the all-year rain region two limits have been used. In the portion west of Port Elizabeth with an average annual evaporation of less than 70 inches (1778 mm), the 400 mm isohyet has been accepted as the lower limit to veld improvement. However, in the area between Port Elizabeth and East London, with a higher evaporation (>70 inches per annum) the 500 mm annual rainfall isohyet becomes the boundary. These limits are close to those suggested for similar regions in New South Wales in Australia (Anon, 1965b). In the summer rainfall region two limits have also been used. On the Drakensberg escarp= ment and in the area east of it, as far as the Indian Ocean, which has an average annual evaporation of less than 80 inches (1932 mm), a lower limit of 500 mm average annual rainfall has been set for radical veld improvement. Observations on the success obtained with planted pastures in the river valleys of Natal and near Stutterheim in the Eastern Cape indicate that this limit is not unreasonable. West of the Drakensberg escarp= ment (>80" average annual evaporation), the limit has been set at 600 mm average annual rainfall. Hall, Meredith and Altona (1955), and Visser (1966) state that benefit from nitrogen fertilization is unlikely to be obtained in the Highveld and in the Orange Free State when the rainfall drops below 625 mm per annum.

The boundary between veld reinforcement and veld replacement has been placed along isohyets 200 mm (in the Winter rain region) and 300 mm (in the other re= gions) higher than the previous boundary. A lower figure has been allocated to the winter rain region, because this region has a much lower evaporation rate during the rainy season, and thus the rainfall is much

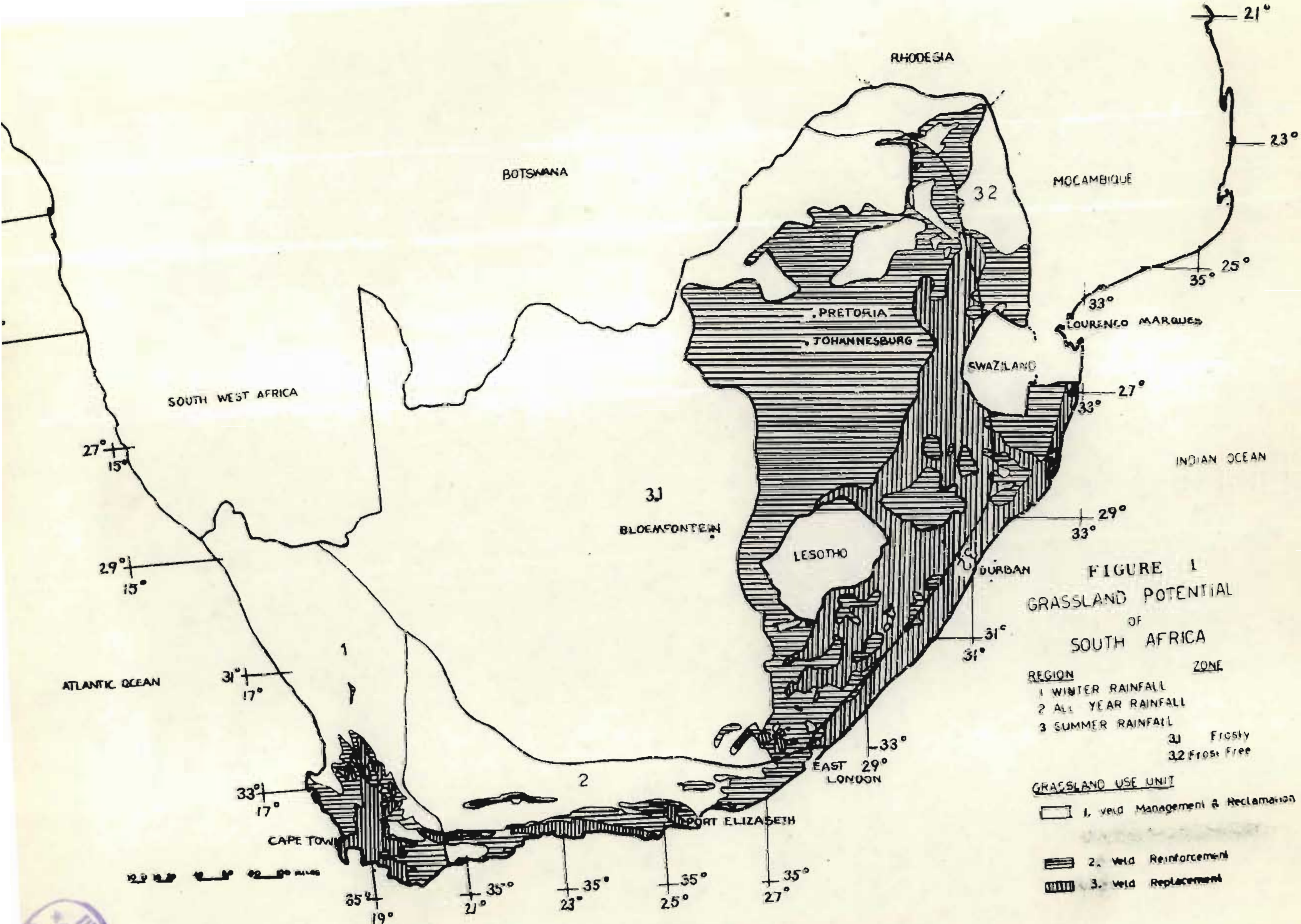


FIGURE 1
GRASSLAND POTENTIAL OF SOUTH AFRICA

Table 1

The ecological regions of South Africa

Region	Zone	Area	Veld-use Unit	Size as % of total area of Republic
1. Winter rainfall (< 33% of total rainfall in summer)		1.1 < 300 mm rainfall per annum	Management & reclamation	8.57
		1.2 300 - 500 mm rainfall per annum	Reinforcement	1.49
		1.3 > 500 mm rainfall per annum	Replacement	1.06
				Total 11.12
2. All-year rainfall (43 - 56% of total rainfall in summer)		2.1 < 400 mm rainfall p.a. < 70" evaporation p.a. & < 500 mm rainfall p.a. > 70" evaporation p.a.	Management & reclamation	7.14
		2.2 400 - 700 mm rainfall p.a. < 70" evaporation p.a. & 500 - 800 mm rainfall p.a.> 70" evaporation p.a.	Reinforcement	1.96
		2.3 > 700 mm rainfall p.a. < 70" evaporation p.a. & > 800 mm rainfall p.a. > 70" evaporation p.a.	Replacement	0.61
				Total 9.71
3. Summer rainfall (> 66% of total rainfall in summer)	3.1 Frost (> 5 minimum temperatures of < 0°C p.a.)	3.1.1 < 500 mm rainfall p.a. < 80" evaporation p.a. & < 600 mm rainfall p.a. > 80" evaporation p.a.	Management & reclamation	46.40
		3.1.2 500 - 800 mm rainfall p.a. < 80" evaporation p.a. & > 600 mm rainfall p.a. > 80" evaporation p.a.	Reinforcement	16.83
		3.1.3 > 800 mm rainfall p.a. < 80" evaporation p.a.	Replacement	7.49
				Total 70.72
	3.2 Frost-free (< 5 minimum temperatures of < 0°C p.a.)	3.2.1 < 500 mm rainfall p.a. < 80" evaporation p.a. & < 600 mm rainfall p.a. > 80" evaporation p.a.	Management & reclamation	2.89
		3.2.2 500 - 800 mm rainfall p.a. < 80" evaporation p.a. & 600 - 900 mm rainfall p.a. > 80" evaporation p.a.	Reinforcement	2.65
		3.2.3 > 800 mm rainfall p.a. < 80" evaporation p.a. & > 900 mm rainfall p.a. > 80" evaporation p.a.	Replacement	2.90
				Total 8.44

(1 inch = 25.4 mm)

more effective. Veld replacement requires wetter con= ditions for success than does veld reinforcement. This is because the remnants of the indigenous flora which are retained when the veld is reinforced, are generally more drought resistant than the species used in veld replacement. Thus, even in very dry seasons, there is always a fair proportion of the plants which survives and sometimes produces, whereas the introduced species may all die leaving the grazier without feed and with bare soil which is subject to erosion. The higher rainfall limits for veld replacement, and the greater reliability of the rainfall at these levels, thus en= sure a stable grassland even in drought years. Obser= vations on the margin of the Highland sourveld indicate, that in this area at least, an average annual rainfall of 800 mm is the lower limit for successful long term plantings of many improved pasture species.

A map of this classification as applied to the Republic (See Figure 1) is presented and the system of classification is summarised in Table 1.

It is emphasised that these are only general boundaries, and that local variations in soil, topo= graphy and climate will alter conditions considerably. Further, in calculating the relative size of the re= gions, zones and units cultivated land has been inclu= ded. A true picture of the amount of veld involved in each area would necessitate the subtraction of the amount of cultivated land.

As has been stated previously the vegetation, as classified into veld types, may provide a valuable in=

dicator to the potential for grassland intensification in an area. However, at this stage insufficient in= formation is available, on the response of planted species in each veld type, to make use of this indica= tor. In an attempt to add to this knowledge the sug= gested classification has been compared with a group= ing of Acocks' (1953) veld types into formations. Booysen and Tainton (Undated) have grouped these veld types into five vegetation formations viz. Fynbos, Karroo, Savanna, Grassland and Forest. The number of veld types of each formation which occur in each region or zone are given in Table 2.

Table 2.

The distribution of Acocks' (1953) veld types in each vegetation formation among the regions and zones in South Africa

Formation	Number of veld types			
	Winter rain region	All-year rain region	Summer rain region Frosty zone	Summer rain region Frost free zone
Fynbos	5	3	-	-
Karroo	7	6	11	-
Savanna	-	1	8	4
Grassland	-	-	20	-
Forest	-	4	5	7
Total	12	14	44	11

The veld types in the Fynbos formation are con= fined to the winter and all-year rain regions, while the Karroo formation is present in all except the frost-free zone of the summer rain region. The Savanna for= mation is confined to the summer rain region, except for the Valley Bushveld (Veld type 23 of Acocks) which extends into the all-year rain region. The Grassland formation is confined to the frosty zone of the summer rain region, while the Forest formation is absent in the winter rain region.

In Table 3 the number of veld types of each for= mation which occur in each grassland use unit are given.

Table 3.

The distribution of Acocks' (1953) veld types in each vegetation formation among the grassland use units in South Africa

	Number of veld types		
Formation	Veld Manage= ment and Re= clamation	Radical Veld Improvement	
		Reinforcement	Replacement
Karroo	24	-	-
Savanna	6	7	-
Grassland	6	11	3
Fynbos	1	7	1
Forest	-	7	9
Total	36	32	13

The Karroo formation is confined to the veld ma= nagement and reclamation veld-use unit, while the Savanna formation does not extend into the intensive veld replacement unit. Veld types of the Grassland formation occur in all three land use units, but the

Fynbos formation is mainly in the veld Reinforcement unit. The Forest formation is confined to the Radi=cal veld improvement units. Thus it would appear that the major vegetation formations are, to a certain extent, associated with the proposed regions and grass=land-use units.

2.3 The implications of large scale intensification of agricultural production by radical veld im=provement

The urgent need for increased food produc=tion in the near future in South Africa was discussed in the introduction to this section. It appears that most of the extra food required will have to be pro=duced from the 35% of the Republic which enjoys fa=vourable rainfall conditions. In particular the greatest scope for development appears to lie in the 20% which has a high rainfall and which is not nor=mally considered to be arable and thus is at present largely undeveloped. However, the 65% of the Republic with a low rainfall should also not be neglected. This area must be conserved and in many instances re=claimed to its original productivity.

The primary concern of this dissertation is the undeveloped high rainfall area which comprises 20% of the Republic. The lack of development in this area is due to steep slopes or stoniness or shallow soils or excessive accumulation of water, which make it un=suitable for cultivation and annual cropping. It is probable that the required future increases in food production will depend largely on these areas. An estimate of the effects of the development of this area velopment will result in marked social changes in the rural areas concerned and will have considerable eco= nomic implications.

The development of the grassland potential of this 20% of the Republic would result in a considerable increase in production. Increased herbage yields resulting from the use of improved plant species and better plant nutrition, would result in a larger num= ber of livestock being successfully carried per unit area. The improved plant species and their balanced nutrition, would result in an improved nutritional quality and palatability of the herbage requiring a high animal potential for optimum utilization but more rapid and greater returns of animal products. These pastures should provide a more equitable distri= bution of herbage production and consequently animal feed over the year. This distribution of production would be achieved by the selection of suitable plant species and by the judicious application of fertili= zers, and would reduce the winter feed requirements of the livestock. As much of this winter feed con= sists of the products of arable lands, more land would then became available for the direct production of human food. It would appear to be reasonable to pre= dict about a three-fold increase in the output of ani= mal products from the 20% of the Republic which is undeveloped and has a high rainfall.

At present many farms in the high rainfall areas are large and are grazed extensively. Under such an extensive system of farming, management and labour tend to be inefficient. The large areas may preclude adequate coverage of breeding stock by rams and bulls, which due to the large distances to be walked and relatively low nutritional plane can not perform effi= ciently resulting in low calving and lambing percentages. Animals are seen infrequently and lack of condition or sickness are often noted when it is too late. Labour spends much time travelling to and from work, and pro= ductive work hours are low. Internal roads are gene= rally poor or expensive to maintain resulting in in= creased transport costs per unit of product. Fencing and other capital costs are also high per unit of pro= duct. Intensification of the area would result in more efficient livestock and farm management and more efficient use of capital and labour. Economic units for intensive grassland farming would be smaller and because more units would be available this should halt and might temporarily reverse the drift of manpower from the land.

The full development of this grassland potential with its subsequent increased production will require large inputs of capital. Twenty percent of the area of the Republic, which is the estimated area to be developed, amounts to 94,600 square miles or about 28.5 million morgen (24.4 million ha). Development of this area would require fertilizer, seed, watering and animal hurbandry facilities and additional live= stock. An estimate of the fertilizer requirements is an average of 150 lb N, 50 lb P, 150 lb K and half-a-ton of lime per morgen (79.5 kg N; 26.5 kg P; 79.5 kg K and 529.5 kg lime/ha) per annum. This at present day prices (Limestone ammonium nitrate 26% N - R40.95 per ton (907 kg), Superphosphate 8.3% P - R23.60 per ton, KC1 50% K - R34.70 per ton and agricultural lime at about R2 per ton) amounts to an initial capital in= vestment in fertilizer alone of R25.50 per morgen. An increase of the carrying capacity of the grassland from an average of about two, to $^2/3$ morgen (1.7 to 0.57 ha) per MLU for the grazing season, means the purchase of an extra animal (± R120) per morgen (0.86 ha). These two items, fertilizer and livestock, alone mean a capital input of R145.5 per morgen, which over the area to be developed amounts to over R4,000 million. However, as the development would take place slowly, much of the additional capital requirements for further development could be provided by the additional profits.

An intensified grassland farming system would simplify agricultural research and the advisory, ser= vices could be used more efficiently. At present the extensive use of much of the high rainfall grass= land allows a great diversity of grassland practices and types of livestock to be employed with success. More intensive farming is likely to narrow the range of successful practices. Thus the range of the re= search worker would be narrowed as would the breadth of knowledge required by the extension officer, which should lead to a semblance of specialization in this field. Such specialist knowledge can only be of bene= fit to the farmer. Further, the extension officers' time could be used more productively with many more productive units being covered in the same time where there are more intensive farming units.

From a purely agricultural point of view much re= search is necessary in these areas. It is, however, clear that the whole enterprise depends largely on the supply of adequate nitrogen to the grassland. It will have to be determined whether this nitrogen will come from the "bag" or from Rhizobium via the legume. It appears that both sources will play a role, the extent of which will depend on environmental conditions, the economic climate and the type of livestock used to uti= lize the grasslands. All these and other factors as= sociated with the development require urgent investiga= tion. This is no research project for a number of scattered individuals; all disciplines associated with the production and utilization of grassland should work together on the problem. This requires a co-ordinated effort in the area of development. It seems obvious that the most favourable situations should be developed first, and consequently research should be directed towards these areas initially.

More intensive farming untis would result in increased population densities in the rural areas, which in turn would eventually result in improved school= ing facilities, social amenities and transport facili= ties in these areas. Greater opportunities would exist for co-operative endeavours such as joint ownership of expensive, necessary, but seldom used, capital equip= ment and for the use of artificial insemination to im= prove livestock. A further benefit of this increased rural population, in areas which at present sparsely populated, would be in the improved internal defence of the country.

The management of intensive high producing grass= land requires technical knowledge and skill as does the management of the highly productive livestock when con= fined to small areas. Under this system of farming, managerial ability is of considerable importance in determining the profitability of an enterprise. There is doubt as to the present lack of ability of the aver= age South African farmer to manage adequately on an intensive grassland farming unit. He has no recent tradition of this type of farming (Edwards, 1966). This skill can undoubtedly be developed under suitable guidance, but this factor requires consideration be= fore embarking on such a programme.

The increased population in the rural areas means a drain on the slender resources of skilled and simi-skilled labour in the country. Imigrants from in= tensive grassland farming areas in Europe and New Zealand might ease this position and may also provide some of the experience required. This increased po= pulation will in turn result in an increased demand for housing, social and transport facilities. These facilities will be strained to capacity throughout the country as a result of the population explosion.

Thus the development of the full grassland poten= tial of our steeper high rainfall areas could result in an agricultural revolution, which would almost certainly involve the urban population as well. What stimulus is required to trigger this off? The main problem restricting the intensification of the high rainfall, non-arable areas in South Africa is an econo= mic one. There are a large number of young vigorous men who would dearly love to "go farming" but are frustrated in this desire by a lack of capital. These are the group who, when adequately trained by the Agricultural Colleges and Agrucultural faculties of our Universities, is required to set an intensive grass=land programme on a sound footing. Few can afford the immense capital outlay (probably a minimum of R50,000) required for farming, and those men of sub=stance who have such capital find the low returns on investment (often less than 5%) unattractive. In=vestments in land today are frequently in the nature of a "hedge" against erosion in the value of the Rand, and sometimes a means of offsetting profits for income-tax purposes. Unfortunately little suitable crown land is available for allocation to suitable candidates, while loans even at low interest rates do not appear to offer an adequate solution – immense bonds do not offer a congenial climate for the development and intensifi=cation of such a hazardous enterprise as farming. Perhaps the solution may be in the hands of the land=owners themselves. Many farms in regions suitable for intensification are too large to be managed by the farmer alone if they were to be developed to their full potential. An apprentice manager could assist in this development and could receive undeveloped land <u>in lieu</u> of part of his wages. The farmer could be compensated, by the state, by a subsidy on every morgen of non-arable land developed to improved grassland. (Payment of subsidies following an inspection three years after establishment of the pastures, should en=sure adequate pasture management and fertilization). Intensive and attractive publicity backed by research results and adequate demonstration would be required to ensure success. It has been suggested that an in= crease in meat prices would solve the whole problem of grassland intensification. However, it is doubt= ful if adequate increases could be justified in the face of overseas competition which, reportedly, can land meat at our parts cheaper than our present market prices. Consumer resistance may also play a role in destroying the benefits, to the farmer, of increased prices. It is suggested that more efficient produc= tion methods and consequently lower costs is a more realistic solution to the problem.

3. THE POLICY, PROBLEMS AND PROCEDURES OF RADICAL VELD IMPROVEMENT IN THE HIGHLAND SOURVELD OF NATAL

3.1 Introduction

In the first portion of this dissertation an attempt has been made to indicate the importance, to the country, of estimating the potential of our grass= lands. A preliminary map, dividing the grasslands into three production potential classes in each of three regions, has been produced. The development of the potential of these areas is, in the first place, dependent on the results of research work directed into this field of study. The object of this research work is to verify the hypothetical production poten= tials, and to determine the most practical and economic means of developing the potential.

Ideally, such a research programme should be initiated on a broad front. To a certain extent this is being done by the widely spread network of research stations of the Department of Agricultural Technical Services. However, it was considered that more intensified research into radical veld improve= ment was necessary. As such a programme of research into methods of intensification could not be undertaken in all regions it was decided to concentrate on one particular area. This area was the Highland sourveld of Natal in which is situated the old established Ta= bamhlope Agricultural Research Station.

The Highland sourveld and the Tabamhlope Research Station both fall within the portion of the Summer rain= fall, frosty zone which is suited to veld replacement

(Region 3.1.3) – a zone with a high grassland potential. The choice of the sample area is thus, consistent with the suggestion that the areas of highest potential should be developed first. Despite the fact that the Highland sourveld of Natal enjoys a high and reliable rainfall, this area is not suited to large-scale annual cropping. This is primarily due to the limitations imposed by climatic, edaphic and topographic factors. The growing season is too short for optimum production of most cash crops. Soils in the area are frequently too shallow, stony or water-logged to permit success= ful annual cropping. The topography of the area varies from undulating to rugged but for the most part slopes are too steep for the cultivation of annual crops. Thus large scale cultivation of the Highland sourveld landscape would almost certainly cause exten= sive soil losses through erosion, increased pollution of the water in the rivers arising in this region and a less stable flow of water in those rivers. The con= sequences of these effects would be not only a serious decrease in the agricultural potential of the area but also severe difficulties for industry in Natal to the extent of curtailing industrial development. This is because the rivers on which the industrial develop= ment of Natal depends arise in and are fed mainly from the Highland sourveld. It seems clear that other than in localized areas, the most suitable form of land use in the area is the production of perennial pasture crops for use by grazing animals. Pasture production would be less limited by the short growing season than would cash crops. In addition they afford the best means of conserving the soil and ensuring the continuation of plentiful and stable water supplies.

There were further advantages to the initiation of a research programme on intensification of produc= tion in the Highland sourveld. The area has been well covered by surveys. Pentz' (1945) agro-ecological survey was followed by Acocks' (1953) vegetation survey, and by the more detailed vegetation (Edwards, 1967) and soil (reference) surveys (v.d. Eyk, Macvicar & De Vil= liers, 1969) of the Tugela Basin undertaken under the auspices of the Natal Town and Regional Planning Com= mission. The Tabamhlope Research Station was establish= ed in 1936 and a comprehensive report on its research activities up until 1948 is contained in Scott's (1951) thesis. The Estcourt Research Complex with its head= quarters at Estcourt, and of which Tabamhlope Research Station is a unit, was reasonably well equipped with facilities for such a research programme. Perhaps more important than all these factors, was the favour= able atmosphere for intensive grassland research which had been developed, over a number of years, by those in charge of research in the area. It was all these fac= tors, together with the development of an agro-hydro= logical research programme in the area, which dictated the suitibility of Tabamhlope Research Station for the development of an intensive radical veld improvement research programme.

From the start it appeared probable to research workers at the Tabamhlope Research Station that the indigenous grassland in its undisturbed state could not make use of the full potential of the area. Preliminary trials, carried out on the fertilization of grassland and on the introduction of improved plant species, indicated that this area had a potential for grass production which was considerably greater than that of well managed veld. Farmers in the Highland sourveld had also achieved some success with a number of small areas of improved pastures. Thus the stage was set for more intensive investigations into ways and means of developing the full grassland potential of the Highland sourveld. Initially, due to the limited fertility of the highly leached soils, attent= ion was focussed on the fertilizer requirements of adapted pasture species. These trials, which were based on the experimental data obtained from trials with annual crops by Scott (1951) and Orchard (1960), provided information on the requirements of grassland crops for the major plant nutrients. This was followed by cultivar trials of adapted pasture species. The experimental programme up until this stage had been carried out on arable soils on reasonable slopes.

In 1962, however, the grassland research programme at Tabamhlope Research Station was switched to a steeper non-arable site. This was the first definite attempt to orientate the research programme to the development of non-arable areas by radical veld improvement, al= though years previously large areas of pastures had been planted on steeper slopes on the Research Station. From 1962 onwards the pasture research programme on this Research Station was aimed at the development and evaluation of practical techniques for the introduction of improved plant species, chiefly legumes, into the veld. Minimum tillage techniques of seed-bed pre= paration for moderate slopes were investigated, as were the use of herbicides, heavy dressings of nitro= gen fertilizer and trampling with cattle as aids to establishment of pastures on less favourable terrain.

Because competition from the natural veld proved to be the main factor limiting the success of oversown species, the effects of grass cover on the establish= ment of these species was investigated in some detail. Due to pre-occupation with these phases of the develop= ment of grassland, the investigations into the fertili= zation of veld were confined to a single experiment. Further investigations in this direction, and also into the grazing management and utilization of over= seeded veld were planned for the future.

3.2 The vegetation and environment of the Highland sourveld

The boundaries of the Highland sourveld in Natal were delimited by Pentz (1945). These bounda= ries are similar to those of Highland sourveld and Dohné sourveld (veld type 44) of Acocks (1953). The Tabamhlope Research Station is situated near the northern edge of the main central block of Highland sourveld in Natal at about $29^{0}39^{1}$east longtitude and $29^{0}02'$ south latitude.

The climate, physiography and vegetation of the area are described briefly in the sections that follow.

3.2.1 Climate

Unfortunately, there is a lack of meteoro= logical data from the Highland sourveld in the vicinity of the Tabamhlope Research Station. Data collected by Scott (1951) indicate that the annual rainfall in the Highland sourveld of the Drakensberg Soil Conser= vation Area is between 32 to 45 inches (800 to 1125 mm).

There are usually between 83 and 109 rainy days annual= ly on 20 to 30 of which, over half-an-inch (12.5 mm) of rain falls. Scott (1951) also found that the rain= fall in the Highland sourveld was more reliable than that of the adjoining Southern Tall Grass Veld (veld type 65 of Acocks, 1953). The average annual rain= fall on the Tabamhlope Research Station is in the region of 1000 mm.

The research station falls within rainfall district 18A (Anon., 1960) in which 82.3% of the total rainfall falls from October to March, and which has a low varia= bility (V=0.143) and a high reliability (R=0.862) of rainfall. The percentage of droughts (i.e. the number of "drought months" expressed as a percentage of the total number of months covered by the available data) in this rainfall district is 2.5%, which is lower than all but one of the other twenty-six districts, and sub-districts, in the Republic. Drought months are re= corded when the moving twelve-monthly totals of preci= pitation fall below 75% of the annual average. The rainfall of the district can, therefore, be considered to be very reliable. Occasional snow falls have been recorded on Tabamhlope Research Station, but the in= terior and more southerly portions of the Highland sourveld experience fairly frequent falls in winter.

Scott (1951) reports that the mean maximum tem= peratures of all the months at Nottingham Road (about 30 miles south-east of Tabamhlope in the Highland sour= veld) were below 32°C (90°F). The winters are cold at Tabamhlope, temperatures of -15°C (5°F) have been recorded in a Stevenson screen four foot above ground level. Frosts are frequent in the area and have been experienced at Nottingham Road during eight months of the year. December, January and February are the hottest months, and June and July the coldest (Anon., 1965a).

The research station falls within the zone ex= periencing less than 1524 mm (60 inch) of evaporation per annum (Class"A" pans), and is thus in one of the lowest evaporation zones in the Republic (Anon., 1965a). However, observation suggests that this evaporation zone should be confined to the borders of the Natal midlands mistbelt (The Ngongoni sourveld of Natal). The Tabamhlope area, and indeed most of the Highland sourveld, has less mist and consequently higher evap= oration rates than the mist belt.

3.2.2 Physiography

3.2.2.1 Topography

The topography of the Highland sourveld is described by Pentz (1945) as undulating. As topography plays an important role in determining the limits of cultivation, and the techniques used in veld replacement and improvement, it was considered desirable to obtain detailed data on this feature in the Highland sourveld. A sample area of over 145,000 morgen in the vicinity of Tabamhlope Research station was selected for this study. The area com= prised the Highland sourveld portions of three existing or proposed Soil Conservation Districts (viz. Lowlands, Mooi River Valley and Kamberg). Some 28,000 morgen of this area, chiefly in the Kamberg Soil Conservation

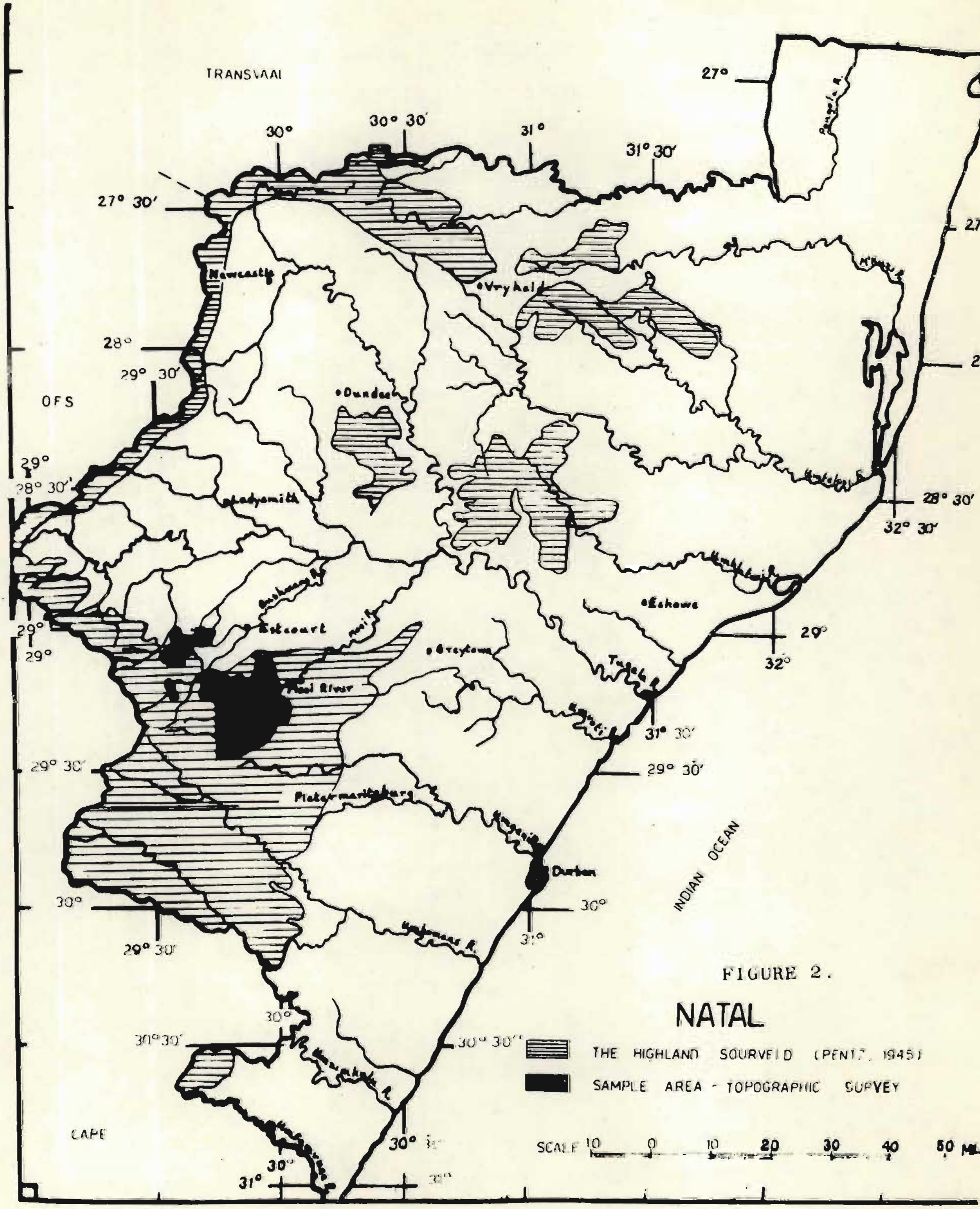


FIGURE 2.

NATAL

District, were eventually omitted from the survey be= cause suitable scale maps were not available. Bantu areas, impinging on the Districts, were also omitted because it was hoped, at a later date, to correlate the results of the survey with those obtained from a quest= ionaire to farmers. The area surveyed stretches from the Tabamhlope Research Station in the north to Notting= ham Road in the south, and from the Giant's Castle Game Reserve and the Forestry Reserve of the Drakensberg in the west to approximately the Estcourt-Mooi River-Not= tingham Road main road in the east. The actual area is shown in Figure 2. The altitude of the area sur= veyed varies from 4400 ft. at Willow Grange to 7000 ft at Spioenkop. However, most of the area lies between 4500 and 5500 ft above sea level.

The area was sub-divided on the basis of the per= centage slope because the extent to which complete cultivation and partial soil disturbance can be prac= ticed without danger of soil erosion is determined largely by slope. Further, the feasibility of making use of implements and tractors for fertilization and seeding is also determined by this factor. Thus a division of the area into categories on the basis of slope would enable suitable establishment techniques to be investigated and developed for each category. The relative areas of each of these categories would also aid in determining research priorities.

Difficulty was experienced in deciding upon the most suitable boundaries. For example, the recom= mended limiting slope to safe cultivation appears often to depend on the relative abundance, or scarcity, of flat land in the country concerned. Ayres (1936) and Kohnke and Bertrand (1959) consider a 12% slope to be safe for cultivation, provided adequate protective constructions (contours and terraces) are made. Sampson (1952), however, points out that factors such as the soil and the crops to be planted should exert a considerable influence. Gericke, Grobler & v.d. Merwe (Undated) used the permeability of the soil as a basis for recommendations on the spacing of contours and the percentage of by crops to be grown. Rainfall intensities should also be taken into consideration.

Based on these thoughts the following five categ= ories were decided upon, admittedly somewhat arbitrarily.

(1) Slope <6¼%. These areas are suited to annual, row-crop cultivation, with protective measures as the slope increases.

(2) Slope 6¼% to 12½%. These areas are suited to restricted cultivation, with protective measures, on the more porous soil types. Extensive use should be made of cover crops and on less porous soils vegetation removal should not be complete.

(3) Slope 12½% to 25%. Very light soil distur= bance and only partial vegetation removal is permissible. This area is not easily accessible to implements.

(4) Slope >25%. Inaccessible to implements but often accessible to livestock and from the air.

(5) Vleis. (Marshes). Inaccessible to imple= ments except for short periods or after drain= age. Drainage operations should not be un=

Table 4

Topographical survey of the Highland sourveld sample area. Area (morgen) in each of five categories (1 morgen = 0.8565 ha)

Area and map reference	Category (% Slope)					
	0-6¼% (morgen)	6¼-12½% (morgen)	12½-25% (morgen)	> 25% (morgen)	Vlei (morgen)	Total (morgen)
N'tabamhlope 2929 BA (Portion)	5,521	5,165	5,818	7,533	1,008	25,045
Estcourt 2929 BB (Portion)	12,434	8,136	6,741	4,113	1,162	32,586
Mooi River 2929 BD (Portion)	25,554	9,988	10,700	5,606	1,314	53,162
Howick 2930 AC (Portion)	3,951	1,342	665	210	466	6,634
Total	47,460	24,631	23,924	17,462	3,950	117,427
Percentage	40.42%	20.98%	20.39%	14.87%	3.36%	100.00%

The technique followed in demarkating the areas is described below:

Large scale topo-codastral maps (1 in 50,000 for maps 2929 BA and BB, and 1 in 18,000 for maps 2929 BD and 2930 AC) were obtained and the boundaries of the sample area demarcated. The first step was to colour-in all areas with a slope greater than 25% (i.e. where the contours on the map were closer than a specific distance appropriate to the scale and the slope). Next the areas with a slope of 12½% to 25% were demarc= ated by shading a different colour all remaining un= coloured areas with a slope greater than 12½%. The 6¼% to 12½% slope was demarcated similarly by shading the uncoloured areas with a slope greater than 6¼%. The vleis, as indicated on the maps were also coloured. The slopes of less than 6¼% were then represented by the remaining uncoloured areas. The total area of each category was then measured by means of a plani= meter, and the results expressed in morgen. In Table 4 the area of each of the five categories, on each map sheet, as well as the percentage of the total area occupied by each category is given.

The forty percent of the area which has less than 6¼% slope is, due to minor depressions, stones and shallow soil, an overestimation of the arable area. Thus, well over 60% of the area can be considered as unsuitable for a annual row crops. A small, but sig= nificant, area (nearly 4000 morgen — 3426 ha) is covered by vleis.

3.2.2.2 Soils

The parent material of the majority of the soils of the Highland sourveld is the Beauford beds of the Karoo system, with small but significant in= trusions of Dolerite. In this area the climate has had a very strong influence in the development of the soils, and generally overrides the effect of the porent material (Orchard, 1954).

In the soil survey of the Tugela Basin more than one hundred distinct soil series are recognised (Ludorf, 1966). The authors of the "Soils of the Tugela Basin" (v.d. Eyk, Macvicar & De Villiers, 1969) have grouped the series into soil associations, of closely related series, which in turn have been group= ed into three major soil groups "... on the basis of their occurrence in three separate physiographic climatic or ecological regions, (v.d. Eyk, 1965) of the area as follows:

I. The Highlands, Midlands Mist Belt and humid Coastal Hinterland, forming on landscapes with highly leached soils.

II. The Interior Basin and sub-humid Coastal Hinterland comprising landscapes with con= siderably, moderately and slightly leached soils.

III. The Interior River Valleys and lower Tugela Valley, forming the landscapes with slight= ly leached or hardly leached soils.

The principal distinguishing feature between these major groups is the degree of leaching". (Ludorf, 1966).

Table 5

Summary of the soils of the Highlands, Midlands mistbelt and Humid costal hinterland (from Ludorf, 1966)

A. Red-Highly leached		B. Yellowish Brown-Highly leached		C. Acid Hydromorphic
A_1. Balmoral-Farningham association (> 35% clay & ± 50% sand)	A_2. Broadmoor-Hutton association (< 35% clay & > 50% sand)	B_1. Helpmekaar-Griffin-Clovelly association (Clayey > 35% clay)	B_2. Clevelànd-Oatdale association (Sandy nature)	C_1.
(1) 1. Balmoral series 2. Tabamhlope series 3. Farningham series (Deep, well drained, stable) (2) 4. Clifford series (Not so well drained, shows hydromorphism)	(3) 1. Broadmoor series 2. Hutton series (Light, subject to wind erosion)	(4) 1. Farmhill series 2. Helpmekaar series Dolerite, High organic matter, strong structure, good infiltration, deep stable. (5) 3. Lidgetton series 4. Griffin series Shales, High organic matter, strong structure good infiltration, moderately deep. (6) 5. Normandien series (Hydromorphism, poor drainage.) (7) 6. Clovelly series 7. Cranwell series 8. Mispah clayey series Shallower, poor structure, poor drainage, wind erosion.	(8) 1. Cleveland series Deep 4-5 ft, clay, weak structure, low organic matter, sandstone, susceptable to erosion. (9) 2. Oatsdale series 3. Mispah sandy series 4. Noxmanci series Shallower, Low clay %, erosion hazzard.	(10) 1. Ivanhoe series 2. Champaigne series (Peat, very erodible.) (11) 3. Katspruit series 4. Emmas series Organic matter % high, High flow of floods (12) 5. Dell series (Sandy, very erodible).

Table 6.

Percentage of various soil associations in the Highland Sourveld sample area. (From Soils of the Tugela Basin: (2929 B (Sheet 12))

Mapping unit	% of sample
Soils of the Highlands and Midland mistbelt	
A_1 Red apedal soils, low in bases - Clayey: Balmoral - Farningham	15.25
A_2 Red apedal soils, low in bases - Loamy: Hutton	18.26
B_1 Yellow apedal soils, low in bases - Clayey: Griffin-Covelly	12.52
B_2 Yellow apedal soils, low in bases- Loamy: Oatsdale-Cleveland	1.57
C_1 Acid gley soils- Clayey and loamy: Katspruit	7.82
Soils of the Interior Basins and sub-Costal Belt	
D_1 Red, apedal & structured soils, non-calcareous - Clayey & Loomy: Doveton-Shortlands-Msinga	0.23
E_1 Yellow, apedal, overlying a plinthic horizon - Clayey & Loamy, with soft plinthic horizon: Avalon-Bergville	2.70
H_1 Margalitic & non-margalitic gley soils - Clayey & Loamy: Rensburg-Willowbrook-Killarney-Estcourt-Uitvlugt	0.66
Miscellaneous soil & Land Types	
L_1 Clayey, Loamy & sandy soils of alluvial land: Maputa-Harris	2.57
M Stony land, steep land or land with very shallow soils	33.72
N Mountainous land, mostly steep, but in=cluding inaccessible land of high plateaux	4.70
Total	100.00

Ludorf (1966) has divided the highly leached soils in= to three main categories and twelve major land use units. This subdivision, together with some of the characteristics of the soils, is presented in Table 5.

By courtesy of the Natal Town and Regional Plan= ning Commission, the writer has had the privilege of a preview of the map sheet covering the Tabamhlope-Nottingham Road area from the Tugela Basin Soil Survey before it was published. The area covered by the topographic survey (section 3.2.2.1) was outlined on the soil map, and the percentage of the total area covered by each of the mapping units in it was deter= mined. Ludorf (1966) explains that it was impossible to map individual soil series on the 1:100,000 scale used, and thus only soil associations were mapped. Steep land, stony land, land with shallow soils, and mountainous land supplied a further two mapping units. The mosaic of colour presented by this map (inspite of these groupings) supports the previous, contention that soil differences, like topography, can be used only on the scale of a single farm plan or surveys such as this. The larger grouping such as the three physio= graphic-climatic regions is more appropriate to the scale used in demarcating the grassland potential regions. The percentage of the sample area covered by the various mapping units is given in Table 6.

It will be seen that only a very small proportion (<3.6%) of the soils in the sample area fall outside Highlands and Midlands mistbelt physiographic-climatic region. These exceptions generally occur near the boundaries of the sample area with the Tall Grass Veld and probably belong to this veld type, and not the

Highland sourveld. Apart from the steep, stony and mountainous areas (38.4%) most of the area (>46%) is covered by three soil associations (15% by clayey and 18% by loamy red apedal soils low in bases, and 12.5% by clayey yellow apedal soils, low in bases). The soils of the bottomlands (7.8%) and of the allu= vial land along the major rivers (2.6%) are also of significance.

It is perhaps unfortunate, from a grassland point of view, that more attention was not devoted to characterising the soils of the stony and mountainous areas. These areas may yet play an important role in increased grassland production. The bottomlands (C_1) and alluvial soils (L_1) are, due to their proximity to water and relatively high base saturation, of con= siderable economic importance. Their agricultural value is great, but in order to achieve full production water table control is usually necessary. Due to the significance of the Highland sourveld as a source of water for the Tugela Basin, and because of the uncer= tainty of the role of vleis in maintaining this supply, the disirability of drainingthese vleis is doubtful at present. A long term study of the hydrological sig= nificance of the vleis is being undertaken at Tabamhlope by the Agro-hydrological section of the Extcourt Re= search Complex.

Ludorf (1966) suggests that the A_1, A_2 and B_1 soil associations are generally suited to cultivation, subject to reservations on slope. The A_1 soils are ".... generally deep well drained soils rich in organic matter, have a high macro-porosity and a structure which promotes a high infiltration rate and good per= meability ..... are strongly leached, acid, of low base status and naturally infertile." (Ludorf, 1966). They are represented by the Balmoral, Tabamhlope, Farningham and Clifford series. The A_2 association (Broadmoor and Hutton series) are loamy to sandy well drained soils. "The organic matter content of the topsoil is high (2-4%), structure is weakly developed and permeability and infiltraiion are exceptionally high ..... (and) the soil is intensely leached and infertile. Their sandy nature makes them somewhat more susecptible to erosion by wind and water than the soils of the A_1 association." (Ludorf, 1966). The soils of the B_1 association (Helpmekaar-Griffin-Clovelly association) consist of eight series having more than 35% clay in the B horizon. The Clovelly land use unit comprises shallower soils than the others in the B unit. "Structural development is weak and because of lower permeability and limited internal drainage, runoff is high." The organic matter content is high, the soils are highly leached and have a high exchangable al'minium content (Ludorf, 1966).

Observation, supported by a comparison of the soils and topographical maps indicates that the A_1 and A_2 associations tend to occur on flatter land than the B_1 series, which often extends up the hill-slopes.

3.2.3 Vegetation

The vegetation of the Highland sourveld has been described in detail by Pentz (1945), West (1949), Scott (1951), Acocks (1953) and Edwards (1967) while Downing (1968) has discussed the ecology of the vleis. Acocks (1953) suggests that the whole area was originally temperate forest and scrub forest, the relics of which are few, small and badly mutilated. Scott (1951) supports this view, but states that today the area is probably a sub-climax grassland due to fire. He showed that in areas protected from fire and grazing – a condition not found naturally in the area – the grassland was replaced by Buddleia salvifolia in some areas and by Leucosidea sericia and Cliffortia nitidula in others which, he concluded, indicated that the climax was not grassland. Although there can be little doubt that the extent of the forests has decreased, it seems probable that fire and grazing have, for many years, played a role in maintaining the grassland. In ancient times fires caused by lightning and later by native hunters were probably a fairly common occurrence on the dry, frosted winter grasslands. The presence of a uniform and distinctive grassland sward over such an extensive area tends to indicate that the present situation has existed for many years. It is tempting to consider the area as a grassland climax (except in the more favourable valley environments) in which fire is considered as a natural factor of the environment.

In view of the wealth of literature on the vegetation of the Highland sourveld, further discussion on the subject is superfluous.

3.3 Materials and methods in pasture experimentation

Standardized techniques of experimentation were followed during the conduct of the majority of the experiments. These techniques were the result of imitation, adaptation and development by the pasture research team at the Estcourt Research Complex. In order to simplify the description of the specific procedures employed in the experiments discussed in other sections of this thesis, it was deemed desirable to devote a separate section to this topic. Only those techniques common to all or most of the experi= ments are discussed here.

3.3.1 The sites

Two sites on the Tabamhlope Research Sta= tion were used for the field experimentation. The first site on the "Old experimental block" at Tabamhlo= pe, is situated on the Farningham soil type (later classified as the n'Tabamhlope sub-type); while the second site was especially selected for Radical Veld Improvement research work on the Clovelly soil type. The characteristics of these soil types have been described in some detail in a previous section and will not be repeated.

The Farningham site is almost flat and rather low lying on a plain above the vlei. It has a slight slope towards the north-west. Prior to the start of the experiments the area had been under cultivation for more than twenty years. It had been used to produce crops such as potatoes, Japanese millet, maize and soyabeans. The basic fertilizer for these crops was superphosphate, and due to the high iron and aluminium content of these soils it is doubtful whether any resi=dues were available to the plants in the experiments. Occasional dressings of compost had been applied to the area prior to 1956. This site might be considered to be typical of, though perhaps somewhat wetter than, other ploughed areas of this soil type in the Highland Sourveld.

The Clovelly site was first developed in 1962/3. It consisted of a 15 to 20 morgen (13 to 17 ha) block of virgin Highland Sourveld in reasonably good con=dition, on a slope of about 10 per cent on a south-western aspect. It was within half a mile of, and about 100 foot (30.5 m) higher than the Farningham block on the opposite side of the vlei. This block was selected because it was considered that in the fu=ture such areas would be extensively used for pasture production in the Highland sourveld. The steeper slopes are unsuited to the growing of annual row crops because of the soil erosion hazard, while these crops usually produce greater returns than pastures on the flatter areas. On the other hand pastures can be planted on the steeper slopes with little danger of soil erosion. The Clovelly soil type occurs frequently on such slopes in the Highland Sourveld, and in most in=stances the developement of this area would involve the cultivation of virgin veld. The slope of ten percent is somewhat less than that under which Veld reinforce=ment would be carried out, but yield measurements, cultivation and other trials could be conducted more conveniently on this site. Further it was considered that the relatively gentle slope would not invalidate the results obtained from techniques designed for steeper areas.

The Clovelly experimental area was designed to cater for grazing experiments. Thus holding-camps (± 3 morgen — 2.6 ha — each) were fenced and planted to the main pasture species with which work was to be done on the adjoining experimental area. Initially two paddocks, one of Paspalum dilatatum alone and the second of P.dilatatum and Trifolium repens were es= tablished. The object of such paddocks, apart from suppling grazing close at hand to the experiments, was to minimise the transfer of soil fertility by animals grazing the experiments for short periods, and to ac= custom the animals to the herbage on offer in the ex= periments. The holding-pastures were adequately fertilized (as were most of the experimental plots). Thus the excreta on the experimental pasture, could be expected to be of similar chemical content and total volume to the material excreted by the animals, after the ingestion of herbage, on the experimental pasture. A further six holding-camps were later established on fertilized veld to cater for the treatments in a veld fertilizer experiment (NP 17/6).

Eventually water was laid on to the experimental area and centrally situated livestock watering points were established. The area was contoured and a small implement shed and office/store was erected. The site was ring fenced and access roads were provided. Trees were planted on two boundaries to provide some shelter on this exposed slope. A cattle dip, crush, handling kraals and weigh-bridge were within a short distance of the area.

The development of this site has been described in some detail, as some of the principles applied are of prime importance in pasture experimentation. Firstly, it is essential that the site selected be representative of the soil, slope, vegetation and micro-climate in which it is intended that the research results be applied. It is not sufficient that it should fall within the general area under consideration. Secondly, space for expansion under suitable environmental conditions should be available in close proximity. Thirdly, the facilities normally associated with grazing animals (e.g. weigh-bridge, dip, crush, kraals and watering facilities) should be available within easy reach. Fourthly, safe access for livestock should be provided, i.e. there should be no possibility of escaped experimental animals damaging nearby crop experiments as can easily occur, when only one experimental area is available for soil, crop, pasture and animal experimentation. Obviously separate and distant research blocks are not always practicable, but fencing should be adequate.

3.3.2 Field methods

Previous experimentation had provided knowledge on the main plant nutrient deficiencies in these soils by the time the bulk of this research programme was started. Thus, being primarily interested in production, as distinct from soil fertility studies, the writer accepted as a general principle the need to evaluate his treatments under a regime of high fertilized in the light of the data available at that time.

The fertilizer was weighed into well labeled plastic bags in the herbage laboratory, and was always applied on a per plot basis. Each type of fertilizer was spread separately by hand. Hand spreading, even with experienced labour, is uneven but in view of the reasonably large amounts of fertilizer used the results were satisfactory. Trace elements, when applied, were mixed with some other more bulky type of fertilizer with which they did not react, to facilitate spreading. Applications of nitrogenous and potassic fertilizer were split into three or more dressings over the season, but all the phosphatic fertilizer was applied in spring.

Initially self-propelled motor scythes with reciprocating cutter-bars were used for cutting her= bage. Due to mechanical failure, these were replaced by a tractor with a rear-mounted, six foot, recipro= cating cutter-bar mower. The cut herbage was raked and collected by hand. The green herbage was weighed in the field on a dial type spring scale graduated in one pound (0.45 kg) divisions.

In some of the earlier trials on "island" method of harvesting the plots was used. A one yard (0.91 m) border was cut round the plot and then the remaining island of herbage was cut and weighed. Inaccuracies on the part of the operator when cutting the border can, however, lead to large errors with this method. Thus in later experiments this technique was replaced by a strip sampling technique. A three foot (0.91 m) border was cut on each end of the plots and, after re= moving the herbage, two yield strips (each of six foot -1.83 m - wide) were cut down the length of the plots. These strips were situated at least one yard (0.91 m) from the edge of the plots and at least one foot (0.3 m) apart. This system when applied to a 7 yd x 12 yd (6.4 m x 11 m) plot with a tractor mower (6 ft — 1.83 m — cut) worked well and yielded a 40 sq. yd (33.44 sq. m) harvest area. This layout is perhaps rather in= efficient in utilizing the area available i.e. 48% of the area is harvested, 43% is border and 9% is not util= ized. It is, however, considered that unless area is severely limiting, the advantages of speed of harvesting and probable increase in accuracy obtained from this system make it worthwhile.

The absence of electricity and consequently un= satisfactory drying facilities on the Tabamhlope Re= search Station presented a problem. The nearest facilities were at Estcourt 23 miles (37 km) distant. There appeared to be two possible solutions to this problem of measuring the dry matter yields of succu= lent pasture herbage. The first possibility was to transport the whole yield of the plots (up to 100 lb — 45.4 kg) to Estcourt as rapidly as possible for weighing, sampling and drying. This appeared to be impracticable and consequently it was decided to in= vestigate the second possibility. This involved the weighing of plot yields <u>in situ</u> and immediately ob= taining a sample, which had to be stored and trans= ported, without loss of moisture or dry material to Estcourt. Plastic bags sealed by means of rubber bands were tested for use as containers for trans= proting the samples. Trials were conducted to deter= mine the loss of weight of herbage samples stored in this way. The results of these trials have been re= ported elsewhere (Edwards, 1965). Insignificant losses of green weight (0.3%), and no significant loss of dry weight were recorded after 23 hours storage in plastic bags. The trials were conducted on both a pure grass pasture (Pennisetum clandestinum) and on a mixed grass/clover pasture (Paspalum dilatatum – Trifolium repens). Because of these results, and be= cause of the apparent accuracy of the experiments (coefficients of variation of less than 6%) it was decided that this method offered a practical solution to the problem. It provided a technique which could be applied except where detailed chemical analysis of certain volatile constituents of the herbage was re= quired.

Herbage for the dry material samples was obtained by grab sampling from the heap of cut material immediat= ely after weighing. Approximately 500 grams of green material was obtained from each plot in this way. Initially, the samples for separation into botanical components (on mixed swards) were also obtained in this way. However, the statistical analysis of these data usually yielded a high coefficient of variation. This figure was reduced considerably by altering the sampling method. The strip between the two six foot sample swathes was reduced to about one foot wide. After weighing the yield of the harvest area, this strip was cut, raked together and quartered. Grab samples were then taken from each quarter. This could also have been done with the larger bulk of the whole plot yield, but would have involved a laborious process. Thus the "separation sample" was derived entirely from the centre strip of the plot, and for this reason may have certain theoretical disadvantages. Separation was carried out, by hand, as soon after harvesting as was possible. Some samples were stored for a short period (two to three days) in a refrigerator.

The livestock used in the grazing trials were provided by the "pasture experimental herd". This herd was made up of about 100 Afrikander X exotic beef breed crosses. Ideally the herd consisted of 50 young animals (12-18 months old) and 50 older animals (24-30 months old). Each year the older group was sold and a new group of young animals was introduced. The object of this arrangement was to utilize the pastures with young growing animals of a high production potential. This ideal balance of age and type of animal was not always possible to maintain.

3.3.3 Laboratory Methods

A herbage handling centre was designed and built to provide facilities for handling the harvested herbage material. The drying of the herbage samples was carried out in a large, thermostatically controlled, forced-draught drying oven at 85 to 95°C until constant weight was attained (usually a period of 12 to 16 hours). The oven had a capacity of 128 trays (17½" long, 5¾" wide and 3" deep — 44 cm x 15 cm x 8 cm) into each of which 300 to 500 grams of green herbage could be fitted. The weighing of samples before and after drying was carried out on a semi-direct reading, oil-dampened, scale on which the dial was graduated in one gram divisions. Samples required for chemical analysis were milled after oven drying and stored in heat sealed polyethylene tubing, until despatch to the regional laboratory for analysis.

All results were recorded on a single form es= pecially designed for this purpose. Sets of three forms with two carbon papers between them were stapled together and attached to a clip-board. In the field the plot numbers, gross plot yields and tare weight were recorded in the appropriate columns and immediate= ly on return to the office one duplicate copy was placed on file. The other two forms were retained, and the green and dry weights of the samples were then recorded opposite their treatment numbers. One of these forms was then used for the computation of the dry matter yields of the plots and further statistical analysis, while the other was filed. All data including ob= servational notes were recorded on these sheets. No field books were employed. This system worked very well and reduced the need for transcription of data to a minimum. The vast majority of the statistical com= putations were carried out at Estcourt. The results of the separation into herbage components were recorded on a similar type of form. One standard procedure was used in numbering herbage samples: a label with the date, number of the experiment, plot number (on both sides) and cut number of that season was inserted into the plastic bag with the green herbage at sampling. This label was retained with the herbage sample through= out weighing (counterbalanced by another label) and oven drying and was inserted into the plastic tube after milling of the herbage. The labels of samples intended for separation into botanical components were prefixed. with an S to distinguish them from samples for dry mat= ter determinations. This system eliminated all need for re-recording the numbers of samples at their vari= ous stages of handling.

3.4 Nitrogen fertilization as a means of Radical Veld Improvement

The title of this chapter may alarm the veld purist, to whom optimum veld condition in high rainfall forest climax areas is reflected by a dis-climax or sub-climax stage in the succession. However, in the context of this thesis optimum veld condition can be defined as "that condition of the veld, which in the long-term, produces optimum economic returns irrespective of the botanical composition of the sward". Reference to retaining sufficient cover to prevent soil erosion is purposely omitted from this definition for should such erosion occur, then long-term production would not be possible.

It has been mentioned previously that the low level of soil fertility is in many instances a factor limiting the production of the natural grasslands of the Republic. It is also one of the few natural limiting factors which, once identified, can be rectified relatively easily. Further, it is common knowledge that grasses in general respond very well to the application of nitrogenous fertilizer. It is, therefore, perhaps rather surprising that, inspite of considerable success on arable lands, this practice has not been extended to non-arable veld areas.

3.4.1 An overall assessment of the concept

Weinmann (1943(a), 1943(b), 1948) considers that the nitrogen and phosphate content of the majority of soils of the Transvaal highveld is low, and that the veld reacts well to fertilization. From over six hundred morgen of veld under fertilizer experiments "scattered all over South Africa from the Cape to the Zambesi" Hall (1948), concluded that veld always gave a good response to nitrogen fertilization. However, for the best results phosphatic fertilizer was also necessary. He also concluded that it seldom paid to fertilize veld which received less than 20 inches of rainfall per annum and, generally better results were obtained when the annual rainfall was above 25 inches. Numerous other workers have also reported increased herbage yields from the application of nitrogenous fer= tilizer to veld (Staples & Taylor, 1929; Hall, 1931; Staples, 1931; Taylor, 1932; Meredith, 1948; Booysen, 1954; Hall, Meredith & Altona, 1955; Ranwell, 1964; Visser, 1966). Increases in the protein content of the herbage (Meredith, 1948; Booysen, 1954; Hall et al., 1955; Ranwell, 1964; Visser, 1966), the live-weight gains of cattle (Rowland, 1938; Hall, Meredith & Altona, 1950; 1955; Botha, 1953; Visser, 1966), and the milk production of cattle (Rose, 1953; Hall et al., 1955) have been recorded on veld fertilized with nitrogen.

The application of nitrogenous fertilizer to the veld generally results in a change in its species com= position (Meredith, 1948; Hall et al., 1950; 1955; Roux, 1954; Booysen, 1954; Visser, 1966). This change is rapid at high rates of nitrogen fertilizer and slower at low rates of application (Hall et al, 1950; Roux, 1954; Barnes, 1956; Patterson & Youngman, 1960). The change in species composition resulting from nitro= gen fertilization usually takes the form of an increase in the pioneer species, and a decline in the density of plants higher in the succession (Booysen, 1954;

Roux, 1954; Hall _et al_, 1955; Barnes, 1956; Rogler & Lorenz, 1957; Ranwell, 1964). Roux (1954) and Jong and Roux (1955) showed that the tolerance of plants to high concentrations of nitrogen declined as succession advanced. Ranwell (1964) found that three types of nitrogen carrier produced similar changes in species composition in the _Cymbopogon_ - _Themeda_ veld. He used ammonium sulphate, calcium ammonium nitrate and a mixture of equal parts by weight of the two as carriers. He also noted that the new plant communi= ties that established themselves as a result of nitro= gen fertilization, contained more species high in mineral and low in fibre content than those of the natural climax community. This would appear to indi= cate that, in this veld type, more nutritious and palatable herbage was obtained with nitrogen fertiliza= tion. This might be expected under conditions such as these where species of the _Digitaria_ and _Panicum_ genera made a significant contribution to the ferti= lized sward. However, Visser (1966) advanced the hypothesis that where the annual rainfall exceeded 625 mm species belonging to _Eragrosteae_ tribe tended to dominate fertilized veld and below this figure species of the tribe _Paniceae_ would dominate. As the _Eragrosteae_ species are often rather high in fibre content, this observation, made by Ranwell (1964), may not have general application in the high rainfall areas.

Ranwell (1964) found that the increased applica= tion of nitrogenous fertilizer and super-phosphate had a depressing effect on the elongation of the aerial parts of _Themeda triandra_, a climax grass species in the veld where he worked. He also concluded that where growth conditions were influenced by fertilizer containing calcium, Panicum coloratum was in a better position to maintain an effective cation: anion balance than T.triandra and Eragrostis curvula. Lowering the pH value, which occurred with nitrogen fertilization, apparently favoured the growth of E. curvula. He states: "It may be accepted, therefore, that an improvement of the fertility status of the soil will result in the full deployment of the growth potentialities of P. coloratum and E. curvula. The development of these two grasses will benefit to a much greater extent than that of T. triandra, where the fertility of the soil is improved." Although these observations appear to be borne out to some extent by other work which has been mentioned previously, care should be taken not to generalize too widely when dealing with a specific plant species. Two of the three species mentioned (T. triandra and E. curvula) occur over a very wide range of soil and climatic conditions in the Republic. Further, it is well known (Vose, 1963) that types, varieties or cultivars of the same species may respond differently to the mineral content and pH of the soil.

In an experiment carried out in the Highland sourveld (reported on in section 3.5.3.4) similar increases in the pioneer species and decreases in the climax grass species were observed. These changes took place very rapidly i.e. within twelve months of the application of heavy dressings of nitrogenous fertilizer (300-600 lb/morgen – 160-320 kg/ha).

The application of nitrogenous fertilizer has produced diverse effects on the basal cover of the veld. Some workers (Meredith, 1948; Hall et al, 1950; 1955; Botha, 1953; Barnes, 1956) have recorded an increase in basal cover due to the application of nitrogenous fertilizer, while others (Fisher, 1954; Booysen, 1954; 1961) have recorded a decline in basal cover. The reason for these conflicting results may be due to one or more of a number of causes. The original composition of the sward, the availability of seed of pioneer species, the method by which the fertilized sward is utilized, the duration of the experiment, and the climatic conditions pertaining during the experimental period are all variable factors which may be responsible for different effects in different experiments. Basal cover could be expected to increase more rapidly after fertilization in a sward containing pioneer and/or stoloniferous grasses and/or a good supply of their seed, than in a sward containing few pioneer species, which is tufted and with little suitable seed available. In the latter type of sward the cover provided by plants higher in the succession would decrease and the colonisation of the bare areas would occur later. This might result in a temporary decline in cover. Booysen (1954) and McKenzie (1961) noted that the lack of seed supplies limited the occurrence of Paspalum dilatatum to one of four replicates on a fertilizer experiment at Ukulinga research station in Natal. In many experiments, basal cover measurements were too infrequent in the initial stages to have recorded a temporary decline in cover, Botha (1953) and Fisher (1954) in South Africa, and other workers overseas (Bharacha & Cave, 1952; Rogler & Lorenz, 1957; Lodge, 1959) have found that varying the method of utilizing fertilized, natural grazings resulted in considerable differences in basal cover. At Athole, in the Eastern Transvaal, Botha (1953) reported differences in basal cover of fertilized veld resulting from different systems of grazing and from different classes of livestock. At Frankenwald, in the Transvaal Highveld, Fisher (1954) found that with frequent clipping the basal cover of heavily fertilized "Eragrostis veld" increased. However, when clipping was less frequent the basal cover declined. A decline in the basal cover of veld due to the excessive accumu= lation of aerial growth has been reported in Natal by Scott (1951) and Edwards (1961, 1968).

A very strong case can thus be made for the ni= trogen fertilization of veld from the point of view of increased production. It can also be accepted that the higher the rainfall the greater the likeli= hood of benefit from fertilizers (Hall, 1948). In= spite of these benefits, the nitrogenous fertilization of veld is carried out only on a very small scale. Two factors appear to have contributed to this conser= vatism viz. changes in botanical composition and the economics of the practice.

1. <u>Changes in botanical composition</u>

It has been suggested that the change towards pioneer species, which is inevitably associa= ted with nitrogen fertilization, reflects an increase in the frequency and duration of soil moisture drought caused by increased evapo-transpiration resulting from the additional herbage production. It is feared that the pioneer perennial grasses will eventually them= selves give way to xerophytic annual grasses and even non-gramineaceous annuals, which have a low grazing value and provide a poor soil cover. Further, there is a natural conservatism leading to a reluctance to lose what is generally considered to be the best grass species in the sward i.e. T. triandra. It is possible that more water is transpired by the vigorous nitrogen fertilized sward, although the additional growth may simply be a reflection of more efficient water usage by the plant. The loss due to evaporation is probably reduced on such a sward, and it is doubtful if the total evapo-transpiration loss is greater than on an unferti= lized sward. Holmes (1968) states that it is a feature of many experiments and observations that grass= land adequately supplied with nitrogen is apparently more drought resistant than when nitrogen is deficient. Both Penman (1948) and Wind (1954) have shown that grassland receiving nitrogenous fertilizer gave in= creased yields (threefold and twofold the yield of unfertilized grassland respectively) without affecting the evapo-transpiration rate. Thus fertilized veld would appear to make more efficient use of the soil moisture - a very important consideration in a semi-arrid country such as ours.

Annual plant species do undoubtedly occur in in= creased numbers on nitrogen fertilized veld, but after long periods of such treatment there does not appear to be any danger of their supplanting the perennial pioneer grass component. This contention is supported by twenty-eight years of fertilization of Cymbopogon - Themeda veld at Potchefstroom (personal observation) and fourteen years of fertilization on the Dohne sour=veld at Dohne (Muzzell, 1969). Furthermore, the pe=rennial pioneer sward frequently provides a better co=ver than the original sward due to the high incidence of Cynodon dactylon particularly on sandy soils.

2. Economic factors

It would appear that the main deterrent to the large scale use of nitrogen fertilizer on veld is an economic one. By this it is not meant that veld fertilization is always uneconomic in terms of cash input and net profit. On the contrary, in most high rainfall areas it should be highly profitable. The problem is a lack of capital within the farming enter=prise to finance such a development. For example, the average farm in the Cymbopogon-Themeda veld of the High=veld Region has in the region of 280 morgen (240 ha) (56% of its area) of veld. If this veld is fertilized with 200 lb of superphosphate and 400 lb of sulphate of ammonia per morgen (106 & 212 kg/ha) the annual carrying capacity should be increased from four morgen to two morgen per MLU. The additional capital input required on such a farm with a price of R24 per ton (907 kg) for superphosphate and R33 per ton for sul=phate of ammonia, would be R2,520 for fertilizer alone. In order to utilize this additional high quality her=bage some 70 MLU of good quality animals would be re=quired. At a cost of say R120 per MLU a sum of R8,400 would be required. Thus in order to start such an enterprise on all the veld each farmer would face a capital input of some R11,000. In a previous section (2.4) it has been estimated that the fertili=zation of the 28.5 million morgen (24.4 million ha) of high rainfall grassland in the Republic would require a capital input of over R4,000 million. The availabi= lity of such capital resources and the ability of in= ternal markets to consume the extra production pose problems.

The answer would appear to be a gradual intensi= fication of the grassland enterprise. Small areas in the most favourable situations should be fertilized first and the profits from this used to finance further de= velopment. The greater proportion of the veld in the Highveld is probably over stocked (Edwards, 1968) and veld fertilization would largely overcome this problem (due to increased herbage production). Here at least extra capital would not be required for the purchase of additional livestock.

3.4.2 A fertilizer trial in the Highland sourveld (NP 17/6)

3.4.2.1 Objective

The object of this experiment was to determine the effect of large amounts of nitrogenous fertilizer, with and without mineral fertilizer, on the production, botanical composition and palatability of the Highland sourveld when grazed. It was not possible to lay out an experiment in which animal pro= duction was measured, so reliance had to be placed on other measurements in the presence of the grazing ani= mal. The inclusion of the grazing animal was consi= dered necessary in view of the effects of trampling and of the return of nutrients in the form of dung and urine.

3.4.2.2 Procedure

The experiment was started in December 1966 on the Clovelly experimental block at Tabamhlope Research Station (see section 3.3.1) and results are available until April 1968.

The experiment consisted of a 3 x 2 factorial design in randomised blocks with four replications. The treatments were constituted by combinations of the listed levels of each of the following two factors:-

Nitrogenous fertilizer:

N_0 = Control (no nitrogenous fertilizer)

N_1 = 300 lb N (as urea, 46% N) per morgen (160 kg/ha)

N_2 = 600 lb N (as urea, 46% N) per morgen (320 kg/ha)

Other fertilizer:

Y_0 = Control (no other fertilizer)

Y_1 = 100 lb P (as double superphosphate, 19.6% P, 14% Ca), 200 lb K (as KC1, 50% K) and 265 lb Ca (as agricultural lime, 36% Ca) per morgen (53 kg P, 106 kg K and 140 kg Ca/ha).

The plots which were ten yards wide and forty yards long were separately fenced. There was no water available in the plots but a stock watering point was situated close to the experiment.

The nitrogenous fertilizer was applied to the treat= ments in three equal dressings, one in October, one in December and the third during February of each year. The phosphate, potash and lime were applied annually in the spring. Urea was used as a source of nitrogen be=

cause the other available sources were not suitable. Sulphate of ammonia, with its severe acidifying effect, was undesirable on these acid soils, and the calcium content (20% Ca) in calcium ammonium nitrate was possibly sufficient to confound the calcium effect in the "other fertilizers." These were the only three types of nitrogenous fertilizer available commercially at the time.

When ever sufficient herbage was available (± 7" — 18 cm — tall) the plots were grazed, with a minimum of two steers per plot for 48 hours. An attempt was made to ensure that the grazing pressure (lb herbage available/animal/day) was constant on all plots. In order to achieve this the grazing period was kept constant but the number of animals per plot was varied in relation to the herbage available. This led to approximations in avoiding fractions of animals. In a previous experiment (N-Ec 12/1) an attempt was made to avoid these approximations by allocating extra hours of grazing on the third day. It was found that this involved a considerable amount of extra work, and doubt existed as to the value of such extra periods. The effectiveness depended on the extent to which the animals used this period for grazing - a factor which varied considerably. In the light of this experience it was decided to use the "approximate method".

The actual number of animals which grazed each plot was determined from the dry matter yields of herbage harvested from each plot on the day before grazing.

The herbage yields of the plots was estimated by mowing a 2 x 10 yd (1.8 x 9.1 m) strip of veld from each plot the day before grazing. The cut herbage was weighed and a sample extracted for dry matter de= termination. The remaining herbage was spread on the area from which it had been cut. This sample area was not protected from grazing during the following two days – a factor which might have led to an overutili= zation of the area and restricted regrowth. In order to avoid resampling the same area the positions for sampling were predetermined at the start of each year. Adequate borders were allowed along the fences (one yard – 0.91 m) and at the gateway (six yards – 5.5 m). One animal grazing-day was allocated for each fifteen pounds (6.8 kg) of oven dry herbage available on the plot. The number of animals was obtained rapidly from tables, which expressed the oven dry yields of the sample area in terms of the number of animals. In a previous experiment (N-Ec 12/1) it was found that increasing the amount of herbage allocated, on <u>Paspalum dilatatum</u> and <u>P.dilatatum</u> - <u>Trifolium</u> <u>repens</u> pastures, from 15 lb (6.8 kg) to 25 lb (11.3 kg) dry material per animal per day only resulted in a small increase (from 12.3 lb – 5.6 kg – to 15.2 lb – 6.9 kg –) in the amount of herbage consumed per animal per day. Thus in order to obtain a high percentage of utilization of the veld, it was decided to allocate only the equiva= lent of 15 lb dry matter per animal per day. The animals used in this and in the previous trial were from the "pasture research herd" (see section 3.3.2) and were thus not full mature livestock units.

In order to reduce the transfer of fertility to and from the experiment, to a minimum the cattle were held on veld, which had been fertilized with the same amounts of fertilizer as the treatments, for at least two days before grazing the experiment (see section 3.3.1). For this purpose six holding camps, each of half-a-morgen in extent were fenced and fertilized, one as for each of the six treatments. The cattle were watered once daily while on the holding camps and in the experiment.

As soon as was possible after grazing (within two days), the whole area of each plot was mown. The cut herbage was weighed, sampled for dry material de= termination, and the surplus herbage removed from the plot. The removal of the surplus herbage resulted in a loss of nutrients to the plots, but experience had shown that even small amounts of cut herbage when left lying on the veld have an adverse effect on the cover. The amount of herbage removed and the conse= quent loss of nutrients was small (see Table 7). The amount of herbage consumed was calculated from the difference between the before grazing ("in") and the after grazing ("out") cuts.

Growth of the veld during the grazing period (2 days), was ignored as it was considered that the expense and labour involved in using cages was not warranted to determine this yield over such a short period.

In order to maintain the vigour of the veld on the experiment, all the plots were to be rested (i.e no grazing or mowing) from the end of January until May every third year for the duration of the experiment. In these years the last grazing of the season would be carried out in May. Spring and seeding rests were considered to be of minor importance in Highland sour=veld which is in good condition.

The basal cover and the species composition of the veld was measured at the start of the experiment in December 1966 with a point bridge. No subsequent data are available. The bridge used contained three points spaced ten inches apart. This spacing was con=sidered necessary in order to avoid striking the same tuft twice. Compared with single points, more closely spaced points give a less accurate estimate, as there tends to be an excess of high and low values and a deficiency of values about the mean (Greig-Smith, 1957). Each plot was stratified into ten belts, for purposes of this analysis, and twenty positions of the bridge were allocated at random along each of these belts. Thus six hundred points were recorded on each plot which provided 2,400 points per treatment. Rodel (1950), working in the Tall Grass Veld, concluded that 1,440 points per treatment produced a sufficiently small co-efficient of variation provided grass species were grouped for purposes of statistical analysis.

3.4.2.3 Results and Discussion

<u>Basal cover of the experiment</u>

The average basal cover, at the start of the experiment in December 1966, was 20.72%. The species composition is given in Table 7.

Table 7.

Average basal cover and species composition of the veld on the veld fertilizer experiment (December 1966)

Sward component	Percent basal cover	
Desirable species (D)		14.49
Undesirable species (U)		6.23
Total		20.72
Arundinelleae		9.03
Tristachya hispida (D)	9.03	
Andropogoneae		8.56
Themeda triandra (D)	4.02	
Elyonurus argenteus (U)	1.93	
Andropogon filifolius (U)	1.61	
Monocymbium ceresiiforme (D)	0.57	
Trachypogon spicatus (D)	0.26	
Heteropogon contortus (D)	0.17	
Paniceae		1.74
Alloteropsis semialata (U)	1.30	
Panicum sp. (D)	0.24	
Digitaria sp. (D)	0.18	
Bracharia serrata (D)	0.02	
Chlorideae		0.36
Harpechloa capensis (U)	0.35	
Microchloa caffra (U)	0.01	
Eragrosteae		
Eragrostis sp. (U)	0.79	
Compositae		0.12
Other		0.12

Table 8.
Herbage yields from veld fertilizer experiment (Ton dry material/morgen).
(1 ton/morgen = 1059 kg/ha; 1 lb = 0.454 kg)

Treatment	Herbage yield (Ton/morgen)														
	"In" cut = Herbage available					"Out" cut = herbage uneaten					"In"-"Out" cut = herbage eaten				
Period Date	(1) 13.3.67	(2) 18.12.67	(3) 19.2.68	(4) 22.4.68	Total	(1) 16.3.67	(2) 21.12.67	(3) 23.2.68	(4) 26.4.68	Total	(1)	(2)	(3)	(4)	Total
Nitrogen (N)															
Nil	1.24	0.89	0.66	0.55	3.34	0.018	0.367	0.306	0.066	0.757	1.22	0.52	0.36	0.48	2.58
300 lb N/m	1.99	0.99	1.05	0.83	4.87	0.034	0.413	0.461	0.132	1.040	1.95	0.58	0.59	0.68	3.83
600 lb N/m	2.51	1.33	1.52	0.89	6.25	0.047	0.389	0.552	0.174	1.161	2.46	0.94	0.97	0.72	5.09
Mean	1.91	1.07	1.08	0.76	4.82	0.033	0.390	0.440	0.124	0.986	1.88	0.68	0.64	0.64	3.83
L.S.D. P = 0.05	0.39	0.28	0.15	0.10	0.53	0.015	-	0.112	0.054	0.231	0.32	0.35	0.21	0.10	0.64
P = 0.01	0.54	0.38	0.21	0.13	0.73	0.021	-	0.155	0.074	0.320	0.44	-	0.29	0.13	0.88
Other fertilizer (Y)															
Nil	1.74	1.00	0.89	0.68	4.32	0.025	0.343	0.348	0.089	0.804	1.72	0.65	0.54	0.59	3.51
100 lb P, 200 lb K & 265 lb Ca/m	2.08	1.14	1.27	0.83	5.32	0.041	0.436	0.532	0.159	1.168	2.04	0.70	0.74	0.66	4.16
L.S.D. P = 0.05	0.32	-	0.13	0.08	0.43	0.012	0.089	0.092	0.044	0.189	0.26	-	0.17	-	0.52
P = 0.01	-	-	0.17	0.11	0.59	-	-	0.127	0.060	0.261	0.36	-	-	-	-
Coefficient of Variation	19.02	24.43	13.48	11.81	10.23	42.70	26.11	23.97	40.49	21.98	15.88	48.00	30.95	56.48	15.55
Significant interaction (NxY)	-	-	NxY	NxY	NxY	-	-	-	-	-	-	-	NxY	-	-

The tribes Arundinelleae and Andropogoneae occupy the largest portion of the basal cover (85%), and the two most common species are T. hispida and T. trianda. The dominance of these two species is in agreement with the findings of Acocks (1953) for the veld type, and of Scott (1951) on a nearby site. However, Edwards (1968), on ungrazed but mown plots on Tabamhlope soil series on the research station, recorded less T. triandra and considerably more A. filifolius. The low proportion of undesirable species when compared with Edwards' (1968) data, indicate that the veld was in good condition.

Herbage yields

Herbage yields, in terms of oven dry material per morgen, are available for "in" and "out" cuts at each of the first four grazings of the experiment. This covers growth of the veld from the first fertilizer application in December 1966 until the end of April 1968. The yields obtained together with an estimate of the amount of herbage consumed are given in Table 8.

The "in" cut. The application of nitrogenous fertilizer increased the herbage yields significantly ($P \leq 0.01$) during each of the four periods. In the second period the first increment of N fertilizer did not increase the yield, and in the fourth period the second increment (600 lb N/morgen) showed no benefit above that obtained from the first increment (300 lb N/morgen). The total yield for the whole period (16 months) was increased by 46% by the lower level and by a further 41% by the higer level of nitrogenous fertilizer.

The application of "other fertilizer" (P, K and Ca) resulted in a significant increase in yield in all but the second period (spring 1967 to 18.12.67). Over the whole period the total yield increased by 23% due to the application of these fertilizers.

During the third and fourth periods and in the total yield there was a significant ($P \leq 0.01$) nitrogen X "other fertilizer" interaction (See appendix table 1). In the absence of nitrogenous fertilizer there was no response to "other fertilizer", but in the presence of nitrogenous fertilizer there was a sig= nificant ($P \leq 0.05$ at 300 lb N/m, and $P \leq 0.01$ at 600 lb N/m) response to the application of "other fer= tilizer". The response to nitrogenous fertilizer al= so appeared to be greater in the presence of "other fertilizer" than in its absence.

It is obvious from the results that the appli= cation of 600 lb N/morgen resulted in a considerable increase in herbage yields (87% on the average). The increase was even more marked (121%) with the addition of "other fertilizer". These results cover only a short period (16 months) of fertilization at th the start of the experiment.

The "Out" cut. The amount of herbage harvested in the "out" cut reflects the amount of herbage re= maining above mowing height after grazing. This figure as such is of little value as it might be ex= pected to be (and was found to be) related to the herbage yield. However, it can be used to assist in deriving the amount of herbage consumed, and can usefully be expressed as the amount of herbage uneaten per animal.

The amount of herbage consumed

These figures were obtained by subtracting the amount of herbage left after grazing, and harvested in the "out" cut, from that available at the start of grazing, as reflected by the "in" cut. These figures are biased to the extent that no allowance is made for growth during the two day grazing period. However, in circumstances such as those pertaining to this experiment, where the grazing pressure is relatively high and constant on all treatments, this figure should reflect fairly accurately the value of the pasture. It is only the acceptable portion of total yield which is of value to the grazing animals.

The application of nitrogenous fertilizer resulted in significantly ($P \leq 0.01$) more herbage being consumed by the grazing animals in all four periods. In the second period the first increment of N fertilizer had no significant effect compared with the control, and in the fourth period the second increment of N fertili=

Table 9.

Number of grazing animals and grazing days on veld fertilizer experiment.

(1 lb = 0.454 kg; 1 sq yd = 0.836 sq m; 1 morgen = 0.8565 ha)

Treatments	No. animals/treatment (1600 sq yd)					Animal grazing days/morgen				
Period	(1)	(2)	(3)	(4)	Total	(1)	(2)	(3)	(4)	Total
Date	13/14.3.67	18/19.12.67	19/20.2.68	22/23.4.68		13/14.3.67	18/19.12.67	19/20.2.68	22/23.4.68	
Nitrogen (N)										
Nil	13.0	8.5	8.0	8.0	37.5	166.4	108.8	102.4	102.4	480.0
300 lb N/morgen	21.0	9.5	11.0	8.5	50.0	268.8	121.6	140.8	108.8	640.0
600 lb N/morgen	25.5	13.5	16.0	9.0	64.0	326.4	172.8	204.8	115.2	819.2
Mean	19.8	10.5	11.7	8.5	50.5	253.4	134.3	149.8	108.8	646.4
Other fertilizer (Y)										
Nil	18.3	9.7	9.7	8.0	46.0	234.2	124.1	124.2	102.4	584.9
100 lb P, 200 lb K & 265 lb Ca/morgen	21.3	11.3	13.7	9.0	55.3	272.6	144.6	175.4	115.2	707.8

zer produced no increase above the first increment. This result was similar to that obtained from the "in" cut. The lower level nitrogenous fertilizer resulted in a 48% increase in consumption, while the higher le= vel resulted in a further 49% increase as measured by the total of the four periods.

During two of the four periods the application of "other fertilizer" resulted in an increase in her= bage consumption. On the average the herbage consump= tion was increased by 18% due to the application of "other fertilizer."

The animal factor

In order to obtain more data on animal preferences, the above data was recalculated on a per animal, per day basis. The number of animals which grazed each treatment and the grazing days per morgen are given in table 9.

The animal numbers used on each treatment are in proportion to the herbage yields. As all the treat= ments were mown at the start of the experiment (19/12/66), the grazing days represent the carrying capacity over approximately one and a half years. The figure of 546 grazing days per morgen per annum, on the high level of nitrogen fertilization, is good. It represents over two M.L.U. per morgen for the normal grazing sea= son in this veld type.

The amount of herbage allocated, the amount eaten, and the amount remaining uneaten per animal, per day are given in Table 10.

Table 10

Herbage per animal per day on veld fertilizer experiment.

(1 lb = 0.454 kg)

Treatment	Herbage per animal per day (lb)														
	Amount allocated					Amount uneaten					Amount consumed				
Period Date	(1) 13.3.67	(2) 18.12.67	(3) 19.2.68	(4) 22.4.68	Mean	(1) 16.3.67	(2) 21.12.67	(3) 23.2.68	(4) 26.4.68	Mean	(1)	(2)	(3)	(4)	Mean
Nitrogen (N)															
Nil	15.05	16.29	12.97	10.78	13.77	0.22	6.81	6.00	1.35	3.60	14.80	9.48	6.96	9.43	10.18
300 lb N/morgen	14.81	16.41	15.22	15.46	15.47	0.27	7.57	6.88	2.69	4.35	14.55	8.84	8.32	12.77	11.09
600 lb N/morgen	15.38	15.51	15.00	15.51	15.35	0.28	4.70	5.63	3.03	3.41	15.09	10.81	9.37	12.48	11.94
Mean	15.08	16.06	14.40	13.92	14.86	0.26	6.36	6.18	2.36	3.79	14.81	9.71	8.22	11.52	11.07
L.S.D. P = 0.05	-	-	1.88	2.18	1.14	-	2.50	-	1.02	0.79	-	-	-	1.88	1.18
P = 0.01	-	-	-	3.02	1.58	-	-	-	1.41	-	-	-	-	2.60	1.63
Other Fertilizer (Y)															
Nil	14.89	16.25	14.53	13.40	14.77	0.22	5.93	5.90	1.78	3.46	14.67	10.32	8.63	11.61	11.31
100 lb P, 200 lb K & 265 lb Ca/morgen	15.25	15.88	14.29	14.44	14.96	0.29	6.79	6.46	2.93	4.12	14.96	9.10	7.81	11.51	10.82
L.S.D. P = 0.05	-	-	-	-	-	-	-	-	0.83	0.65	-	-	-	-	-
P = 0.01	-	-	-	-	-	-	-	-	1.15	-	-	-	-	-	-
Coefficient of Variation	8.03	12.85	12.27	14.72	7.21	54.72	37.09	29.10	40.60	19.61	8.09	30.01	28.02	15.34	10.02
Significant interaction (NxY)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Amount of herbage allocated per animal

On the average 14.86 pounds (6.75 kg) of herbage were allocated per animal, per day. This is very close to the 15 pounds per animal per day stipulated in the procedure. However, it will be noted that, on the average and during the last two periods, the animals on the plots which received no nitrogen fertilizer were allocated significantly ($P \leq 0.01$) less herbage than the animals on the plots receiving nitrogen fertilizer. This was the result of the relatively low rate of growth on these plots and the requirement of a minimum of two animals per plot. This could have been avoided by not grazing all the plots at the same time i.e. this treatment could have been witheld at the third grazing, and grazed with more animals at the fourth grazing. However, the decision as to whether or not sufficient herbage is available must be taken before cutting, for once the herbage samples are cut the process of grazing must also be carried out. This is not an easy decision due to the varied nature of the growth on the different treatments.

Herbage uneaten per animal per day

On the average, more herbage ($P \leq 0.05$) remained uneaten per animal, per day on the treatments receiving 300 lb N/morgen than on the treatments receiving no ni= trogen fertilizer, and on the treatments with an appli= cation of 600 lb N per morgen. A similar result was obtained at the second grazing, but at the fourth gra= zing the amount of herbage remaining uneaten (per ani= mal, per day) increased with increasing applications of nitrogenous fertilizer. During the first and third grazings there was no significant difference between the treatments.

On the average, and at the fourth grazing the amount of herbage remaining uneaten per animal per day, was greater on the plots receiving "other fertili= zer" than on those not receiving it. It is interest= ing to note that in the two autumn grazings (first and fourth grazings) less herbage was left per animal, per day than during the mid-summer grazings.

Herbage consumed per animal per day

The amount of herbage consumed per animal per day was greater, at the fourth grazing and on the average, on the plots recieving nitrogenous fertilizer than on the control plots. This result is probably a reflec= tion of the smaller amounts of herbage allocated to the animals on the control plots during the last two cuts. No other significant differences, in the amounts consumed per animal per day, were apparent.

The amount of herbage consumed per animal, per day in the two autumn grazings was considerably greater than in December and in February. This might be due to the greater live-weight of the experimental animals at the end of the season, compared with earlier in the year. However, this result is contrary to the belief that, the consumption of this sourveld by livestock declines in the autumn. It is suggested that a de= crease in nutritive value of the veld in autumn, rather than a reduced intake, may be mainly responsible for the decline in livestock condition noted during this period.

It is also surprising that nitrogenous fertiliza= tion had such a small effect on the consumption rates.

Conclusions

This experiment has been in progress for too short a period to determine the effects of the treat= ments on botanical composition. However, even over this short period it is apparent that the application of nitrogenous fertilizer resulted in a marked in= crease in herbage yields. The response to nitrogen was increased particularly at the high level by the addition of other fertilizer (P, K and Ca), however, these other fertilizers were of no benefit in the absence of nitrogen. It might be anticipated that the response to nitrogen will be larger in seasons of higher rainfall (the rainfall for the period under consideration was below average) and when the botani= cal changes associated with nitrogen fertilization are further advanced. These changes are usually toward species which are more responsive to nitrogen fertilization.

The results of the amount of herbage consumed confirm those obtained from the herbage yield. Ni= trogen fertilization resulted in a marked increase in consumption. The other fertilizers also resulted in an increased consumption on the average even in the absence of nitrogenous fertilizer.

From the data available it is not possible to assess the profitibility of the enterprise. The costs involved in veld fertilization can be estimated but the dry material yields available from this ex=

Table 11.

Costs of and income derived from veld fertilization on NP 17/6 1967-68 season

Treatment (1)	Cost of fertilization (2) morgen	Yield ton/morgen	Income at R20 per ton dry material Gross	Net	Increased yield required to cover cost of fertilization	Income based on Factor for quality (3) Gross	Net	Increased yield required to cover cost
N_oY_o	R 0.00	2.04	R40.74	R40.74	-	R 40.74	R 40.74	-
N_oY_1	R25.97	2.16	R43.30	R17.33	1.30 ton/morgen	R259.80	R233.83	0.22 ton/morgen
N_1Y_o	R23.36	2.72	R54.38	R31.02	1.17 ton/morgen	R326.28	R302.92	0.19 ton/morgen
N_1Y_1	R49.33	3.04	R60.80	R11.47	2.47 ton/morgen	R364.80	R307.07	0.41 ton/morgen
N_2Y_o	R45.23	2.97	R59.40	R14.17	2.26 ton/morgen	R356.40	R311.17	0.37 ton/morgen
N_2Y_1	R71.20	4.52	R90.34	R19.14	3.56 ton/morgen	R542.04	R470.84	0.59 ton/morgen

(1) Treatments:

N_o = No nitrogen fertilizer
N_1 = 300 lb N/morgen
N_2 = 600 lb N/morgen
Y_o = No other fertilizer
Y_1 = 100 lb P, 200 lb K and 265 lb K/morgen.

(2) Costs:

Fertilizer: Urea R63.75 per ton
Superphosphate R23.60 per ton
KCl R34.70 per ton
Lime R1.80 per ton

Transport: 20c per ton mile over 15 miles = R3.00

Spreading: 50c per morgen per application.

(3) Income on quality

Coetsee (1969) shows that fertilized veld as hay has 6X the value of unfertilized.

(1 morgen = 0.8565 ha; 1 lb = 0.454 kg; 1 ton/morgen = 1059 kg/ha)

periment do not adequately reflect long term average yields. Coetsee (1969) has shown that liveweight increases of animals fed on fertilized veld hay bear no relation to the increases in hay yields obtained by fertilization. Over a ten year period a 2.9 fold increase in hay yield, due to the fertilization of veld, resulted in a 19.3 fold increase in the liveweight gain on feeding the hays to beef cattle. This means that the hay from fertilized veld had approximately six times the value of that from unfertilized veld. The costs and estimated income resulting from the fertilization of this experiment which are presented in Table 11 are therefore very tentative.

On the basis of the hay yields for the 1967-68 sea= son the fertilization of veld did not pay when the dry material harvested was valued at R20 per ton (907 kg). On the basis of the valuation suggested by Coetsee's (1969) results (i.e. R120 per ton) fertilization pays hansomely. No doubt, the true value of hay from fer= tilized veld is greater than that from unfertilized veld. A realistic value is probably less than R20 per ton for dry material from unfertilized veld and greater than R20 for material from fertilized veld. It is reasonably certain that the fertilization of this veld type is a payable proposition because yields of between five and six tons per morgen (4500-5400 kg) of dry material are not impracticable (see 3.5.3.4).

The technique used in this experiment worked well, and appears to be suitable for the determination of herbage yields in the presence of grazing animals, and of herbage consumption. The errors (as measured by the co-efficient of variation) were within reasonable limits

3.5 Overseeding as a method of veld improvement

Charles (1962) in his review of pasture es=tablishment by surface-sowing methods states: "The plough has a well-established place in the pre=paration of a seed bed for resowing grassland. Large areas of land exist, however, which are too steep, too stony or too wet for the use of conventional tech=niques and it is in these difficult circumstances that surface-sowing methods offer possibilities for pasture improvement."

Charles (1962) quotes various authors to illus=trate the extent to which oversowing has been applied in recent years. In New Zealand (Robinson & Cross, 1960), New South Wales (Sardone, 1961) and in Scotland (Gardner, 1961 & Copeman, 1961) large areas of pastures have been surface sown. Since 1961, it is apparent that this practice has been extended in both Australia and New Zealand (Edwards, 1968).

There are great possibilities for further develop=ment. Charles (1962) reports that in the U.S.A. 50 million acres, in New Zealand 13 million acres and in Ireland 1.5 million acres await development by over=seeding. In the Highland sourveld of South Africa it appears that some 40% of the total area (slopes >12½% and vleis - section 3.2.2.1) are suited to development by overseeding and/or fertilization. If this figure is extended to apply to the two radical veld improve=ment zones of regions 1, 2 and 3.2 and if a figure of 20% were applied to these zones of region 3.1 (it is flatter than the other region) of the Grassland Poten=tial map of the Republic (section 2.2); some 13 million morgen (28 million acres) are apparently suited to overseeding in the Republic. (The 15% of potentially arable land does not fall within these slopes and vleis, and can therefore be ignored).

Charles (1962) considers the following to be es= sentials for successful oversowing: "(a) the correction of mineral deficiencies in the soil, (b) the elimina= tion of the old sward, (c) getting the seed into con= tact with the soil, (d) suitable grazing management during and after establishment." A fifth factor, (e) the availability of suitable plant species for over= seeding, could be added to this list.

The aim of overseeding is to convert low produ= cing, low quality grazing into high producing, good quality grazing by reinforcing, and replacing it with improved plant species. This is nearly always asso= ciated with fertilization, and the success attained, overseas, has depended largely on legumes to provide the initial nitrogen supply.

When considering the possibilities of overseeding in new area, it is first necessary to investigate each of the five essentials, mentioned previously. Each of the factors must be weighed up against the local conditions, and considered in the light of available information. In the research programme at Tabamhlope Research Station much of the required information on soil fertility and species adaptation was obtained from trials on cultivated areas. From 1962 to 1967 much attention was concentrated on methods of reducing the existing cover and getting the seed into contact with the soil. It was considered that this order of priority was the one most suited to the area. It was intended that subsequent trials should concentrate on the management of the improved grassland. Thus the research programme discussed in this section deals with four of the five essentials of overseeding.

3.5.1 The search for suitable species

"The choice of species and variety is one of the most important considerations in good grassland management. Few factors are so completely under the control of the grassland farmer, and he should make the most of his opportunity" (Harlan, 1956). This state= ment implies that the grassland farmer knows the value of the species and cultivars available to him. It is the duty of the grassland research worker to acquire this knowledge, and disseminate it to the farmer by way of the extension and publicity divisions of his department. The research worker must acquire this knowledge by a continuous process of testing and eva= luation.

In Canada a co-ordinated programme of forage crop testing is facilitated by the network of stations of the Federal Department of Agriculture. Breeding is confined to a few stations but testing is on a more extensive basis (Knowles, 1960). In England a similar position exists with the breeding being concentrated at Aberystwyth. In New Zealand, the plant breeding is concentrated at Palmerton North, and evaluation is carried out at a number of centres under the guidance of the plant breeder (Edwards, 1968). The Republic of South Africa has had a network of testing stations in operation for a number of years (Anon, 1938, 1940, 1951). However, in many instances there has been little uniformity in the factors evaluated, the system used in evaluation or in the methods used in establish= ment and management at such stations.

It is apparent that, in a comparison of species, or cultivars results obtained under one set of field conditions might vary considerably under another set of conditions (Hunter & Leake, 1933). Such variation might be caused either by environmental conditions or by management practices. Variations in environmental conditions, which are generally of a climatic or edaphic nature, can only be evaluated by replicating the trials at various centres. It is conceivable that the vast number of management practices which are possible can be limited and standardised. This can be done if due consideration is given to the use to which the plants will be put when tested and to the nature of the trials conducted. In the same way the observations made and records kept should be selected in relation to the ultimate object of the trials.

Factors affecting the performance of plant varieties

(a) Environmental factors

The importance of climatic factors such as precipitation, temperature extremes, relative humidity and day-length in determining the performance of plant species and cultivars is common knowledge. The eco= logical behaviour of tribal groups can be of some value in determining which species are most likely to be successful in a given area. There is no suitable sub= stitute for research, however, and it is necessary to demonstrate the adaptation of spe cies and cultivars to given situations (Harlan, 1956). The value of trials for the screening of cultivars is considerably enchanced by repetition in different environments (Green, 1959).

In several countries, England (Green, 1963), Kenya (Brogdan, 1960), Canada (Knowles, 1960) and South Afri= ca (Anon, 1938, 1940, 1951), it has been found neces= sary to test species and varieties under the specific conditions of a number of climatic regions. A problem which requires careful consideration in such testing is the degree of local adaptation required (Knowles, 1960). This problem is of prime importance to the plant breeder but, should never-the-less, also be con= sidered in the testing of spe cies. The extent of the climatic regions and the relative importance of fodder crops in each unit should be considered care= fully before selecting sites for trials. There are many advantages of having varieties adapted to large areas. Perhaps the most important of these advantages is to be found in seed production (Knowles, 1960).

Edaphic conditions can influence the performance of plant species and varieties to a considerable extent. Extremes in soil moisture within a single area affect the performance of species. Irrigation will also af= fect the choice of species. Numerous instances of dif= ferential response of plant varieties to unfavourable contents of soil minerals and soil pH have been reported (Vose, 1963).

Numerous cultivar differences have been proved in relation to resistance to toxicities of saline conditions (Vose, 1963). Cultivars are also often selected for their adaptation to acid soil (Vose, 1963).

(b) Management factors

The fertilization grazing or cutting and weed control measures applied to plant trials have a large influence on the relative performance of plant species and cultivars.

Fertilization

In South Africa the fertilizer regime which has been applied in the testing of plant material has varied considerably. Under irrigation, at Estcourt, Scott, West & Ward Cox (1940) did not apply any fertilizer to the nursery plots. However, Scott et al. (1940) Preller (1940, 1951) and van Wyk (1962) fertilized trials conducted under dry land conditions. Preller (1940, 1951) handled his plots in "as near normal farming conditions as possible". He did not attempt abnormally high fertilization with compost or artificials. On the other hand, Scott et al (1940) applied "the best possible treatment of the soil from the fertilizer point of view."

Differential response of plant species and cultivars to phosphate fertilization, nitrogen fertilization, calcium fertilization and zinc requirements, have been reported (Vose, 1963).

Breeders have paid little attention in plant breeding and selection to nutritional factors *per se*. However, they must take into consideration so many factors that they are loth to add an ad= ditional one (Vose, 1963). Soil fertility may obscure differences between cultivars, and diffe= rences might be shown by testing at lower fertili= ty levels. However, it is doubtful if these differences would be significant agronomically. There seems to be a need to develop cultivars sui= ted to high fertility conditions (Cowling, 1960).

Competition

In perennial pastures intra- and inter- specific competition, from both planted and in= vading species, plays an important role in the ecological changes which take place. These chan= ges may influence the production, nutritive value, palatability and economic value of a pasture. It is therefore little wonder that the effects of competition, in the testing of plant material for perennial pastures, has been the subject of much experimentation. Plant material may be planted in three ways: (a) in plots or rows of spaced plants, which are usually clean cultivated, (b) in broadcast swards of single species or (c) in mixed swards usually consisting of the cultivar under test and one other, previously tes= ted species. The companion spe cies is usually a legume if the species being tested is a grass and *vice versa*. Foreign plants are seldom re= moved from the swards and are allowed to exert their effects.

Lambert (1963 found that a square pattern of spaced plant material was excellent for testing cocksfoot cultivars. In the examination of newly introduced plants and new developments of commonly used species, Davies (1955) also used spaced plants. Codd (1940) and Foster (1940) used rows of plants which were clean cultivated between the rows. Several workers have, however, shown that strains of grass which were inferior when grown in spaced plots gave equal or greater yields when planted in broadcast plots (Alghren, Smith, Nielsen, 1945 & Kramer, 1952). Correlations between characte= ristics of spaced plants, and their hay yields when grown in swards are usually low, and can not be used for predicting hay yields (Nissen, 1960). Nissen (1960) states that spaced plant experiments can never replace swards but may be used for spe= cial reasons e.g. (a) to test for special desirable characters, which may be more easily observed in spaced plants than in swards, (b) for identifica= tion purposes and (c) to screen "source material" in breeding work.

Lazenby & Rogers (1960) state that results from comparisons of relative yields of spaced plants and swards have been conflicting. Some= times there has been similar relative cultivar performance, although differences detected in spaced plants were often reduced in swards: on other occasions little relationship was found between varietial behaviour in the two "environ= ments." They found, in experiments with planting densities of Lolium perenne, that (a) yields of cultivars were not always in the same order for the different densities used, and (b) the potential tillering capacity and tiller weight were affected by the densities used. Greatest yields per unit area of land were obtained from swards.

Harlan (1956) states that compatability of species should be considered in the choice of species for a pasture. The species must respond similarly to the same management and they should be nearly of the same palatability under the management used. Various workers have preferred to use mixtures for testing species, which are normally grown in association with others (Weiss, Kukerji, 1950; Thoughton, 1955; Hausmann, 1960). It was found in Sweden, that if cultivars of timothy and cocksfoot were tested in pure stands and in a mixture with red clover the relationship between cultivars could be distinctly different in the two types of stand. It was concluded that cultivar tests with herbage plants must, therefore, be made in mixed as well as pure stands (Akerberg, 1960). Attwood & Gaber (1942) demonstrated differential clonal performance and persistence under competition with white clover clones transplanted into an area sown to Kentucky bluegrass seed, as compared with when they were grown in pure clover swards. Other workers have found that strain differences, apparent in single species swards, were masked to some extent in mixed sowings (Churchill, 1947; Pavlychenko, 1942). Pergande (1954), growing five cultivars of <u>Lolium perenne</u>

in pure culture and in five mixtures, found that they exhibited the same characteristic properties under each system, and he concluded that ryegrass cultivars could be satisfactorily tested when sown alone.

Wright (1960b) found that there was no con= sistent relationship between cultivars of Lolium perenne when grown as spaced plants, pure-sward or grass/clover swards. The correlations between any two techniques were variable. He suggests that grass/clover swards, managed so as to stimu= late normal farming practice, provide the plant breeder with the soundest method of assessing the true agronomic potential of strains. On the other hand, Wilsie (1949) found close agreement between row and pure stand yields and from those from mixtures with legumes. Fransden (1956) concluded that a reliable progeny test of the yield of forage species could be made only from pure or mixed swards. Wright (1960) concluded that there was a place for spaced plants in se= lecting for many characteristics, but for yield, growing in a mixture is essential. He also found that spaced plants showed a higher degree of in= fection to "blind seed disease in ryegrass" than did swards. Clover appeared to act as a mechani= cal barrier to the spread of the disease.

Harvesting and utilization

The method emplyed in harvesting the produc= tion from and the utilization of plant cultivar trials may have a marked influence on the produc= tion obtained and on the relative performance of cultivars.

The stage of development at which pasture plants are cut or grazed and also the frequency of such cutting or grazing may influence the relative per= formance of spe cies or cultivars (Johnstone-Wal= lace, 1945; Ahlgren, 1947; Green & Eyles, 1960; Voison, 1960; Green, Anslow, Corrall & David, 1963). The height to which pasture plants are cut or gra= zed may also influence the relative performance of species and cultivars (Hughes, 1937; Ahlgren, 1947; Lynch, 1947; Jones, 1959; Voison, 1960).

Yields from cultivar trials are usually mea= sured by cutting and weighing the herbage produced. Some workers have found that the correlation between results obtained from plots which are mown and those which are grazed are poor (Jones, 1934; 1935; Gar= rigus & Rusk, 1939). On the other hand a number of workers have obtained close correlations between the results from mown plots and from grazed plots (Ahlgren, Bashtedt, Aamodt, 1938; Brandt & Ewalt, 1939; Hodgson, Knott, Miller, Walberg, 1942; Line= han & Lowe, 1946; Linehan, Lowe, Stewart, 1952). Generally higher yields have been reported from plots which were cut than from those which were grazed (Brown, 1937; Jones, Ewalt & Haag, 1937; Ahlgren _et al._, 1938; Brandt & Ewalt, 1939; Hodgson _et al._, 1942). Significant changes may occur in the botanical composition of pastures which are mown continuously and these changes usually differ from those occuring on grazed pastures (Stapledon & Jones, 1947; Hein & Henson, 1942). The diffe=

rences in growth, composition and reaction of species to mowing and grazing are probably due to one of three factors : (1) Differences between the two methods, associated with the method of removal of the herbage e.g. in mowing an even height of defoliation, an arbitrary height of de= foliation, the frequency of defoliation, sudden and severe defoliation and the method by which the grass is sheared. (2) The grazing animal tramples the plants and compacts the soil. (3) The loss of soil fertility in herbage which is cut and re= moved from the sward as compared with grazing (Brown, 1954).

The nature of the observations in the recording perfor= mance of plant cultivars

Lazenby (1960) has suggested that the problems in evaluating established cultivars should be separated from the problems involved in breeding. In the pre= liminary screening of plant material the questions to be asked are: (1) will it survive? (2) will it grow?. The classification and selection of cultivars poses more searching questions and may involve the use of management practices and the recording of details which are unnecessary in the preliminary trials. Harlan (1956) stresses the importance of selecting plant spe= cies in relation to the purpose of the pasture. The main purpose of the pasture might be soil improvement, nutrition of livestock, to provide fodder at special times of the year, the control of soil erosion, the prevention of run-off of rain water or the production of seed for other areas (Harlan, 1956; Knowles, 1960). The testing of plant species or cultivars is simplified, if the purpose for which they are to be used can be defined. The characteristics which are to be observed and the most appropriate method of testing should be selected in relation to the ultimate use of the pasture. A clear definition of the object of the pasture also enables the control species to be selected with greater precision (Lazenby, 1960; Green, 1963).

Yield of dry matter is usually the main measure of the value of spe cies and cultivars (Mostert & van Plotzen, 1951; Preller, 1951; Brogdan, 1960; Knowles, 1960; van Wyk, 1962). Knowles (1960) considers that dry matter yield, better than any other factor, indi= cates the usefulness and general adaptation of grasses and legumes.

Various workers have indicated that considerable differences exist in the nutritional value and content of chemical constituents of plant cultivars (Robinson, 1942; Seay & Henson, 1958; Akerberg, 1960; Vose & Koontz, 1960). It has been reported that protein content of herbage gives a good estimate of the content of most other chemical constituents (Akerberg, 1960). Deter= mination of the dry matter yield alone can result in wrong conclusions concerning the practical value of the plants and a mixture of chemical analyses are also re= quired (Akerberg, 1960). The determination of the nutrient content of herbage by means of chemical ana= lysis, however, does not always present a true reflec= tion of the feed value (Crampton & Finlayson, 1935; Crampton & Forshaw, 1940; Hardison, Ried, Martin & Woolfolk, 1954; Davies, 1959). Two plant varieties having the same content of a chemical constituent may differ in their feed vlue or digestibility of this constituent (Crampton, 1934; Morris, Wright & Fowler, 1936; Maynard, 1937 & Morrison, 1949). The measure= ment of digestibility and biological value of plant cultivars is, however, seldom made at this early stage of evaluation.

Palatability (Harlan, 1956, Jones, 1959; Akerberg, 1960), the presence of toxic substances and those cha= racteristics which influence the value of the product during conservation (Akerberg, 1960) should also be considered in the estimate of the quality of plant cul= tivars.

In Europe considerable emphasis is placed on the recording of seasonal production and the tolerance of leaf growth to frosting in cultivar trials. The an= nual production of two cultivars of grass may be iden= tical but the distribution of growth over the year may vary considerably (Jones, 1959). In selection em= phasis is laid on early spring growth (Jones, 1959), autumn growth (Davies, 1955) and "winter greenness" or winter hardiness (Davies, 1955; Serviss & Ahlgren, 1955; Harlan, 1956; Brogdan, 1960; Knowles, 1960). Jones (1959) emphasises the difference between early spring growth and peak spring growth. The former is the awakening period and the latter the zenith period.

Mostert & van Pletzen (1951) classified species and varieties on their growth habit and Davies (1955) selected cultivars for their leafiness. In South Africa drought resistance is a quality for which plant cultivars might be selected. Harlan (1956) considers that the type of livestock which will utilize the pasture should be taken into consideration in the eva= luation of plant cultivars.

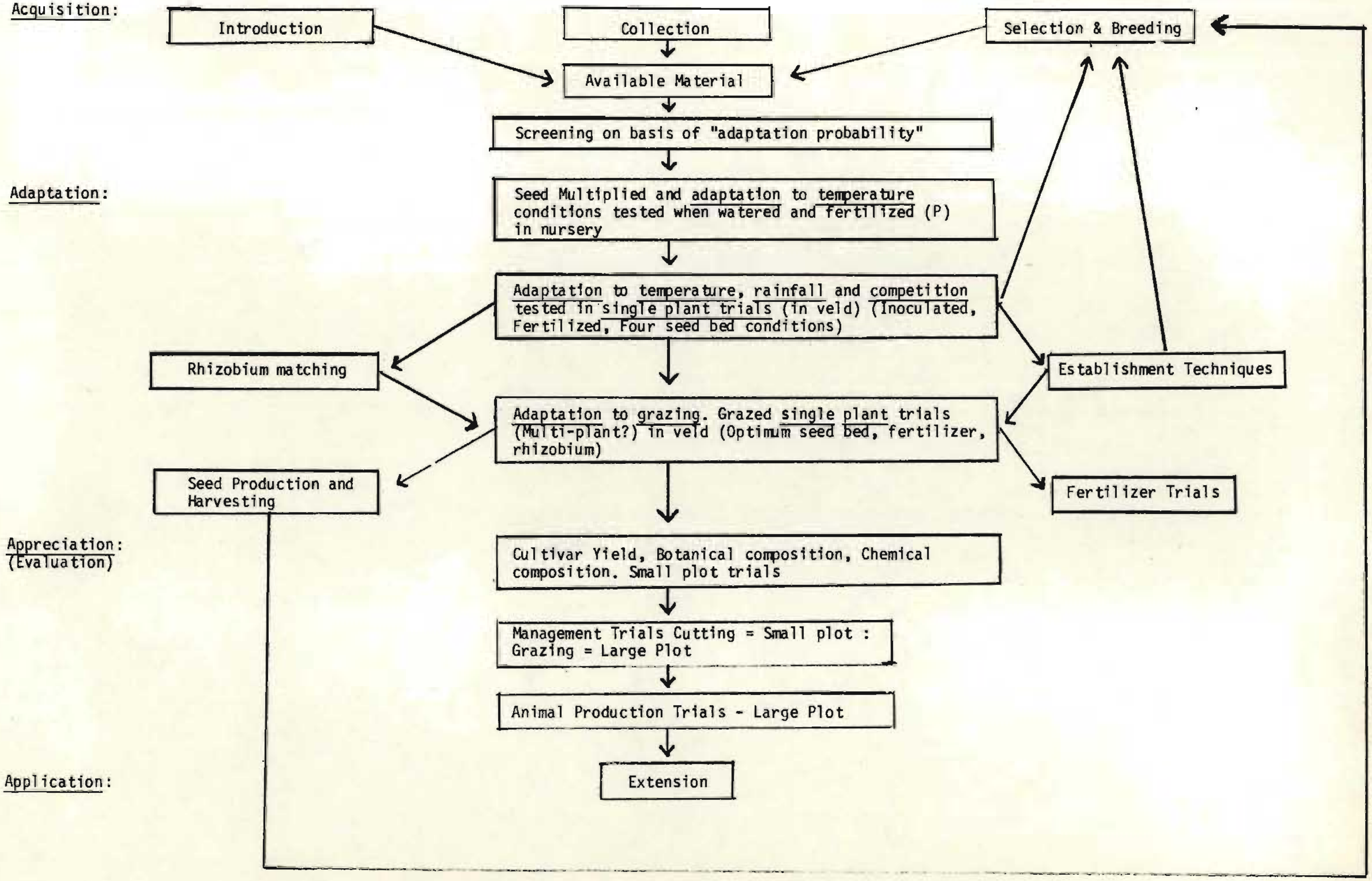
When the purpose of the pasture is soil improvement, the legumes selected must have the capacity for abun= dant nitrogen fixation and the pasture must give a high yield of forage for the soil to receive a high return of animal manures (Harlan, 1956). Jones (1959) sug= gests that the grass cultivar itself has an influence on the soil quite apart from the clover content of the pasture. The percentage of water stable aggre= gates in the soil, which is a measure of soil struc= ture, formed by various plant species and cultivars may vary (Stevenson & White, 1941; Pavlychenko, 1942; Williams, 1955).

The effectiveness of various plant cultivars in controlling soil erosion and slowing up the flow of water varies considerably (Ayres, 1936; Bennett, 1947; Harlan, 1956).

Several workers have taken agressiveness and persistency into consideration when selecting plant species and cultivars (Mostert & van Pletzen, 1951; Serviss & Ahlgren, 1955; Jones, 1959). Others con= sider disease resistance to be an important factor in selection (Knowles, 1960; Wright, 1960b). The number of seeds germinating and the percentage of seedlings which become established may be of importance (Preller, 1940), while in seed producing areas the seed produc= tion of a species or cultivar for export to other areas may be the prime consideration in selection (Knowles, 1960).

Figure 3

Multistep Programme for the Introduction of Legumes into the Veld when selections are numerous but Seed Supplies small



A somewhat idealized scheme of the processes in= volved in selecting and evaluating plant species for overseeding is illustrated in Figure 3.

This scheme consists of four steps: (a) The acquisition of material, (b) testing the adaptation of this material, (c) the evaluation of its production potential, and (d) the application of the results in the field

Plant material may be acquired by importation from other areas, by the collection of selected local material or by sophisticated selection and breeding programmes. This mass of available material should be screened for the "probability" of it being adapted to the area. By screening on the "adaptation probabi= lity" of a species, is meant the selection of those species adapted to the climatic conditions of the area, and to the use to which it is to be put. In this process Mediterranean species, adapted to winter rain= fall, would be excluded from a summer rainfall area; tropical species would be excluded from an area with severe winter frost, and prostrate species might be selected for grazing in preference to upright types. This process depends on the availability of data on each species and on the ability to reason logically. In the absence of sufficient or suitable adapted ma= terial, it may be necessary to seek plants from less promising sources. The "adaptation probability" process can eliminate some valuable material. Some plants have a very wide range of adaptability (e.g. Medicago sativa), however, as knowledge of such a characteristic is generally available, the loss of material should be minimal.

This material, which is apparently adapted, must now be tested to determine its actual adaptation. The tests may be stringent, and of a nature such as to determine the adaptability of a plant for a spe= cific purpose (e.g. for overseeding and grazing in a specific area), or they may be of a more general na= ture (i.e. adaptability to climatic conditions only). Whatever the nature of the tests, the evaluation should be carried out under a favourable fertilizer, and in the case of legumes a favourable Rhizobium regime, unless adaptation to low fertility conditions is the object of the exercise. Single plants or rows (replicated) are usually adequate for this stage of the investigation, as seed supplies one frequently limited.

Promising species are then compared on the basis of their production. Optimum management practices should also be evolved if possible. Ideally, the yardstick in this phase is usable animal products (Davies, 1961), but frequently herbage yields are a more practical measure.

The final step is the dissemination and applica= tion of the results. (The press, radio, television, lectures, field demonstrations and contact with indivi= dual farmers are some means of transmitting the results). The success of the whole programme is, in the final reckoning, measured by the extent to which the produc= tion of the area has been increased by the application of the measure. It is, therefore, also obvious that adequate, reasonably priced seed of any new introduc= tion must be available before the final phase can be implemented. (Research may be required into seed production and harvesting techniques).

During the period 1936 to 1954 a considerable amount of plant material was tested, in nurseries and in other trials, at Tabamhlope Research Station (Scott, 1938; 1940, 1951, 1955), while Gosnell (1957) carried out a cultivar trial with selections of E. curvula. Much useful data had been obtained from these trials and many successful pastures had been established in the area. The most common components of these pastures were: P. dilatatum, D. glomerata, P. clandestinum, T. repens and T. pratense. E. curvula was established later on a large scale, and L. multiflorum, A. sativa and S. cereale were commonly grown as annual cool season pastures.

Between 1955 and 1966 one grass species, and four grass and clover cultivar trials were established to obtain a more detailed evaluation of promising species at Tabamhlope. These trials, and those prior to 1954, were all conducted on arable land, and as such were perhaps not ideal for selecting material for overseeding. However, this material did provide the basis for later trials on overseeding.

3.5.1.1 Grass species trial (NP 19 T)

As has previously been mentioned, a large number of grass species had been tested at Tabamhlope Research Station prior to 1956. However, as most of these trials were conducted on unfertilized plots, and in view of the unfertile soils in the area, it was decided to attempt a more detailed evaluation of some of these species on fertilized plots. In February 1958 a grass species trial, which included both temperate and sub-tropical species, was established at the Tabamhlope Research Station. This trial was conducted in an attempt to narrow down the number of grass species which might prove to be useful in developing the grassland potential of the Highland Sourveld.

A summary of the results obtained from this experiment has been published in the form of a popular article (Edwards, 1964). Detailed results are presented hereunder.

Objective

The object of the experiment was to determine the hay production, potential of seventeen perennial grass species, which were supposedly adapted to the area, under conditions of adequate fertilization. The effect of two different row spacings was also investigated.

Precedure

The experiment was conducted on the "Farningham" experimental site (see section 3.3.1) on the Tabamhlope Research Station. It was planted on a finely prepared seed-bed, into which the fertilizer had been disced. The seed was sown by hand in rows, and vegetative material (where seed was not available) was also planted in rows. Planting was carried out on a moist soil.

The seventeen grass species were planted in six replications in a randomised block design, with a split plot treatment for six inch and one foot spacing between rows.

The species planted and the seeding rates used were as follows:

Species	Seeding rate (lb/morgen -0.53 kg/ha)
Eragrostis curvula (Ermelo)	6
Paspalum dilatatum	120
"Ronpha" (Probably a *Phalaris* hybrid)	Vegetative material
Phalaris tuberosa	10
Agrostis tenuis	100
Hemarthria altissima	Vegetative material
Paspalum urvillei	60
Andropogon appendiculatus	Vegetative material
Lolium perenne S.101	50
Pennisetum clandestinum	Vegetative material
Dactylis glomerata S.26	60
Festuca elatior var. *arundinacea* K.Y.31	40
Bromus catharticus	50
Panicum coloratum var. *makarikariensis*	30
Paspalum scrobiculatum var. *commersonii*	40
Cynodon plectostachyus	Vegetative material
Digataria tricholaenoides	Vegetative material

All the seed was obtained from commercial sources and the vegetative material was obtained locally. The gross size of each sub-plot was 7 x 6½ yards (6.4 x

5.9 m) and whole plots were 7 x 13 yards (6.4 x 10.8 m).

The yields obtained from this experiment were subjected to the conventional randomised block, statis= tical analysis although such an analysis is not strict= ly valid. Statistical comparisons of yields obtained from different species and genera of plants is compli= cated by the possibility of each species having a dif= ferent variance. Further as certain species failed to establish, there were in fact some treatments mis= sing from the original design. However, even without statistical analysis, the mean yields over the period of the experiment, from six replications in a randomised block design; probably provide a reliable estimate of the performance of the species.

At establishment the soil was fertilized with 80 lb N in the form of urea (46% N), 35 lb P in the form of superphosphate (8.3% water soluable P) and 100 lb K in the form of muriate of potash (50% K) per morgen (42, 19 and 53 kg/ha). Four tons of lime and 400 lb of magnesium sulphate per morgen (4236 and 212 kg/ha) were also disced into the soil before planting. A mixture of trace elements was applied to the soil be= fore planting. This mixture consisted of:

30 lb $CuSO_4.5H_2O$,

30 lb $ZnSO_4.7H_2O$,

30 lb Borax, and

8 oz. $(NH_4)_6\ Mo_7O_{24}.4H_2O$ per morgen (15.9, 15.9. 15.9 and 0.26 kg/ha).

Similar amounts, to those applied at establishment, of N, P and K were spread in the spring of 1958, 1959 and 1960. During the 1959-60 and 1960-61 seasons a topdressing of 30 lb (13.6 kg) and 50 lb (22.7 kg) K was applied for each ton of dry material harvested from each treatment. This fertilizer was applied not longer than one week after each cut. The object of applying this fertilizer was to ensure that the yields of the more productive treatments did not decline as a result of the depletion of soil fertility.

At the end of the 1960-61 season the fertilizer rates were reviewed on the basis of the yields obtained during the first two seasons. The average composition of the herbage was estimated to be 2%N, 0.13%P and 0.8%K. From 33 to 60% of the N, a maximum of 30% of the P and about 70% of the K applied in the form of fertilizer are taken up by grass plants (Russel, 1954). On a basis of these figures it was found that the requirements of most species were greater than the amounts of N and P applied, and considerably less than the amounts of K applied. The fertilizer rates were then amended as follows:

Basal spring dressing:

The rate of application of P was increased from 50 lb per morgen to 110 lb per morgen (58 kg/ha), and the dressing of N was increased from 80 lb to 100 lb per morgen (53 kg/ha) while the K remained unchanged.

Topdressing

The amount of fertilizer applied per ton of dry material harvested was increased from 30 to 60 lb (27.2 kg) in the case of N, and decreased from 50 to 33 lb (15 kg) in the case of K.

During the first season (1958-59) production was generally poor. This season was, therefore, considered as an establishment period and yields were not recorded, but the plots were mown regularly to control weed growth. Yields were first recorded during the 1959-60 season. The herbage was harvested whenever it reached an average height of from 6 to 8 inches (15-19 cm) on each treat= ment. Harvesting was carried out on the "island" method and samples were taken for dry matter content determi= nations (see section 3.3.3). Twenty-five (5 x 5 yd -4.6 x 4.6 m) square yards were cut and weighted on each sub-plot.

Results and Discussion

Establishment and survival. Of the seventeen grass species which were planted, only twelve became ade= quately established. The failure of five species during this period emphasised the need for adequate preliminary screening of material (in single plant or row trials) before embarking on more elaborate trials. A considerable amount of land and effort were wasted and the statistical design was jeopardised. *C. plec= tostachyus* and *P. scrobiculatum* var. *commersonii*, al= though well established in autumn 1958, failed to sur= vive the first winter. This was due to a lack of adaptation to the cold, dry winters of the area. It was not found possible to obtain a full stand of D. tricholaenoides inspite of repeated replanting — occasional tufts did become established and grew well. P. coloratum var. makarikariensis and B. catharticus survived the establishment period, but their growth was so poor that over 90% of the material harvested from their plots was weed. The yields obtained were not representative of that of the spe cies, and were discarded.

The yields obtained from P. urvillei and A. appendiculatus were not recorded during the 1959-60 season. Extraneous material accounted for the greater portion of the herbage harvested from these plots during this season. All the other species established well, and so little extraneous material was present that botanical separation of the cut herbage was considered unnecessary.

The split-plot treatment of row spacing had no obvious effect on establishment.

Dry material yields. The yields of oven dry material obtained from the experiment during three years are given in Table 12.

Outstanding yields were obtained from E. curvula during each season, culminating in a yield of 23.42 tons oven dry material per morgen (24.8 M kg/ha) during the 1961-62 season. P. dilatatum and "Ronpha" yielded an average of 12.61 and 10.64 tons per morgen (13.4 and 11.3 M kg/ha) of dry material respectively, and P. urvillei and A. appendiculatus, once established, also yielded

Table 12

Estimated[1] seasonal yields of dry material from twelve grass species. (Three year average).

Species	Yield lb. per morgen per day			
	Spring (1/9-1/12) 92 days	Summer (2/12-1/3) 90 days	Autumn (2/3-26/4) 56 days	(1/2-26/4) 85 days
Eragrostis curvula - Ermelo	137	270	176	183
Paspalum dilatatum	62	210	108	116
"Ronpha"	110	167	98	112
Phalaris tuberosa	98	163	110	128
Agrostis tenuis	27	76	79	80
Hemarthria altissima	57	107	78	83
Paspalum urvillei	68	157	115	125
Andropogon appendiculatus	67	143	98	105
Lolium perenne S.101	47	92	68	76
Pennisetum clandestinum	36	30	69	59
Bactylis glomerata S.26	39	65	64	64
Festuca elatior var. arundinacea K.Y. 31	38	74	59	64

(1 lb/morgen = 0.53 kg/ha)

(1) Estimated yields, as dates of harvesting did not always co-incide with the start of the seasons.

well. There was a considerable upsurge in production during the third season, which was probably the result of more favourable climatic conditions and improved fertilization. This improved production was particu= larly noticable in the case of "Ronpha" and P. tuberosa. The average annual yields of L. perenne, P. clandestinum, D. glomerata and F. elatior var. arundinacea were poor.

Table 13.

Yield of dry material from twelve grass species.

Species	Yield (Tons per morgen)			
	Season			
	1959-60	1960-61	1961-62	Average
Eragrostis curvula - Ermelo	15.89	18.22	23.42	19.18
Paspalum dilatatum	10.17	12.35	15.31	12.61
"Ronpha"	8.98	7.61	15.33	10.64
Phalaris tuberosa	3.84	3.77	14.90	7.51
Agrostis tenuis	9.53	5.30	6.86	7.23
Hemarthria altissima	3.09	3.17	9.59	6.95
Paspalum urvillei	-	7.17	13.41	6.86
Andropogon appendiculatus	-	5.50	12.24	5.92
Lolium perenne S.101	6.39	2.71	8.20	5.77
Pennisetum clandestinum	6.50	4.38	4.95	5.28
Dactylis glomerata S.26	5.81	2.66	6.49	4.99
Festuca elatior var. arundinacea	5.27	2.29	6.75	4.77
Mean	6.29	6.68	11.45	8.14
Whole Plots				
L.S.D. P = 0.05	1.27	1.57	1.93	1.10
L.S.D. P = 0.01	1.70	2.11	2.58	1.47
Coefficient of variation (%)	14.43	20.15	14.42	11.59
Sub. Plots				
6" spacing	7.54	6.62	11.44	8.12
12" spacing	7.55	6.74	11.47	8.17
F =	$0.01^{N.S.}$	$0.50^{N.S.}$	$0.01^{N.S.}$	$0.04^{N.S.}$
Interaction : Spacing x species.				
F =	$0.49^{N.S.}$	$1.97^{N.S.}$	$1.04^{N.S.}$	$0.42^{N.S.}$

(1 ton/morgen = 1059 kg/ha)

N.S. = Not significant.

The row-spacing treatment did not affect the yields, nor was there any interaction between the spacing and the species.

The estimated daily production of each species during each of four growth periods is given in Table 13.

This data was derived by dividing the total pro=duction from one cut by the number of days since the last cut. This data for the three years was then averaged over each of the four seasons. The estimate, obviously, is less accurate the less frequently the species was cut - usually the lowest yielding species were cut least frequently.

During spring (1 September to 1 December), E. curvula gave the greatest production, while "Ronpha" and P. tuberosa also produced well. The heaviest yields during the summer (2 December to 1 March) were obtained from E. curvula and P. dilatatum. "Ronpha", P. tuberosa, P. urvillei and A. appendiculatus also produced good yields during this period. Autumn (2 March to 26 April) production was led by E. curvula, with P. urvillei, P. tuberosa, P. dilatatum, "Ronpha" and A. appendiculatus also proving satisfactory. Practically no growth took place, on any species, during the winter period (27 April to 31 August). Even the temperate, winter green species such as L. perenne and F. elatior were dormant. This problem may be solved, partially, by the use of foggage — this is the grazing, during winter, of grass spared during the latter part of the summer and in autumn. The estimated yields of the species during the period (1 February to 26 April) are given in Table 13. The greatest yield during this period was obtained from E. curvula, while P. tuberosa, P. urvillei, P. dilatatum and "Ronpha" also produced reasonable yields.

General Observations. E. curvula and A. appendicula=tus herbage had a consistently low moisture content compared with that of the other species.

Due to their decumbent growth habit, the grazable yields of A. tenuis and P. clandestinum were, probably, considerably underestimated by the harvesting technique which was employed. This may also have applied, to a lesser extent, to other grasses such as P. dilatatum, F. elatior, D. glomerata, H. altissima and L. perenne. Jones (1959) notes that the yields of two D. glomerata varieties varied considerably, in relation to one another, depending on the height of cutting.

The acceptability of "Ronpha" to the grazing ani=mal has frequently been questioned by the farming com=munity. The plots in this trial were not grazed, but when heaps of cut herbage from a number of species in the trial were offered to lactating Ayrshire cows, they showed preference for "Ronpha" and P. tuberosa above P. dilatatum, D. glomerata, F. elatior and E. curvula. This is, of course, in no way conclusive evidence as many other factors (stage of maturity, time elapsed after cutting, and fertilization) could have been responsible for the variation in acceptabi=lity of the herbage.

The leaf growth of L. perenne, F. elatior and P. tuberosa was not frosted. Signs of frost damage were apparent on the leaves of "Ronpha", D. glomerata and A. tenuis during July, and most of the leaves of the two Paspalum species were frosted. All the other species were severely frosted in winter.

L. perenne, which was attacked by rust on occasions, was the only species which showed signs of disease.

It is apparent that the split-plot treatment of row spacing was superfluous and provided an unnecessary complication during planting, harvesting and computation of the results.

Conclusions

The most suitable species, of those tested, for hay or ensilage appear to be those with the highest yields. Possible exceptions are E. curvula and A. appendiculatus, which due to their low moisture contents, may be better suited to hay than to ensilage.

The growth habits of L. perenne, A. tenuis, F. elatior, D. glomerata, P. clandestinum, P. dilatatum and H. altissima indicate their suitability for grazing. The fact that these species, generally, produced low yields may indicate that the methods used were not appropirate for evaluating grazing types of grasses.

Due to the dormancy of all the species in winter, it may be desirable to make use of foggage during this period. Grasses such as P. tuberosa, P. urvillei,

P. dilatatum and A. tenuis appear to be best suited to this purpose. E. curvula and "Ronpha" if acceptable to the animal at this stage, would also be of value.

The four highest yielding species also, generally, produced the greatest amount of herbage during all seasons of the year. The exceptions were the low yield of P. dilatatum in spring, and the high yields of P. urvillei and A. appendiculatus in late summer and autumn.

Experience indicates that P. clandestinum and possibly some of the other species (e.g. L. perenne) require a high level of soil fertility for optimum production. It is probable that the levels used in this experiment were too low for this species.

There appeared to be little advantage in continuing investigations into perennial temperate species such as L. perenne, F. elatior and D. glomerata in this area. From this same group Phalaris species warrant further investigation. It is also apparent from the performance of E. curvula, A. appendiculatus and H. altissima that the testing of selected indigenous species should not be neglected in this area. The last mentioned two species were taken from the veld into the trial without any prior selection of suitable types. Further, they were grown somewhat out of their normal vlei margin environment. More thorough selection and evaluation of our indigenous grasses may be very rewarding, and is a field which has largely been neglected in the high rainfall areas.

3.5.1.2 Paspalum dilatatum cultivar trial (N-Ec 10/2

The previous trial (NP 19 T-section 3.5.1.1) indicated that P. dilatatum was very produc= tive in the Highland Sourveld and could, therefore, be of considerable value in developing the grassland po= tential of the area. In 1962, when plant material from a large number of selections of P. dilatatum, made by Dr. Reusch at Cedara College of Agriculture, became available, a detailed evaluation of them in the Highland Sourveld was considered to be desirable. Vegetative material of fifteen of his most promising selections was obtained and planted under irrigation, in the plant multiplication centre at De Hoek Research Station in the Estcourt Research Complex. The experi= ment was planted by the writer in 1964 and a final re= port was submitted by Theron in 1967.

Objective

The object of this experiment was to determine the herbage yield and the palatability of sixteen se= lections of P. dilatatum, when grown in a mixture with T. repens.

This grass is usually grown with white clover as a mixed pasture in Natal, where it is utilized for gra= zing. For this reason it was decided to evaluate the selections in a mixed pasture, and in the presence of grazing animals.

Procedure

The experiment was started in the spring of 1964 on the "Clovelly" experimental block (see section 3.3.1) at the Tabamhlope Research Station. Clonal material (from De Hoek Research Station) of each cultivar was planted in rows, six inches apart with the plants within each row being spaced at six inch (15 cm) centres, on each of three plots for each species. The plots were 7 x 12 yd (5.5 x 10.9 m) in extent. Planting was started when the soil was wet, but as the operation took about three weeks to complete a water cart was used to assist establishment. The _T. repens_ (Ladino) was sown on each plot at the rate of 5 lb per morgen (2.6 kg/ha), after the grass had been planted. The seed was inoculated with the appropriate strain of _Rhizobium_ bacteria, and was rolled into the soil with a Cambridge roller. Yields were not measured during the first season (1963-64) and the pasture was allowed to establish with the aid of occasional mowings. The experiment was terminated in April 1967, and thus re-sults are available for only two seasons.

A triple lattice design involving sixteen treat-ments was used. (The treatments were fifteen selections from Cedara and one locally adapted type of commercial origin from a nearby pasture). The code numbers of the selections are given in Table 14.

The experimental area was fertilized uniformly at establishment with applications of:

600 lb superphosphate (8.3% P)
400 lb muriate of potash (50% K)
200 lb urea (46% N)
2 tons of agricultural lime per morgen (318, 212, 106 and 2118 kg/ha).

In addition to repeating the above fertilizer programme (except for the lime) each year in spring, a further 200 lb of urea per morgen was applied each year during January.

Whenever the herbage on the most vigorous cultivar reached an average height of about six inches, one strip of 2 x 10 yards (1.8 x 8.1 m) was cut from each plot of the experiment. The herbage was weighed and samples were taken from this cut herbage for dry matter and botanical composition determinations (see section 3.3.3). After this all surplus herbage including that cut from the border rows was spread back on the por= tion of the plot from which it had been cut. Fifty head of cattle from the "Pasture Research herd" were then introduced into the experiment, and allowed to graze for two to three days. This was done in order to obtain an estimate of the relative palatability of the cultivars, and also to obtain the effect of trampling, grazing and the return of dung and urine to the pasture. The animals were held on a similar type of pasture for a few days prior to entering the expe= riment. After grazing a second strip of pasture (2 x 10 yds) was cut, weighed and sampled in order to determine the amount of herbage remaining after grazing. The position of the strips which were cut before and after grazing were alternated at each harvest. Seve= ral objections can be raised to the technique used to assess palatability, but inspite of this it was hoped that large differences in palatability (which would be of practical importance) would be apparent.

The germination of seed, collected from each se= lection at the De Hoek Research Station, was tested by

Table 14a.

Dry matter yields of sixteen selections of P.dilatatum during the first season of assessment.

Cultivar	Yields 1965-66 (ton/morgen)			
	Before grazing		After grazing	
	Grass	Associated Clover	Grass	Associated Clover
C 56/34	4.27	1.62	0.88	0.31
C 56/155	3.93	1.16	0.70	0.21
C 56/19	3.74	1.69	0.91	0.29
C 56/70	3.61	1.51	0.66	0.20
C 56/56	3.43	1.42	0.73	0.20
C 56/162	2.86	2.16	0.76	0.35
C 56/129	2.76	1.67	1.27	0.23
C 56/186	2.66	1.80	0.66	0.71
C 56/125	2.65	2.49	0.72	0.31
Commercial strain	2.51	2.76	0.60	0.51
C 56/168	2.46	2.31	0.89	0.32
C 56/63	2.34	3.03	0.59	0.14
C 56/172	2.30	2.77	0.61	0.18
C 56/187	2.23	1.66	0.57	0.25
C 56/71	2.01	2.33	0.35	0.18
C 56/89	1.79	2.56	0.34	0.49
Mean	2.85	2.06	0.70	0.30
L.S.D.: P = 0.05	1.03	1.01	0.43	0.30
P = 0.01	1.41	1.37	0.58	0.41
Coefficient of Variation	21.39	28.78	35.74	58.18

(1 ton/morgen = 1059 kg/ha)

Table 14b.

Dry matter yields of sixteen selections of P.dilatatum during the second season of assessment.

Cultivar	Yields 1966-67 (ton/morgen)			
	Before grazing		After grazing	
	Grass	Associated Clover	Grass	Associated Clover
C 56/129	4.07	1.68	0.95	0.254
C 56/56	3.68	1.74	0.61	0.129
C 56/70	3.46	2.31	0.53	0.103
C 56/155	3.20	2.51	0.62	0.187
C 56/19	2.94	2.59	0.48	0.167
C 56/168	2.90	2.97	0.39	0.195
C 56/34	2.89	2.32	0.72	0.125
C 56/186	2.72	2.94	0.33	0.103
C 56/63	2.62	2.96	0.43	0.141
C 56/125	2.50	3.18	0.44	0.154
C 56/162	2.48	2.34	0.43	0.109
C 56/172	2.38	2.62	0.38	0.147
C 56/89	2.27	2.91	0.34	0.086
C 56/187	2.21	2.17	0.38	0.114
C 56/71	1.85	2.49	0.22	0.088
Commercial strain	1.43	2.92	0.38	0.096
Mean	2.73	2.54	0.48	0.137
L.S.D.: P = 0.05	0.39	1.00	0.37	0.146
P = 0.01	0.52	1.37	0.50	0.200

(1 ton/morgen = 1059 kg/ha)

the South African Seed Testing service in Pretoria.

Results and Discussion

The herbage yields of the selections, and that of the associated clovers, are given in Tables 14(a) and 14(b).

During the first season (1965/66) the five top yielding selections did not differ in yield from one another, and they all yielded significantly ($P \leq 0.05$) more than all the other cultivars. The five top yielding cultivars were C 56/34, C 56/155, C 56/19, C 56/70 and C 56/56. During 1966/67 these five selections were among the top seven in yield. C 56/12[illegible] which was seventh during the first year, was the top yielding selection during the second year. The local Commercial strain was tenth in 1965/66 and last in 1966/67. The poorest selections yielded 42% (1965/66) and 45% (1966/67) of the yield of the highest yielding selection. In 1965/66 the Commercial strain yielded 59%, and in 1966/67 only 35% of the yield of the top selection. The doubling in yield obtained by selection, in an apomictic species such as P. dilatatum (Boshaw & Holt, 1958; Reusch, 1961), indicates the vast scope for selection amongst tropical grass species. This variation which was obtained in the performance of the top fifteen selections out of about 200 selections, made by Reusch indicates considerable variability in what is considered to be a very uniform species.

The yield of the associated clover appeared to be inversely related to the grass yields. This is as might be expected as a result of competition.

Table 15.

P. *dilatatum* germination (21 days)

Selection	% Germination Detrans= foremed	% Germination Transformed (Stevens angular trons)
C 56/56	17.9	27.969
C 56/168	17.3	27.463
C 56/125	14.0	24.545
C 56/34	13.3	23.920
C 56/155	13.1	23.788
C 56/129	12.9	23.554
C 56/89	12.8	23.494
C 56/63	12.4	23.041
C 56/71	11.7	22.407
C 56/162	11.6	22.343
C 56/187	11.1	21.853
C 56/19	10.5	21.249
C 56/172	9.8	20.431
C 56/186	9.1	19.689
C 56/70	7.0	17.245
Mean	12.3	22.866
L.S.D. P = 0.05	-	3.006
P = 0.01	-	3.999
Coefficient of Variation	-	10.40%

The amount of herbage that was harvested after grazing does not appear to provide a satisfactory measure of relative palatability of the selections. This figure appears to be proportional to the total herbage yield. (This may in fact be a true reflection of the relative palatability at the stage of harvesting, but is probably unrelated to the relative palatability at similar growth stages). However, the relatively large amount of uneaten grass on C 56/129 during both seasons suggests poor palatability — a factor which should be investigated in a more sophisticated palatability trial. The amount of herbage which was eaten was also closely related to the yield of grass, and because of the absence of any control over grazing pressure, these figures are considered to be unsatisfactory as a measure of relative palatability.

The percentage germination of the seed, collected from each of the selections when growing at De Hoek, are given in Table 15.

The results indicate that there was a marked, and statistically significant difference between the germination percentages of the seed of some of the selections. Selection C 56/56 gave the highest germination percentage (17.9%) and C 56/70 the lowest (7.0%). These results could have been influenced to some extent by the maturity of the seed at the time of harvesting, but as the seed was hand plucked when ripe it is unlikely that this factor played an important role.

The amount of labour involved in establishing this trial was considerable, and in view of its short duration, a more effective means of establishment should be sought. As a result of the apomictic nature of the species, and because it produces lots of seed, it is suggested that future trials be based on seeded plots and not plantings of clonal material. The possible de=lay can be compensated for further by information ob=tained on the relative seed production, and seed viabi=lity of the selections. Although the assessment of palatability was not possible, the advantages of gra=zing such trials (even without weighing the "out" cut) should not be overlooked. This does not involve much labour or expense. The grazing of the trial and the use of the companion clover provide such an experiment with "a practical look", and are considered to be worth-while.

3.5.1.3 Eragrostis curvula cultivar trial (N-Ec10/4)

In the species trial (NP19T) on the Ta=bamhlope Research Station, Eragrostis curvula proved to be the highest yielding species and thus one which should be considered for grassland improvement. It is also a popular hay grass in the Highland Sourveld probably due to its ability to survive and produce on poor soils and yet respond magnificently to ferti=lizer applications. Disappointment is, however, often expressed at the apparent lack of palatability of hay made from this grass. This is probably the result of poor fertilization practices. Gosnell (1957) grew four selections of E. curvula on the "Farningham" ex=perimental block at Tabamhlope Research Station. He found that the dry matter yields varied from 4.5 ton/

morgen/annum (4.77 M kg/ha) for the Springfontein se= lection to 11 ton/morgen/annum (11.65 M kg/ha) for the Ermelo selection. By 1964, however, seed of only one of the four selections, grown by Gosnell, was available. However, seed of three other selections and the Ermelo type, was available commercially at this stage. It was therefore decided to compare these four selections.

Objective

The objectives of this experiment were to determine the herbage yield, and the palatability of the cut her= bage of four selections of E. curvula.

Procedure

The experiment was established at the end of Sep= tember 1965 on the "Clovelly" block (see section 3.3.1) at the Tabamhlope Research Station. The seed was seeded at a rate of 12 lb/morgen (6.4 kg/ha) on a well prepared and fertilized seed-bed on a moist soil, and it was rolled into the soil by means of a Cambridge roller.

Four selections: Ermelo, Witbank, Kromdraai and American leafy were planted in a 4 x 4 latin square de= sign on plots of 7 x 12 yards (6.4 x 10.9 m). The plots were fertilized with 400 lb urea (46% N), 600 lb superphosphate (8.3% P), 400 lb K Cl (50% K) and 2 tons agricultural lime per morgen (212, 318, 212 and 2118 kg/ha) at establishment. Topdressings of 200 lb superphosphate (in spring) and 1300 lb K cl and 1800 lb urea (in six equal monthly, dressings from October to March) per morgen (106, 689 and 954 kg/ha) were applied annually.

The herbage on all the plots was cut whenever the herbage on the most advanced plots reached 8-9 inches (20-23 cm) or when seed heads appeared. The herbage was harvested by the strip method and was sampled for dry matter determinations (see section 3.3.3).

In order to obtain some estimate of the relative palatability of the selections, the cut herbage from each plot was transported to a feeding area where it was laid out in heaps. The heaps (one from each plot) were placed in the same latin square design as in the experiment. Twenty head of cattle from the "pasture herd" (see section 3.3.2) were then driven into the feeding area and allowed to feed freely on all the heaps for two hours. (This period was extended to three hours during the second season). After this period the uneaten herbage from each heap was collected to= gether, weighed and sampled for dry matter determinations. The palatability of this herbage would probably differ from that of hay, the use of which was precluded by the practical problems involved in curing so many samples.

Results and Discussion

The dry material yields and the percentage of the cut material eaten are given, for two years, in table 16.

The production during the establishment year (1965-66) was considerably lower than that from the five cuts taken during the second year (1966-67). During the establishment year the Ermelo selection yielded significantly less ($P \leq 0.01$) herbage than did

Table 16.

Dry matter yields and percentage of cut material eaten of four cultivars of E. curvula

Cultivar	Yield: Dry material (ton/m)		Percentage of cut material eaten			
	1965-66	1966-67	1965-66		1966-67	
			Transformed*	Normal	Transformed*	Normal
American leafy	9.81	17.46	40.25	41.97	45.33	42.65
Kromdraai	9.74	18.10	33.49	30.78	49.13	48.62
Witbank	9.74	17.81	28.12	22.54	46.83	45.00
Ermelo	8.96	17.46	38.43	38.57	48.19	47.14
Mean	9.56	17.71	35.07	33.46	47.37	45.85
L.S.D.: P =0.05	0.45	N.S	8.46		2.81	
P =0.01	0.68		12.82		N.S	
Coeficient of Variation	2.72		13.95		6.57	

(1 ton/morgen = 1059 kg/ha)

* Transformation = Angular transformation

$0 = 50 - \sqrt{1000}$ arc sin (1-2p)

the other three cultivars. During the second year there was no significant difference in the yield of the four species. The yields in the second year were of the same order as those obtained from the "Farningham" block in trial NP 19 (T). The yields during the second season represent a return of 42 lb (19 kg) oven dry herbage per pound of nitrogen fertilizer applied during that year. Supposing a 3% N content of the herbage, this represents 0.84 lb (381 g) herbage N per pound of applied N. Soil nitrogen and possibly unused nitro= gen from the establishment year also contribute to this figure.

During the first season a significantly ($P \leq 0.05$) lower percentage of cut herbage was eaten from the Wit= bank selection than from either the American Leafy or Ermelo strains. In 1966/67, however, significantly less herbage was eaten from the Ermelo selection than from the Kromdraai selection. (There were no other significant differences during this season). Addi= tional data is required before any conclusions can be drawn on the relative palatability of the selections.

Observations indicated that the Ermelo and Ameri= can Leafy selections were similar and of a narrow, light or yellow-green leaf type. The Kromdraai and Witbank selections were of a broader, blue-green leaf type. The latter two selections also appeared to be more prostrate and produced seed heads very quickly after cutting, while the former were inclined to pro= duce more leaf before seeding and were more upright.

3.5.1.4 _Trifolium_ _repens_ and _T_. _pratense_ cultivar trials (N-Ec 10/1 & N-Ec 10/3)

Legumes have played a very important role in grassland improvement in many overseas countries, in particular in New Zealand. In the Highland Sour= veld, white (_T_. _repens_) and red (_T_. _pratense_) clover are two legume species which have proved to be well adapted, and the large number of selections available commercially made their further evaluation desirable. In 1962 five cultivars of white and six cultivars of red clover were available locally from commercial sour= ces, and it was decided to evaluate these under High= land Sourveld conditions. Some of the results of these trials have been published in a popular article by Edwards & Moppledoram (1965).

Objective

The object of these trials was to determine the herbage yields of five cultivars of T. repens and six cultivars of T. pratense, in two separate experiments in the Highland sourveld of Natal.

Procedure

In January 1962 five cultivars of T. repens were established in a randomised block design with four replicates, on the "Farningham" experimental block (see section 3.3.1) at Tabamhlope Research Station. The cultivars were: Aberystwyth S.184 and S.100, Ladino, Tongala and New Zealand Wild White.

The six cultivars of T. pratense were planted in February 1962 in a similar design on an adjacent site to that of the T. repens cultivars. The six cultivars were: Kenland, Chilean, Giant Perennial Cowgrass, Montgomery Late Flowering, Aberystwyth S.123 and S.151. Of these cultivars Kenland, Chilean, Giant Perennial Cowgrass and Aberystwyth S.151 are early flowering or "broad leaf" types, while Montgomery Late Flowering and Aberystwyth S.123 are late flowering or single cut cultivars.

The seed of both species was sown on fine seed beds and was rolled with a Cambridge roller after seeding. The plots were 7 x 12 yards in extent. The seed was inoculated with the appropriate strain of Rhizobium before planting.

At establishment the plots in both experiments were fertilized as follows:

2 tons (2118 kg/ha) agricultural lime
100 lb (53 kg/ha) urea (46% N)
500 lb (265 kg/ha) superphosphate (8.3% P)
200 lb (106 kg/ha) K Cl (50% K)
400 lb (212 kg/ha) $MgSO_4 . 7H_2O$
30 lb (16 kg/ha) $CuSO_4 . 5H_2O$
30 lb $ZnSO_4 . 5H_2O$
30 lb Borax, and
8 oz (265 g/ha) $(NH)_4 6 Mo_7 O_{24} . 4H_2O$ per morgen.

The trace elements applied in the "shotgun" mixture as above were suggested by Prof. E.R. Orchard (of the Natal Agricultural Research Institute) as these may be deficient in this area. It was considered that sufficient sulphur was supplied by the sulphate radical of the superphosphate and the other trace elements.

Annually in spring (1962, 1963 & 1964) 2000 lb superphosphate and 200 lb K Cl per morgen (1059 and 106 kg/ha) were broadcast over the plots. A further 500 lb K Cl per morgen (529 kg/ha) was broadcast annually, in three dressings during mid-November, early January and mid-February.

Table 17

The dry matter yields and clover percentage of five cultivars of <u>T.repens</u>

Cultivar	Yield: Clover + Other herbage (ton/m)				Yield: Clover only (ton/m)				% Clover in dry material			
	1962-3	1963-4	1964-5	Mean	1962-3	1963-4	1964-5	Mean	1962-3	1963-4	1964-5	Mean
Ladino	8.58	7.26	6.65	7.49	5.41	6.92	6.29	6.21	63.05	95.32	94.59	84.32
Tongala	6.46	5.77	5.63	5.96	3.60	5.01	4.85	4.49	55.73	86.83	86.14	76.23
Aberystwyth S.100	5.75	5.71	5.74	5.73	0.92	3.99	4.26	3.06	25.00	69.88	74.22	56.37
Aberystwyth S.184	6.12	5.56	5.76	5.81	1.53	3.53	3.64	2.90	20.85	63.49	63.19	49.18
New Zealand Wild White	5.85	5.57	5.77	5.72	1.22	3.44	3.45	2.70	16.00	61.76	59.79	45.85
Mean	6.55	5.97	5.91	6.12	2.54	4.58	4.50	3.87	36.13	75.46	75.59	62.39
L.S.D. : P = 0.01	0.83	0.69	0.73	0.47	1.01	0.94	1.24	0.88				
P = 0.05	1.17	0.97	1.02	0.66	1.41	1.32	1.74	1.24				
Coefficient of Variation	8.27	7.49	8.02	5.00	25.78	13.35	19.41	14.83				

(1 ton/morgen = 1059 kg/ha)

Whenever the herbage on the most advanced plots reached 6-7 inches (15-18 cm) (T. repens) or 8-9 inches (20-23 cm) (T. pratense) in height the plots were cut by the strip method and samples were taken for dry mat= ter determinations and botanical separation (see section 3.3.3). Later, it was found that the emergence of a second set of leaves at the base of the plant, was a better indicator of the optimum stage for cutting red clover.

It was originally intended that the experiments should continue for five years, but they were termina= ted after three productive years. The T. pratense experiment was discontinued because of the poor survi= val of clover plants, and the T. repens trial was dis= continued because of the invasion of certain cultivars into adjoining plots. This invasion was particularly noticable on the plots adjoining the Ladino cultivar, where the spread of stolons and seedlings resulted in a rapid contamination. The three year period of the trials was also apparently adequate for evaluation of the cultivars.

Results and Discussion

T. repens: The dry matter yields, and the clover content of the herbage harvested from the five culti= vars is given in Table 17.

Significantly ($P \leq 0.01$) more herbage (clover and other herbage) was produced, in all three years, from the plots of the Ladino cultivar than on those of any of the other four cultivars. There was no significant difference in the total herbage yields obtained from the other four cultivars. Much of the "other herbage" harvested was annual "landsgrass" species which have a reasonable feeding value.

The Ladino cultivar also produced consistently greater yields of clover than did the other four cul=tivars. It gave, on the average, a 38% increase in clover yield over that of the next best cultivar (Ton=gala), and a 130% increase in yield over the lowest yielding cultivar (New Zealand Wild White). On the average and during two of the three years, the Ton=gala cultivar produced significantly greater yields of clover than did the two Aberystwyth cultivars and New Zealand Wild White. During the third season Tongala was no better than the Aberystwyth strains but was still superior to New Zealand Wild White. It is possible that the harvesting method was not ideally adapted to measure the yield of the more prostrate New Zealand Wild White cultivar.

There was, consistently, a greater percentage of clover in the harvested material on the Ladino plots than on the plots of any of the other cultivars. The average percentage clover was low (36%) during the first season, but increased to 75% during the se=cond and third seasons. The percentage of clover in the herbage was greatest during November and December in all cultivars. This percentage dropped in all cul=tivars during January and February, but in Ladino and Tongala the percentage of clover increased again during March and April. In the other three cultivars the February level was maintained throughout the autumn.

Table 18

The dry matter yields and clover percentage of six cultivars of <u>T.pratense</u>

Cultivar	Yield: Clover & Other herbage (ton/m)				Yield: Clover only (ton/m)				% Clover in dry material			
	1962-3	1963-4	1964-5	Mean	1962-3	1963-4	1964-5	Mean	1962-3	1963-4	1964-5	Mean
Kenland	7.97	7.21	6.87	7.35	6.16	4.39	4.83	5.12	77.29	60.89	70.31	69.50
Chilean	7.65	7.83	4.85	6.78	6.34	2.58	1.85	3.58	82.88	32.95	38.14	51.32
Aberystwyth S.151	7.09	6.56	6.50	6.71	3.64	3.03	3.13	3.27	51.34	46.19	48.15	48.56
Giant Perennial Cowgrass	7.55	6.88	5.45	6.63	5.56	3.36	2.64	3.96	73.64	48.84	48.44	56.97
Aberystwyth S.123	7.02	6.19	5.52	6.25	2.33	2.23	2.88	2.38	33.19	36.03	52.17	40.46
Montgomery Late Flowering	6.90	5.88	5.28	6.02	2.37	2.47	2.11	2.32	34.35	42.01	39.96	38.74
Mean	7.36	6.76	5.74	6.62	4.40	3.01	2.91	3.44	58.78	44.48	49.53	50.93
L.S.D. P = 0.05	0.85	1.05	1.66	0.85	1.62	1.41	1.01	0.61				
P = 0.01	1.17	1.45	2.29	1.17	2.24	1.94	1.40	0.84				
Coefficient of variation	7.63	10.30	19.14	8.45	24.45	30.99	23.10	11.76				

(1 ton/morgen = 1059 kg/ha)

Although the percentage of clover in the herbage was lowest during mid-summer, the actual yield of clo= ver reached a peak in January, for Ladino, and in De= cember for the other four species. These results show that the so-called spring and autumn clover flushes do not indicate peaks of clover production in this area, but indicate an increase in the ratio of clover to grass in the herbage. The relatively late (January to Fe= bruary) production peak of Ladino is of considerable advantage. The protein content of the natural gra= zing in the Highland Sourveld declines rapidly after December, and because of the high protein content of clover, this cultivar can be used to offset the decline in quality of the natural grazing.

T. pratense

The yields of total dry matter and of clover, and the percentage of clover in the cut herbage from six cultivars of *T. pratense* are given in Table 18.

The total yield (clover & other herbage) of the Kenland cultivar was significantly ($P \leq 0.05$) greater than that of the two late flowering cultivars (Aberys= twyth S.123 and Montgomery) on the average and during 1962-63. It also outyielded Aberystwyth S.151 in 1962-63, Montgomery in 1963-64 and Chilean in 1964-65.

On the average and in the third season the *Ken= land* cultivar produced significantly ($P \leq 0.05$) more clover than did any of the other cultivars. During the first season it also produced more clover than Aberystwyth S.123 and S.151 and Montgomery, while in the second season it produced more than Aberystwyth

S. 123, Montgomery and Chilean. On the average and in the first season <u>Giant Perennial Cowgrass</u> produced more clover than did the two Aberystwyth strains and Montgomery. The <u>Chilean</u> cultivar produced more clover in the first season than did the two Aberystwyth strains and Montgomery, and on the average it produced more than Aberystwyth S.123 and Montgomery. However, in the third season <u>Aberystwyth S.123</u> produced more clover than did Chilean. <u>Aberystwyth S.151</u> produced more clover on the average than did Aberystwyth S.123 and Montgomery, and in the third season it produced more than did Chilean and Montgomery.

The Kenland cultivar maintained a consistently high percentage (69.50% average) of clover, in the total herbage harvested, throughout the duration of the experiment. The herbage from the Giant Perennial Cowgrass and Chilean red clover plots also had a high percentage of clover during the first year, but this declined considerably in the second year. Aberystwyth S.151 and Montgomery maintained a relatively low clover content in the herbage (48.56% and 38.74% respectively) throughout the three year period. However, the clover content of Aberystwyth S.123 increased during the second and third years. The whole picture of the clover content of the herbage over this three year period is complicated by the change (from annual to perennial) of the species making up the non-clover component of the herbage.

During August 1963 (i.e. the end of the winter after the first productive season) a large number of dead clover plants were visible on the plots. These plants were counted in five, one metre square areas on each plot. These counts were repeated at the end of the following winter (October 1964), while at the end of the second productive season (May 1964) the number of living clover plants was counted. This data is pre= sented in table 19.

Table 19.

Number of dead and of living clover plants on plots of six cultivars of T. pratense

Cultivar	Number of Clover plants per sq. metre		
	Dead plants 22/8/63	Dead plants 8/10/64	Living plants 28/5/64
Kenland	0.4	0.7	21.2
Giant Perennial Cowgrass	3.5	2.7	6.8
Chilean	8.3	1.7	4.3
Aberystwyth S.151	0.5	1.0	7.0
Aberystwyth S.123	0.7	1.7	8.2
Montgomery Late Flowering	0.6	2.0	6.7
Mean	2.3	1.6	9.0
L.S.D.: P=0.05	5.5	N.S	3.3
P=0.01	7.6		4.5

At the end of the first winter there were signi= ficantly ($P \leq 0.01$) more dead plants visible on the Chi= lean plots than on the plots of any of the other culti=

vars except Giant Perennial Cowgrass. At the end of the second winter there was no marked difference in the number of visible dead plants. There were considerably more (21.2 per sq. metre) living plants on the plots of the Kenland cultivar at the end of the second year, than on those of any other of the cultivars. The Aberystwyth S.123 cultivar also had more living plants than did the Chilean cultivar.

This data indicates that the Chilean and Giant Perennial Cowgrass cultivars have a large component of high yielding annual material. The other four cultivars are of a more perennial nature, and of them Kenland is by far the highest yielding. These observations apply to the conditions under which the experiment was conducted, but probably also apply throughout the Highland Sourveld.

During the first productive season the percentage of clover in the cut herbage was lowest in the first cut (December) and highest in the last cut (April). This trend was reversed in all species during the second season (possibly due to the death of plants), and in the Kenland cultivar in the third season. In the third season Aberystwyth S.123 reached its peak clover percentage in the last cut, and the other species reached a peak in January.

The yield of clover generally reached a peak between January and February for all cultivars during all three seasons. This characteristic could be of value in supplementing the poor quality of veld at this time of the year. It could also be used to advantage

3.5.1.5 Discussion

This series of four cultivar trials has once again emphasised the immense variation in yield and other characteristics which is present within a single plant species. Such differences may be empha= sised or minimised by the cultural practices (fertili= zation and utilization) employed during their evalua= tion. However, it is suggested that a real attempt should be made to simulate the cultural practices which would be followed on a farm scale when evaluating such material.

The marked differences in yield obtained from superficially similar P. dilatatum selections, empha= sises the dilemma of the field worker. He is faced with a vast number of species of unknown potential, and even the results of species trials (such as NP 19 (T)) may help but little in screening this mass of material. It may occur, that the selection of a spe= cies which was used in such a trial was unsuited to his area — other selections may have been superior. A possible solution to this problem is to base the introduction of species on their "adaptation probabi= lity" (see Section 1 of this chapter). A reasonable sample from the "spectrum" of material available from such species with a good "adaptation probability" should be introduced. (By the "spectrum" of material available for a species, is meant the range of selec= tions of a species. Of a large range of selections, varying from prostrate to upright or from frost resis= tant to frost killed, a few are selected covering the two extremes and the mean of each characteristic).

Wide collections of many species are becoming increa= singly available. (e.g. Stylosanthes guiensis, S. humu= lis and Glycine javanica amongst others in Australia).

The success obtained with local species such as H. altissima and A. appendiculatus, in trial NP 19 (T), is indicative of the vast wealth of untested, and po= tentially valuable, plant material available in our veld. The collection and selection of this material should prove rewarding. Similar considerations apply to indigenous perennial legumes, particularly in the drier (sub-700 mm annual rainfall) areas, where impor= ted perennial legumes have met with scant success.

It is obvious that to take the evaluation of pas= ture species to its logical conclusion (i.e. large scale plantings on farms), adequate good quality seed must be available. The local pasture plant seed in= dustry will have to develop considerably, and research into seed production and harvesting techniques will have to be intensified if this aim is to be achieved.

3.5.2 Soil fertility as a factor limiting production

Scott (1951) showed that crops grown without fertilizer on certain soils (Farningham soil series) in the Highland Sourveld failed completely after a few years. Similar indications of the low fertility status of these soils have been obtained by Orchard (1960) and Edwards (1959). These results have been confirmed on a number of soil types in this area in more recent studies (Ludorf, 1966). Scott (1951) was, however, able to produce good crop yields as a result of the incorporation of large quantities

(20 tons per morgen - 21.2 Mkg/ha - per annum) of compost into the soil. The use of equivalent amounts of N, P and K in the form of artificial fertilizers gave poor results. However, superphosphate and lime alone gave fair results. Scott used sulphate of ammonia as his source of nitrogen, and this caused a considerable increase in the acidity of the soil. This drop in pH was probably the cause of the disappointing results obtained with artificial fertilizers (iron and aluminium toxicity was suspected). Orchard (1960), using the result of a factorial experiment on maize, with three levels of N, P, K and Ca and a split-plot treatment for trace elements, was able to show that good yields were possible on these soils provided the artificial fertilizer was balanced (in most essential plant nutrients). The earlier trials were prejudiced by the unsuitability, for these soils, of the extraction technique used in the laboratory analysis of the soil potash. These analyses indicated adequate available potash, while later field experiments produced good responses to the application of potash fertilizer.

It was thus apparent that the correction of the mineral, plant nutrient deficiencies in the soil would play an important role in the improvement of grassland in the Highland Sourveld. Except for some preliminary work by Scott (1951) no results were available on the soil fertility requirements of pasture species in this area. Consequently it was decided to lay out a series of three fertilizer-production trials on pasture plant species which were adapted to the area. These trials were designed primarily to achieve optimum production and were not intended as studies in soil fertility.

The species selected consisted of a mixture of annual grasses, a perennial grass, and a bi-ennial/perennial legume all of which were known to be adapted to the area. This adaption had been tested largely under sub-optimum soil fertility, although compost often provided for an adequate and balanced nutrition of the plants. The plant species selected for the trials were thus widely varied, and should provide an indication of the type of variation in response to fertilization which might be expected from grassland species in this area. Some of the results of these trials have recently been published (Edwards, 1969).

3.5.2.1 "Lands grass" fertilizer experiment (N-Th 10)

In the Highland sourveld old fallow lands are rapidly colonized by annual grass species. These species are *Panicum laevifolium*, *Setaria pallide-fusca*, *Digitaria sanguinalis* and *D. horizontalis* which are collectively known as "Lands grass." They can be maintained for many years by discing or ploughing the lands annually in spring. If the lands are not cul= tivated the annual grasses are replaced by perennial *Eragrostis* species. "Lands grass" is used extensively for making hay and ensilage in the Highland Sourveld. Both Scott (1951) and Fisher (1963) obtained outstanding yields from these volunteer grasses when fertilizer or compost had been applied.

As the soils of the Highland sourveld are generally severely leached and infertile it was decided to deter= mine the effect of certain fertilizers on the yield of "Lands grass." In the spring of 1959 a factorial fer= tilizer experiment was laid out perimental farm.

Objective

The object of this experiment was to determine the effect of three levels of each of nitrogenous, phos= phatic and potassic fertilizer and of two levels of lime, on the hay production of "Lands grass" in the Highland Sourveld.

Procedure

The experimental plots were sited on deep, sandy, fairly well drained soil on a slight slope with a wes= tern aspect on the "Farningham" experimental block (see section 3.3.1) at Tabamhlope experimental farm. The soils are of the Tabamhlope soil series (v.d. Eyk, de Villiers, McVicar & Ludorf, 1965) and are derived from colluvial material of mixed dolerite-shale origin. The clay minerals comprise predominantly kaolin with accessory amounts of vermiculite and gibbsite. The pH of the soil is in the region of 4.5 and the total exchange capacity in the neighbourhood of 14 milligram equivalent percent. The bases K, Ca and Mg account for only 2-3 m.e.% the balance being made up mainly by NH_4 and H ions so that the soil may be described as being in a highly unsaturated state. The mean carbon content of the topsoil is about 2-3% which is associated with about 0.25% nitrogen. The soil can therefore be regarded as rich in organic matter and nitrogen (Orchard, 1947).

The treatments were applied in a 3 x 3 x 3 x 2 fac= torial design, with confounding, in three blocks of 18 plots each and with no replication (Li, 1944). Th plot size was 12 x 7 yards (6.4 x 10.9 m) inclusive of a one yard (0.91 m) border resulting in a net plot size of 10 x 5 yards (9.1 x 4.6 m) or equivalent to 0.00488 morgen (0.0042 ha).

The treatments are presented in Table 20.

Table 20.

Fertilizer treatments applied (N-Th 10)

Element	Source	Content of ele=ment	Levels of application (lb/morgen/annum)		
Nitrogen	Urea	46%N	0(N)	600(N)	1200(N)
Phosphate	Double super=phos=phate	19%P	0(P)	133(P)	266(P)
Potash	Muriate of potash	50%K	0(K)	375(K)	750(K)
Calcium	Agricul=tural lime	80-90% $CaCO_3$	0(Agric. lime)	4000(Agric. lime)	

(I lb/morgen = 0.53 kg/ha)

Micro-elements and magnesium were applied to the whole experimental area, in the first year only, at the following rates:

400 lb Magnesium sulphate/morgen (212 kg/ha)
30 lb Copper sulphate/morgen (16 kg/ha)
30 lb Zinc sulphate/morgen
30 lb Borax/morgen
8 oz Ammonium molybdate/morgen (265 g/ha).

The magnesium, micro-elements and lime were broad= cast on the soil and disced into it in the spring of 1959. All the phosphatic fertilizer and half of the nitrogenous and potassic fertilizers were broadcast and disced into the soil annually in spring. The other half of the nitrogenous and potassic fertilizers were broadcast as topdressing in mid-January every year.

Urea was selected as a source of nitrogen because of its favourable price per unit of N when compared with limestone ammonium nitrate, and because of its high content of N results in a saving of transport in areas distant from railheads and sources of supply. The high calcium content (20%) of limestone ammonium nitrate would also have introduced a further complica= ting factor in such an experiment where lime was a treatment. Sulphate of ammonia was discarded as a source of nitrogen because of its strong acidifying effect on the already acid soils. The advantages of urea are negated to some extent by the greater losses of organic nitrogenous compounds on the soil surface and as a result of the urease activity in the soil, and by its slightly acidifying effect (Collings, 1955).

During the first two years (1959 and 1960) "Lands grass" seed, which had been collected locally by hand, was broadcast over the whole experimental area at the rate of 10 lb per morgen and disced and rolled into the soil. In subsequent years this seeding was found to be unnecessary and the experimental plots were disced and rolled with a "Cambridge" roller without seeding them.

The herbage on the plots was cut by means of a self-propelled mower fitted with a low cutter bar attach= ment. The herbage was cut whenever it reached a height of from 8-12 inches (20-30 cm). However, some of the treatments were generally cut when the herbage was much shorter as their rate of growth was very slow. Sam= ples of cut herbage were taken for oven dry matter deter= minations (Edwards, 1965) and yields were expressed in terms of dry matter in tons per morgen.

Results and Discussion

(1.) Dry matter yields

(1.1) Nitrogen (In the form of urea 46% N) (See table 21).

The application of nitrogenous fertilizer significantly increased the dry matter yields of "lands grass." This response was large and consistent during all five years. There was, however, a falling off in response at the highest level of fertilizer application, i.e. the 1,200 lb N/morgen application did not produce a sig= nificant increase in yield over the 600 lb N/ morgen application.

$N_{600} - N_0 = 5.16 \pm 0.147$ ton/morgen/annum
(5.46 ± 0.16 Mkg/ha)

$N_{1200} - N_{600} = -0.21 \pm 0.147$ ton/morgen/annum
(-0.22 ± 0.16 Mkg/ha)

The response to nitrogenous fertilizer was smal= lest during the first year (1959-60) and there= after was larger and reasonably consistent.

Table 21.

The main effects of nitrogen fertilization on the yield of "lands grass" (ton oven dry material/morgen) (1 ton/morgen = 1059 kg/ha)

Year	N applied(lb/morgen/annum								Standard error
	Nil		600		1200	Mean	P=0.05 (*)	P=0.01 (**)	
1959-60	3.52	<**	5.89	NS	6.10	5.17	0.42	0.	0.15
1960-61	2.60	<**	8.47	NS	8.08	6.38	0.74	1.00	0.25
1961-62	0.68	<**	7.54	NS	7.89	5.37	0.62	0.85	0.21
1962-63	1.99	<**	7.54	>**	6.24	5.23	0.52	0.70	0.18
1963-64	1.80	<**	6.59	NS	6.96	5.12	0.71	0.96	0.24
Mean	2.12	<**	7.19	NS	7.05	5.45	0.43	0.58	0.15

(1.1.1) Nitrogen x Phosphate interaction (See appendix table 2)

The response to nitrogenous fertilizer was greater in the presence of phosphatic fer= tilizer than in its absence. This interac= tion was statistically significant during each year. The maximum yield of 8.86 ton/morgen/ annum (9.37 M kg/ha) was obtained at N_{1200} P_{266}.

(1.1.2) Nitrogen x Potash interaction (See appendix table 3)

The response to nitrogenous fertilizer increased with increasing applications of pot= assic fertilizer, but the rate of increase was not maintained at the high potassic fertilizer level (K_{750}). The nature of the response, i.e. the relation of N_{600}-N_0 and N_{1200}-N_{600} was not consistent over the levels of potassic fertili= zer N_{1200} tending to depress yield over N_{600}, this depressing effect was most marked at K_{375}. The maximum yeild of 8.93 ton/morgen/annum was obtained at $N_{600}K_{750}$.

(1.1.3) Nitrogen x Lime interaction

This interaction was not statistically significant during any of the five years. This indicates that the application of lime did not influence the response to nitrogenous fertilization.

(1.2) Phosphate (In the form of double superphosphate 19% P) (See table 22)

The application of phosphatic fertilizer significantly increased the yields of "lands grass" during each of the five years. The application of 266 lb P/m orgen gave a signi= ficant increase in yield over the application of 133 lb P/morgen. However, there was a falling off in the response which was signifi= cant on the average and during two of the five years.

$P_{133} - P_0 = 1.63 \pm 0.147$ ton/morgen/annum
(1.72 ± 0.16 Mkg/ha)

$P_{266} - P_{133} = 0.61 \pm 0.147$ ton/morgen/annum
(0.64 ± 0.16 Mkg/ha)

Table 22.

The main effects of phosphate fertilizer on the yield of "lands grass" (ton oven dry material/morgen) (1 ton /morgen = 1059 kg/ha)

Year	P applied (lb/morgen/annum)								Standard error
	Nil		133		266	Mean	(*) P=0.05	(**) P=0.01	
1959-60	4.37	<**	5.28	<**	5.86	5.17	0.42	0.57	0.15
1960-61	5.66	<*	6.44	NS	7.05	6.38	0.74	1.00	0.25
1961-62	3.69	<**	5.98	NS	6.44	5.37	0.62	0.85	0.21
1962-63	3.96	<**	5.50	<*	6.22	5.23	0.52	0.75	0.18
1963-64	2.73	<**	6.02	NS	6.60	5.12	0.71	0.96	0.24
Mean	4.08	<**	5.84	<**	6.43	5.45	0.43	0.58	0.15

(1.2.1) Phosphate x Nitrogen interaction (See appendix table 2)

The response to phosphatic fertilizer increased with increasing applications of nitrogenous fertilizer.

(1.2.2) Phosphate x Potash interaction (See appendix table 4)

The response to the application of phos= phatic fertilizer also varied over the levels of potassic fertilization. At K_0 the re= sponse was very small but at K_{375} and K_{750} significant responses to phosphatic fertili= zation were evident. The maximum yield of 8.16 ton/morgen/annum (8.64 m kg/ha) was ob=

(1.2.3) Phosphate x Lime interaction

This interaction was not significant in any of the years. This indicates that the response to phosphatic fertilizer was unaf= fected by the application of lime.

(1.3) Potash (In the form of KCl 50% K) (See table 23)

The application of potassic fertilizer re= sulted in a significant increase in yield during all five years. There was a significant "fal= ling off" in the rate of response at the high level of fertilizer application and the 750 lb/ morgen application gave a significant response over the 375 lb/morgen application during only three of the five years.

$K_{375}-K_{0} = 3.00 \pm 0.147$ ton/morgen/annum
(3.18 ± 0.16 Mkg/ha)

$K_{750}-K_{450} = 0.39 \pm 0.147$ ton/morgen/annum
(0.41 ± 0.16 Mkg/ha)

The response to potassic fertilization was reasonably consistent throughout the five year period.

(1.3.1) Potash x Nitrogen interaction (See appendix table 3)

In the absence of applied nitrogenous fertilizer the response to potassic fertili= zer was not significant but when nitrogenous fertilizer was also applied large responses to potassic fertilizer were obtained. The highest level of potassic fertilization

Table 23.

The main effects of potash fertilizer on the yields of "land grass" (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha)

Year	K applied (lb/morgen/annum)						LSD		Standard error
	Nil		375		750	Mean	P=0.05 (*)	P=0.01 (**)	
1959-60	3.49	<**	5.72	<**	6.31	5.17	0.42	0.57	0.15
1960-61	3.96	<**	7.47	NS	7.72	6.38	0.74	1.00	0.25
1961-62	2.50	<**	6.31	<**	7.29	5.37	0.62	0.85	0.21
1962-63	3.89	<**	6.19	>*	5.59	5.23	0.52	0.70	0.18
1963-64	2.49	<**	6.05	<*	6.82	5.12	0.71	0.96	0.24
Mean	3.27	<**	6.35	NS	6.75	5.45	0.43	0.58	0.15

(K_{750}) gave a non-significant response over the second level (K_{375}) at all levels of application of nitrogen.

(1.3.2) Potash x Phosphate interaction (See appendix table 4)

The response to potassic fertilizer increased with increasing application of phosphatic fertilizer.

(1.3.3) Potash x Lime interaction

The response to potassic fertilizer was apparently not affected by the application of lime.

(1.4) Lime (as agricultural lime). (See Table 24)

There was a small but consistent response to the application of lime which was significant in all but the first year.

Table 24.

The main effects of agrucultural lime on the yields of "lands grass" (ton oven dry material/morgen). (1 ton/ morgen = 1059 kg/ha)

Year	Lime applied (lb/morgen in 1959)				LSD		Standard error
	Nil		4000	Mean	P=0.05 (*)	P=0.01 (**)	
1959-60	5.14	NS	5.21	5.17	0.35	0.47	0.12
1960-61	6.01	<*	6.76	6.38	0.60	0.82	0.21
1961-62	5.05	<*	5.70	5.37	0.51	0.69	0.17
1962-63	4.72	<**	5.73	5.23	0.43	0.58	0.15
1963-64	4.79	<*	5.45	5.12	0.58	0.79	0.20
Mean	5.14	<**	5.77	5.45	0.35	0.47	0.12

(1.4.1) Lime interactions

The application of lime apparently did not influence the yield response obtained from nitrogen, phosphate and potash fertilizers.

(2) Phenological observations

(2.1) <u>Eleusine africana</u>

In February 1961 it was noted that Eleusine the experiment than on others. Observations indicated that the occurrence of this grass appeared to be influenced by nitrogenous and potassic fertilizer. It occurred in greatest quantities on the plots which received nitrogenous fertilizer and were not fertilized with potash. Its occurrence did not at this stage appear to be influenced by phosphatic fertilizer or lime applications. During March 1963 further observations were made on the occurrence of this grass on the experiment. It was obvious that all the plots which were fertilized with nitrogen but which had received no potassic fertilizer were covered almost completely with short (less than three inches tall), *E. africana* the leaves of which were dark blue-green and were scorched to a brownish colour at the tips and margins. (This scorch is usually considered to indicate a potash deficiency – Wallace, 1961). *E. africana* was also present in lesser quantities on the other plots. The plants were lush (12" - 30 cm - high) and green where both potassic fertilizer and nitrogenous fertilizer had been applied but were short (3" - 10 cm - high) and yellow in the absence of nitrogenous fertilizer applications. At this time (March 1963) an estimate was also made of the percentage contribution of *E. africana* to the herbage yield of each plot. The application of nitrogenous or phosphatic fertilizer increased the contribution made by this grass to the herbage yields. However, the application of potassic fertilizer appeared to depress the contribution of *E. africana* to the herbage yield. This latter effect (i.e. the apparent depression of *E. africana* by potash fertilizer) is probably not due to antipathy of the grass to potash. It may be due to competition by the other "lands grass" species. *E. africana* is a shorter growing grass than either *P. laevifolium* and *S. pallidefusca* and is overshadowed by them when all nutrient elements which are necessary for their growth are present.

(2.2) Phosphate fertilization and *S. pallide-fusca*

During the first two years of the experiment the application of phosphatic fertilizer significantly depressed the yield of the second cut, but in the first and third cuts it significantly increased yield. At first this was thought to be due to an antipathy of *S. pallide-fusca* to phosphatic fertilizer, as this grass was the main component of the second cut and *P. laevifolium* and *D. sanguinalis* were the main components for the first and third cuts respectively. However, it is now thought that the luxuriant growth of *P. laevifolium* on the plots which received phosphatic fertilizer prevented the development of *S. pallide-fusca* seedlings. These plots then remained bare for a considerable proportion of the period between the first and second cuts. This belief is strengthened by the observation that taking the first cut when the grass was shorter, removed the depressing effect due to phosphatic fertilizer second cut, during the third and subsequent seasons.

(2.3) Rumex acetosalla

Just prior to discing the experiment, in October 1960, it was noted that a heavy infes= tation of Rumex acetosalla occurred on certain plots. It was found that this plant was con= fined, almost entirely, to those plots which had received phosphatic fertilizer but which had not received nitrogenous fertilizer. Fer= tilization with potassic fertilizer and lime did not appear to influence its occurrence.

These results were confirmed by further observations made in October 1962.

(2.4) Cyperus rotundus

During the last three years large numbers of C. rotundus plants made their appearance on the plots of the experiment. The plant was most prominent in spring and early summer. During November 1961 an estimate was made of the occurrence of this plant on each plot of the experiment. Greater numbers of this plant occurred on the plots which had been fertilized with nitrogen or phosphate or potash or lime than on those which had not been fertilized.

On cursory inspection these results appear to contradict the findings of Preller & Van Wyk (1958), who found that the higher the appli= cation of nitrogenous fertilizer to Eragrostis curvula the lower was the occurrence of C.

tundus and C. esculentus in the ley. In the experiment under discussion it will be noted that C. rotundus was prominent in spring and early summer (i.e. only before the first cut), and at a stage when the "Lands grass" seed= lings could offer only limited competition. Preller and van Wyk (1958) were, however, dealing with established perennial E. curvula plants which would be in a better position to respond to nitrogen applications than lands grass seedlings. Their results may be explain= ed by increased competition from E. curvula at high levels of nitrogenous fertilizer result= ing in a decline in Cyperus sp., rather than an antipathy of these species to nitrogenous fertilizer.

(2.5) Helichrysum sp.

In October 1962, before discing the experi= ment, large numbers of plants of Helichrysum sp. were present. Greater numbers of these plants occurred on the plots which had recei= ved nitrogenous or phosphatic or potassic fer= tilizers or lime than on the plots which had not received these fertilizers. The highest level of application of nitrogenous fertilizer did, however, appear to depress the numbers of this plant.

(2.6) Mole activity

In October 1962 the greatest activity of moles as judged by mole-heaps, occurred on the

Table 25.

Residual effects of fertilizer treatments on "Lands grass" herbage yields (Ton dry matter/morgen)
(1 ton/morgen = 1059 kg/ha)

Treatment	Season 1964-65	1965-66
Nitrogen		
Nil	3.42	1.20
600 lb N/morgen	4.82	2.33
1200 lb N/morgen	6.33	4.17
Phosphate		
Nil	3.73	3.28
133 lb P/morgen	5.29	2.26
266 lb P/morgen	5.57	2.16
Potash		
Nil	3.96	1.55
375 lb K/morgen	5.12	2.56
750 lb K/morgen	5.51	3.59
Lime		
Nil	4.47	2.60
2 ton lime/morgen	5.25	2.53
Mean	4.86	2.56
L.S.D.: N, P, K P =0.05	0.77	1.64
P =0.01	1.05	1.77
Lime P =0.05	0.62	1.34
P =0.01	0.85	1.61

genous fertilizer or lime.

(3) Residual effects of fertilizer

The experimental area was not utilized after the termination of the experimental treatments, and from 1964 to 1966 the residual effects of the previous treatments was recorded. In the spring of 1964 the whole experiment was planted to Ja= panese Millet. The millet established poorly in competition with the selfsown "lands grass". No fertilizer was applied, and the herbage on the plots (millet and "lands grass") was harvested in March 1965. The plots had last been ferti= lized in December 1963. The residual effects were still visible in the folowing season, and the yields of volunteer "lands grass" on the plots were harvested in January 1966. The yields of these two harvests are given in Table 25.

The application of nitrogen during the pre= vious years resulted in a significant increase in yields during both 1964-65 and 1965-66. During both years the response was linear i.e. there was no "falling off" in response at the highest level of nitrogen fertilization. In 1964-65 the re= sponse to nitrogenous fertilizer was not consis= tent over the levels of phosphate fertilization. There was a larger response to nitrogen in the presence of phosphatic fertilizer than in its ab= sence. During the 1965-66 season the interaction was not statistically significant ($P<0.05$), and the response to nitrogen fertilizer was unaffected

During the 1964-65 season the application of phosphatic fertilizer, during the experimental period, resulted in an increase of yields on the average. There was a tendency for the rate of increase to decline at the highest level of fer= tilizer application (i.e. Both the linear and quadratic effects were significant). However, in the 1965-66 season there was no response to the residual phosphatic fertilizer, in fact there was a small (non-significant) decline in yield due to its application. During the 1964-65 season, the response to the previous applications of phospha= tic fertilizer was not consistent over the levels of nitrogenous fertilizer. The response to phos= phatic fertilizer was greater in the presence of nitrogenous fertilizer than in its absence.

The application of potassic fertilizer, du- ring the experimental period, increased the yields on the average during both seasons. There was no statistically significant evidence of a "falling off" of the responses at the highest level of ap= plication.

During the 1964-65 season there was a signi= ficant ($P \geq 0.05$) increase in yields due to the lime applied in 1959. In 1965-66, however, this response was not apparent.

Residual effects of such long duration (up to two years) due to the application of nitroge= nous fertilizer (urea) are of interest and could provide a field for a more detailed study of the nitrogen "balance sheet" under such a ...

is just possible that the effects noted were due to improved soil conditions on the high yielding plots, rather than the result of residues of nitrogen.

Conclusions

The results of this experiment indicate that, under the pedological and climatic conditions prevailing, large responses in yield can be obtained by the fertilization of "Lands grass." The application of each of nitrogenous, phosphatic and potassic fertilizer resulted in marked increases in dry matter yields. In the absence of these fertilizers, yields were poor. Significant interactions between nitrogenous phosphatic and potassic fertilizers indicate the additional benefit which accrues from a fertilizer which is well balanced in these three nutrients.

The application of agricultural lime resulted in only a small increase in yield. On such acid soils a greater response to lime might have been expected. Some of the calcium requirements of the plants might have been satisfied by the double superphosphate which was applied. The absence of significant interactions between agricultural lime and the other fertilizers applied may also have been due to some extent, to this 14% of calcium present in double superphosphate.

Generally the highest levels of fertilization produced little benefit when compared with the second highest levels. Owing to the wide range between the three fertilizer levels this result should not be interlevel of fertilization. This experiment was designed as a preliminary investigation into the sort of yield responses, which might be expected from "Lands grass" at high levels of fertilization. The most economic level of application of fertilizer will have to be as= sessed from further studies.

The remarkable and varied responses of various annual grass species to the application of fertilizer elements might, if studied further, prove to be of va= lue in farming on these infertile soils. A grass with a low fertilizer requirement for a certain element may be used to economise on this element when fertilizing.

It is apparent that "Lands grass" in the Highland sourveld of Natal, can if fertilized, make a valuable contribution to the winter fodder supply if cut and conserved. It is equally obvious that this mixture of annual volunteer grass species can be maintained for at least five years, on old lands which are disced and rolled annually in spring.

3.5.2.2 *Eragrostis curvula* fertilizer experiment (N-th 8)

In the Highland sourveld fertilized *Eragrostis curvula*, produced high yields of herbage, which due to its leafy nature and relatively low mois= ture content can be harvested and cured for hay with relative ease (Edwards, 1964). In view of the poverty of these soils and due to the potential of this grass for radical veld improvement it was decided to inves= tigate the effects of fertilizers on *Eragrostis curvula* at the n'Tabamhlope Research Station. Various authors have shown that E. curvula responds to nitrogenous fer=

tilizer (Poultney, 1952, Botha & Hamburger, 1953, Anon, 1963a & JOnes, 1964 & 1965), phosphatic fertilizer (Botha & Hamburger, 1953, Jones, 1964 & 1965) and pot= assic fertilizer (Anon., 1963a). The response to phosphatic and potassic fertilizer was generally appa= rent only when they were applied in association with nitrogenous fertilizer.

Objective

The object of this experiment was to determine the effect of nitrogenous, phosphatic and potassic fertili= zation and lime application on the hay yields of E. curvula.

Procedure

The experimental plots were sited on the "Farning= ham" experimental block (see section 3.3.1) on the hlope Research Station. The soils have been de= scribed in detail in section 3.3.1 and in experiment N-Th 10.

The treatments were applied in a 3 x 3 x 3 x 2 factorial design, with confounding, in three blocks of 18 plots and with no replication (Li, 1944). The plot size was 12 x 7 yards (6.4 x 10.9 m) of which two strips of 10 x 3 yards (9.1 x 1.8 m) each (= 40 sq yd) formed the net yield plot. (See section 3.3.2).

The treatments applied are given below in tabular form:

Element	Source	Content of element	Levels of application (lb element/morgen/annum)		
Nitrogen	Urea	46% N	80(N)	(830(N)	1580(N)
Phosphate	Double super= phosphate	19.6%P	44(P)	175(P)	306(P)
Potash	Muriate of potash	50% K	100(K)	411(K)	722(K)
Calcium	Agricultural lime	36% Ca	0(Ca)	288(Ca)	

(1 lb/morgen = 0.53 kg/ha)

Micro-elements and magnesium were applied to the whole experimental area, in the first year only, at the following rates per morgen:

400 lb Magnesium sulphate (212 kg/ha)
30 lb Copper sulphate (16 kg/ha)
30 lb Zinc sulphate
30 lb Borax
8 oz Ammonium molybdate (265 g/ha)

The magnesium, micro-elements and lime were broad= cast on the soil and disced into it in the autumn of 1961. At establishment an application of 80 lb N (urea), 44 lb P (double superphosphate) and 100 lb K (KCl) per morgen (42, 23 and 53 kg/ha) was broadcast over and disced into the whole experimental area. Annually in spring these same amounts of N, P and K were braodcast over the whole experimental area. The additional treatment fertilizer was applied annually (except for agricultural lime which was all applied at establishment). All the phosphatic fertilizer was applied in spring, but the nitrogenous and potassic fertilizer were applied in six equal dressings, one in spring, one in November and thereafter at approximately monthly intervals with the last one in March.

The plots were seeded to E. curvula (Ermelo culti= var) at 15 lb per morgen (7.9 kg/ha). Seeding was carried out in March 1961 on a well prepared seed bed.

The herbage on all plots was cut whenever the seed heads started to emerge on the most advanced plots. This was usually at a leaf height of from 9 to 12 inches (23-30 cm). Some plots were therefore always cut when much shorter than this as their growth rate was slower. Samples of cut herbage were taken for oven dry matter determinations (Edwards, 1965) and yields were expressed in terms of oven dry matter in tons per morgen.

During the first four years of the experiment five cuts were taken annually but, due to a dry autumn, only four cuts were harvested during the 1965-66 season.

Results and Discussion

The yields obtained from the individual cuts during each year did not differ markedly from the an= nual total yields.

Nitrogen (In the form of urea 46% N) (See table 26)

There was a statistically significant response in yeild to the application of nitrogenous fertilizer, at rates in excess of 80 lb N per morgen, on the ave= rage and during each of the five years of the experi= ment. There was, however, a falling off in response at the highest level of fertilizer application i.e. 1580 lb. N/morgen application did not produce a sig= nificant increase in yield over the 830 lb N/morgen application.

$N_{830} - N_{80}$ = 8.71 ton/morgen/annum (9.22 Mkg/ha)
$N_{1580} - N_{830}$ = -0.02 ton/morgen/annum (-0.02 Mkg/ha)

The response to nitrogenous fertilizer was smallest during the first year (1961-62) and thereafter was larger and reasonably consistent.

Table 26.

The main effects of nitrogenous fertilizer on the yield of <u>E. curvula</u>

(Ton oven dry material/morgen)

(1 ton/morgen = 1059 kg/ha)

Year	N applied (lb/m/annum) 80	830		1580	Mean	L.S.D. P=0.05	P=0.01	Standard Error
1961-62	15.02	<18.71	N.S.	18.04	17.25	0.78	1.06	0.26
1962-63	8.08	<18.69	N.S.	18.14	14.97	0.65	0.88	0.22
1963-64	6.59	<16.68	N.S.	17.16	13.47	0.64	0.86	0.22
1964-65	6.01	<14.60	N.S.	14.35	11.65	0.92	1.25	0.31
1965-66	3.19	<13.75	N.S.	14.63	10.52	0.92	1.24	0.31
Mean	7.78	<16.49	N.S.	16.47	13.58	0.47	0.63	0.16

Phosphate (In the form of double superphosphate 19.6% P)
(See table 27)

On the average and during all seasons there was an overall significant response in total yield to the application of phosphate fertilizer at rates greater than 44 lb P/morgen. The application of 175 lb P/mor= gen gave a significant increase in yield over the ap= plication of 44 lb P per morgen. However, response was not generally apparent at the highest level of fertilizer application.

$P_{175} - P_{44}$ = 1.56 ton/morgen/annum (1.65 kg/ha)

$P_{306} - P_{175}$ = 0.29 ton/morgen/annum (0.31 kg/ha)

Table 27.

The main effects of phosphatic fertilizer on the yield of E. curvula (Ton oven dry material/morgen)
(1 ton/morgen = 1059 kg/ha)

Year	P applied (lb/m/annum) 44	175		306	Mean	L.S.D. P=0.05	P=0.01	Standard Error
1961-62	16.32 <	17.47	N.S.	17.97	17.25	0.78	1.06	0.26
1962-63	13.73 <	15.61	N.S.	15.57	14.97	0.65	0.88	0.22
1963-64	12.38 <	13.64	<	14.40	13.47	0.64	0.86	0.22
1964-65	10.41 <	12.41	N.S.	12.13	11.65	0.92	1.25	0.31
1965-66	9.21 <	11.03	N.S.	11.33	10.52	0.92	1.25	0.31
Mean	12.44 <	14.00	N.S.	14.29	13.58	0.47	0.63	0.16

Potash (In the form of KCl 50% K) (See table 28)

The application of potassic fertilizer, at rates of over 100 lb K:morgen, resulted in a significant increase in yield on the average and during all but the first year (1961-62) of the experiment. This re= sponse was not generally maintained at the highest level of fertilizer application, i.e. the 722 lb K/mor= gen application produced a significant response over the 411 lb K/morgen application during the second year only.

$K_{411} - K_{100}$ = 2.10 ton/morgen/annum (2.22 kg/ha)
$K_{722} - K_{411}$ = -0.13 ton/morgen/annum (0.14 kg/ha)

Table 28.

The main effects of potassic fertilizer on the yield of <u>E. curvula</u>
(Ton oven dry material/morgen)
(1 ton/morgen = 1059 kg/ha)

Year	K applied (lb/m/annum) 100		411		722	Mean	L.S.D. P=0.05	P=0.01	Standard Error
1961-62	16.91	N.S.	17.65	N.S.	17.19	17.25	-	-	0.26
1962-63	13.73	<	15.24	<	15.94	14.97	0.65	0.88	0.22
1963-64	11.74	<	14.20	N.S.	14.48	13.47	0.64	0.86	0.22
1964-65	10.05	<	12.54	N.S.	12.36	11.65	0.92	1.25	0.31
1965-66	8.75	<	11.78	N.S.	11.04	10.52	0.92	1.24	0.31
Mean	12.22	<	14.32	N.S.	14.19	13.58	0.47	0.63	0.16

Lime (As agricultural lime) (See table 29)

There was no response to the application of agri= cultural lime on the average nor during any of the five years.

Significant interactions

On the average three interactions showed statis= tical significance. These were the nitrogen x phosphate interaction, the nitrogen x potash interaction and the phosphate x potash interaction. The response to phos= phatic fertilizer was greater at the higher levels of nitrogenous fertilizer than at the lowest level. (See appendix table 5). There was no response to potassic fertilizer at the lowest level of nitrogenous

Table 29.
The main effects of agricultural lime on the yield of E. curvula (Ton oven dry material/morgen)

Year	Agricultural lime applied (lb/morgen) 0		4000	Mean	Standard error
1961-62	17.10	N.S.	17.41	17.25	0.21
1962-63	14.75	N.S.	15.19	14.97	0.18
1963-64	13.49	N.S.	13.45	13.47	0.18
1964-65	11.75	N.S.	11.55	11.65	0.25
1965-66	10.35	N.S.	10.69	10.52	0.26
Mean	13.48	N.S.	13.68	13.58	0.13

fertilization, in fact the highest level of potassic fertilizer significantly depressed yields. There was a significant response to potassic fertilizer at the two higher levels of nitrogenous fertilizer but only up to the K_1 level. (See appendix table 6).
The response to potassic fertilizer was least at the lowest level of phosphatic fertilization, and the response to phosphatic fertilizer was least at the lowest level of potassic fertilizer. (See appendix table 7).

Seasonal effects on yield

It will be noted (tables 26 to 29) that there was an annual decline in the yield of the experiment. This decline might be attributed to one or more of the following four reasons:

(1) a general decline in the productivity of the experimental area,

(2) a decline in productivity of sections of the experimental area,

(3) a decline in growth conditions (chiefly rainfall) or

(4) a decline in productivity associated with ageing and deterioration of the planted sward.

In table 30 certain data has been gathered which aid in clarifying the cause of the decline in yield. These data concern the yields of the plots with and without the lowest level of any one nutrient element which produced a significant response, and of the sum= mer and winter rainfall.

It will be noted that the average yield of the experiment and that of the 38 treatments with low le= vels of fertilizer decline annually from 1961-2 to 1965-6. On the other hand, the yield of the sixteen plots receiving the second and third levels of N, P and K is reasonably consistent at between 19 and 20 tons per morgen (20 to 21 M kg/ha) for the first three years but drops to 17 tons during the fourth and fifth years. There is an annual decline in the summer rain= fall (October to March) from 1961-2 to 1965-6. However, there is also a marked drop in summer rain= fall during the last two years.

From these data it appears that the decline in yield on the 38 plots, receiving the lowest level of one or more element, may be associated with a decline in soil productivity and/or a deterioration of the sward and/or a decline in summer rainfall. On the other hand it is more probable that the decline in

Tablo 30.
Annual rainfall and yields of E. curvula.
(1 ton/m = 1059 kg/ha)

Rainfall and Yield	Year 1961-2	1962-3	1963-4	1964-5	1965-6	Mean
Rainfall (m.m.):						
Total	1059.2	927.5	856.8	884.8	800.0	907.5
October - March	879.2	827.1	777.6	631.4	600.8	743.2
April - September	180.0	100.4	88.2	253.4	199.2	164.3
Yield (ton/m):						
Experiment average (54 plots)	17.25	14.97	13.47	11.65	10.52	13.57
Average of 15 plots with second of third level of N, P and K	19.46	20.41	19.11	16.96	16.90	18.57
Average of 38 plots with lowest level of at least ons of N, P or K	16.32	12.68	11.10	9.41	7.83	11.47

yield of the 16 well fertilized plots, during the last two years, was solely due to a decline in summer rainfall.

Conclusions

The results indicate that, under the pedological and climatic conditions prevailing, large responses in yield can be obtained from the fertilization of E. curvula. The application of nitrogenous, phosphatic and potassic fertilizer resulted in significant respon= ses in yield of dry matter. The most marked response was that to the application of nitrogenous fertilizer. At the lowest level of fertilization yields declined rapidly after the first year. Significant interac= tions, between phosphatic fertilizer and nitrogenous fertilizer, and between potassic fertilizer and nitro= genous fertilizer, indicate the importance of these fertilizers at high levels of nitrogenous fertiliza= tion. The significant interaction between phosphatic and potassic fertilizers indicate the additional bene= fit which accrues from a fertilizer, which is well balanced in so far as these three nutrient elements are concerned.

The application of agricultural lime did not re= sult in any increase in yield. On such acid soils a response to the application of lime might have been ex= pected. The calcium requirements of the plants may have been satisfied by the 14% of calcium in the double superphosphate which was applied.

Generally the highest levels of fertilization pro= duced little benefit when compared with the second high= est levels. Owing to the wide range between the three fertilizer levels this result should not be interpreted to mean that the second level is the optimum level of fertilization. This experiment was designed as a pre= liminary investigation into the sort of yield responses which might be expected from <u>E. curvula</u> at high levels of fertilization. The most economic level of applica= tion of fertilizer will have to be assessed from further trials.

3.5.2.3 *Trifolium pratense* fertilizer experiment (N-Th 9)

In the Highland Sourveld of Natal there is a shortage of high quality (protein) roughage for animal feed during winter (Scott, 1948; Fisher, 1955). *T. pratense* when grown as a short term pasture and when ensiled or put up for foggage provides a valuable source of high protein feed in this area (Fisher, 1955; Edwards & Mappledoram, 1965). This species, because of its rapid growth immediately after planting which enables it to compete with the indigenous vegetation and possibly create more favourable conditions for other more slowly developing perennial species, also appeared to have a high potential for grassland im= provement. Observations indicated that this crop re= sponded to fertilizer applications in the Highland Sourveld (Fisher, 1963). In view of the pverty of these soils (Orchard, 1947) it was decided, in 1960, to start a fertilizer experiment on the Tabamhlope Re= search Station with this crop.

Objective

The object of this experiment was to determine the effect of four levels of each of phosphatic and potassic fertilizer and two levels each of nitrogenous fertilizer and lime, on the hay production of *T. pratense* in the Highland Sourveld.

Procedure

The experimental plots were sited on the "Farning= ham" experimental block on the Tabamhlope Research Sta= tion (see section 3.3.1). The soils have been described

The experiment was laid out in a 4 x 4 x 2 x 2 factorial design, with confounding, in blocks of 16 plots and there were no replicates (Cochran & Cox, 1957). The plot size was 12 x 7 yards (10.9 x 6.4 m) gross.

The treatments consisted of four levels of total phosphate (44, 96, 149 and 201 pounds per morgen – 23, 51, 79 and 107 kg/ha – per annum), four levels of potassium (100, 274, 449, and 623 pounds per morgen – 53, 145, 238 and 330 kg/ha – per annum), two levels of nitrogen (0 and 105 pounds per morgen – 0 and 56 kg/ha – per annum) and two levels of agricultural lime (2 and 4 tons calcium carbonate per morgen – 2.1 and 1.1 M kg/ha) applied only at the start of the experi= ment. The nitrogen was applied in the form of urea (46% N), phosphate in the form of double superphosphate (19.6% P) and potash in the form of muriate of potash (50% K).

Micro-elements and magnesium were applied to the whole experimental area, in the first year only, at the following rates:

400 lb magnesium sulphate/morgen (212 kg/ha)
30 lb copper sulphate/morgen (16kg/ha)
30 lb zinc sulphate/morgen
30 lb borax/morgen
8 oz ammonium molybdate/morgen (265 g/ha).

The magnesium, micro-elements and lime were broad= cast and disced into the soil in February 1960. At establishment an application of 44 pounds of P (super= phosphate), 100 pounds K(KCl) and 20 pounds N (Urea) per morgen was spread over and disced into the whole experimental area. The treatment fertilizer appli= cations were applied annually (except for the lime which was all applied at establishment). All the phosphate was applied in spring but the nitrogen and potash were applied in four equal dressings, one in spring, one in mid-November, one in early January and the final one in mid-February.

The plots were seeded to 6 pounds Australian cow= grass cultivar, 6 lb Kenland red cultivar and 6 lb Montgomery late flowering red cultivar of Trifolium pratense per morgen (2.7, 2.7 and 2.7 kg/ha). The seed was innoculated with a suitable strain of Rhizo= bium bacteria. Seeding was carried out in February 1960 on a well prepared seed-bed.

The yield of oven dry herbage was measured each time the most advanced plots were fit for cutting. The stage of cutting of the plots was determined by the growth of new leaves from the base of the plants. Cutting was so timed that a large number of these new leaves would be left on the plant after mowing.

During the first harvest year and the first two cuts of the second year the amount of foreign material in the cut herbage was visually estimated. In all plots during this period the percentage of foreign ma= terial was estimated to be less than 10%. However, after the second cut in the second year the amount of foreign material in the cut herbage increased consider= ably. At this stage it was decided that the system of estimation was unsatisfactory, and the cut herbage was then sampled and separated by hand into clover and non-clover components. Thus, although total yield figures are available for the whole five year period, clover weights and percentages are available for only the last three years. However, the average clover percentage for the first year and at least half the second year was probably over 90%.

Results

Nitrogen

There was a statistically significant response in total yield (clover+ foreign material) to the appli= cation of nitrogenous fertilizer on the average and in all but the first year of the experiment (1960-61). (See table 31).

Table 31.

The main effects of nitrogenous fertilizer on the yield of clover + weed (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha)

Year	N applied (lb/m/annum)				LSD	
	0		105	Mean	P=0.05	P=0.01
1960/61	10.14	NS	10.34	10.24	0.38	0.52
1961/62	8.61	<	9.77	9.19	0.58	0.78
1962/63	7.25	<	8.31	7.78	0.33	0.44
1963/64	4.99	<	6.22	5.60	0.44	0.59
1964/65	4.72	<	5.88	5.30	0.45	0.60
Mean	7.14	<	8.10	7.62	0.26	0.34

In the second year there was no response to nitro= genous fertilizer when the non-clover material was ex= cluded in the third or fourth cuts.

The application of nitrogenous fertilizer did not affect the yield of clover during the third and fifth years and on the average; but in the fourth year (1963-64) it significantly depressed the dry matter yield of clover. (See table 32).

Table 32.

The main effects of nitrogenous fertilizer on the yield of "clover only" (ton oven dry material/morgen. (1 ton/morgen = 1059 kg/ha).

Year	N applied (lb/m/annum)				LSD	
	0		105	Mean	P=0.05	P=0.01
1962-63	2.25	NS	2.28	2.26	0.38	0.51
1963-64	1.18	>	0.92	1.05	0.22	0.30
1964-65	1.43	NS	1.07	1.25	0.42	0.56
Mean	1.62	NS	1.42	1.52	0.33	0.45

The application of nitrogenous fertilizer resul= ted in a significant reduction in the clover content in the harvested herbage (See table 33).

Table 33.

The main effects of nitrogenous fertilizer on the clover content in the material harvested (clover as a percentage of oven dry weight and then transformed by angular transformation, underlined - re-transformed data not underlined).

Year	N applied (lb/m/annum)				LSD	
	0		105	Mean	P=0.05	P=0.01
1962-63	33.42 30.34	>	30.83 26.25	32.12 28.27	0.92	1.24
1963-64	28.00 22.04	>	21.18 13.06	24.59 17.32	2.00	2.69
1964-65	32.66 19.10	>	22.80 15.01	27.73 21.66	4.96	6.68
Mean	31.42 27.17	>	27.58 21.50	29.50 24.25	2.89	3.89

Phosphate

There was a statistically significant overall response in total yield to the application of phosphatic fertilizer, at rates of over 44 lb P per morgen, on the average and during the first, third and fifth seasons. The nature of this response was linear in all cases except in the third season when it was quadratic. (See table 34).

Table 34.

The main effects of phosphatic fertilizer on the yield of clover + weed (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha)

Year	P applied (lb/m/annum)							Mean	LSD	
	44		96		149		201		P=0.05	P=0.01
1960-61	9.95	<	10.30	NS	10.54	NS	10.48	10.24	0.54	0.73
1961-62	8.69	NS	9.16	NS	9.50	NS	9.42	9.19	0.82	1.10
1962-63	7.52	NS	7.77	NS	8.16	>	7.66	7.78	0.46	0.62
1963/64	5.31	NS	5.64	NS	5.74	NS	5.74	5.61	0.62	0.84
1964/65	5.01	NS	5.07	NS	5.29	NS	5.84	5.30	0.78	1.05
Mean	7.24	NS	7.59	NS	7.85	NS	7.83	7.63	0.36	0.49

There was no response to the application of phosphatic fertilizer, at rates of over 44 lb P per morgen, in the yield of clover. (See table 35).

Table 3 .

The main effects of phosphatic fertilizer on the yield of "clover only" (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha)

Year	P applied (lb/m/annum)							Mean
	44		96		149		201	
1962-63	2.28	NS	2.18	NS	2.44	NS	2.20	2.27
1963-64	1.05	NS	1.07	NS	1.09	NS	0.99	1.05
1964-65	1.11	NS	1.48	NS	0.98	NS	1.43	1.25
Mean	1.48	NS	1.58	NS	1.50	NS	1.54	1.54

The application of phosphatic fertilizer (over 44 lb P per morgen) did not appear to affect the clover con= tent of the harvested herbage. (See table 36).

Table 36.

The main effects of phosphatic fertilizer on the clover content in the material harvested (clover as a percen= tage of oven dry weight).

Year	P applied (lb/m/annum)				Mean
	44	96	149	201	
1962-63	29.11	27.94	28.65	27.37	28.27
1963-64	18.36	18.68	15.86	15.16	17.19
1964-65	21.21	25.38	16.35	24.12	21.66
Mean	24.16	25.53	23.96	23.30	24.24

Potash

On the average and in all years except the fifth year (1964-65) there was an overall significant re= sponse in total yield to the application of potassic fertilizer at rates greater than 100 lb K per morgen. The nature of the response was linear, but on the aver= age and in two years the yields for some levels differ= ed in a quadratic way. (See table 37).

Table 37.

The main effects of potassic fertilizer on the yield of clover and weed (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha).

Year	K applied (lb/m/annum)								LSD	
	100		274		449		623	Mean	P=0.05	P=0.01
1960-61	9.28	<	10.11	NS	10.58	NS	10.99	10.24	0.54	0.73
1961-62	7.66	<	9.68	NS	9.54	NS	9.88	9.19	0.82	1.10
1962-63	6.96	<	7.81	NS	8.18	NS	8.17	7.78	0.46	0.62
1963-64	4.91	<	5.58	NS	5.94	NS	6.00	5.61	0.62	0.84
1964-65	5.20	NS	5.42	NS	5.49	NS	5.10	5.30	0.78	1.05
Mean	6.80	<	7.72	NS	7.95	NS	8.03	7.63	0.36	0.49

On the average and during the third and fourth years there was a significant response in the yield of clover to the application of potassic fertilizer at rates of over 100 lb K per morgen. This response was linear, i.e. there was no statistical evidence of a decline in the rate of response at the higher levels of K. (See table 38).

Table 38.

The main effects of potassic fertilizer on the yield of "clover only" (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha).

Year	K applied (lb/m/annum)								LSD	
	100		274		449		623	Mean	P=0.05	P=0.01
1962-63	1.50	<	2.16	<	2.73	NS	2.71	2.27	0.54	0.73
1963-64	0.70	NS	0.81	<	1.31	NS	1.37	1.05	0.31	0.42
1964-65	0.92	NS	1.30	NS	1.43	NS	1.36	1.25	0.59	0.80
Mean	1.04	NS	1.42	NS	1.82	NS	1.81	1.52	0.47	0.64

There was a significant linear response to the application of potassic fertilizer, at rates of over 100 lb per morgen in the clover content in the her= bage harvested. (See table 39).

Agricultural lime

The application of four tons of lime per morgen did not result in any signficant difference in total yield, yield of clover or clover content of the har= vested herbage when compered with the application of two tons of lime per morgen.

Table 39.

The main effects of potassic fertilizer on the clover content in the material harvested (clover as a percentage of oven dry weight and transformed by angular transformation, underlined - re-transformed data not underlined).

Year	K applied (lb/m/annum)								LSD	
	100		274		449		623	Mean	P=0.05	P=0.01
1962-63	27.45	<	31.41	<	34.84	NS	34.80	32.12	1.31	1.76
	21.26		27.16		32.64		32.57	28.27		
1963-64	21.19	NS	21.93	<	27.42	NS	27.81	24.59	2.82	3.08
	13.07		13.95		21.21		21.77	17.32		
1964-65	22.99	<	28.01	NS	29.31	NS	30.62	27.73	7.01	9.44
	15.25		22.06		23.97		25.94	21.66		
Mean	26.30	NS	28.29	NS	31.57	NS	31.83	29.50	4.09	5.51
	19.62		22.46		27.41		27.81	24.25		

Significant interactions

Significant interactions in the analysis of only total yields (i.e. five years in the case of clover + weed and 3 years in the case of clover only) are discussed hereunder.

The phosphate x potash interaction was statistically significant in the case of total yield (clover + weed) on the average. Increasing applications of the one element generally resulted in the increased responses to the other element. (See appendix table 8). The phosphate x potash interaction was also statistically significant for the clover content of the herbage har= vested. (See appendix table 9).

On the average the phosphate x nitrogen interac= tion on total yield (clover + weed) was statistically significant. Increasing applications of one fertili= zer generally resulted in increased responses to the other element. (See appendix table 10).

Conclusions

The results indicate that, under the pedological and climatic conditions prevailing on the experimental area, T. pratense responded chiefly to potash fertili= zer.

The application of nitrogen fertilizer failed to produce a response in yield when the clover content was high on the plots (i.e. during the first year and the first two cuts of the second year). It did not affect the yield of "clover only" except in the fourth year when the yield was depressed. The application of nitrogen fertilizer also resulted in a reduced clover content in the harvested herbage. On the other hand, the application of nitrogen fertilizer resulted in an increase in total yield during the last three years of the experiment. From these results it may be assumed that nitrogen fertilization produced increased yields in the non-clover components of the sward, which were chiefly grasses. It can also be assumed that the Rhizobium used was effective.

The application of phosphatic fertilizer at rates of over 44 lb P per morgen resulted in a general increase in total yield. This response was not reflected in the yield of "clover only" during the last three years of the experiment, nor was it reflected in the percentage contribution of clover to the total yield during the same period. It seems possible that additional phosphatic fertilizer may benefit the clover in the establishment period but that this response may not continue after the first season.

Powrie (1963) suggests a parallel to this on the siliceous sands in the Upper South-East of South Australia. Under these conditions he has found clover based pastures to have a high initial superphosphate requirement, but a "declining super need" in following years due to accumulation of available phosphorus in the soil.

There was a general response to the application of potassic fertilizer at rates of over 100 lb K per morgen. This response was apparent in total yield, yield of clover only and in the amount of clover in the herbage in all years but the fifth. It is doubtful if 623 lb K per morgen gave any practical benefit over 449 lb K per morgen.

The application of four tons of lime per morgen once in five years to these acid soils did not give any benefit over the application of two tons per morgen.

The reason for the depression of the amount and percentage of clover present in the sward during the 1963-4 season is not evident.

In this experiment all plots were harvested (cut) on the same day. The time of cutting was decided upon from the development of the most advanced plots. This tended to discriminate against the slower growing plants on certain treatments. This could be overcome by mowing the plots separately when plants on each plot reached the correct stage of development. This, however, was impracticable due to the distance to be travelled (50 miles) for each harvest, and due to limitations of facilities.

3.5.2.4 Discussion

It is apparent, that the soil on which these experiments were carried out is lacking in sufficient supplies, of the three major plant nutrient elements N, P and K, for optimum grassland production unless it is fertilized. Although these experiments give an indication of the approximate amounts of fertilizer required, the exact requirements can be expected to vary from site to site on this soil type. Other soil types in the area may have slightly different requirements, although climatic factors do appear to have an over-riding influence (over parent material) in the formation of the soils of the Highland Sourveld. Recent studies by Graven (as quoted by Frean, 1969) indicate that the Clovelly soil series, while having adequate sulphur in the top-soil, is dificient in this element in the sub-soil. This result explains an observation that, on the "Clovelly" block, *Medicago sativa* roots did not penetrate beyond the "A" horizon (2-3 inches - 5 to 8 cm - deep) and were unthrifty.

The question is often posed as to which should be investigated first - suitable plant species or soil fertility in a new area. Ideally both should vestigated concurrently in the same experiment. Practically this is impossible, due to the large num= ber of potential treatments. Depending on the fer= tility status of the soil (ascertained by the obser= vation of plant growth) soil fertilizer trials may follow or can be run concurrently, in separate experi= ments, with species trials. With the use of compost or kraal manure, or with available knowledge of plant fertilizer requirements a satisfactory soil fertilizer programme, which will allow plant species evaluation to continue, should be available. Unless extreme soil fertility deficiencies exist, the fertilizer trials should be delayed until suitable plant species have been selected.

The trials which have been discussed in this sec= tion made it possible to proceed with grassland research work on a reasonably sound soil fertility basis.

3.5.3 The establishment of overseeded species

The steeper slopes and stony areas of the Highland Sourveld, where grassland improvement is most likely to find its niche, are unsuitable for conven= tional seedbed preparation and seeding techniques. Consequently the improvement of these areas by the in= troduction of improved plant species will depend large= ly on the success obtained in the establishment of overseeded species on these rough seedbeds.

The establishment of overseeded species in influ= enced to a marked extent by the ability of the seed, and the seedling, to absorb sufficient moisture from its micro-environment. The nature of this micro-environment is largely dependent on its micro-topography, which can be manipulated by man. In fact, the various techniques employed to aid the establishment of oversown seeds all depend on the manipulation of two factors (micro-relief and/or vegetative cover) for thier success. Consequently it was decided to investigate the effect of these two factors, in some detail, in the Highland Sourveld of Natal.

3.5.3.1 The effect of competition

Warren Wilson and Leigh (1964) have noted the differences in vegetation resulting from shallow (2 cm) depressions, while Harper, Williams and Sagar (1965) have illustrated the marked effect of minor variations in soil micro-topography on the germination of Plantago seeds.

Harper et al (1965) state that the density of the seeded plant population is a function of the soil surface, and that the population may be said to be regulated by the frequency of "safe sites." "Safe sites" are sites suitable for the germination and establishment of the seeded species (Harper, Clatworthy, McNaughton and Sagar, 1961). Harper et al (1965) suggest that there is considerable subtlety in the requirements of different species for "safe sites." "The densities of species in a mixture may be independently determined for each species because of specialized requirements for germination which are satisfied at different places on a rough soil. The observation that the different optimal topgraphies for establishment of two species corresponded with different optimal topgraphies for water uptake by seeds, supports the view that micro-topography exerts its influence through modifying seed-water re= lationships. It seems likely that subtle variations in structure of the soil surface may influence both abundance of a particular species and the balance be= tween species." (Harper et al. 1965).

If such minor variations in soil surface micro-topography can cause major variations in the germina= tion of seeds, then it is apparent that the relatively large variation in micro-topgraphy caused by grass tufts might also influence the germination of seeds. At the size scale of a weed seed, the soil surface is a very complicated pattern of exposed and sheltered micro= sites (Harper, 1959). Little literature can be traced on this subject. However, certain hypotheses may be advanced. These are:

(1) The mere physical presence of grass tufts and leaves will influence the distribution pattern on the soil surface of broadcast seeds. This pattern may vary, depending on the density, type, foliar area and arrangement of plant species.

(2) A certain proportion of seed will be intercepted by the grass tufts themselves and never reach the soil. Some of this seed may germinate in the grass tuft, some may be dislodged by rain and wind and eventually reach the ground and the rest remains in the grass tuft under conditions un= favourable for germination. This latter portion of seed is destroyed by insects, eaten by birds or finally loses vitality and dies.

(3) Of the seed reaching the soil surface some will be closer to the grass tufts than others. The

in relation to the tuft may determine the amount of water, heat and light available to the seed. This is because the living plant (and probably even dead tufts) moderates the moisture content, air temperature (Luff, 1965) and the light inten= sity at the soil surface in its immediate vicinity.

Unfortunately the measurement of these micro-en= vironmental factors on the scale of the micro-topography which is of importance to small seeds is impracticable. Harper et al (1965) do however, suggest that increases in the weight of small seeds placed in the various microsites indicate the moisture available on the soil surface. This water uptake might also be partially dependent on temperature and light conditions and the seeds used.

The number of "safe sites" for the germination of oversown seeds in a grassland sward may be expected to be a function of the density of the sward. However, plants seldom grow in a systematic or even a completely random arrangement. The commonest situation is that plants tend to be more or less gregarious or clumped in patches of varying size and density within an area (Greig-Smith, 1957). Where this happens the mean density of plants per unit area gives a misleadingly low impression of the mean distance apart of indivi= duals, and so of their effective density (Harper, 1959). It should be remebered that the converse is also true. Unvegetated patches of larger area than indicated by the average density will also be present. The arrangement and size of these bare patches may be of importance in seedling establishment.

3.5.3.1.1 The effect of grass tufts on the scatter of oversown seeds (N-Ec 17/7)

During the process of overseeding grassland, as a means of radical veld improvement, the indigenous vegetation remaining due to the incomplete seedbed preparation would have considerable effect on the establishment of overseeded spe cies. One of the factors which would determine the extent of the influ=ence of the vegetation might be expected to be the amount of seed intercepted, and thus prevented from reaching the ground, by the canopy of the plant cover. This aspect of competition was investigated first.

Objective

The object of this experiment was to determine the amount of oversown seed of three pasture species, which was intercepted by grass tufts of three different veld grass species. A further object was to gain in=formation on the distribution of these seeds, on the soil surface, in relations to the position of the tufts.

Procedure

Seeds of each of three pasture plant species, P. dilatatum, T. repens (Ladino) and T. pratense (Ken=land), were dropped from a height of two feet on to artificial swards of dead tufts of T. hispida, E. cur=vula and A. filifolius. The tufts were mounted on soft-board in a laboratory. Each species was mounted at two densities (16% and 4% basal cover, using plants of 4 sq in. basal area) in a systematic square pat=tern. The experiment consisted of a 3 (subject spe=cies tufts) x 2 (densities) factorial design with three "split plot" (types of oversown seed) treatments, and was replicated three times.

The grass tufts were collected in the Highland Sourveld at the end of summer at which time they sup= ported a full seasons unutilized foliage. The tufts were cut off just below the crown, and after drying the base was trimmed to fit snugly into a cylinder with an internal diameter of 2.256 inches (4 sq inch - 25.8 sq cm - area). These tufts were then mounted on a square of softboard at the required density and pattern so as to provide a net plot of 20 inches x 20 inches (50.8 x 50.8 cm), with a one plant border around it (see appendix plan I).

The seeds of each of the three pasture species were dropped, in turn, on each of the three veld grass species at each density. Nine hundred seeds (on the 16% basal cover) and one thousand two hundred and twen= ty-five seeds (on the 4% basal cover) were dropped on each gross plot. The area of the gross plot was di= vided into imaginary one inch squares, and one seed was dropped from a height of two feet, at the centre of each of these squares. A plate, with $^1/8$ inch (0.3 cm) diameter holes at the desired positions, was mounted above the plots to facilitate the correct po= sitioning of the seeds before they were dropped.

After the seeds had been dropped the tufts were lifted carefully and shaken to remove the seed which had lodged in them. The number of seeds thus collec= ted from each tuft was counted. The number of seeds remaining in each square inch of the board was also recorded.

The average dimensions of the veld grass tufts which were used are given in table 40.

Table 40.

The average dimensions of the subject tufts (1 sq in. = 6.45 sq cm; 1 inch = 2.54 cm; 1 cu in = 16.39 cc)

Dimension	Species of subject plant			
	T. hispida	*E. curvula*	*A. filifolius*	Mean
Base area (sq in)	2.0	2.0	2.0	2.0
Height (in)	7.89	20.75	10.84	13.16
Width (in)	3.86	3.08	2.64	3.19
Weight (g)	17.12	12.25	9.13	12.83
Volume ($\pi \frac{1}{2}$ width x height = cu in)	92.31	154.59	59.29	102.06
Density (Weight g ÷ Volume cu in)	0.185	0.079	0.154	0.139

The *E. curvula* tufts were twice the height of those of the other two species, but the foliage on the *T. hispida* tufts was heavier. The *E. curvula* tufts occupied a greater volume, and were less dense than those of the other species.

Results and Discussion

The number of seeds retained per tuft was influenced by the subject species concerned and by the basal cover of the subject species. On the average the type of oversown species had no effect on the retention of seed by the subject plants. These results are presented in table 41.

Table 41.

Percentage of oversown seed intercepted by grass tufts.

Treatments		Percentage seed intercepted Normal	4 x 4% cover
<u>Subject plants</u>			
<u>T</u>.<u>hispida</u>		24.29	35.96
<u>E</u>.<u>curvula</u>		19.82	32.11
<u>A</u>. <u>filifolius</u>		12.71	21.50
Mean		18.94	29.86
L.S.D.	P=0.05	3.29	3.78
	P=0.01	4.61	5.30
<u>Basal cover</u>			
4%		7.28	29.12
16%		30.60	30.60
L.S.D.	P=0.05	2.69	NS
	P=0.01	3.77	NS
<u>Type of seed</u>			
<u>P</u>.<u>dilatatum</u>		20.08	29.71
<u>T</u>.<u>repens</u>		19.47	31.81
<u>T</u>.<u>pratense</u>		17.26	28.06
L.S.D.	P=0.05	NS	NS
	P=0.01	NS	NS

On the average, over the different densities and types of seed, 24.29% seed was retained by T. hispida compared with 19.82% by A. filifolius, and 12.7% by E. curvula. These results appear to bear some relationship to the density (weight in grams ÷ volume in cu in) of the foliage, and possibly bear an inverse relationship to the height of the foliage. The denser, shorter herbage appeared to intercept more seed than the more open tall herbage.

The 4% cover retained 7.28% of the seed compared with 30.60% which was retained by the 16% cover, on the average. This was proportional to the percentage cover; as when the amount of seed retained by the 4% cover was multiplied by four, the result did not differ significantly from that obtained with 16% cover.

The interaction between the subject plants and the seeded species was statistically significant (Appendix table 11). T. hispida intercepted more P. dilatatum and T. repens than it did T. pratense seed, but there was no difference in the amounts of these seeds intercepted by either E. curvula or A. filifolius. More P. dilatatum and T. repens were intercepted by T. hispida than by the other two species, however, A. filifolius intercepted more T. pratense than did E. curvula. This high rate of interception of P. dilatatum seed by T. hispida may have been due to the hairiness of the latters leaves and the furry low density, seed of the former. The reason for the high rate of interception of T. repens seed by T. hispida and T. pratense seed by A. filifolius is not obvious. Multiplication of the amount of seed intercepted by the 4% cover, by four, also produced a significant subject species X seeded species interaction (Appendix table 12). This interaction was similar to that obtained prior to multiplication, except that A. filifolius intercepted less P. dilatatum seed than it did T. pratense seed.

The interaction between subject plants and basal cover was also statistically significant (Appendix table 13). These results indicate that there was no difference in the amount of seed intercepted by the different subject species at 4% cover, but at 16% cover T. hispida intercepted more ($P \leq 0.01$) seed than did A. filifolius which in turn intercepted more seed ($P \leq 0.01$) than did E. curvula. This interaction was also statistically significant when the amount of seed intercepted by the 4% cover was multiplied by four (Appendix table 14). These results indicate that, although the correction eliminated the difference between the two covers on the average and when E. curvula and A. filifolius were subject plants, the correction did not account for the difference when T. hispida was the subject plant. The results indicate that T. hispida intercepted more seed at a 16% cover than would be anticipated on the basis of the seed it intercepted at 4% cover. This did not occur in the case of the other two subject plants. The increased interception of seed at 16% cover by T. hispida may have been the result of seed, bouncing from one plant, being intercepted by a neighbouring plant. The large area covered by the leaves of this species (3.86 inch – 9.8 cm – width/plant) and the hairiness of the leaves, when relative to the other subject species, resulted in little open space being present at a 16% cover.

The scatter of the seeds on the base board after the removal of the tufts was examined by means of scatter diagrams. The distance between the centres of the one inch squares and the centre of the tufts varied from four inches to 11.2 inches (28.4 cm) at 4% cover, and from four inches to 5.6 inches (14.2 cm) at a 16% cover. However, all squares appeared to be occupied by similar numbers of seeds on all treatments. This result is contrary to the expectation that the interception of seed by the tufts would reduce the amount of seed in the squares closest to the base of the tuft. This effect may have been counteracted by seeds which bounced and whose movements were arrested by the bases of the tufts.

3.5.3.1.2 The effect of dead grass tufts on the early establishment of oversown species (N-Ec 17/3)

In the preceeding experiment the phy= sical effect of grass tufts on the amount of oversown seed reaching the ground was investigated. However, the grass tufts have a further physical function in the establishment of oversown seeds. This is the creation of their own micro-climatic complex due to shading, re= duction of wind velocities and the associated changes in temperatures, evaporation losses and soil moisture content in the vicinity of the overseeded seeds. The effect of these two purely physical actions of grass tufts (micro-climate and seed interception) on the establishment of overseeded species was studied by making use of dead grass tufts. Apart from provi= ding some basic information on the mode of action of the competition process, these results from dead tufts approximate the practical situation obtained when areas are sprayed with herbicides, which is an accepted method of seedbed preparation for overseeding.

Objective

The object of this experiment was to determine the effect of the micro-topography created by dead grass tufts on the early establishment of oversown seeds of three pasture species.

Procedure

The experiment was carried out on the "Clovelly" experimental block at Tabamhlope Research Station, (section 3.3.1) during the 1966-67 season.

Seeds of three pasture species (P. dilatatum, T. repens and T. pratense), were sown on artificial swards of dead tufts of three Highland sourveld grass species (T. hispida, E. curvula and A. filifolius) spaced at two densities (4% and 16%). The treatments were laid out in a 3 x 2 factorial design randomised in the blocks of four replications. The results were analysed separately for each of the seeded species.

The grass tufts, collected and shaped as in the previous ecperiment, were placed in the soil at their original depth. They were also arranged in the plots in the same systematic square pattern as was used in the previous experiment (Appendix plan I). The soil between the tufts was cultivated and raked level before seeding.

The number of seeds used was calculated on the normal seeding rates used when such a mixture is planted for radical veld improvement. (This is about double the rate used on a fine seed bed). The suggested seeding rates for radical veld improvement in the Highland Sourveld are as follows:

P. dilatatum	-	160 lb per morgen (84.7 kg/ha)
T. repens	-	12 lb per morgen (6.4 kg/ha)
T. pratense	-	32 lb per morgen (16.9 kg/ha)

As it was intended to spread the seeds on the plot in a systematic square pattern, it was necessary to calculate the number of seeds required per unit area from the number of seeds per pound of seed. The number of seeds per pound (0.454 kg) are given variously as follows:

P. dilatatum	-	220,000 (Anon, 1948, Wheeler & Hill, 1957) *315,000 (Local data)
T. repens		
(Ladino)	-	*800,000 (Anon, 1948, Wheeler & Hill, 1957)
(Wild white)	-	814,000 (Robinson, 1953)
(Dutch)	-	740,000 (Robinson, 1953)
T. pratense	-	*275,000 (Anon, 1948, Wheeler & Hill, 1957)
		250,000 (Robinson, 1953).

*Rates used in calculations.

The figures given above are reasonably consistent except for those of *P. dilatatum*, where the local data is probably more reliable when applied to local commercial seed.

This seed has a poor "full caryopsis" content (± 30%) and as seed separated by flotation in benzene was used, allowance was made when calculating the numbers of _P. dilatatum_ seed to be used. The actual seed analysis and germination of the seed used (as supplied by the S.A. Seed Testing Service) is given in Appendix table 15. The seeds were spread over each plot at the following rates and distances apart:

Species	Seeds/gross plot (30"x30"- 76.2x76.2 cm)	Distance apart of seeds	Seeds/net plot (20"x20" -50.8x50.8 cm)
P. dilatatum	900	1"	400
T. repens	676	1.154"	300
T. pratense	576	1.25"	256

The area of the plot was divided into imaginary squares (900 of 1" x 1" (2.54 x 2.54 cm) for _P. dilatatum_, 675 of 1.154" x 1.154" (2.9 x 2.9 cm) for _T. repens_ and 576 of 1.25" (3.175 x 3.175 cm) for _T. pratense_). One seed of each species was dropped, from a height of two feet, at the centre of each of these squares. In order to ensure correct spacement of the seeds at the "dropping position" a plate with 1/8" (0.3 cm) diameter holes drilled through it was used, each hole was at the centre of one of the squares. Seeding was completed within a period of three days.

The number of seedlings of each species which survived was counted at three weeks and at six weeks, after planting. One year later the herbage yield of the surviving plants was measured on each plot.

Table 42

Percentage establishment of <u>Trifolium pratense</u>

Percent Basal Cover	Establishment at 3 weeks				Establishment at 6 weeks			
	Species of subject plant				Species of subject plant			
	T.hispida	E.curvula	A.filifolius	Mean	T.hispida	E.curvula	A.filifolius	Mean
4%	29.98	29.49	24.61	28.03	28.61	28.51	23.63	26.92
16%	8.40	47.36	45.70	33.83	2.73	39.26	47.85	29.95
Mean	19.19	38.42	35.15	30.92	15.67	33.88	35.74	28.43
L.S.D.'s		P = 0.05	P = 0.01			P = 0.05	P = 0.01	
Basal cover means		N.S.	N.S.			N.S.	N.S.	
Species means		9.60	13.28			6.39	9.04	
Interaction (Body of table)		13.58	18.78			8.84	12.50	
Coefficient of variation		29.14%					21.01%	

Results and Discussion

(a) Early establishment

So little *P. dilatatum* seed became established (an average of 0.84% and 0.79% at three and six weeks respectively) that this data was discarded as unreliable.

T. pratense

On the plots of *T. hispida* significantly less ($P \leq 0.01$) *T. pratense* became established (at both three and six weeks) than on the plots of *E. curvula* and *A. filifolius* (See table 42).

On the average the plant density (basal cover) had no effect on establishment. However, the interaction between the subject plants and the plant density was statistically significant ($P \leq 0.01$) at both three and six weeks after seeding. These results indicate that the establishment was, in fact, influenced by the density of the subject plants. With *E. curvula* and *A. filifolius* as subject plants a better establishment was obtained at 16% basal cover than at 4% basal cover. For *T. hispida*, however, the reverse applied. At the 4% cover there was no significant difference in the percentage of plants which became established under the three subject plants. However, at 16% basal cover establishment was poorer ($P \leq 0.01$) under *T. hispida* than under *E. curvula* and *A. filifolius*. There was little difference between the number of plants counted at three weeks and at six weeks after seeding. The average establishment of about 30% was considerably less than the 81% germination obtained in the laboratory.

Table 43

Percentage establishment of T.pratense (Corrected for seed intercepted by tufts)

Percent Basal Cover	Establishment at 3 weeks				Establishment at 6 weeks			
	Species of subject plant				Species of subject plant			
	T.hispida	E.curvula	A.filifolius	Mean	T.hispida	E.curvula	A.filifolius	Mean
4%	32.28	31.07	27.36	30.24	30.70	30.04	26.15	28.96
16%	11.73	57.30	71.79	46.94	38.15	47.42	75.19	53.59
Mean	22.00	44.18	49.57	38.59	34.42	38.73	50.67	41.27

L.S.D.'s:	3 weeks P = 0.05	3 weeks P = 0.01	6 weeks P = 0.05	6 weeks P = 0.01
Basal cover means	9.62	13.31	6.78	9.38
Species means	11.29	15.02	8.31	11.49
Interaction (Body of table)	16.67	23.05	11.75	16.24
Coefficient of Variation	28.68%		18.89%	

When the amount of T. pratense seed intercepted by the tufts (as recorded in N-Ec 17/7) was subtracted before determining the percentage establishment, a somewhat different picture emerged. (See table 43).

At three weeks after seeding these results were the same as those of the uncorrected data, in-so-far as the effect of the subject species was concerned. However, six weeks after seeding, the percentage of T. pratense plants on the T. hispida plots had increased and those on the E. curvula plots had decreased to the extent that there was now no difference between the two treatments. Both had a lower percentage establishment than on the A. filifolius plots. The above result might indicate that seed fell from the T. hispida plants and became established during the three to six week period.

The corrected data indicate that a higher percen= tage of the T. pratense seed which reached the ground became established under the 16% cover than did under the 4% cover. The interaction between the subject plants and density was also statistically significant at both three weeks and six weeks. This latter re= sults is similar to that obtained from the uncorrected data.

The results obtained are probably due to the in= terplay of three factors in the various treatments applied. These factors are:

(a) The interception and subsequent release of varying amounts of seed by the canopy of the subject species.

Table 44

Percentage establishment of T.repens

Percent Basal Cover	Establishment at 3 weeks Species of subject plant				Establishment at 6 weeks Species of subject plant			
	T.hispida	E.curvula	A.filifolius	Mean	T.hispida	E.curvula	A.filifolius	Mean
4%	13.33	19.00	12.42	14.92	13.42	16.92	13.33	14.56
16%	0.33	16.50	14.25	10.36	0.58	12.50	11.83	8.30
Mean	6.83	17.75	13.33	12.62	7.00	14.71	12.58	11.43

L.S.D.'s	P = 0.05	P = 0.01	P = 0.05	P = 0.01
Basal cover means	3.76	5.20	2.07	2.86
Species means	3.07	4.24	1.69	2.34
Interaction (body of table)	5.31	7.35	2.93	4.05
Coefficient of variation	27.90%		17.19%	

(b) Extremes of the canopy cover reduce the light at the soil surface to a level below the optimum for early establishment of the red clover seedlings. (The average area of the canopy of the T. hispida tufts was 238 sq in – 1535 sq cm – of E. curvula 152 sq in – 980 sq cm – and of A. filifolius 112 sq in – 722 sq cm –). After a few weeks in the field the canopy of T. hispida tended to collapse, and at 16% cover provided on almost total ground cover.

(c) The denser canopies reduce the evaporation of moisture from the soil, and produce more favourable moisture conditions.

When the establishment percentages at six weeks are plotted against the relative density of the canopy (Fig. 4), it is apparent that the establishment of T. pratense increased up to a certain density and then dropped sharply.

T. repens

Significantly less T. repens became established (three weeks and six weeks counts) on the plots where T. hispida was the subject species, than on the plots of the other two species. More T. repens became established on the E. curvula plots than on those of A. filifolius (See table 44).

Fewer plants became established at the 16% density than did at the 4% density. The interaction, subject species x density, was statistically significant at both counts (3 and 6 week). At both counts less

Table 45

Percentage establishment of overseeded T.repens

(Corrected for seed intercepted by tufts)

Percent Basal Cover	% Establishment at 3 weeks				% Establishment at 6 weeks			
	Species of subject plants				Species of subject plants			
	T.hispida	E.curvula	A.filifolius	Mean	T.hispida	E.curvula	A.filifolius	Mean
4%	14.53	20.47	13.68	16.23	14.62	18.22	14.69	15.84
16%	0.58	20.86	16.14	12.53	1.02	15.80	14.10	10.31
Mean	7.55	20.66	14.91	14.38	7.82	17.01	14.39	13.07

L.S.D.'s	3 weeks P = 0.05	3 weeks P = 0.01	6 weeks P = 0.05	6 weeks P = 0.01
Basal Cover Means	4.37	6.04	2.51	3.46
Species Means	3.57	4.94	1.45	2.00
Interaction (Body of table)	6.18	8.55	3.54	4.90
Coefficient of Variation	28.54%		17.99%	

FIGURE 4. PERCENTAGE ESTABLISHMENT OF OVERSOWN CLOVER AT VARIOUS DENSITIES OF CANOPY COVER

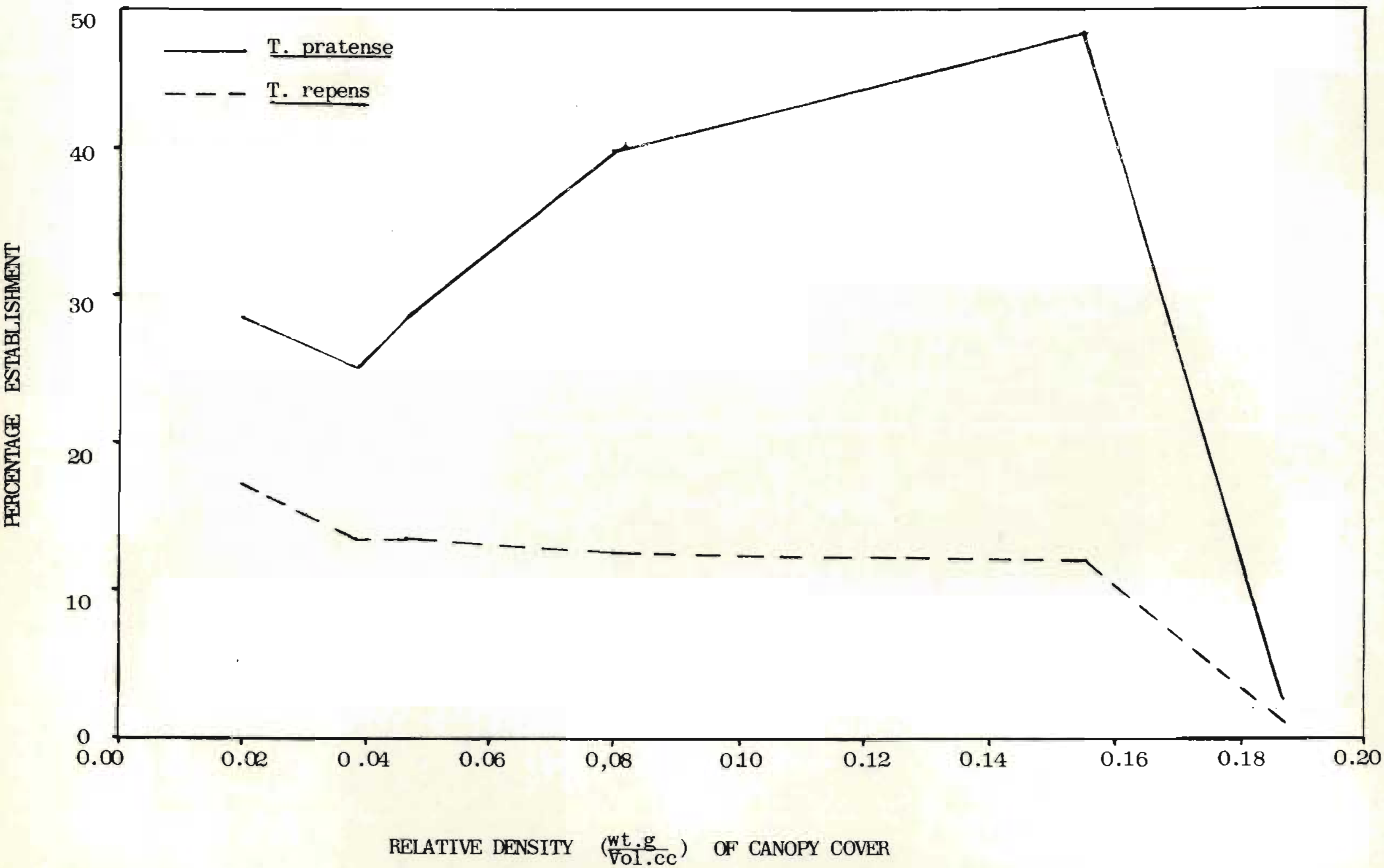


Table 46

Percentage establishment of seeded species

(T.repens + T.pratense + P.dilatatum)

Percent Basal Cover	% Establishment at 3 weeks				% Establishment at 6 weeks			
	Species of subject plant				Species of subject plant			
	T.hispida	E.curvula	A.filifolius	Mean	T.hispida	E.curvula	A.filifolius	Mean
4%	13.00	14.28	10.80	12.69	12.55	13.34	10.83	12.24
16%	2.35	18.10	16.92	12.46	1.02	14.67	16.55	10.75
Mean	7.67	16.19	13.86	12.57	6.78	14.00	13.69	11.49

L.S.D.'s	P = 0.05	P = 0.01	P = 0.05	P = 0.01
Basal Cover Means	N.S.	N.S.	N.S.	N.S.
Species Means	2.85	3.94	1.74	2.40
Interaction (Body of table)	4.07	5.63	2.46	3.40
Coefficient of Variation	21.26%		14.18%	

T. repens became established under T. hispida at 16% cover than at 4% cover. At three weeks there was no difference in the establishment at the different densities on the plots of the other two species. At six weeks the establishment was better at 4% cover than at 16% cover under E. curvula, but there was no difference under A. filifolius. At 4% cover E. curvula proved to be the best subject species for establishment, while there was no difference between T. hispida and A. filifolius. However, at 16% cover the establishment under both E. curvula and A. filifolius was better than under T. hispida.

Correcting for the amount of seed intercepted made very little difference to the results. (See Table 45).

The average establishment of about 12% of T. repens was very low compared with the 82% germination of the seed under laboratory conditions.

Examination of the graph of establishment of T. repens plotted against relative density of canopy (Fig. 4) indicates that the establishment of this species decreased with any increase in density of canopy.

The percentage establishment of the seeded pasture as a whole (T. pratense plus T. repens plus P. dilatatum) is given in table 46.

At both counts (3 and 6 weeks) there was a poorer total establishment under T. hispida than under the other two species. There was no significant difference in the establishment at the two basal covers. The significant interaction indicates that while the percentage establishment tended to increase with an increase in basal cover of *E. curvula* and *A. filifolius*, it decreased with an increase in the basal cover of *T. hispida*. At 4% cover there was little difference in the establishment under the different species, but at 16% cover the establishment was poorer under *T. hispida* than under the other two species.

It is significant that, within the limits of the treatments, the establishment of *T. repens* declines with any addition of canopy cover. On the other hand, the establishment of *T. pratense* improves up to a certain point with an increase in canopy, and then declines. These responses could result in the development of pastures of different compositions from the same seeded mixture. It would appear that *T. pratense* is more suited than *T. repens* for overseeding when some of the vegetative canopy is retained on the seed bed. Further, it is apparent that excessive canopy cover, even when dead, is undesirable for the establishment of both species. Thus the use of herbicides on a very dense and leafy cover provides a poor seed bed.

(b) Herbage yields

The herbage yields, of the seeded species, on the plots one year after seeding are given in table 47.

The yields of the plots, under the same treatment, varied considerably. However, the yield under *T. hispida* was less ($P \leq 0.10$) than under the other two species. This result is not unexpected considering the

Table 47.

Dry matter yield of surviving oversown species (gram/plot of 400 sq in - 2580 sq cm).

Treatment		Dry matter yield (g)
Species		
T. hispida		10.5
E. curvula		21.2
A. filifolius		23.5
Mean		18.4
L.S.D.	P=0.05	9.8
	P=0.10	N.S.
Density		
4%		18.7
16%		18.5
L.S.D.	P=0.05	N.S
	P=0.01	N.S.
Coefficient of Variation		66.79%

poor establishment that was obtained under this spe= cies.

3.5.3.1.3 The effect of living grass tufts on the early establishment of oversown species (N-Ec 17/9)

In the two previous experiments the phy= sical effects of grass tufts on the success of overseed=

ing was investigated. However, it might be expected that living grass tufts, as a result of transpiration, might have a somewhat different effect on the establish= ment of overseeded species. This subject was the ob= ject of the third experiment in this series.

Objective

The object of this experiment was to determine the effect of living grass tufts of different plant species, at two densities, on the early establishment of over-seeded pasture plant species.

Procedure

This experiment was also conducted on the "Clovel= ly" experimental block on the Tabamhlope Research Sta= tion in 1967 and 1968. The treatments, seeding tech= nique and design of the experiment were identical to that of the previous experiment (N-Ec 17/8). However, living grass tufts which had been established previous= ly provided the subject plants, and not dead tufts as in N-Ec 17/8. Tufts of a uniform size were planted but, the growth and death of tillers up until seeding resul= ted in a variety of tuft sizes. The basal area at the time of seeding was less than the prescribed density. The yields obtained from these subject plants and their basal area, two months prior to overseeding, is given in table 48.

Table 48.

Yield and basal cover of plots prior to overseeding

Treatment	Yield (g) gross plot 12.12.67	Percentage basal cover
Species		
T. hispida	220	8.12
E. curvula	1096	8.73
A. filifolius	109	3.44
Mean	425	5.57
Basal Cover		
"4%"	492	4.13
"16%"	458	7.01

The seed on this experiment germinated well, but most of the seedlings were burnt off by exceptionally hot weather just after germination resulting in a poor early establishment. Once again very little *P. dilatatum* became established and these figures are not included in the results. Seedlings were counted only six weeks after seeding, and due to uncertainty in the identification of the seedlings only totals for both clovers (*T. repens* plus *T. pratense*) are presented.

Results and Discussion

The early establishment of clover, six weeks after seeding, is given in table 49.

Table 49.

Percentage establishment of clover plants on plots of living grass tufts six weeks after seeding.

Treatment		Percentage Establishment	Transformed data (stevens-angular)
Species (S)			
T. hispida		0.967	6.124
E. curvula		2.002	9.136
A. filifolius		0.652	4.055
Mean		1.207	-
L.S.D.	P=0.05	-	1.374
	P=0.01	-	1.900
Basal Cover (D)			
"4%"		0.825	4.886
"16%"		1.590	7.991
L.S.D.	P=0.05	-	0.647
	P=0.01	-	0.896
Significant interaction		-	DxS
Coefficient of variation		-	20.20%

More clover plants became established under E. curvula than under T. hispida which in turn provided for a better establishment than did A. filifolius. The establishment at "16%" basal cover (actually 7%) was greater than at 4% basal cover. The interaction subject species x plant density, was statistically sig= nificant ($P \leq 0.05$). Better establishment was obtained at "16%" cover than at 4% cover under T. hispida and A. filifolius, but there was no difference under E. cur= vula. At 4% cover the establishment was greater under T. hispida than under A. filifolius, but at "16%" cover there was no difference in the establishment under these two species. The best establishment was obtained under E. curvula at both densities of cover.

Examination of Figure 5, in which the percentage establishment is plotted against the percent basal cover, reveals that the percentage establishment in= creased with an increase in basal cover up to 11%, and then declined sharply. This result, when compared with those of the previous experiment, suggests that the vast majority of the seedlings which became es= tablished were T. pratense. These results also empha= sise the danger of attempting to overseed on too dense a cover.

3.5.3.1.4 The effect of the pattern of grass tufts on the early establishment of oversown species

The arrangement or pattern of grass plants is usually gregarious but may also be random or systematic. These patterns clearly provide a variety of shapes and sizes of open spaces between grass tufts at the same basal cover. If the proximity to a tuft influences the establishment of oversown seed, it seems probable that variation in the arrangement of the grass tufts will also influence establishment, because the area of soil at any one distance from the tuft will vary.

Management or fertilizer practices applied to grass= land swards may alter the pattern of grass tufts with, or without, altering the basal cover. Thus such changes in pattern may be of importance in determining the success obtained with the establishment of over= sown pastures.

Objective

The object of this experiment was to determine the effect of systematic, random and contagious distribu= tion patterns of grass tufts, at the same basal cover, on the early establishment of three oversown pasture species.

Procedure

Gleason (1920) and Svedberg (1922), independently, demonstrated that the distribution of several species of plants were markedly non-random. Greig-Smith (1957) states that plants seldom grow in a systematic or even a completely random arrangement. The commonest situ= ation is that plants tend to be more or less gregarious or clumped in patches of varying size and density within the area.

Svedberg (1922) used the terms "overdispersion" or "underdispersion" in referring to the distribution curve of the data in non-random patterns of vegetation. This does not refer to the pattern of the individuals on the ground. As this has led to some confusion Greig-Smith (1957) proposed that the terms "contagious" and "regular" should replace "overdispersion" and "un= derdispersion."

Following the demonstration that the observed dis= tribution of individuals in a plant community did not fit a Poissons series (a random distribution), a con= siderable effort was made to find some mathematical series to which field data of this nature could be sa= tisfactorily fitted. Greig-Smith (1957) and Kershaw (1964) discuss, in detail, the various mathematical models which have been advanced to fit field data. The main proposals examined are those of Neyman (1939), Thomas (1949) and Robinson (1954). Neyman (1939) as= sumed a random distribution of clusters and the number per cluster also being random within arbitrary limits to the cluster size. Thomas' Double Poisson distri= bution is based on similar assumptions to those of Ney= man. Clusters were assumed to be randomly distributed and the number of units, additional to the first, also being at random. Robinson suggested the use of the Negative Binomial distribution. This meant that the groups were randomly distributed but that the number of individuals per group followed a logarithmic dis= tribution.

Several authors (Archibald 1948, 1950, Barnes & Stanbury, 1951 and Thomson, 1952) have found that these models fit the field data satisfactorily, but in other cases field data do not fit the models. Greig-Smith (1957) states:

"In comparing the various suggested distributions, it must be remembered that there are so many possible theoretical distributions of this type that the satis= factory fit of data to one of them can scarecely be regarded as evidence for its validity, in the absence of strong and independent biological evidence for the truth of its underlying assumptions."

Most of the distributions suggested are based on the assumption that contagion in vegetation is largely due to the morphology of the individual plant or the efficiency of seed dispersal mechanisms and operates on a small scale only (kershaw 1964). Unfortunately two considerations minimise the value of these models:

(a) More recent work has shown that contagion in ve= getation is due to a multitude of factors and is present on numerous scales in any one site (Greig-Smith, 1957 & Kershaw 1964).

(b) The mathematical parameters employed to define the distribution and generate the series have no meaning ecologically, or at least it is impossible to relate known ecological factors to these para= meters (Kershaw, 1964).

Both Greig-Smith (1957) and Kershaw (1964) say that, due to the large number of variables to be con= sidered, the ecologist should fall back on the "rather simpler empirical approaches."

A further problem in the detection of non-random= ness is the effect of quadrat size upon it. Both Greig-Smith (1957) and Kershaw (1964) show how, depen= ding on the quadrat size used, the same population may appear to have either a random or a contagious distri= bution.

Most of the literature on this subject of mathe= matical models has been based on the need to transform data into a form in which it may be satisfactorily analysed by statistical methods. However, the problem in this project is that of creating artificial popula= tions of plants in a preconceived pattern. It is apparent, from the foregoing discussion, that there is no single model available to describe the distribution of vegetation in contagious patterns. Departure from randomness may be caused by a number of biological and environmental factors, few of which may be expected to remain constant for different plants and different environments. It therefore appears that, for purposes of this project, the only reasonable basis which can be used in creating patterns are those based on the morpho= logical development of the plant and restricted seed dispersion. Kershaw (1964) used this basis in deve= loping a model of plants in a contagious distribution. He developed a population consisting of random parents with hypothetical offspring grouped at random round the "parents." This approximates Neyman's (1939) and Thomas' (1949) distributions.

For purposes of this project it was not only neces= sary to create patterns but it was also necessary to test the patterns, once created, to ensure that they conformed to the required standards. For this purpose a number of tests are available and they are discussed by Greig-Smith (1947). The two tests most usually employed are:

1. the significance test of the difference between the observed and expected variance: mean ratio;

2. the X^2 test to compare the terms of the Poisson's series with observed data.

Evans (1952) has pointed out that these two tests may give a widely different estimate of non-randomness, and it may be necessary to use more than one such test. Kershaw (1964) states that, in general, the X^2 test of goodness of fit is a more reliable indication of non-randomness than the variance: mean ratio.

Preparation of models

All models had a 16% basal cover.

(a) Systematic pattern: A systematic pattern was developed on a square system and was the same in all replications.

(b) Random pattern: The random patterns have been derived by dividing the plot area into 225 squares and selecting thirty-six of these at random. These represent plant positions. A new set of random positions was used in each replication.

(c) Contagious pattern: The contagious patterns are based on random individual "parent" plants, with hypothetical random numbers of offspring.

Nine "parent" plants were laid out at random and a further 27 plants were associated with these "parents". The number of "parents" to receive 0, 1, 2, 3 etc. additional plants was calculated from a Poisson series with a mean of 3. The ac= tual position of the additional plants was at random, at a distance of 4.5 inches (11.4 cm) from the centre of the parent plant. (A procedure similar to this was used by Greig-Smith (1952) in constructing artificial patterns).

The calculated number of tufts to receive 0, 1, 2, 3 are given in the following table. Because of the restricted number of extra plants available (27), due to limitations to a 16% cover, this data had to be modified slightly as is shown in the table:

Number of extra plants per tuft=x	Number of tufts receiving x extra plants. Calculated	Actual	Number of extra plants allocated
0	0.45	0	
1	1.34	2	2
2	2.02	2	4
3	2.02	2	6
4	1.51	1	4
5	0.90	1	5
6	0.45	1	6
7	0.19		
> 7	0.12		
	9.00	9	27

Separate patterns were derived for each of the eleven replicates.

It was possible that, despite these attempts to obtain random and contagious patterns, the patterns derived may not have conformed to the desired type. For this reason it was thought necessary to test each pattern for randomness by means of the X^2 test of goodness of fit and by the Variance: mean ratio. The re=

sults of these tests for each of the plots is given below. The data for the tests was derived by dividing each plot into 25 square quadrats of equal size and counting the number of plants within each quadrat.

Pattern	X^2	P	D.F.	Variance: Mean	t	P	D.F.
Systematic	16.119	<0.01	3	0.352	2.245	<0.05	24
Random (1)	3.340	>0.30	3	0.641	1.244	>0.20	24
Random (2)	4.107	>0.10	2	0.844	0.541	>0.50	24
Random (3)	1.357	>0.70	3	0.757	0.842	>0.40	24
Random (4)	1.091	>0.50	2	0.743	0.891	>0.40	24
Random (5)	1.887	>0.50	3	0.757	0.842	>0.40	24
Random (6)	1.357	>0.70	3	0.757	0.842	>0.40	24
Random (7)	3.126	>0.50	4	1.335	1.161	>0.20	24
Random (8)	1.407	>0.30	2	0.641	1.244	>0.20	24
Random (9)	1.357	>0.70	3	0.757	0.842	>0.40	24
Random(10)	1.091	>0.50	2	0.743	0.891	>0.30	24
Random(11)	0.767	>0.80	3	0.901	0.343	>0.70	24
Contagious(1)	11.688	<0.05	5	1.856	6.431	<0.01	24
Contagious(2)	21.866	<0.001	5	2.493	5.173	<0.01	24
Contagious(3)	59.232	<0.001	5	3.506	8.683	<0.01	24
Contagious(4)	21.391	<0.001	5	2.262	4.373	<0.01	24
Contagious(5)	20.704	<0.001	5	2.203	4.168	<0.01	24
Contagious(6)	32.153	<0.001	5	2.319	4.570	<0.01	24
Contagious(7)	33.683	<0.001	5	2.203	4.168	<0.01	24
Contagious(8)	21.866	<0.001	5	2.493	5.173	<0.01	24
Contagious(9)	24.837	<0.001	5	2.146	3.971	<0.01	24
Contagious(10)	24.379	<0.001	5	2.088	3.770	<0.01	24
Contagious(11)	109.819	<0.001	5	4.056	10.589	<0.01	24

From these data it would appear that the models used were in fact systematic, random and contagious.

The experiment was conducted on the "Clovelly" block at the Tabamhlope Research Station. The treat= ments were laid out in a completely randomised design of three treatments with eleven replications. Because of the small area occupied by the experiment (12 ft 6 inches – 3.8 m – by 27 foot 6 inches – 8.4 m), it was thought that soil and other variations within the site would be insignificant, a factor which called for a completely randomised design rather than a block de= sign. The plots were laid out in three rows of eleven plots across the slope.

Thirty six living grass tufts of E. curvula (each of 4 sq in – 25.8 sq cm – basal area) were planted on each plot. When the tufts were well established, the pasture species were overseeded at the rates, and by the technique, described in a previous experiment (N-Ec 17/8).

Counts of the total number of clover plants on each plot were carried out six weeks after seeding (See N-Ec 17/9). The grass tufts on the plots were cut a month before seeding. At this stage the pattern did not appear to have much effect on their dry material yields (715 g, 730 g and 736 g dry material per plot was harvested respectively for the systematic, random and contagious distributions. These differences were not statistically significant).

Results and Discussion

Due to unseasonably hot weather after seeding many seedlings died before they were counted at six weeks after seeding. As in previous experiments the P. dilatatum established very poorly. It was apparent that the establishment in the third row of eleven plots was considerably better than in the other two rows. (An average of 95 plants become established on each plot in the third row compared with ten plants per plot in the first row and eleven in the second row). Consequently it was dicided to analyse the results from the third row separately. An analysis of the data on the basis of the geographic corrections proposed by Wellman, Thurston and Whaley (1948) was also conducted. The results of these analyses are presented in table 50.

Table 50.

The effect of pattern of grass tufts on the establish=ment of oversown clovers (Percentage establishment of de-transformed data).

Method of Analysis	Pattern			Coeffi=cient of Variation	F. value
	Systematic	Random	Contagious		
Blocks 1 & 2 Nor=mal (Transformed)	1.8%	1.3%	1.7%	35.62	< 1
Block 3 Normal (Transformed)	18.7%	18.5%	13.3%	21.03	< 1
Whole experiment: Geographically corrected as per Wellman et al (1948)(Tranformed)	6.8%	7.0%	3.9%	30.72	2.82 N.S.

N.S. = Not significant at P=0.05

The results of these analyses indicate that the density of 16% basal cover all resulted in a similar percentage establishment of oversown species. Other densities of cover, other subject species and other climatic conditions might produce different results.

3.5.3.1.5 The effect of canopy on establishment

The effect of grass canopy on the es= tablishment of oversown seeds was also investigated in two other experiments. These experiments which in= volved soil disturbance (N-Ec 17/3) and spraying with paraquat and nitrogen fertilization (N-Ec 17/1) are described more fully in sections 3.5.3.2.2, 3.5.3.3.3 and 3.5.3.4. In both experiments half the plots were mown a few weeks before overseeding while the other half of the plots were left with a dense canopy cover.

In the soil disturbance experiment the amount of canopy present at seeding did not affect the yield of the overseeded species. However, there was a statis= tically significant effect due to this factor in the other experiment. There was less clover present ($P \leq 0.01$), in the second and third cuts of the first season, on the plots which were not mown prior to seeding on this experiment. This difference was less marked during the second season. It is probable that the cultivation destroyed the effect of the canopy in the first experiment.

3.5.3.1.6 Discussion

It is apparent from this series of ex= periments that the physical presence of a grass cover affects the establishment of oversown seeds. The fol=

lowing points have become apparent:-

(a) a significant amount of oversown seed (up to 40%) is intercepted and retained by the leaves and crown of grass plants. Some of this seed reaches the ground at a later stage and may then germinate;

(b) the amount of seed intercepted depends on the species comprising the grassland sward, on the density of its canopy and on the type of seed sown;

(c) the density of the canopy cover of dead grass tufts influences the establishment of over=seeded clovers. This effect is caused by competition for growth factors other than plant nutrients, and is probably due to a balance between improved soil moisture con=ditions and declining light intensity;

(d) the two clover species used in these trials did not react in the same way when subjected to different densities of canopy cover.

Within the limits of the experiment, the percentage establishment of T. repens declined with an increase in the density of cover. On the other hand, the percentage establishment of T. pratense increased with an increase in density of the canopy, up to a certain point then dropped very sharply;

(e) the results obtained from living grass tufts were similar to those obtained from dead tufts;

(f) at this early stage of establishment the balan=ce between the advantages of canopy for pro=

tection from the elements, and its disadvan= tage of reduced light intensity appear to be delicately balanced;

(g) the pattern or arrangement of E. curvula tufts at 16% basal cover did not affect the density of the canopy, nor did it affect the early establishment of oversown clover seed. Bearing in mind that one experiment (N-Ec 17/8) indicated that this type of cover (16% basal cover of E. curvula) appears to be close to the optimum for establishment, it is probable that the pattern may affect establishment under other conditions (e.g. basal cover, species, climate);

(h) In the dense cover of undistrubed Highland Sourveld the removal of some of the canopy by mowing benefits the early establishment of oversown legumes.

The practical implications of these results are far reaching. Firstly, it appears that the use of herbicides alone on a dense grassland cover, even when the grasses are all killed, may not always provide a satisfactory "seed-bed" for oversowing. Delaying seeding until the canopy collapses does not appear to be the answer, by the time this material has reached the ground weeds will have taken over and will provide severe competition. Secondly, it is also apparent that the complete removal of all vegetative cover does not necessarily provide the optimum condition for the establishment of overseeded species. On the other hand, some manipulation of the existing cover is neces= sary. The ideal balance between competition and pro=

tection probably differs depending on: the grassland cover, the climatic conditions after seeding and the species seeded. It would appear that a few simple experiments, directed at determining the optimum ba= lance between these two factors (competition and pro= tection), in each area where overseeding is contemplated would form a sound basis for more applied research. This series of projects should be followed by more de= tailed investigations of the specific attributes of competition and protection.

3.5.3.2 Minimum tillage as a method of seedbed prepa= ration

Having investigated some of the more ba= sic aspects of the effects of competition, on the es= tablishment of oversown species for grassland improve= ment, the following step in the research programme was to test out the efficiency of a variety of techniques in reducing this competition and in improving the es= tablishment of seedlings. One of these techniques is that of partially eliminating the existing sward with tillage implements.

The conventional method of eliminating the old sward and getting the seed into contact with the soil is to plough the soil and prepare a seed-bed. How= ever, large areas of land exist which are too steep, too stony or too wet for the use of these conventional methods (Charles, 1962). Agababjan (1960) states that the improvement of grassland by ploughing is usually best done in the plains, but even on slopes in hilly regions it is found that ploughing once provides a good chance of establishing a good meadow. Areas where the danger of erosion is greatest are avoided in Armenia.

Tillage implements which are less drastic than the plough have also been used. Sprague, Robinson & Clyde (1947) state that extensive and timely discing is ef= fective, but difficult, dangerous and costly. Surface tillage provides a mulch which reduces soil erosion and, when sufficiently intense, kills the vegetatively re= productive parts of plants by desiccation. Tillage alone has often been ineffective because discings have been insufficient to kill the old sward; regrowth has inhibited seedling development and re-seeded pastures have reverted to their former botanical composition within only 1 or 2 years (Ahlgren, Wall, Muckerhirn & Burcalow, 1944).

Recently developed machines introduce the seed and fertilizer direct into the turf. These sod-seeders have been used extensively in Australia (Breakwell, 1957; Mead, 1960; Shroder, 1961), New Zealand (Cross & Glendag, 1957; Robinson & Cross, 1960) England (Gardner, 1961) and N. America (Hulbert, 1959). Gardner (1961), how= ever, pointed out that it is necessary to remove a wider furrow on a dense grass sward than on a more open sward. Mead (1960) found difficulty introducing legumes into actively growing grass swards, when the normal narrow-cut sod-seeder was used. He obtained the best results with a 5 inch (12.7 cm) cut and a 9 inch (22.9 cm) pas= ture width. Krog, Theron and Andrews (1969) designed, manufactured and used with success a seeder incorpora= ting 6", 12" or 18" (15, 30 or 45 cm) sweeps which also allowed for the placement of both seed and fertilizer. O'Brien (1968), on short grass pastures in Australia, found a "Roto-seeder", which rotavates a strip and mixes the seed, soil and fertilizer, very effective. Jones and Davies (1962) found only a slight improve= ment when oversowing was followed by cultivation. Only drastic treatments such as rotary cultivation seemed to give satisfactory establishment.

In the Highland sourveld at Tabamhlope, Fisher (1963) successfully established pastures with tillage of the veld. The tillage was light consisting of disc= ing and ripping to a depth of 2-3" followed by seeding and rolling. The pastures established were of a more or less permanent nature provided fertilization and management were of a high order. These pastures out= yielded the natural grassland 4 to 5 times. Shallow working was necessary to avoid mixing the infertile and inert subsoil with the thin layer of fertile top soil, which is rich in or ganic matter. This method has more recently been used to establish improved pastures on slopes of up to 15%. The only visible soil erosion was caused by the discharge from a road drain which passed through the established area. Within two months of establishment the seeded pasture probably provides as good protection against soil erosion as does the natural grassland.

Although the technique which is described above removes all the natural grassland there is good reason to believe that, in the Highland sourveld, such exten= sive cultivation is not necessary. A trial in which an attempt was made to introduce legumes into the veld was started at Tabamhlope in 1956 (Edwards, 1957). Without cultivation plant strike was poor and most of these plants failed to become established. With disc= ing of the veld lightly, with the discs in the open position, an excellent establishment of legumes was obtained. These legumes persisted and yielded well for as long as they were managed. The nature of the discing was such that rows of undamaged veld remained after discing. The extent of protection against soil erosion was considerably greater than on more intensive= ly worked areas.

3.5.3.2.1 The effect of soil micro-topography on early establishment

The use of tillage implements in the preparation of a seed bed for the establishment of oversown seeds has the dual effect of reducing the grass competition and of disturbing the soil surface. The disturbance of the soil surface results in micro-topographical changes in the soil surface which might prove to be of significance in the establishment of overseeded species. A knowledge of the nature of this change in the soil surface and of its significance, might be of value in the selection or design of imple= ments for this purpose. Thus a larger experiment in which herbage yields were measured (see section 3.5.3.2.2) was accompanied by a small one, in which the effects of various tillage implements on micro-topography and seedling establishment were measured.

Objective

The object of this experiment was to investigate the effect of soil disturbance caused by tillage im= plements on the germination of over-seeded pasture species.

Procedure.

The experiment was carried out on the "Clovelly" experimental block at the Tabamhlope Research Station. The experiment consisted of six treatments in a ran= domised block design with four replicates. The treat= ments which are given in table 45 are similar to those used in a second, larger scale experiment (3.5.3.2.2) in this series. The treatments were applied in Janu= ary 1968, after which over-seeding was carried out as described in section 3.5.3.1.2 of this chapter. The two treatments on which the grass was burnt were in= cluded in an attempt to remove the influence of the grass canopy on the micro-topography. Burning was carried out, before the soil disturbance, by means of a paraffin fueled flame thrower.

The micro-topography was measured by me ns of the equipment designed by Harper _et al_ (1965) for this pur= pose. The equipment consisted of a "frame holding a line of ten pins arranged so that they were free to move vertically. The tips of the pins were fitted with pointers which rested against a graph paper scale. The frame was lowered horizontally on the soil surface un= til the points of all the pins rested on soil. Readings were

then taken of the heights of the pointers. Three such sets of ten readings were taken from each pot of soil." (Harper _et al_, 1965). It is essential to hold the frame horizontal when readings are taken and for this purpose the frame was fitted with a level bubble. The frame constructed for use in this experiment was the length of the net plot (i.e. 20" – 50.8 cm– and twenty holes were spaced at equal distances apart (1" – 2.54 cm –) over its length. It was found that the points of the rods used tended to sink into the soil. This was overcome by rivetting a small plate ($\frac{1}{4}$ x $\frac{1}{4}$" – 0.6 x 0.6 cm–) to the tip of each rod. The plot was divided into twenty imaginary rectangles of 1" x 20" (2.5 x 50.8 cm). Ten of these rectangles were selected at random on each plot, as sites for pla= cing the frame. At each placing of the frame ten of the twenty holes were selected, at random, to provide positions for the insertion of pins to measure soil micro-topography. This provided one hundred measure= ments per plot.
The division of the plot into 1" x 20" rectangles was done at right-angles to the direction of working of the implements used for soil disturbance. This was done in order to avoid any possibility of this strati= fication being in phase or in rhythm with the spacing of the tines, discs or rollers of the implements.

The reason for the randomised arrangement of points, as opposed to Harper _et al_ (1965) systematic arrangement, is twofold:

(a) It was intended to test the results obtained from this project for significant differences.

(b) Due to the nature of the implements used to con= struct the soil micro-topography the possibility of rhythms in topography existed. This was over= come by randomisation.

Neither of these factors applied in the experi= ment conducted by Harper _et al_ (1965). The micro-topographical data was collected from each plot. The data was treated as suggested by Harper _et al_ (1965): "The absolute values obtained from such readings have no very useful meaning but the variance of the values gives a measure of soil micro-topography. This parameter may be called 'soil micro-topographical variance' (S.M. - T.V.). The values for the S.M. - T.V. represent the error variance in an analysis of variance of pointer readings, after partitioning and removing the variance due to differences between re= plicate plots and due to differences between the "three" (ten) positions of the aligned pins in each plot. Determination of the S.M. - T.V. in this way makes it irrelevant whether or not the apparatus is held at the same height for every set of ten readings, and makes this measurement possible in a field operation." Thus a single micro-topographical variance figure was ob= tained for each plot. These data were then analysed to evaluate treatment effects on S.M.-T.V.

The number of clover seedlings on the plots was counted six weeks after seeding. No _P. dilatatum_ plants were visible at this stage, and no attempt was made to distinguish between the two clover species.

The soil micro-topographical variance data (presented in table 51) indicate that rotavation results in a smoother seedbed than do any of the other treatments. The two treatments which were rotavated had a significantly lower ($P<0.01$) soil micro-topographical variance than did any of the other four treatments. There were no other significant differences between treatments.

Observations, made during the establishment counts, indicated that better establishment was obtained where herbage material remained on the soil surface.

The results of this experiment have shown that the implements used, and consequently the soil surface condition, in preparing a seed-bed for oversown clover seed has a marked influence on the establishment of the clover. The average establishment on five treatments was 32.82% (23.16% to 38.17%) compared with 79.09% on the treatment that was tilled. These results can not satisfactorily be explained in terms of soil micro-topographical variance only. Discing after tilling and/or burning before tilling had little effect on the m icro-topography but, produced a marked decline in the establishment (See treatments (3) to (6)). It would appear that the amount of herbage on the soil surface, living or dead, also played a role - the more herbage the better the establishment.

3.5.3.2.2 The effect of soil distrubance on the establishment of overseeded species (N-Ec 17/3)

The acid test for any method of grassland improvement is the extent of production increases resulting from the application of the technique. Thus it was necessary to evaluate the minimum tillage techniques in terms of this parameter.

Objective

The object of this experiment was to determine the effect of different degrees of soil disturbance on the establishment of overseeded pasture species. The effect of two seeding rates and two amounts of canopy cover was also investigated.

Procedure

The experiment was started in 1966 on the "Clovelly" block at the Tabamhlope Research Station. The experiment consisted of five whole-plot treatments in a randomised block design, with four sub-plots per whole-plot in a 2 x 2 factorial lay out. The design was not confounded and comprised four replications. The treatments were as follows:

Five soil disturbance treatments (whole plot treatments):

(1) disced once with the discs in an open position;
(2) disced as above and then tilled with a "soilmaster" (A tined implement with heavy tines set ten inches apart)"
(3) six-inch (15 cm) strips rotavated with twelve inch (30 cm) undisturbed strips between these;
(4) thirty-inch (76 cm) strips rotavated with

twelve inch (30 cm) undisturbed strips be= tween these;

(5) the whole area of the plot rotavated and rolled after seeding.

The two amounts of canopy cover and the two seed= ing rates provided the sub-plot treatments (2 x 2):

(1) unmown veld seeded at the low seeding rate;
(2) unmown veld seeded at the high seeding rate;
(3) veld mown before seeding at the low rate;
(4) veld mown before seeding at the high rate.

The low seeding rate was 100 lb (45.4 kg) P. dila= tatum + 6 lb (2.7 kg) T. repens (Ladino) + 12 lb (5.4 kg) T. pratense (Kenland) per morgen. The high seed= ing rate was double these amounts. The high seeding rate was applied to compensate for the anticipated loss of seedlings due to unfavourable seed-bed condi= tions.

The veld on which the treatments were applied was good quality Highland Sourveld which had been mown in August 1965, and was not utilized from then until the treatments were applied in January 1966. The treat= ments were carried out in the following sequence: mowing, soil disturbance and then seeding. Due to a poor establishment of P. dilatatum the plots were reseeded with this species in the spring of 1967 with= out any further soil distrubance.

Each time the herbage on the most advanced plots reached a height of about six inches, the plots were

Table 52

Soil disturbance experiment : Dry Material Yields Ton/m

(1 ton/morgen = 1059 kg/ha; 1 inch (") = 2.54 cm)

Treatment	1966/67 Cut 1				1966/67 Cuts 2 + 3				1966/67 Total (3 cuts)				1967/8 Total (3 cuts)			
	Clover	Paspalum	Residue	Total	Clover	Paspalum	Residue	Total	Clover	Paspalum	Residue	Total	Clover	Paspalum	Residue	Total
Soil Disturbance																
Disc.	0.108	0.012	3.597	3.719	0.289	0.048	1.406	1.743	0.399	0.060	5.003	5.460	0.418	0.262	2.643	3.323
Disc. & Till	0.241	0.017	2.737	2.996	0.457	0.099	0.822	1.378	0.698	0.115	3.559	4.372	0.337	0.527	1.374	2.238
Rotavate - 6" width	0.023	0.000	4.459	4.482	0.198	0.040	1.484	1.722	0.222	0.040	5.943	6.203	0.510	0.085	2.550	3.145
Rotavate - 30" width	0.198	0.016	3.437	3.651	0.351	0.085	1.038	1.475	0.550	0.101	4.474	5.123	0.416	0.421	1.905	2.742
Fine seed bed.	0.437	0.046	1.600	2.083	0.744	0.206	0.442	1.392	1.181	0.252	2.042	3.473	0.370	1.135	1.158	2.663
Mean	0.201	0.018	0.317	3.394	0.408	0.096	1.038	1.542	0.610	0.114	4.204	4.926	0.410	0.486	1.926	2.822
L.S.D. P = 0.05	0.281	-	0.943	0.885	0.354	0.121	0.217	N.S.	0.452	N.S.	0.894	0.722	N.S.	0.374	0.652	N.S.
P = 0.01	0.394	-	1.322	1.241	0.496	0.172	0.304		0.633		1.253	1.013		0.524	0.914	
Seeding Rate																
Low	0.161	0.023	3.286	3.469	0.335	0.077	1.094	1.505	0.496	0.100	4.379	4.973	0.418	0.485	2.024	2.926
High	0.242	0.014	3.046	3.302	0.481	0.114	0.983	1.578	0.724	0.128	4.029	4.880	0.403	0.488	1.828	2.718
L.S.D. P = 0.05	N.S.	-	N.S.	N.S.	0.083	0.033	0.107	N.S.	0.151	N.S.	0.270	N.S.	N.S.	N.S.	0.185	0.200
P = 0.01		-			0.109	0.045	0.143		0.201		0.361				0.247	0.267
Condition of veld at seeding																
Unmown	0.162	0.014	40.51	4.226	0.287	0.091	1.107	1.486	0.449	0.106	5.159	5.711	0.386	0.462	2.025	2.873
Mown	0.241	0.022	22.80	2.544	0.529	0.100	0.969	1.598	0.771	0.122	3.249	4.137	0.439	0.510	1.827	2.772
L.S.D. P = 0.05	N.S.	-	0.252	0.236	0.083	N.S.	0.107	N.S.	0.151	N.S.	0.270	0.253	N.S.	N.S.	0.185	N.S.
P = 0.01		-	0.336	0.316	0.109		0.143		0.201		0.361	0.338			0.247	
C of Variation %	96.741	-	17.66	15.48	44.61	77.42	22.86	17.20	54.87	79.47	14.28	11.39	40.21	42.51	21.35	15.71
Significant interactions	Nil	-	D.C.	D.C.	Nil	CDS	Nil	Nil	Nil	C.D. CDS	C.S. C.D.	C.S. C.D.	Nil	Nil	Nil	Nil

mown by the strip method (section 3.3.2) and the dry matter yields recorded. Samples were also taken for botanical separation into P. dilatatum, clover and "residue" fractions. Yields are available for the first two productive seasons of the experiment, (1966-67 and 1967-68) during which the rainfall was well below the average. The yields of the first cut taken in 1966-67 reflect the influence of the mowing treatment in the "residue" yields, and have thus been separated.

Results and Discussion

The yields obtained from this experiment during the first two seasons are given in table 52.

The influence of the soil disturbance treatments was only apparent in the total yield (P. dilatatum + clover + residue), during the first cut of the first season. At this stage the complete seed-bed preparation produced significantly less herbage than did all other treatments, while the treatment which was disced and tilled produced less than did the two treatments in which strips were rotavated. In fact, yields at this stage were in a negative relationship to the severity of the soil disturbance treatments. These effects were also reflected in the total yield for the first season where the six-inch rotavated strips produced the highest yields.

The yield of clover varied significantly, as a result of the soil distrubance treatments, at all the cuts in the first season, but in the second season there were no differences due to these treatments. In the first cut, and in the total of all cuts during the first season, more clover herbage was harvested from the fine seedbed than from any of the other soil dis= turbance treatments. In the combined second and third cuts, this treatment also yielded significantly more ($P \leq 0.05$) clover herbage than did any of the other treat= ments except that which was disced and tilled. The total yield of clover during the first season, was greater on the plots which were disced and tilled than on those in which a narrow (six inch) strip was rotava= ted. The clover yields appear to bear a positive re= lationship to the severity of the soil disturbance treatments during the first season.

Significantly more _P. dilatatum_ herbage was harves= ted, during the second and third cuts of the first sea= son, from the plots of the complete seed bed than from all the other soil disturbance treatments except the one which was disced and tilled. The complete seed bed also yielded more _P. dilatatum_ herbage than did the other soil disturbance treatments during the second season. During the second season the treatment which was disced and tilled yielded more _P. dilatatum_ herbage than did the treatment in which six inch strips were rotavated. The more severe soil disturbance treat= ments appeared to be most suitable for the establishment of _P. dilatatum_.

The "residue" herbage comprised chiefly veld gras= ses, except on the complete seed-bed where annual "lands grasses" and dicotyledonous weeds made up the bulk of this separate. Throughout the first season there was less herbage in this category on the complete seed-bed than on any of the other soil disturbance treatments. This effect continued during the second season except that then there was no difference between this treat= ment and the disced and tilled plots. On the plots with incomplete soil disturbance, the "residue" was generally greatest on the six inch rotavator strips and least on the disced and tilled plots.

It is apparent from these results that, where prac= tical, the complete preparation of a seed-bed produces the best results. (This treatment yielded, on the average, 75% more herbage of the seeded species than did the next best treatment.) Discing and tilling resulted in a yield, of sown species, of 96% greater than did the lowest yielding soil disturbance treatment (6" rotavated strips). The 30" rotavator strips and the disced plots yielded, 74% and 33% respectively, more herbage of seeded species than did the poorest treatment. Discing and tilling can be recommended in situations where complete soil disturbance is not advisable. However, relatively wide rotavator strips (30") with undisturbed strips between which can be ro= tavated once the first strips are established may pro= vide good results.

The seeding rates had no effect on the yields ob= tained at the first cut. Subsequently, however, the amount of "residue" herbage was suppressed significantly by the high seeding rate when compared with the lower rate. In the second and third cuts of the first sea= son, there was more P. dilatatum and clover herbage at the high seeding rate. This difference was not appa= rent during the second season. It is apparent that much of the benefit obtained from the high seeding rate was confined to the first season, and doubt must exist as to the value of this treatment.

The effect of the mown treatment, as might be expected, was apparent in the "residue" and total herbage yield of the first cut. However, it was also evident in later harvests. In the second and third cuts, of the first season, the yield of clover was greater on the plots which had been mown than on the unmown ones. This effect was also apparent during the second year although the differences did not reach statistical significance. Throughout the two year period the mowing treatment depressed the yield of "residue" material. The mowing of the veld prior to overseeding was of general benefit to the establishment of the pasture, and due to the value of the veld hay at this stage can be recommended with confidence.

In several instances various interactions were significant. These effects are discussed briefly below:

(1) In the first cut and in the total yield for 1966-67, mowing of the veld prior to seeding, reduced the yield of all the soil disturbance treatments except on the complete seed-bed. This reflects the destruction of the cover during the preparation of the complete seed-bed.

(2) The "residue" yield, in the first year, was higher at the low seeding rate than at the high seeding rate on unmown veld, but on mown veld there was no difference between the two seeding rates.

(3) During the first year, the yield of *P. dilatatum* was not affected by mowing on the disced and tilled and two rotavator treatments. However, mowing depressed the yield of this grass on the complete seed-bed and increased its yield on the disced treatment. This may be due to the reduction of competition on the lightly disturbed disced plots and due to a less satisfactory seed-bed tilth (due to the reduced organic material) on the complete seed-bed.

When the treatments were not mown the complete seed-bed produced greater yields of *P. dilatatum* than did all other treatments, but when mown it outyielded only the disced treatment and the six inch rotavator strips.

(4) In the first season, the *P. dilatatum* on the complete seed-bed outyielded that on the disced and tilled and the 30 inch rotavator strips when the plots were mown prior to seeding. However, when the plots were not mown there was no difference between the three treatments. On the complete seed-bed the yield of *P. dilatatum* was greater at the high seeding rate than at the low seeding rate where the plots were not mown at seeding. However, when the plots were mown there was no difference due to the seeding rate on this soil disturbance treatment. The yield of *P. dilatatum* on the disced and tilled treatment was greater at the high seeding rate, than at the low when the plots were mown prior to seeding. However, on the unmown plots th

no difference between the seeding rates on this treatment.

3.5.3.2.3 The application of the method

There are obvious limitations to the use of minimum-tillage methods for the establishment of overseeded pastures, which are frequently ignored. In the first place it appears to be a half-hearted way of attacking the problem on relatively flat land, where complete replacement and seeding by conventional methods are called for. On such sites, due to the competition of low potential, indigenous species, the yields ob= tained can be expected to be lower from these methods than where complete seed beds and conventional seeding is applied. At the other end of the slope (topography) scale there are physical limitations to the use of con= ventional traction implements. (I have seen very steep slopes worked by heavy crawler tractors in Australia, but it is doubtful wether this practice is profitable.) Stones and vleis are also obstacles in the use of these implements.

The potential use of such minimum tillage techni= ques for pasture establishment is clearly definable. The suggested limits are between 5 and 15% slopes, al= though these figures should be modified bringing into consideration such factors as the erodibility of the soil and the hydrolic pattern of the surrounds. The land which falls into this category frequently has a high grassland potential and is of considerable economic importance. It is estimated that about 30% of the area of the Highland sourveld falls into this category;

a factor which justifies more research into this aspect.

Sod-seeding, a method of minimum tillage, was not investigated in these experiments. This expensive im= plement (a sod-seeder) was not used because none were available. However, it is suggested that this imple= ment, which was designed to introduce an extra compo= nent (often clover) into good quality swards, would have proved rather ineffective in the veld. The com= petition from the veld grasses would probably have supressed the sown seedlings - this is supported by the relatively poor results obtained from the six inch strips which were rotavated.

3.5.3.3 Herbicides as a means of seed bed preparation

Herbicides offer a means of preparing seed-beds, favourable to the establishment of overseed= ed pastures, on areas which are inaccessible to imple= ments. In such areas hand spraying on small areas, or air spraying on a larger scale may be practicable.

Charles (1962) states that the use of herbicides is one of the major recent lines of advance to offer possibilities for extensive use of surface sowing. Paraquat (1.1 dimethyl - 1, 4, 4, - bipyridilium cation) is one of the herbicides which has been used extensively in such conditions.

Uses of Paraquat

Paraquat is used to control a wide range of grass species and broad-leaved plants (Anon, 1961; Robson & Proctor, 1963; Blackmore, 1964; Mathews, 1964). More specifically it has been used for the following pur= poses:

(a) to suppress grass in grass-clover pastures (Jones, 1962; Blackmore, 1964),

(b) for the control of aquatic weeds including sed= ges (Mathews, 1963; Robson & Proctor, 1963),

(c) pre-crop emergence weed killer (Robson & Proctor, 1963),

(d) desiccation of crops before harvest to ripen seed (Mathews, 1964), and

(e) in suppression or killing of existing pastures to provide opportunities for reseeded species to become established.

It is on this latter use of paraquat that this re= view will concentrate.

<u>The properties of Paraquat</u>

Paraquat has several properties which set it ahead of other herbicides for use in the preparation of swards for surface seeding. These properties are:

(a) Paraquat is non-explosive (Anon, 1961).

(b) Paraquat is non-inflammable (Anon, 1961); Mathews, 1964).

(c) Paraquat has a low mammalian toxicity at normal rates of application (Robson & Proctor, 1963; Mathews, 1964), but it is not recommended for direct application on edible crops (Mathews, (1964).

(d) Paraquat is non-volatile (Anon, 1961; Mathews, (1964).

(e) Paraquat is soluble in water and the solution is stable under normal conditions. It is however, unstable under alkaline conditions, (Anon, 1961; Robson & Proctor, 1963; Mathews, 1964).

(f) Only non-ionic or cationic wetting agents should be used with paraquat (Anon, 1961; Blackmore, 1964; Mathews, 1964).

(g) Paraquat is inactivated on contact with the soil. When it comes in contact with the soil it is ad= sorbed on the clay particles and thus made inac= tive and unavailable to plants (Anon, 1961). It therefore has almost no residual activity in the soil (Anon, 1961; A; Jones & Davies, 1962; Robson & Proctor, 1963; Mathews, 1964, Blackmore, 1964), although on extremely sandy soils with a low absorption capacity it may remain available for two to three days following application (Anon, A). Results obtained by Warboys and Ledson (1965) indicate that, in the presence of a grass mulch, the rate of emergence and growth of grass seeds might be restricted for as long as fourteen days after the application of paraquat sprays. This general lack of residual activity means that no toxic build-up is possible with repeated appli= cation (Robson & Proctor, 1963) and is most im= portant in that it allows seeding and fertilization on the same day as spraying is done (Robson & Proc= tor, 1963; Mathews, 1964; Blackmore, 1964). The seed can be sown as soon as the spray has dried off but lime, if applied at the time of spraying completely nullifies the effect of paraquat (Blackmore, 1964).

(h) Paraquat is less affected by rain after application than many other sprays (Anon, 1961; A; Robson & Proctor, 1963; Blackmore, 1964), and Mathews (1964) found the kill unaffected by rain 1-2 hours after spraying.

(i) Paraquat is rapidly adsorbed by plants (Anon, 1961; Blackmore, 1964) and may be translocated to some extent (Anon, 1961; Robson & Proctor, 1963; Mathews 1964). It has rapid action on aerial parts of plants especially grass (Anon, 1961).

(j) Paraquat is safe to use when woody stemmed plants are around (Mathews, 1964), if their bark is brown (Robson & Proctor, 1963).

<u>Herbicidal activity of Paraquat</u>

Paraquat is absorbed rapidly and is translocated to some extent (Anon, 1961; Robson & Proctor, 1963; Mathews, 1964). It interferes with the photosynthetic process so that the green aerial parts are desiccated and killed (Robson & Proctor, 1963). There is a rapid kill of the aerial parts (Anon, A). Too sudden death of the aerial parts may inhibit chemical movement within the plant and regrowth follows soon after treatment (Anon, 1961; Mathews, 1964). Mathews (1964) and Robson & Proctor (1963) therefore suggest the use of the minimum lethal dose as paraquat is translocated in the plant to at least ground level. The phytocidal action does not normally extend below soil level (Anon, 1961).

Regrowth may occur in perennial plants with large underground storage organs or in perennial plants which can regrow from underground rooting systems (Anon, A). Germinating seedlings, buried seed and bulbs are not affected before emergence, as there is no lateral movement in the soil of paraquat because it is inactivated on contact with the soil (Robson & Proctor, 1963; Mathews, 1964).

Rates of application of Paraquat

Paraquat has been used with success at rates of between ¼ lb and 4 lbs (0.1 to 1.8 kg) active ingredient per acre (0.4 ha) (Anon, 1961; A; Jones, 1961; Jones & Davies, 1962; Thompson, 1962; Robson & Proctor, 1963; Mathews, 1963; 1964; Blackmore, 1964). It is generally used at the low rates as a selective weedicide in reseeding of existing pastures in which it is not desired to kill all the component species (Blackmore, 1964). The higher rates, over ¾ lb/ac (¾ kg/ha) are generally used in preparing areas for the replacement of pastures by over-seeding.

There are indications of varying susceptibility among grass species to paraquat sprays. However, as nearly all the species mentioned in the literature do not occur in natural Highland sourveld, there is no point in discussing this aspect. Rhizomatous grasses and Paspalum dilatatum (Thompson, 1962) are generally fairly resistant to paraquat.

The amount of water used to dilute the spray varies from 12 gallons (55 litre) (Blackmore, 1964) to 100 gallons (455 litre) (Anon, A; 1961; 1962) per acre.

Non-ionic spreaders are added in many instances (Anon, 1961, 1962; Blackmore, 1964; Mathews, 1964).

Method of application of Paraquat

Robson & Proctor (1963) state that paraquat can be applied through all conventional types of spray machinery. Mistblowers are not recommended, however, because of the dangers of inhalation and eye irritation unless a mask is worn. A knapsack sprayer may be used to avoid these effects (Anon, 1963b).

The spray boom should be set about 21 inches (53 cm) above the grass (Anon, A). It is important to ensure that all jets are working (Anon, A) in order that the area should be sprayed evenly - uneven spraying gives patchy results. The minimum effective rates of chemicals cannot be exploited unless the spray pattern is even (Blackmore, 1964). Spray drift should be avoided (Blackmore, 1964).

Effect of the time of the year of spraying and conditions of the sward on the "kill" when using paraquat

The time of the year when herbage is sprayed with paraquat is, in practice, generally determined by the time of the year which is most suitable for the establishment of the oversown species. Provided they are still green, many grasses tend to be most susceptible in late autumn (Anon, A), Mathews (1963) and Robson & Proctor (1963) suggest spraying in late autumn when immediate overseeding is not necessary as the onset of winter hinders the recovery of *Paspalum*, and perennial rhizomatous and bulbous species. The timing of the spraying operation, however, generally depends on the latest date for sowing seeds (Anon, A) i.e. as early as is possible in autumn while the soil is still warm enough for a quick strike of sown seed (Blackmore, 1964) and when there is little risk of drought for the new seedlings (Anon, 1962; A).

The toxicity of paraquat may vary according to: (1) the type of grass, (2) the stage of growth and (3) the rate of growth. The latter two factors can be controlled by management (Fryer & Chancellor, 1958). Paraquat acts more effectively when plants are green, i.e. when photosynthesis is taking place. (Foreman, 1956; Anon, 1962; A). Paraquat is less effective in a rank overgrown sward (Anon, A; Blackmore, 1964). It does not translocate readily and its efficiency is greatest when the pasture is short (Blackmore, 1964). In fact Foreman (1956) states that it is unable to be translocated at all in dead or mature herbage.

The sward is apparently ideal for the application of paraquat at a height of about three inches (Anon, 1962; A). The pasture should be mown or grazed some time before spraying to encourage the development of maximum leaf numbers and area, to ensure good spray in= terception (Anon, 1962; Blackmore, 1964). The ideal quantity of leaf growth might be achieved by burning, cutting or grazing (Anon, A).

If the sward is too long the amount of trash might interfere with broadcast seed, reaching the soil (Anon, A). A further disadvantage of the dead herbage is the consequent damage that can be caused to young seedlings by pests, particularly slugs, once the main source of their feed has been destroyed (Blackmore, 1957; Mathews, 1959). On the other hand the dead herbage maintains a favourable microclimate, moisture is retained and shelter is provided from cold winds for the seedlings. Soil erosion is greatly reduced, the surface layer is more fertile and the number of weed seeds which germi= nate is practically nil (Blackmore, 1957; Simpson, 1959).

Effect of climatic conditions at time of spraying on efficiency of paraquat

Under bright sunlight paraquat is quick acting and translocation possibilities are lower (Robson & Proctor, 1963; Mathews, 1964). For the herbicidal effect it is best used in dull weather, towards evening when most downward translocation occurs within the plant (Anon, 1962; Robson & Proctor, 1963; Mathews, 1964). Rain falling shortly after application (1 to 2 hours) does not reduce the effectiveness of paraquat (Robson & Proctor, 1963; Mathews, 1964).

These characteristics of paraquat, in particular the weak residual effect, make it ideally suited for the establishment of overseeded pastures. The absence of a residual effect allows for seeding very soon after the application of the herbicide. This is a very im= portant advantage as it allows maximum utilization of favourable soil moisture conditions. It also allows the full utilization of the competition free period (i.e. after scorching the existing herbage but before regrowth and weed establishment) for the establishment of the seedlings.

Hardly any work on the use of this herbicide had, at this stage, been undertaken in the Republic. Con= sequently it was decided to investigate its effect on the grasses of the Highland sourveld, a region with a large area of high rainfall but very steep slopes. In the first trial the effect of paraquat on the early establishment of pasture species was investigated. In a second trial the effect of paraquat on a number of common Highland sourveld grass species was measured, while the third trial was conducted to determine the effect of spraying veld with paraquat, on the establish= ment of oversown pasture species. Subsequently two further trials, in a glass house at Potchefstroom, were carried out in an attempt to provide further information on the herbicidal action of paraquat.

More recent information (Edwards, 1968) together with the results of the previous experiments suggests that the effects of paraquat are barely severe enough for satisfactory seed bed preparation. This infor= mation also suggests that Dalopon (2, 2 - dichloropro= pionic acid) produces a better kill of grasses, and that the residual effect of this herbicide is consider= ably less than was originally supposed (4-8 weeks in= stead of three to six months). As a result two preli= minary trials were initiated, in a glass house, to ob= tain some information on this herbicide.

3.5.3.3.1 The residual effect of paraquat on germina= ting seeds (N-Ec 17/4)

Paraquat is inactivated on contact with the soil and is then unavailable to plants (Anon, 1961). It therefore has almost no residual activity in the soil

(Anon, 1961, Jones & Davies, 1962; Robson & Proctor, 1963; Matthews, 1964; Blackmore, 1964), although on extremely sandy soils with a low absorption capacity it may remain available for two or three days following application (Anon, A). This lack of residual acti= vity means that no toxic buildup is possible with re= peated application (Robson & Proctor, 1963) and is most important in that it allows seeding and fertilization on the same day as spraying is done (Robson & Proctor, 1963; Matthews, 1964).

"The successful establishment of sown species in a chemically killed tuft depends on the time interval between spraying and sowing. The herbicidal activity on a pasture has been phased as follows: the period of direct action by the chemical; the period when the chemical is present only as a toxic residue; and the period when the herbicide no longer directly influences the sward (Elliot, 1960). Seeds should be sown so as to germinate at the end of the second phase. Sow= ing earlier carries the risk of damage from herbicide residues in the soil; sowing later however, subjects the seedlings to strong competition from germinating and recovering plants. The duration of the second phase varies (Davies & Jones, 1963). For paraquat, the last phase follows the first as the chemical has no residual activity being adsorbed on contact with the soil.

However, Hammerton & Johnson (1962) have reported residual activity of paraquat on the soil in a sod-seeding experiment. Warboys & Ledson (1965) undertook a trial in which they demonstrated that herbage cut from grass sprayed 7 days previously with paraquat re= stricted the germination and growth of barley, rape and perennial ryegrass when it was used as a seedling mulch. They suggest that the "Disappointing results" of re= sowing in the past, where soil disturbance was minimal, could be attributed partly to this residual activity. In the experiment conducted by Warboys and Ledson (1965) 1½ inches (3.8 cm) of "mulch" was spread over the seeds. This thich mat of herbage may be consider= ably in excess of that encountered by seedlings when oversown on paraquat treated swards. The normally re= commended pretreatment of swards, which are to be spray= ed with paraquat, is the removal of overgrown rank her= bage by mowing or by fire and the spraying of young vigorously growing leaf (Anon, A).

Warboys and Ledson (1965) suggest, from the evi= dence available to them, that this short term residual effect of paraquat is unaffected by rainfall. This assumption is, however, not based on direct experimental comparisons.

The existence of such a residual effect and its duration are important considerations in the over= sowing of pasture species on sprayed swards. As the nature and duration of this effect may be related to the sprayed species and to the soil type, it was con= sidered necessary to investigate this matter.

Objective

The object of this experiment was to determine effect and duration of the residual action (if any) of paraquat, and the effect of simulated rainfall on this effect, on the germination and early growth of oversown pasture species.

Procedure

The experiment was conducted at the Estcourt Research Station during 1967. Thirty wooden boxes with internal dimensions of 30 inches by 30 inches (76 x 76 cm) and eight inches deep were used. The boxes were filled with topsoil of the Clovelly soil series obtained from Tabamhlope Research Station, and after watering 36 tufts of E. curvula were planted in each box. The tufts (circular in shape and with a diameter of 2.256 inches - 5.7 cm) were obtained from this same soil type at Tabamhlope Research station and were spraced at five inch centres. Planting was car= ried out in spring and the plants were watered when= ever necessary.

By February 1967 the plants had become well es= tablished and the treatments were commenced. The treatments were applied in a 5 x 2 factorial design with three replications. The plants were sprayed with paraquat at five different times, before and after seed= ing, and each of these treatments was compared with and without simulated rainfall.

The times of spraying were:

(1) *E. curvula* sprayed two days after seeding;

(2) *E. curvula* sprayed two days before seeding;

(3) *E. curvula* sprayed seven days before seeding;

(4) *E. curvula* sprayed fourteen days before seed=ing;

(5) *E. curvula* not sprayed at all.

The paraquat was sprayed at a rate of two pounds (0.9 kg) active ingredient in 100 gallons (455 litre) of water per morgen (0.86 ha). A wetting agent had been included in the liquid by the manufacturers.

Six of the boxes were moved into the herbage labo=ratory and seeded on 31/1/1967, these comprised the first treatment. On the 2/2/1967 the remaining 24 boxes were moved into the laboratory and all boxes except those of the control treatment, were sprayed with paraquat. The following day the boxes were moved into the sun for about eight hours and were then moved back into the laboratory. This move was made to sti=mulate the effect of the paraquat. (A period in dull light and darkness followed by bright sunlight stimu=lates the action of paraquat (Boon, Undated)). Seed=ing rates and the method of seeding were similar to those used in N-Ec 8. Seeding was carried out at different dates for each treatment (31/1/67 - treat=ment 1, 4/2/67 - treatment 2, 9/2/67 - treatment 3, 14/2/67 - treatment 4, and 16/2/67 - treatment 5). Seeding of all the treatments on the same day spraying on different dates might have been more satisfactory, but was not possible in practice.

Rainfall was simulated by spraying two inches of water, from the vertical position two feet above the boxes, two days after the plants had been sprayed with paraquat. Apart from this treatment no water was applied to the boxes from the time of spraying until seeding. Just prior to seeding each box was soaked, care being taken not to wet the grass leaves during this process. Irrigation, subsequent to seeding, was applied to keep the seed bed moist but not saturated, and once again care was excercised to ensure that the *E. curvula* leaves were not washed.

After a few weeks in the herbage laboratory it was found that, inspite of good indirect and artificial lighting, the plants were long and spindly. In order to remedy this the boxes were moved onto a east facing veranda. The move was made after each treatment had been inside for three weeks after seeding.

Seedling counts were carried out three and six weeks after seeding. Sixty days after spraying, the herbage yield of the *E. curvula* tufts was weighed after they had been cut. The moisture content of the herbage was also calculated. The temperature and relative humidity in the herbage laboratory was recorded throughout the experimental period by means of a thermohydrograph.

Results and Discussion

The percentage of seeds which become established on each treatment, and the yield and dry matter content of the *E. curvula* herbage are given in Table 53.

Table 53

The residual effects of paraquat on the establishment of oversown seeds, and its effect on E. curvula herbage

Treatment	% Establishment						*Eragrostis* 60 days after spraying		
	Species						Yield gm/400 sq in	% Dry Matter	
	P.dilatatum		T.repens		T.pratense				
	3 wk	6 wk	3 wk	6 wk	3 wk	6 wk		Trans	De-trans
Time of spraying									
Not sprayed	4.29	8.25	110.94	78.17	43.94	23.89	68.0	47.173	45.5
Sprayed 2 days after seeding	7.37	5.83	32.94	16.22	23.24	5.73	38.3	77.880	88.6
Sprayed 2 days before seeding	17.70	12.46	77.27	66.50	54.68	16.79	31.0	87.247	96.2
Sprayed 7 days before seeding	10.71	10.58	53.45	44.84	53.25	19.46	32.0	83.198	93.4
Sprayed 14 days before seeding	7.16	11.83	45.30	43.17	34.63	15.69	33.7	79.956	90.6
Mean	9.45	9.79	64.00	49.78	41.95	16.31	40.6	75.091	85.6
L.S.D. P = 0.05	3.67	3.09	53.19	47.85	10.99	9.69	22.6	7.420	-
P = 0.01	5.03	4.23	62.84	51.71	15.06	13.28	30.9	10.163	-
Simulated rainfall									
With	8.85	9.50	63.64	45.48	39.97	16.41	39.5	75.930	86.6
Without	10.05	10.08	64.36	62.29	43.93	16.22	41.7	74.252	84.7
L.S.D. P = 0.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	-
P = 0.01									-
Significant interactions	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-
Coefficient of Variation %	31.96%	26.01	68.63	75.27	21.60	48.99	45.89	8.15	-

(1 sq in = 6.45 sq cm)

Simulated rainfall, two inches, two days after spraying with paraquat, had no significant effect on the percentage establishment of any of the overseeded species. Nor did this treatment interact significant= ly with any of the other treatments.

The percentage establishment of P. dilatatum appeared to be stimulated by the application of para= quat before seeding. This stimulus was most marked when the paraquat was applied two days before seeding and was least noticeable when paraquat was applied fourteen days before seeding. The establishment on plots sprayed two days after seeding was no different from that obtained on the unsprayed plots.

The percentage establishment of T. repens was suppressed by the spraying of the E. curvula with paraquat. This effect was most severe on the plots which were sprayed after seeding. Due to the high co-efficient of variation obtained on statistical analysis this set of results should be viewed with caution. The 111% establishment obtained on the control treatment, three weeks after seeding, could be due to one or more of the following sources of error:

(a) An exceptionally large proportion of the seed from the border area may have bounced or been diverted into the net plot. The wooden edges of the box, which were above soil level may have contributed to this.

(b) Poor seeding - more than one of the very small white clover seeds may have been drop= ped through some holes in the seeding plate.

(c) Inaccurate counts of the seedlings.

The early establishment of T. pratense was sup= pressed by the spraying of paraquat after seeding, but was not affected by spraying from two to fourteen days before seeding.

Spraying with paraquat after seeding had a depres= sing effect on the establishment of both clover species but had no effect on P. dilatatum. However, spraying before seeding appeared to stimulate the establishment of P. dilataum, have no effect on that of T. pratense but suppressed the establishment of T. repens. The reaction exhibited by P. dilatatum is contrary to ex= pectations and the experiment should be repeated to confirm these results. However, due to the transfer of the writer such repetition has not yet been possible. Several attempts have, however, been made to obtain a logical explanation for this result. Firstly the temperature data for the relevant period in the labor= tory was examined, as seeding of the treatments took place at different dates. It was, therefore, possible that temperature variations may have affected the re= sults. (See table 54).

The mean maximum and minimum temperatures during the whole six week period were slightly higher for the treatments seeded two days before and two days after spraying, than for the other treatments. The lower temperatures, particularly during the first three weeks, might have had a depressing effect on the germination of P. dilatatum. This species has relatively high temperature requirements for germination. (The Depart=

Table 54

Maximum and minimum temperatures during the early establishment period (from a thermograph in the laboratory °C)

Period	Mean minimum temperature °C Treatment					Mean maximum temperature °C Treatment				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
First week	19.8	20.9	20.0	18.0	19.3	25.7	26.3	26.0	24.3	26.0
First two weeks	19.9	20.4	19.0	16.2	17.1	26.0	26.7	24.6	24.6	23.9
First three weeks	19.4	19.0	17.5	15.2	16.0	24.6	23.9	24.9	21.0	22.9
First six weeks	16.9	16.4	15.3	14.1	14.7	24.3	24.2	23.5	22.6	23.0

ment of Agriculture Seed Testing Service recommends alternating temperatures of 35°C for eight hours in light and 20° for 16 hours in darkness for germination tests.)

In September a series of germination trials, to determine the effect of various concentrations of para= quat on P. dilatatum, were carried out under controlled temperature conditions. In these trials a logrithmic series, and also a number of other, amounts of para= quat were applied to seeds in petri dishes before ger= mination. (The amounts tested, covered a range from three times to $^{1}/1000$ of the amount of paraquat which would have been applied to the area of the petri dish (9.62 sq in — 62 sq cm), at a rate of two pounds of paraquat in 100 gallons of water per morgen). It was found that $^{1}/10$ or more of this amount of paraquat suppressed germination. When the amount reached the equivalent of two pounds paraquat per morgen, germina= tion was almost completely inhibited. In no instance did the application of paraquat result in germination. _T. repens_ and _T. pratense_ showed simi= lar effects but were not quite as sensitive as _P. dila= tatum_ at the two pound per morgen of paraquat equiva= lent. Thus the possibility of paraquat acting as a stimulant to germination appears to be remote.

The fact that the herbage of the grass canopy collapses after spraying with paraquat (see section 3.5.3.3.5), and that this collapse becomes more marked with lapse of time after spraying; probably accounts for the decline in establishment of _P. dilatatum_ when there was a long interval between spraying and seeding. Previous experiments (section 3.5.3.1) have shown that too dense a canopy, apart from intercepting large amounts of seed, has a detrimental effect on the es= tablishment of oversown seeds.

The data in table 53 indicates that the paraquat had a marked effect on the dry matter content, and the yield of the _E. curvula_ tufts, when they were harves= ted sixty days after spraying. The plants which were not sprayed yielded twice as much, and had half the dry matter content of the sprayed plants.

3.5.3.3.2 The effect of paraquat on individual High= land sourveld grass species (N-Ec 17/2)

There is considerable evidence of the selective action of paraquat on various plant species (Jones, 1961; 1962; Anon, 1962; Jones and Davies, 1962; Ross, 1962, Thompson, 1962 and Robson & Proctor, 1963; Mathews, 1963; 1964; Davies and Williams, 1964; Douglas, Levis & McIlvenny, 1965). Unfortunately little of the information provided on relative selectivity concerns plant species occurring in the Highland Sourveld.

It should be understood that for purposes of reseeding grassland, a complete kill of the existing species is not necessarily a prerequisite. It is frequently the case that sub-lethal dosages of herbicide may be sufficient to retard the existing grassland sufficiently for seeded species to become established and suppress the original grassland (Elliot, 1960). Thus susceptibility to the herbicide cannot be measured in terms of kill only, it may be equally important to record a reduction in the rate of regrowth. Reports of the susceptibility of species to paraquat are generally made on the result of the measurement of kill in mixed swards.

Regrowth, after spraying with paraquat, may occur in perennial plants with large underground storage organs or in perennial plants which can regrow from underground rooting systems (Thompson, 1962; Jones, 1962; Mathews, 1964).

Thompson (1962) reports that Paspalum dilatatum recovered from rates of 3.6 lb paraquat/acre. Trifolium repens is unaffected by applications of paraquat at 1.8 lb a.i./acre apart from initial leaf scorch (Jones & Davies 1962). Mathews (1964) agrees with this and says that in mixed pastures the application of paraquat leads to clover dominance. Robson & Proctor (1963) state that paraquat at ¼ lb/acre is satisfactory only as a "knockdown" chemical for Cynodon dactylon, at rates up to 2 lb per acre it is of doubtful value in the control of *Pennisetum clandestinum* and at 1-2 lb/ acre provides only "knock-down" action on *P. dilatatum*. *Trifolium* spp. are suppressed at low rates of applica= tion of paraquat but rapid regeneration occurs at rates higher than 1 lb per acre (Anon, 1962).

Objective

The object of this experiment was to determine the effect of spraying with paraquat, at different rates, planted stands of a number of Highland sourveld grass species.

Procedure

In 1966 small tufts of each of ten veld grass species were transplanted from the veld into plots. One hundred and fifty four plants were planted on each plot in rows of twenty-two plants spaced six inches apart in rows and between the rows. Excluding a bor= der one plant wide, there remained a net plot of 100 plants.

Due to unfavourable climatic conditions and in spite of watering, many plants failed to strike and had to be replaced as many as ten times. By September 1967 a reasonable stand of all species except *Alloterop= sis semialata* had been obtained and, it was decided to proceed with the experiment. There were two replica= tions of each treatment. The treatments were as fol= lows:

Plant species

1. *Tristachya hispida*
2. *Themeda triandra*
3. *Paspalum dilatatum*
4. *Eragrostis plana*
5. *Eragrostis curvula*
6. *Andropogon filifolius*
7. *Digitaria trichalaenoides*
8. *Monocymbium ceressiforme*
9. *Harpechloa falx*
10. *Alloteropsis semialata* (Discarded because of poor establishment).

Veld condition

Each species was sprayed in two conditions:

1. Mown 104 days before spraying (November).
2. Mown 31 days before spraying (January).

Rate of paraquat (Sprayed 12.2.1968)

Each species in each condition was sprayed at three rates of paraquat:

1. No paraquat
2. 1 lb/morgen (0.53 kg/ha) paraquat
3. 4 lb/morgen (2.12 kg/ha) paraquat

Four species, *P. dilatatum*, *E. plana*, *E. curvula* *D. trichalaenoides* were also sprayed with 2 lb/morgen (1.06 kg/ha) paraquat when short (i.e. mown in January).

The paraquat was applied with a knapsack spray using 100 gallons of water per morgen. The paraquat

Table 55

Percentage kill and yields from grass species sprayed with paraquat (1 lb/m = 0.53 kg/ha)

Species	Treatment	% Strike	% Kill of tufts: Trans-formed data	% Kill of tufts: Detrans-formed data	Dry matter yield gram/25 sq ft (2.33 sq m): 0-4 weeks after spraying	Dry matter yield gram/25 sq ft (2.33 sq m): 4-8 weeks after spraying	Dry matter yield gram/plant: 0-4 weeks after spraying	Dry matter yield gram/plant: 4-8 weeks after spraying
Tristachya hispida	Long grass : No paraquat	83.5	0.327	0.0	517	101.0	6.14	1.285
	1 lb/m paraquat	82.0	11.897	3.3	289	59.0	3.42	0.698
	4 lb/m paraquat	81.5	21.866	11.2	335	41.5	4.15	0.550
	Short grass : No paraquat	85.5	0.327	0.0	265	73.0	3.22	0.813
	1 lb/m paraquat	68.5	18.242	7.8	103	88.5	1.53	1.130
	2 lb/m paraquat	-	-	-	-	-	-	-
	4 lb/m paraquat	81.0	34.109	25.9	87	24.0	1.11	0.305
	Mean	80.3	-	8.0	-	-	-	-
Themeda triandra	Long grass : No paraquat	47.0	0.327	0.0	488	85.5	10.68	1.942
	1 lb paraquat/m	54.0	0.327	0.0	674	92.5	12.96	1.974
	4 lb paraquat/m	30.0	5.643	0.7	314	53.0	11.12	1.826
	Short grass : No paraquat	39.0	0.327	0.0	237	70.0	6.24	1.883
	1 lb paraquat/m	43.0	6.363	1.9	222	42.0	5.06	1.122
	2 lb paraquat/m	-	-	-	-	-	-	-
	4 lb paraquat/m	56.5	0.327	0.0	185	44.0	3.31	0.308
	Mean	44.9	-	0.4	-	-	-	-
Paspalum dilatatum	Long grass : No paraquat	97.5	0.327	0.0	866	108.0	8.89	1.102
	1 lb paraquat/m	92.0	0.327	0.0	714	139.0	8.00	1.324
	4 lb paraquat/m	94.0	0.327	0.0	818	100.5	8.78	1.083
	Short grass : No paraquat	96.0	0.327	0.0	304	96.0	3.20	1.024
	1 lb paraquat/m	92.0	0.327	0.0	435	71.0	4.63	0.795
	2 lb paraquat/m	96.0	9.159	1.9	365	45.0	3.82	0.425
	4 lb paraquat/m	95.0	4.814	0.5	255	103.5	2.73	1.080
	Mean	94.4	-	0.3	-	-	-	-
Eragrostis plana	Long grass : No paraquat	91.5	0.327	0.0	1273	111.0	14.15	1.182
	1 lb paraquat/m	91.5	18.059	7.6	1013	84.0	11.08	0.915
	4 lb paraquat/m	84.5	12.725	3.8	1025	56.5	12.18	0.659
	Short grass : No paraquat	93.5	0.327	0.0	331	54.5	3.57	0.584
	1 lb paraquat/m	87.0	5.035	0.6	216	55.5	2.48	0.643
	2 lb paraquat/m	89.0	6.191	0.9	183	55.0	2.05	0.618
	4 lb paraquat/m	93.5	33.768	25.4	520	73.0	5.40	0.755
	Mean	90.3	-	5.5	-	-	-	-
Eragrostis curvula	Long grass : No paraquat	95.0	0.327	0.0	1363	165.0	14.32	1.737
	1 lb paraquat/m	94.0	3.650	0.3	901	103.5	8.62	1.105
	4 lb paraquat/m	93.5	11.610	3.1	972	118.5	10.35	1.284
	Short grass : No paraquat	100.0	0.327	0.0	475	137.5	4.75	1.375
	1 lb paraquat/m	95.0	6.103	0.8	792	201.5	8.53	2.084
	2 lb paraquat/m	96.5	7.743	1.4	426	126.5	4.36	1.289
	4 lb paraquat/m	91.5	28.016	18.0	221	56.0	2.42	0.612
	Mean	93.6	-	3.4	-	-	-	-

Table 55 (contd.)

Species	Treatment	% Strike	% Kill of tufts: Transformed data	% Kill of tufts: Detransformed data	Dry matter yield gram/25 sq ft (2.33 sq m): 0-4 weeks after spraying	Dry matter yield gram/25 sq ft (2.33 sq m): 4-8 weeks after spraying	Dry matter yield gram/plant: 0-4 weeks after spraying	Dry matter yield gram/plant: 4-8 weeks after spraying
Andropogon filifolius	Long grass : No paraquat	62.0	0.327	0.0	311	61.0	5.22	0.974
	1 lb paraquat/m	57.5	10.455	2.5	261	29.9	4.97	0.506
	4 lb paraquat/m	46.5	45.861	43.5	65	11.0	2.62	0.266
	Short grass : No paraquat	49.5	0.327	0.0	144	42.5	2.32	0.842
	1 lb paraquat/m	44.5	20.408	9.7	72	18.5	1.45	0.398
	2 lb paraquat/m	-	-	-	-	-	-	-
	4 lb paraquat/m	80.0	30.415	21.0	67	22.0	0.84	0.273
	Mean	56.7	-	12.8	-	-	-	-
Digitaria trichalaenoides	Long grass : No paraquat	78.0	0.327	0.0	395	66.5	5.53	0.905
	1 lb paraquat/m	65.5	0.327	0.0	124	76.5	2.05	1.189
	4 lb paraquat/m	70.5	9.039	1.9	229	67.0	2.98	0.831
	Short grass : No paraquat	54.0	0.327	0.0	191	42.0	3.47	0.746
	1 lb paraquat/m	68.5	0.327	0.0	112	37.5	1.69	0.565
	2 lb paraquat/m	61.0	18.794	8.3	97	37.5	1.51	0.666
	4 lb paraquat/m	56.0	8.479	1.6	94	12.0	1.74	0.224
	Mean	64.8	-	1.7	-	-	-	-
Monocymbium ceressiforme	Long grass : No paraquat	34.0	0.327	0.0	212	25.0	6.23	0.735
	1 lb paraquat/m	69.5	0.327	0.0	431	55.5	6.29	0.822
	4 lb paraquat/m	41.5	0.327	0.0	451	69.5	12.76	1.516
	Short grass : No paraquat	73.5	0.327	0.0	253	36.0	3.50	0.482
	1 lb paraquat/m	81.5	0.327	0.0	160	37.5	1.96	0.460
	2 lb paraquat/m	-	-	-	-	-	-	-
	4 lb paraquat/m	48.0	0.327	0.0	77	15.5	1.59	0.323
	Mean	58.0	-	0.0	-	-	-	-
Harpechloa falx	Long grass : No paraquat	67.0	0.327	0.0	766	134.0	11.03	2.051
	1 lb paraquat/m	67.5	0.327	0.0	235	99.5	3.13	1.008
	4 lb paraquat/m	70.0	0.327	0.0	682	74.0	9.74	1.058
	Short grass : No paraquat	86.0	0.327	0.0	450	130.0	5.35	1.549
	1 lb paraquat/m	85.0	0.327	0.0	249	73.5	2.93	0.865
	2 lb paraquat/m	-	-	-	-	-	-	-
	4 lb paraquat/m	79.5	17.960	7.6	276	74.0	3.68	1.015
	Mean	75.8	-	1.3	-	-	-	-
	General mean	73.2	-	3.7	-	-	-	-
L.S.D. P = 0.05		-	12.196	-	296.0	86.8	4.32	1.148
P = 0.01		-	16.231	-	394.0	115.6	5.75	1.528

used contained a "built in" wetting agent. A light drizzle started three hours after spraying and developed into a steady rain overnight. At 8 a.m. the following morning 21.8 mm were recorded.

The number of living tufts on each plot was coun= ted the day before spraying with paraquat. Twenty-eight days after spraying the number of plants which had been killed was counted on each plot. The dry material yields of herbage, from the plots, was mea= sured four weeks after spraying and again four weeks later.

The experiment was originally designed as a 8 x 8 simple lattice with two replications, but due to the failure of A. semialata it was analysed as a randomised block design, ignoring the plots of this species.

Results

The percentage of dead tufts (4 weeks after spray= ing) and the yield per plot and per plant for the first and second four weeks after spraying are given in table 55. The number of living plants, at the time of spraying, is also given in this table.

Unfortunately the measured yields are influenced by the hereditary growth characteristics of the plant species and by the interaction of the season of the year on these characteristics. Thus direct comparison of yields between species is not valid. However, com= parisons within species and of the "percentage kill" are justified.

The differences in yield between the two "conditions of veld" at four weeks after spraying are partly due to growth prior to spraying. Thus comparisons between the two conditions, at this stage, do not reflect the efficiency of the herbicide.

1. Strike of plants

Alloteropsis semialata established poorly, giving on the average 29% strike with half the plots having less than 20% strike. Consequently it was decided to discard this species. Of the remaining nine species *Themeda triandra* (45%) gave the poorest strike. The best strike, over 90%, was obtained with *P. dilatatum* and the two *Eragrostis* species. These three species are pioneer types.

2. The effect of paraquat on the species

2.1 *Tristachya hispida*

Four pounds/morgen of paraquat, on long grass, resulted in a significant (11.2%) kill of this species, while on short grass one pound/morgen was sufficient to produce a significant kill (7.8%). On short grass four pound/morgen was also more effective than one pound/morgen (25.9% kill). The herbicide did not result in a significant (P=0.05) reduction in the herbage yield either in the first or second four weeks after spraying. The results do, however, indicate a "non-significant", reduction in yield due to spraying in both these periods.

2.2 Themeda triandra

The use of paraquat did not result in a sig= nificant kill of this species. There is some indi= cation that 4 lb/morgen of paraquat reduced yields slightly.

2.3 Paspalum dilatatum

Paraquat did not result in a significant kill nor, did it produce a marked reduction in the yield of this species.

2.4 Eragrostis plana

Paraquat produced a significant kill of this species. When sprayed on long grass both 1 and 4 lb/ morgen were effective but, on short grass only 4 lb/ morgen produced a significant kill. There was no in= dication that paraquat significantly reduced yields - in fact 4 lb/morgen sprayed on short grass apparently increased yields.

2.5 Eragrostis curvula

Four pounds of paraquat per morgen resulted in a significant kill of short E. curvula. The yield, during the first four weeks after spraying long grass, was significantly reduced by the use of both 1 and 4 lb/morgen of paraquat. One pound per morgen, sprayed on short grass, significantly increased the yield. These effects were also apparent during the second four week period.

2.6 <u>Andropogon filifolius</u>

The use of 4 lb/morgen paraquat on long grass resulted in a significant kill (43.5%), while on short grass both one lb/m and 4 lb/morgen were effective. There was also a non-significant, reduction in yield due to the use of the herbicide.

2.7 <u>Digitaria trichalaenoides</u>

On short grass 2 lb/morgen of paraquat resul= ted in a significant kill. Four lb/morgen of paraquat appeared to reduce the yield of this species.

2.8 <u>Monocymbium ceressiforme</u>

This species was apparently unaffected by paraquat.

2.9 <u>Harpechloa falx</u>

On short grass 4 lb/morgen paraquat resulted in a significant kill of this species. On long grass, during the first four week period 1 lb/morgen paraquat depressed yields compared with 4 lb/morgen and no para= quat. Generally paraquat appeared to depress herbage yield.

Discussion

Overseas, paraquat has proved to be a useful tool in aiding the overseeding of natural grazings. No information is, however, available on its effect on lo= cal indigenous grass species. In spite of considerable variation in the results of the experiment under con= sideration, some useful preliminary information on this aspect may be gleaned.

On the results obtained, the species under consi= deration, can be ranked, in order of decreasing sus= ceptibility to kill by paraquat, as follows: A. filifolius>T. hispida>E. plana>E. curvula> D. trichalaenoides = H. falx>T. triandra = P. dilatatum = M. ceressiforme. The latter species is apparently unaffected by the herbicide.

The data on the regrowth for eight weeks after spraying is very variable but, generally, with the ex= ception of M. ceressiforme at 1 lb/morgen of paraquat, herbage yields were reduced as a result of spraying with the herbicide. This conclusion is confirmed by the results obtained from the spraying of veld.

Generally the percentage of plants killed was higher when short grass was sprayed than when long grass was sprayed. Four pounds per morgen of para= quat was generally more effective in killing plants and reducing regrowth than one pound per morgen.

In the Highland Sourveld of Natal paraquat ap= pears to be less useful, in reducing competition from the existing sward, than might have been expected. However, it should not be assumed that 100% kill of the veld is a prerequisite to successful overseeding nor, that 100% kill will necessarily provide optimum seed bed conditions.

3.5.3.3.3 The effect of paraquat on herbage regrowth in darkness

Due to the importance which paraquat has assumed overseas as an aid to the establishment of overseeded species it was considered to be desirable to attempt to obtain additional information on the mode of action of this herbicide. This information, if obtained from several of the more important Highland Sourveld grass species might lead to a more effective employment of the herbicide. Consequently a pot trial was carried out to investigate this aspect.

Objective

This project had two main objects:

(a) The first object was to determine the effect of paraquat on the regrowth in darkness of _T. hispida_ and _A. filifolius_, and to compare this with the regrowth of these same species when subjected to varying periods without light. In this way it was hoped to obtain information on the mode of action of the herbicide, and on any association between this action and a reduction in carbohydrate reserves.

(b) The conventional method of regrowth measurement in darkness requires that the plants be defoliated. However, it is possible that this defoliation might affect the action of herbicides used in such trials. Thus a second experiment was carried out to determine the effect of defoliation in such instances.

Procedure

In March 1969 a number of tufts of _T. hispida_ and A. filifolius were transplanted into pots (7" - 10 cm diameter) of Clovelly soil, and were kept in a glass house. Three months later twenty-one tufts of each species were selected, for uniformity, and were used in the experiment. Seven tufts of each species were placed in each of three replicates, and one of each of the following treatments were applied to a tuft of each species in each replicate:

(a) The plants were kept in darkness for 72 hours before cutting and placing in a light-free cabinet.

(b) The plants were kept in darkness for 48 hours before cutting and placing in a light-free cabinet.

(c) The plants were kept in darkness for 24 hours before cutting and placing in a light-free cabinet.

(d) No treatment before cutting and placing in a light-free cabinet.

(e) The plants were sprayed with paraquat 72 hours before cutting and placing in a light-free cabinet.

(f) As for treatment (e) except that the plants were <u>not</u> cut before placing in the cabinet.

(g) As for treatment (d) except that the plants were <u>not</u> cut before placing in the cabinet.

The regrowth of the plants in darkness was com= pared in two separate analyses. The first experiment consisted of a comparison of treatments (a) to (e), and was analysed as a 2 (species) x 5 (treatments) factorial in three randomised blocks. The second ex= periment was made up of treatments (d) to (g) and was analysed as a 2 (species) x 2 (levels of paraquat) x 2 (levels of cutting) factorial, also in three randomised blocks. Thus treatments (d) and (e) were common to both experiments. This procedure was adapted so as to be able to accommodate both experiments in the ca= binet at the same time. This procedure saved time and labour. All fourteen pots in each replicate were randomised in three blocks in the cabinet. Some theoretical objections could be raised to this arrange= ment as the pots in each experiment could not be ran= domised separately, however, the practical advantages outweigh this slight error.

The light-free treatments were applied and re= growth in darkness was measured in a drying oven. After one week of regrowth the plants in the oven were inspected and it was found that growth was very slow. This was attributed to the low temperatures inside the inactivated oven. This was then remedied by heating the oven to 35^{0}C three times a day by means of a forced drought of hot air. This treatment induced more rapid growth. The regrowth in darkness, and the total her= bage yield in the case of uncut tufts, was first measured fourteen days after placing the plants in the cabinet. Further cuts were taken three and four weeks later. Each time the plants were cut, the num= ber of leaves were counted before oven drying and weigh= ing. The average diameter of the tufts was also mea= sured at the time of the first cut. The plants were cut to a height of one and a half inches above soil level.

Table 56a

Regrowth of grass tufts during 42 days in darkness

Treatments	Regrowth in darkness: Number of leaves after 14 days	Yield/tuft (g)	Yield/sq in tuft area (g)	Yield/leaf (g)
Species				
T.hispida	39.6	0.157	0.0398	0.0049
A.filifolius	116.9	0.465	0.0921	0.0076
Mean	78.2	0.311	0.0659	0.0062
L.S.D. P = 0.05	30.7	0.151	0.0345	N.S.
P = 0.01	42.1	0.207	0.0472	
Treatment				
72 hours in darkness	38.8	0.236	0.0420	0.0070
48 hours in darkness	35.2	0.343	0.0666	0.0062
24 hours in darkness	69.0	0.337	0.0672	0.0099
Control	122.0	0.384	0.0830	0.0038
Sprayed with paraquat	126.0	0.255	0.0709	0.0044
L.S.D. P = 0.05	48.6	N.S.	N.S.	N.S.
P = 0.01	66.6			
Coefficient of Variation	51.23%	63.22%	54.48%	120.66%
Significant Interaction	S x T	Nil	Nil	Nil

Table 56b

Significant interaction between species and treatments for number of leaves which regrew in darkness

Species	Treatment: 72 hrs dark	48 hrs dark	24 hrs dark	Control	Paraquat	Mean
T.hispida	26.0	26.3	61.0	41.3	43.0	39.6
A.filifolius	51.7	44.0	77.0	202.7	209.0	116.9
Mean	38.8	35.2	69.0	122.0	126.0	78.2

L.S.D. Body of table P = 0.05 = 68.7 P = 0.01 = 94.1

The paraquat was applied at the equivalent of two pounds (908 g) active ingredient in 150 gallons (682 litre) of water per morgen (0.8565 ha). The applica= tion was carried out with the aid of an aerosol spray= pack, and the tufts were surrounded by a screen to re= duce spray drift.

Results an Discussion

The first experiment

The regrowth in darkness from the five treatments when applied to A. filifolius and T. hispida are given in table 56.

After fourteen days in darkness, significantly more leaves had regrown on A. filifolius than on T. his= pida. The three treatments which had been subjected to dark treatment prior to the commencement of the re= growth measurements, had significantly fewer leaves than did those which had not received such treatment. The significant interaction of spe cies and treatments does, however, indicate that the dark treatment was less effective in reducing the number of leaves of T. hispida, than of A. filifolius. Spraying the plants with paraquat did not affect the number of leaves which regrew.

On the average the regrowth yield of T. hispida was less, per tuft and per unit area of tuft, than that of A. filifolius. None of the treatments in this experi= ment affected the yield of regrowth in darkness. It would, therefore, appear that the treatments were not sufficiently severe to produce a measurable reduction in carbohydrate reserves and consequently regrowth. In the case of the three dark treatments this was pos= sibly due to the low temperatures (<10°C at 8 pm) in the cabinet where the treatments were applied. These low temperatures probably reduced respiration, and consequent= ly the use of carbohydrate reserves, to a very slow rate. Unfortunately this feature was observed only during the regrowth period.

The second experiment

The total herbage yield (i.e. the yield of herbage on the tufts at the time of treatment plus the regrowth after fourteen days in darkness) is given in Table 57.

A. filifolius yielded more "total herbage", per tuft and per unit area of tuft, than did *T. hispida*. Spraying the herbage with paraquat did not affect the herbage yields during this period, but the yield per unit area of tuft was increased by cutting the herbage at the time of placing the tufts in the cabinet. This effect is probably due to the greater respiration by the uncut herbage, if cutting had eliminated the long-term (>72 hour) effects of paraquat such a reaction would have been reflected by a significant cutting x paraquat interaction — which was not present.

The regrowth in darkness of the grass tufts during the 28 days following the first regrowth cut (taken after 14 days in the cabinet) are given in Table 58.

Table 57.

Total herbage yield - Pretreatment yield + yield after 14 days in darkness

Treatment		Herbage yield Per tuft (g)	Per sq in (6.45 sq cm) tuft area (g)
<u>Species</u>			
<u>T. hispida</u>		7.85	1.55
<u>A. filifolius</u>		15.58	2.81
Mean		11.71	2.18
L.S.D.	P=0.05	2.74	0.42
	P=0.01	3.97	0.58
<u>Paraquat</u>			
Nil		11.35	2.14
2 lb/m		12.08	2.22
L.S.D.	P=0.05	N.S	N.S
	P=0.01		
<u>Cutting</u>			
Not cut before dark period		10.50	1.74
Cut before dark period		12.92	2.62
L.S.D.	P=0.05	N.S.	0.42
	P=0.01		0.58
Coefficient of Variation		26.72%	22.08%
Significant Interactions		Nil	Nil

Table 58a

Regrowth of grass tufts during 28 days in darkness, following 14 days in the dark (1 sq in = 6.45 sq cm)

Treatment	Number of leaves after 35 days	Regrowth in darkness Yield/tuft (g)	Yield/sq in tuft area (g)	Yield/leaf (g)
Species (S)				
T.hispida	33.9	0.140	0.0288	0.0038
A.filifolius	197.5	0.340	0.0602	0.0017
Mean	115.7	0.240	0.0445	0.0027
L.S.D. P = 0.05	34.6	0.095	0.0220	0.0015
P = 0.01	48.6	0.133	-	-
Paraquat (P)				
Nil	133.7	0.318	0.0594	0.0029
2lb/morgen	97.7	0.162	0.0296	0.0026
L.S.D. P = 0.05	34.6	0.095	0.0220	N.S.
P = 0.01	-	0.133	-	
Cutting (C)				
Not cut before dark period	105.5	0.264	0.0432	0.0030
Cut before dark period	125.9	0.216	0.0458	0.0025
L.S.D. P = 0.05 P = 0.01	N.S.	N.S.	N.S.	N.S.
Coefficient of variation	33.65%	44.87%	60.30%	59.68%
Significant interactions	S x C	Nil	Nil	Nil

Table 58b

Significant interaction between species and cutting for number of leaves which regrow in darkness

Species	Cutting (No. leaves) Not cut	Cut	Mean
T.hispida	41.7	26.2	33.9
A.filifolius	169.3	225.3	197.5
Mean	105.5	125.9	115.7

L.S.D. Body of Table P = 0.05 = 49.0; P = 0.01 = 68.7

The number of leaves which had regrown at the time of cutting, 35 days after placing the pots in the cabinet, was significantly greater on A. filifolius than on T. hispida. The significant interaction between species and cutting indicates, that while the number of leaves of T. hispida tended to decrease as a result of cutting (at the time of placing the pots in the cabinet), the number of leaves increased on A. filifolius as a result of this treatment. Spraying the herbage with paraquat resulted in a significant reduction of the number of leaves at this stage.

During the period under discussion, the regrowth yield, per tuft and per unit area of tuft, of T. hispida was less than that of A. filifolius, but the individual leaves of the former were heavier than those of the latter. The yield of regrowth, per tuft and per unit area of tuft, was reduced as a result of spraying the tufts with paraquat. It appears that this reduction in yield was chiefly due to a reduction in the number of leaves as the yield per leaf did not show any significant reaction to the paraquat treatment.

These two experiments appear to provide contradictory results of the effect of paraquat on the regrowth in darkness. In the first experiment paraquat had no significant effect, but in the second it suppressed the regrowth in darkness. Closer examination of the results of the first experiment does, however, indicate a non-significant depression of regrowth yield by paraquat. It would, therefore, appear that the second experiment was either more accurate (less variability) or that uncut herbage allowed greater efficiency of the herbicidal action. Inspite of the absence of a significant cutting x paraquat interaction in the second experiment, the latter suggestion appears to be more probable, although both factors may have been responsible for the significant effect due to paraqaut in the second experiment.

These experiments indicate that paraquat is more effective when the herbage is left on the plant for two weeks after spraying, than when cut off after three days. It would also appear that regrowth after spraying with paraquat is reduced chiefly as a result of a reduction in the number of active growing points.

3.5.3.3.4 The use of paraquat in seed-bed preparation (N-Ec 17/1)

A second means of seed-bed preparation for the overseeding of grassland, namely the use of a herbicide -paraquat, was also investigated in a herbage yield trial. As a means of experimental expedience the use of paraquat and of nitrogenous fertilizer for seed-bed preparation were evaluated in the same experiment. The object, procedure, results obtained and a discussion of the results of the whole experiment (N-Ec 17/1) have been included under section 3.5.3.4 and will not be repeated here.

3.5.3.3.5 A comparison of the effects of paraquat and dalapon

In view of the somewhat disappointing results obtained from the use of paraquat as a means of seed-bed preparation for the overseeding of grassland,

and because of the reported success of dalapon for this purpose; it was decided to compare the relative effectiveness of the two herbicides on several Highland Sourveld grass species when grown in a glasshouse.

Objective

The object of this experiment was to compare the effects of spraying tufts of three Highland sourveld grass species with dalapon and paraquat.

Procedure

Single grass tufts of _T. hispida_, _A. filifolius_ and _E. curvula_, which had been established in wooden boxes containing Clovelly soil at Estcourt, were transplanted into porcelain pots containing the same soil at Potchefstroom. Each tuft was planted into a 7 inch (18 cm) diameter pot, and the pots were transferred immediately into a glass house which could be heated by warm air. The plants were transplanted in March 1969, they suffered little set back and were well established in May 1969 when the treatments were applied.

The treatments consisted of each of the three grass species sprayed with each of dalapon (70 lb active ingredient per morgen – 37.1 kg/ha) and paraquat (2 lb active ingredient per morgen –1.06 kg/ha), in a 3 x 2 factorial design. The pots were arranged on the floor of the glass-house with all of the treatments randomised within each of the four replicates. The herbicides were mixed with the equivalent of 150 gallons (682 litres) of water per morgen and in the case of dalapon, a wetting agent "Agral 90" was also added at the equi=

valent of 24 fluid ounces (682 cc) per morgen — the paraquat used had its own "built-in" wetting agent. The spray was applied, with the aid of an aerosol spray pack, from above the grass tufts which were enclosed in a tubular screen to reduce spray drift. The amount of spray applied to each tuft was based on the internal surface area of the pots (12.25 sq in — 79 sq cm). The pots remained in the glass-house until the experi= ment was completed in July 1969, and were well watered throughout this period.

The spread of each tuft at each inch of its height was measured before spraying and one, eight and fifteen days after spraying. These measurements were made in order to obtain an idea of the rate of collapse of the canopy after spraying, a factor which affects the in= terception of seed and the light available to over= sown species. Six weeks after spraying, the leaves on each tuft were clipped (approximately 1½ inches — 3.8 cm — above soil level in the pots), separated into dead, partly scorched, and green leaves and then dried and weighed. The regrowth on the tufts was cut, dried and weighed and the number of leaves were coun= ted at two and at four weeks after the first harvest. These measurements would, it was hoped, provide in= formation on the relative efficiency of the two her= bicides in restricting the growth of these three High= land sourveld grass species.

Results and Discussion

The spread of the canopy of the grass tufts at each of the four times of measurement is illustrated diagramatically in Figures 6 to 8, and the average

FIGURE 6. SPREAD OF <u>ERAGROSTIS CURVULA</u> BEFORE AND AFTER SPRAYING.

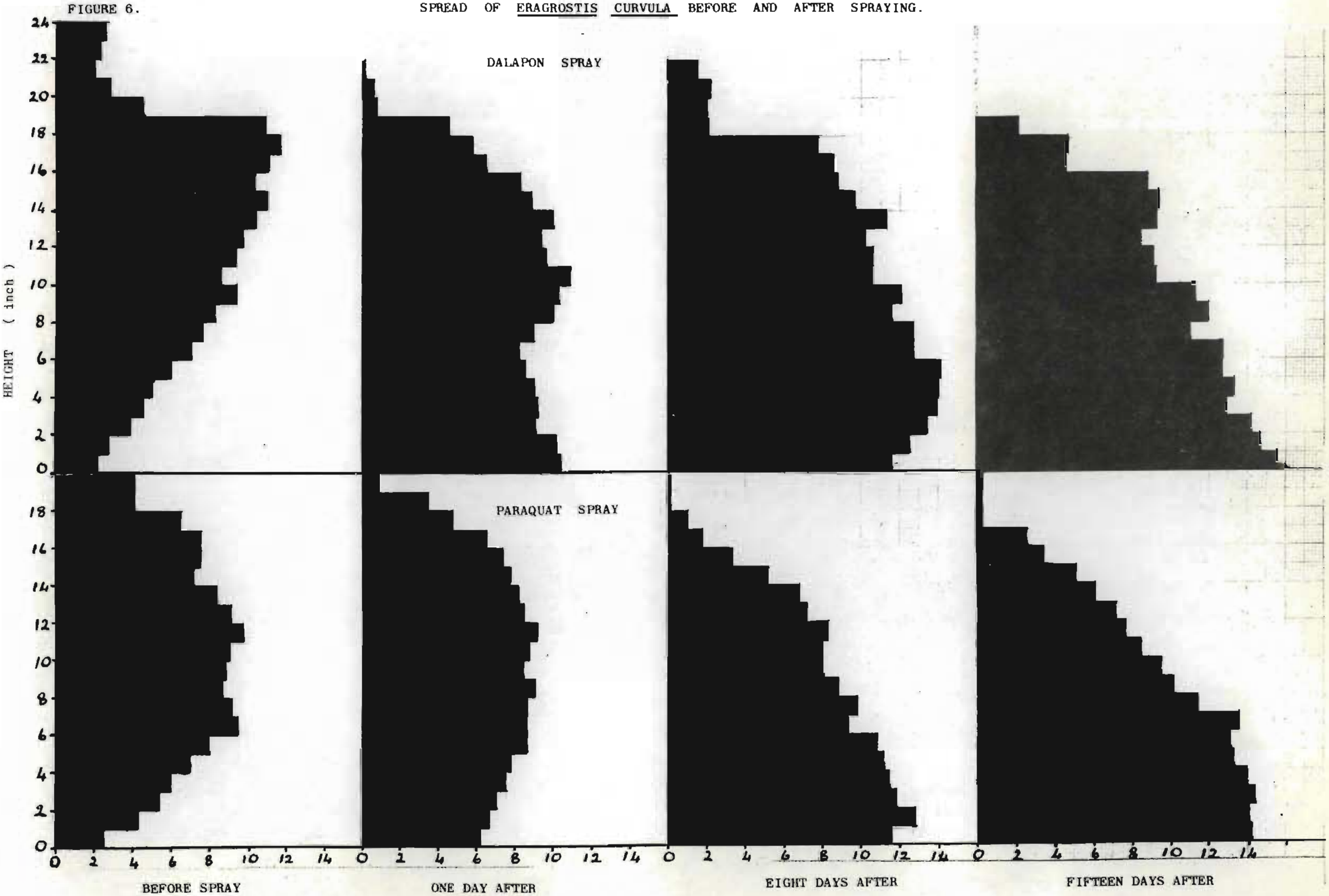


FIGURE 7. SPREAD OF ANDROPOGON FILIFOLIUS BEFORE AND AFTER SPRAYING.

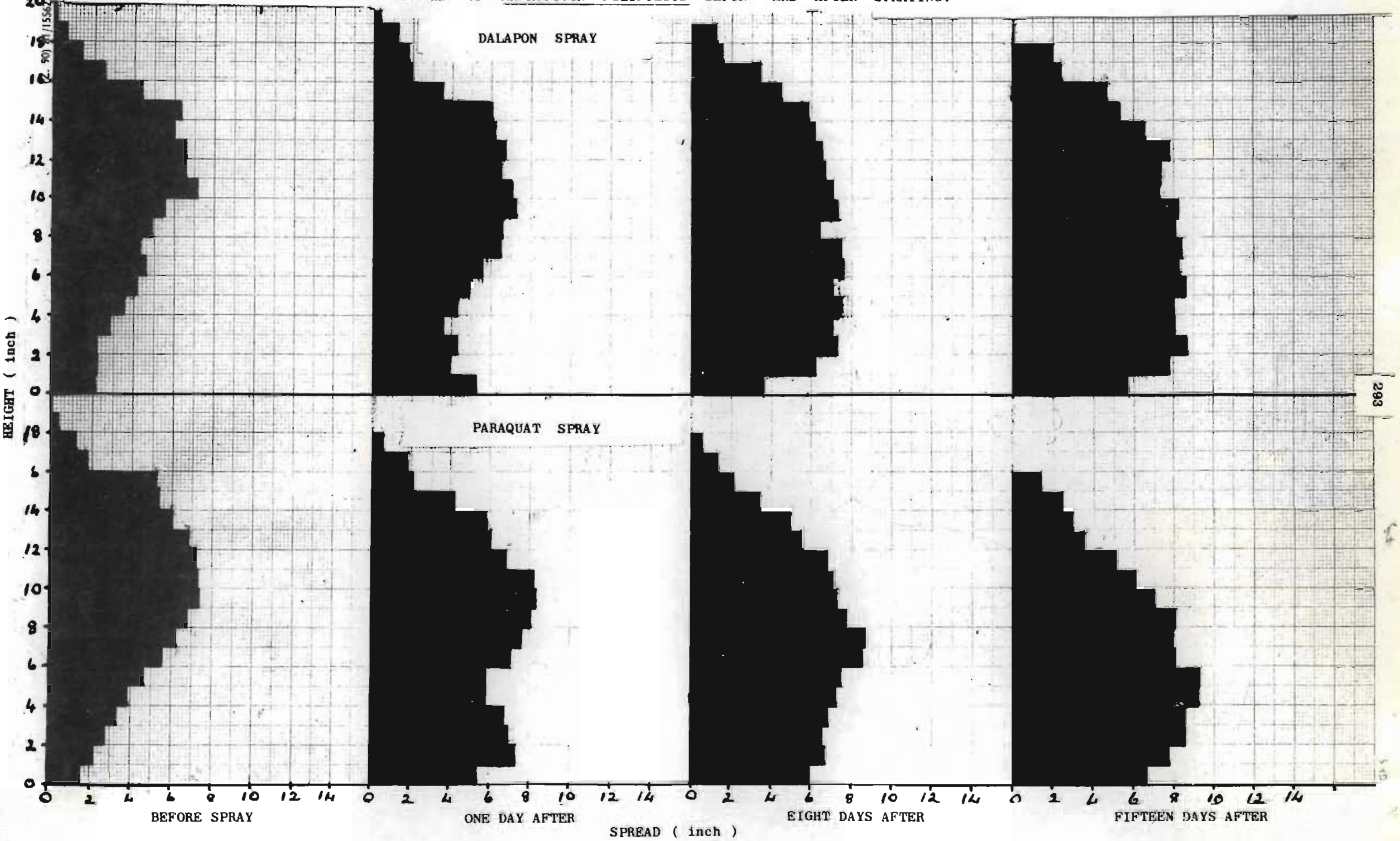


FIGURE 8. SPREAD OF TRISTACHA HISPIDA BEFORE AND AFTER SPRAYING.

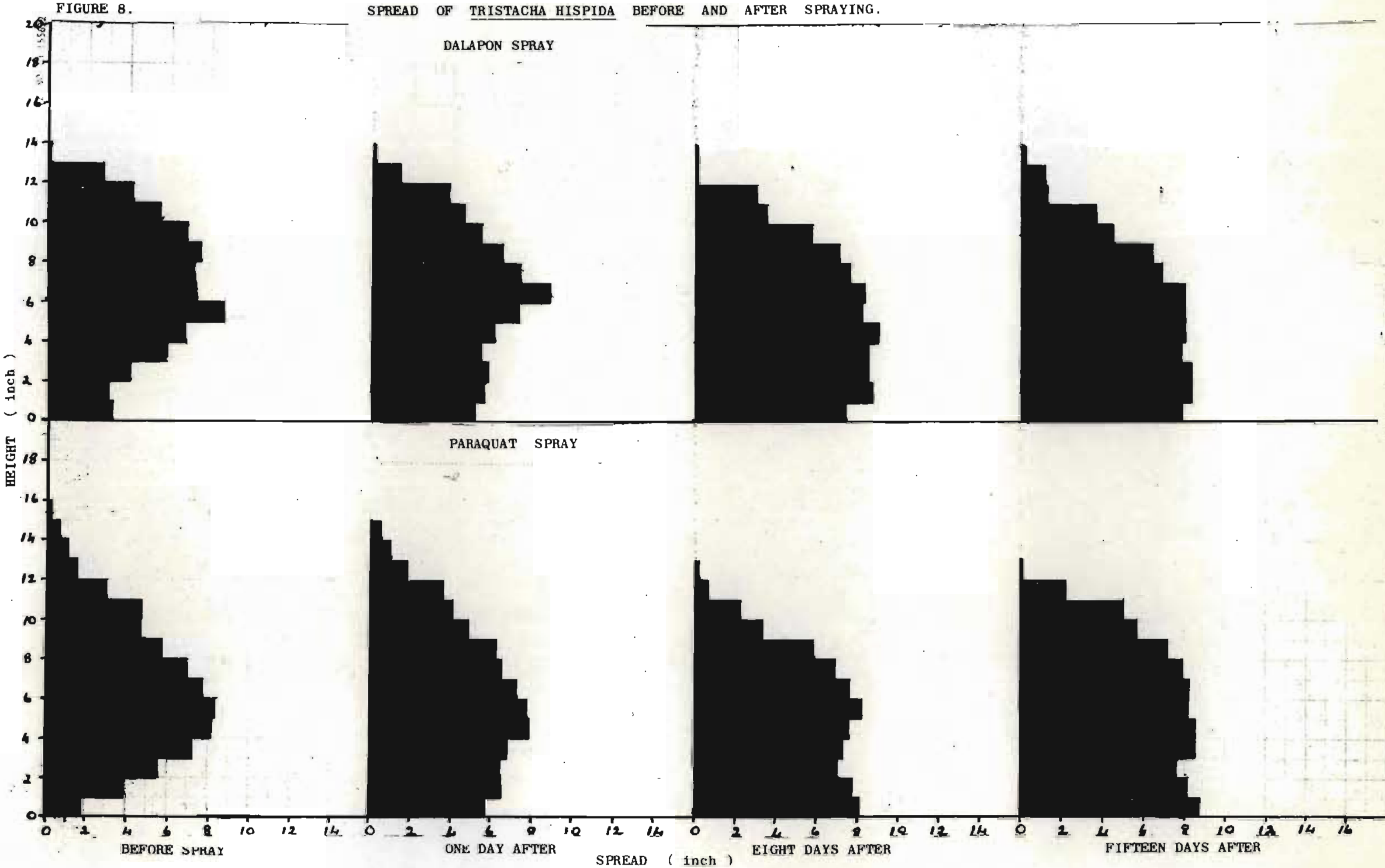


Table 59

The average diameter of the canopy, at soil level, of grass tufts sprayed with herbicides (Average of four tufts)

Treatment	Average diameter of canopy at soil (inch -2.54 cm)			
	Days after spraying			
	0	1	8	15
T.hispida - Dalapon	6.5	10.2	14.9	15.8
- Paraquat	3.9	11.7	16.2	17.4
Mean T.hispida	5.2	10.9	15.5	16.6
A.filifolius - Dalapon	4.3	10.7	7.1	11.4
- Paraquat	3.1	11.0	11.9	13.4
Mean A.filifolius	3.7	10.8	9.5	12.4
E.curvula - Dalapon	4.2	20.6	23.3	31.3
- Paraquat	5.0	12.4	23.3	28.5
Mean E.curvula	4.6	16.5	23.3	29.9
Mean Dalapon	5.0	13.8	15.1	19.5
Mean Paraquat	4.0	11.7	13.8	19.8
General mean	4.5	12.7	14.4	19.6

(1 inch = 2.54 cm)

diameters of the canopies at soil level are given in Table 59.

It is apparent, from these results, that the spread of the canopy at soil level increased considerably over the fifteen day period after spraying. This increase was apparent in all three grass species and with both herbicides. The diameter of the basal canopy of *T. hispida* increased by 3.2 times, that of *A. filifolius* 3.4 times and that of *E. curvula* 6.5 times over the fifteen day period. The change took place rapidly and

Table 60a

Condition of herbage six weeks after spraying with herbicides

Treatment	Percentage of leaves						Number leaves/ plant
	Dead		Partly scorched		Wholly green		
	Normal	* Transformed	Normal	* Transformed	Normal	* Transformed	
Species							
T.hispida	53.6	52.254	34.4	39.985	5.7	15.526	362.2
A.filifolius	49.9	49.934	35.9	40.938	12.4	23.078	818.7
E.curvula	39.3	43.175	57.2	54.569	1.2	7.157	271.2
Mean	-	48.454	-	45.164	-	15.254	484.0
L.S.D. P = 0.05	-	N.S.	-	7.605	-	7.235	165.4
P = 0.01	-	N.S.	-	10.518	-	10.005	228.6
Herbicide							
Dalapon	38.1	42.396	54.9	55.109	1.2	7.378	391.7
Paraquat	57.1	54.511	27.5	35.218	12.5	23.130	576.4
L.S.D. P = 0.05	-	6.427	-	6.208	-	5.908	152.0
P = 0.01	-	8.888	-	8.586	-	8.171	N.S.
Coefficient of Variation	-	15.25%	-	15.80%	-	44.51%	32.06%
Significant Interaction	-	Nil	-	Nil	-	S x H	Nil

N.S. = Not significant

* = Transformed by $\sqrt{1000}$ arc sin (1 - 2p)-Stevens

Table 60b

Interaction between species and herbicides for wholly green leaves (Percentage - Transformed data)

Herbicide	Species			Mean
	T.hispida	A.filifolius	E.curvula	
Dalapon	0.327	21.480	0.327	7.378
Paraquat	30.725	24.677	13.993	23.132
Mean	15.526	23.078	7.160	15.255

L.S.D. Body of Table: P = 0.05 = 10.218, P = 0.01 = 14.131.

even one day after spraying the diameter had doubled on _T_. _hispida_, trebled on _A_. _filifolius_ and nearly quadrupled on _E_. _curvula_. There was apparently little difference in the effect of the two herbicides on these measurements. The diagrams (Fig. 6, 7 & 8) illustrate a clear change, from a decreasing diameter in the upper strata of the canopy to an increasing diameter in the lower portion of the canopy, with a lapse in time af= ter spraying. On the _T_. _hispida_ tufts, which were the shortest (14.5 " – 36.8 cm – high) of the three species, this change took place at between five and six inches above soil level, while on the _E_. _curvula_ tufts, which were the tallest (21" – 53.3 cm – high) the change was apparent at ten to eleven inches above soil level. The change on the _A_. _filifolius_ tufts (18.5" –39.4 cm – high) was between nine and eleven inches above soil level. These results could also have been influenced by the natural growth of the leaves and by soil moisture deficiencies. However, these factors probably did not play a significant role in this experiment as the collapse occurred very rapidly and the soil was main= tained in a moist condition. The significant of these results has been discussed in a previous section (3.5.3. 3.1).

The percentage of the leaves, in each of the three classes of damage, at six weeks after spraying are given in Table 60.

There was no difference in the percentage of dead leaves on the three species, but the tufts which had been sprayed with paraquat had a significantly higher percentage of dead leaves than did those sprayed with were already dead at the time of spraying. A higher percentage of leaves of E. curvula were partly scorched than of the other two species, and dalapon caused the partial scorching of a higher percentage of leaves than did paraquat. A. filifolius had a greater percentage of wholly greeen leaves (these were chiefly young leaves which had emerged after spraying) than did the other two species, and T. hispida also had a greater percentage of these leaves than did E. curvula. There was a significantly lower percentage of wholly green leaves on the plants sprayed with dalapon than on those sprayed with paraquat. The significant interaction between the species and the herbicides indicates that, while dalapon suppressed the percentage of wholly green leaves on T. hispida and E. curvula when compared with paraquat there was no difference in the effect of the two herbicides on A. filifolius. This also resulted in A. filifolius having a higher percentage of wholly green leaves than did the other species when all were sprayed with dalapon. Spraying with dalapon resulted in less leaves per plant on the average than did spraying with paraquat, this is probably due to the inhibition of the production of new leaves by dalapon.

The results given in Table 61 show that there were no significant differences in the herbage yields, and dry matter content of the herbage six weeks after spraying.

Table 61.

Oven dry yield and dry matter content, of herbage six weeks after spraying

Treatment		Herbage yield gram/tuft	% Dry matter in herbage
Species			
T. hispida		10.0	61.90
A. filifolius		11.4	54.10
E. curvula		12.1	55.15
Mean		11.2	57.05
L.S.D.	P=0.05	N.S	N.S
	P=0.01	N.S	N.S
Herbicide	Dalapon	9.9	55.02
	Paraquat	12.4	59.08
L.S.D.	P=0.05	N.S	N.S
	P=0.01	N.S	N.S
Coefficient of variation		33.27%	15.81%
Significant interaction		Nil	Nil

The number of leaves which regrew following the cut six weeks after spraying are given in Table 62.

Table 62a.

The number of leaves which regrew, following cutting, six weeks after Spraying with herbicides

Treatment	Number of leaves		Number of leaves as % of number at cutting	
	Regrown After 2 weeks	Regrown after a further 2 weeks	Regrown After 2 weeks	Regrown after a further 2 weeks
Species				
T.hispida	46.1	49.0	11.81%	12.54%
A.filifolius	186.2	117.0	22.95%	14.84%
E.curvula	58.2	38.4	17.39%	10.42%
Mean	96.8	68.1	17.38%	12.60%
L.S.D. P = 0.05	60.5	40.9	4.64%	N.S.
P = 0.01	83.5	56.5	6.42%	N.S.
Herbicide				
Dalopon	48.0	28.7	8.30%	4.95%
Paraquat	145.7	107.6	26.47%	20.25%
L.S.D. P = 0.05	49.2	34.6	3.79%	6.05%
P = 0.01	68.2	46.2	5.24%	8.36%
Coefficient of Variation	58.51%	56.29%	25.04%	55.18%
Significant interaction	Nil	Nil	SxH	SxH

Table 62b

Interaction between species and herbicides on percentage of growing points 2 weeks after cutting

Herbicide	Species T.hispida	A.filifolius	E.curvula	Mean
Dalopon	1.52	23.37	0.00	8.30
Paraquat	22.09	22.53	34.79	26.47
Mean	11.80	22.95	17.39	17.38

L.S.D. Body of Table: P = 0.05 = 6.56, P = 0.01 = 9.08

Table 62c

Interaction between species and herbicides on percentage of growing points 4 weeks after cutting

Herbicide	Species T.hispida	A.filifolius	E.curvula	Mean
Dalopon	0.44	14.41	0.00	4.95
Paraquat	24.63	15.26	20.84	20.24

A. filifolius produced more leaves than did the other two species at both regrowth harvests. When this data was corrected for the original number of leaves on the tufts (i.e. the total number of leaves six weeks after spraying) this species also had a higher percentage regrowth than both other species at the first cutting of regrowth. However, at the second cutting of the regrowth there was no significant difference between the species. At the first regrowth cut E. curvula had a higher percentage of leaves than did T. hispida.

Both the number of leaves and the percentage of leaves which regrew at both cuttings was significantly greater on the tufts which had been sprayed with paraquat than on those which were sprayed with dalapon. However, the significant interactions of species on herbicides, for the percentage of leaves at both cuts, indicates that this effect was not consistent over all the species. The different herbicides did not affect the percentage of leaves of A. filifolius which regrew, but there was a significantly lower percentage of regrowth leaves on T. hispida and E. curvula when sprayed with dalapon than when paraquat was applied.

The yields of regrowth following the cut six weeks after spraying are given in table 63.

The yields were calculated per tuft, per leaf at six weeks and per leaf at spraying. The number of leaves at spraying, was estimated from the number counted six weeks after spraying minus the number of wholly green leaves at this time - these green leaves were con=

Table 63a.

Dry matter weight of herbage regrowth, following cutting six weeks after spraying.

Treatment	Regrowth gram/tuft	Regrowth/leaf at 6 weeks ($\frac{1}{1000}$g)	Regrowth/leaf at spraying ($\frac{1}{1000}$g)
Species			
T.hispida	0.544	1.404	1.765
A.filifolius	0.589	0.782	1.271
E.curvula	1.508	3.826	4.063
Mean	0.880	2.006	2.366
L.S.D. P = 0.05	N.S.	N.S.	N.S.
P = 0.01	N.S.	N.S.	N.S.
Herbicide			
Dalapon	0.190	0.339	0.571
Paraquat	1.571	3.669	4.162
L.S.D. P = 0.05	1.348	2.292	2.197
P = 0.01	N.S.	3.170	3.038
Significant Interactions	Nil	sxH	sxH

Table 63b.

Interaction between species and herbicides on regrowth per growing point at six weeks.

Treatments	Species T.hispida	A.filifolius	E.curvula	Mean
Dalapon	0.049	0.969	0.000	0.339
Paraquat	2.759	0.596	7.651	3.669
Mean	1.404	0.782	3.825	2.006

L.S.D. Body of Table P = 0.05 = 3.972.

Table 63c.

Interaction between species and herbicides on regrowth per original growing point

Treatments	Species T.hispida	A.filifolius	E.curvula	Mean
Dalapon	0.049	1.663	0.000	0.571
Paraquat	3.481	0.879	8.125	4.162
Mean	1.765	1.271	4.062	2.366

L.S.D. Body of table P = 0.05 = 3.806.

sidered to be regrowth after spraying. There was no significant difference in the amount of herbage which regrew on the different species. However, in each of these three categories there was less regrowth on the tufts sprayed with dalapon than on those sprayed with paraquat. The significant interaction between the species and herbicides indicated that the response of A. filifolius was, once again, the same for both her= bicides while the other two species were suppressed by dalapon to a greater extent than by paraquat.

All the data gathered from this experiment indi= cates that dalapon is considerably more effective than paraquat in suppressing the regrowth of T. hispida and E. curvula. There is, however, little difference in the effect of the two herbicides on A. filifolius. In the absence of a control treatment (no herbicide) it is not possible to state categorically whether both sprays were ineffective or whether they were both equally effective, in suppressing the regrowth of this species. However, data from experiment N-Ec 17/2 (section 3.5.3.3.2) indicate that paraquat does sup= press the regrowth of A. filifolius, and it might, therefore, be concluded that both herbicides did suppress its regrowth to some extent. The differen= tial response of Highland sourveld grasses to the herbi= cides does, however, indicate that any form of gene= ralization about their effects is dangerous.

3.5.3.3.6 The residual effects of dalapon on the germination of overseeded species

Dalapon is a potentially useful herbicide for use in seed-bed preparation in the overseeding of grassland. It has a more severe killing effect than does paraquat in some instances, but this advantage is countered, to some extent at least, by the longer duration of its residual effect. This residual effect is likely to cause damage to the seedlings of overseeded species unless sufficient time lapses between spraying and seeding. Thus it is apparent that a knowledge of the precise duration and extent of this effect is essential prior to the use of this herbicide for seed-bed preparation. A pot experiment was conducted with this object in view.

Objective

The object of this experiment was to determine the duration of any residual effects of dalapon on seedlings when it was sprayed onto the soil.

Procedure

Twenty-four porcelain pots, each with an internal diameter of seven inches (18 cm) were filled with Clovelly topsoil, waterd and placed in a glass-house, which could be heated, at Potchefstroom. The pots were divided into four blocks (replicates) of six pots each to which the six treatments were applied. Sets of four pots (one from each replicate) were sprayed eight, four, two and one week before seeding on the 2nd July 1969, when the fifth set was sprayed and the sixth set was left unsprayed. The pots were sprayed

Table 64

The residual effect of dalapon upon the germination and early establishment of pasture seedlings

Treatments	Percentage establishment						
	Deformed seed-lings	Healthy seedlings					Grand total
		P. dilatatum	Clover			Total healthy	
			T. repens	*T. pratense*	Total		
Not sprayed	0.9	5.0	34.5	22.2	28.4	20.1	21.5
Sprayed 8 weeks before seeding	5.3	2.7	20.7	14.5	17.6	12.7	17.2
Sprayed 4 weeks before seeding	11.8	4.7	13.0	13.0	13.0	10.2	22.1
Sprayed 2 weeks before seeding	12.2	2.2	4.7	3.2	4.0	3.5	15.7
Sprayed 1 week before seeding	4.8	1.2	0.0	0.2	0.2	0.6	5.4
Sprayed on day of seeding	7.2	1.2	0.0	0.0	0.0	0.5	7.7
Mean	7.1	3.0	12.2	8.9	10.5	8.0	14.9
L.S.D. P = 0.05	4.4	N.S.	13.5	10.5	11.5	7.8	8.7
P = 0.01	6.2		18.6	14.5	15.9	10.8	12.1
Coefficient of variation	42.4%	80.8%	73.4%	78.3%	72.5%	64.8%	38.8%

with dalapon at the equivalent of 70 lb (31.8 kg) active ingredient, mixed with 24 fluid ounces (682 cc) "Agrol 90" wetting agent in 150 gallons (682 litres) of water, per morgen (0.8565 ha). The spray was applied with the aid of an aerosol spray-pack, and screens were placed round each pot to reduce spray drift.

One hundred seeds of each of _T. repens_, _T. pratense_ and _P. dilatatum_ (floated seed) were sown on the surface of each pot. The seeds were taken from the same batches as were used in the previous trials. Forty days after seeding the seedlings were pulled out and divided into deformed and healthy plants. The number of healthy seedlings of each species was counted, but the other category was not subdivided as it was not possible to distinguish between the two clover species when they were deformed. The pots were all kept moist from the time of the first application of dalapon until the seedling counts. During most of this period warm air was circulated through the glass-house at night.

Results and Discussion

The percentage of sown seeds which were counted in each category, forty days after seeding, are given in table 64.

Spraying with dalapon resulted in a reduction of the total number of plants and in the number of healthy plants which became established. The shorter the period between spraying and seeding, the more severe were the effects of the herbicide. There were significantly fewer plants on the pots which had been sprayed one week before seeding than on all other treatments, except the one which was sprayed at seeding. This latter treatment also had fewer plants than did the control treatment and the treatments which were sprayed four and eight weeks before seeding. There were also significantly fewer healthy plants in the pots sprayed one week before and at seeding than on all the other treatments except that sprayed two weeks before seeding. This latter treatment had fewer healthy plants than did the control treatment and the treatment which was sprayed eight weeks before seeding. The treatment sprayed four weeks before seeding also had fewer healthy plants than did the unsprayed plots.

Spraying with dalapon resulted in an increase in the number of deformed plants. There were significantly fewer deformed plants on the unsprayed plots than on all other treatments. The number of deformed plants was at a maximum on the plots which were sprayed with dalapon at four and at two weeks before seeding, which had significantly more deformed plants than did any of the other treatments.

There were no significant differences in the percentage of healthy *P. dilatatum* seedlings on the various treatments. The germination of this species was poor (3%). However, the number of healthy red and white clover plants decreased as the period between spraying and seeding shortened. The pots sprayed one week before, and on the day of seeding had practically no healthy red or white clover plants. The unsprayed pots had significantly more healthy red clover plants than did all the sprayed pots, and also had more white clover than all the pots sprayed two weeks or less be= fore seeding. The pots which were sprayed eight weeks before seeding had more healthy clover plants of both species than did those sprayed two weeks or less be= fore seeding.

It is apparent that under the conditions of this experiment, Clovelly soil when sprayed with dalopon should/not be overseeded until at least four weeks have elapsed after spraying. A small reduction in the per= centage establishment is probable even eight weeks after spraying.

3.5.3.3.7 The application of the method

Herbicides have been used with success, overseas, to reduce the competition from the existing sward in the establishment of overseeded pastures, however, they are generally used in combination with some form of soil disturbance. In inaccessible areas they have the advantage that they can conveniently be applied from the air. Paraquat, in particular, ap= pears to have the further advantage of the absence of residual effects harmful to germinating seedlings.

The series of trials which were carried out tend to confirm these impressions obtained from overseas experiments. They also indicate that dalopon has a re= latively short period of residual activity, and because of its greater inhibitary effect on the growth of some grasses it might prove more effective than paraquat.

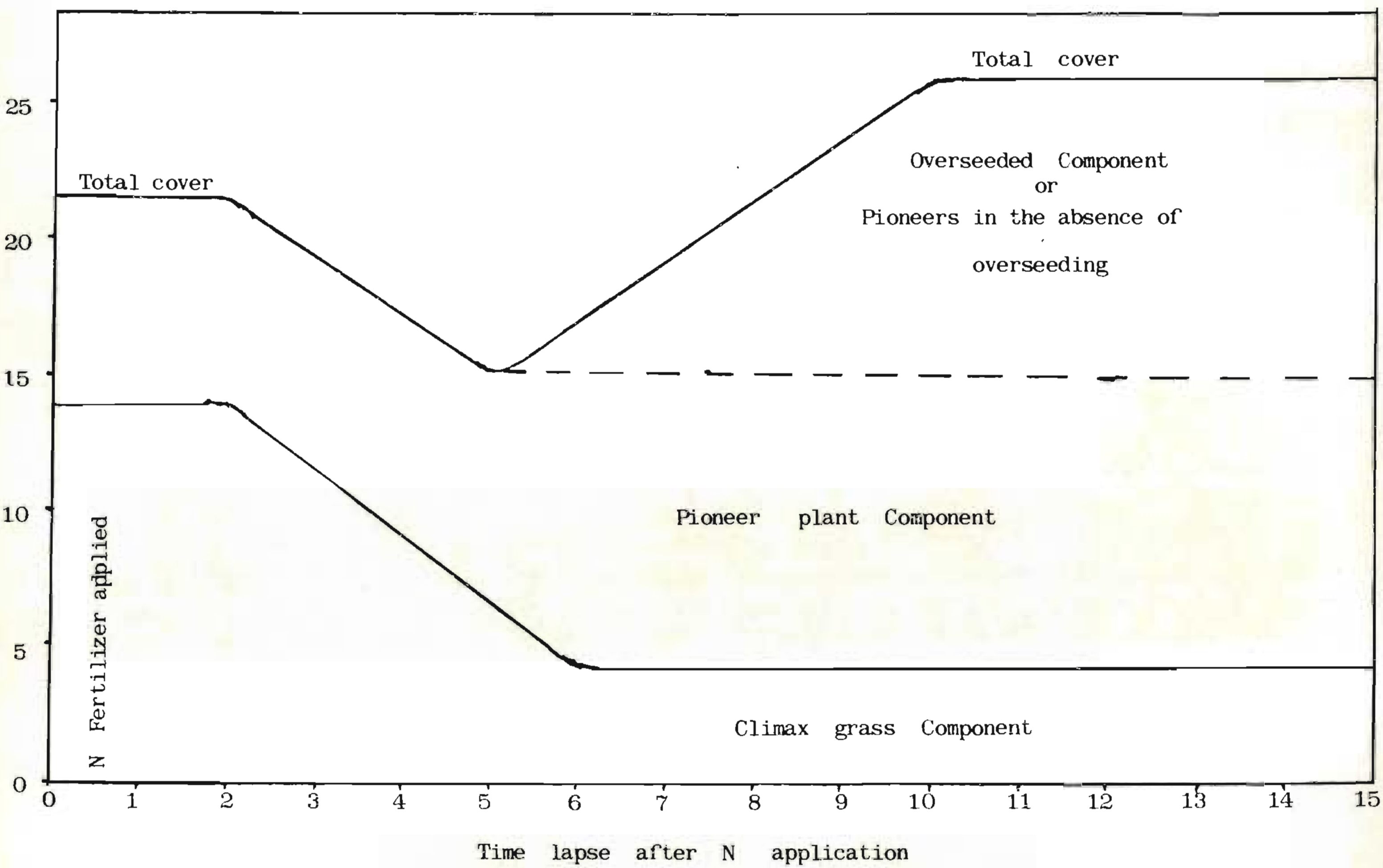
It is apparent that there is a considerable difference in the reaction of Highland Sourveld grasses to these herbicides. Consequently varied success could be expected from the use of these herbicides, depending on the species composition of the grassland sward. A fair amount of improvement was achieved in the one field trial in which paraquat was used, however, greater success was achieved using other preseeding techniques. In such cases, however, herbage yields may be inade= quate measures of the value of the improvements; even small increments of high quality improved species may be sufficient to adjust the nutrient deficiencies in the animals diet, and may result in considerable in= creases in animal production. This technique should be coupled with mowing or burning to ensure that old herbage does not smother the seedlings.

The herbicides have obvious advantages for use on steep slopes, vleis and stony areas where imple= ments can not penetrate. However, at present prices they are unlikely to prove profitable when used in conjunction with other techniques such as soil dis= turbance. Because of the costs of the herbicides and because of uncertainty as to their effectiveness on all types of grassland swards; it does not appear to be reasonable to recommend their general use at this stage. Further field trials should be effective in clarifying this point. It would be of considerable advantage if these trials could be conducted in such a way as to yield results in terms of livestock pro= duction.

3.5.3.4 Nitrogen fertilization as a means of seed-bed preparation (N-Ec 17/1)

Conflicting results have been obtained on the effects of nitrogen fertilizer on the basal cover of veld. Some workers (Meredith, 1948; Hall et al, 1950; 1955; Botha, 1953; Barnes, 1956) have re=corded an increase in basal cover due to the applica=tion of nitrogen to the veld, while others (Fisher, 1954; Booysen, 1954; 1961) have recorded a decline in basal cover. The reason for these conflicting results might be due to one or more of several causes. These are: variation in the original composition of the sward, availability of seed of pioneer species, the method by which the sward was utilized, and the duration of the experiment. Basal cover will probably increase more rapidly after fertilization on a pioneer sward containing stoloniferous grasses with a good supply of seed, than on a sward with few pioneer spe=cies and little of their seed available. In the latter sward the plants, which are higher in the suc=cession, would die out fairly rapidly but the coloni=sation of the bare areas by pioneers might be a lengthy process which would perhaps result in a temporary de=cline in basal cover. Booysen (1954) and McKenzie (1961) have noted that the lack of seed supplies has limited the rate of invasion of pioneer grass species on a fertilizer experiment at Ukulinga. In many of the fertilizer experiments on veld the basal cover has not been noted during the first few years, thus the initial stages of killing and colonisation have not been recorded.

FIGURE 9. HYPOTHETICAL CHANGES IN BASAL COVER AFTER NITROGEN FERTILIZATION OF VELD.



Botha (1953) and Fisher (1954) in South Africa and other workers overseas (Bhanucha & Dave, 1952; Rogler & Lorenz, 1957; Lodge, 1959) have found considerable differences in the basal cover of fertilized natural grazing, caused by different methods of utilization. At Athole, Botha (1953) reported differences in the basal cover of fertilized veld caused by the system of grazing and class of livestock used. At Franken=wald, Fisher (1954) found, that with frequent clipping, the basal cover of heavily fertilized "Eragrostis veld" increased. However, when clipping was less frequent the basal cover declined.

It was concluded that the fertilization of veld with large amounts of nitrogen could, in some circum=stances, bring about a drop in basal cover. This drop in cover might be of a temporary nature resulting from a decline in cover of the climax grass species. In=creases in the pioneer species cover, at a later date, might compensate for the decline. (See Fig. 9). It was also concluded that the drop in basal cover might be accentuated by lax utilization of the herbage in the early stages of fertilization. It was reasoned that this low point in basal cover might prove to be a favourable time for the establishment of overseeded species, which once established might substitute for and replace the increase of pioneer species. Con=sequently an experiment along these lines was started in the Highland sourveld. For the sake of convenience these treatments were combined in one experiment with two paraquat spray treatments, which have been discus=sed in section 3.5.3.3.4.

Objective

The objects of the experiment were to investigate the influence, of preseeding treatment of the veld with nitrogenous fertilizer and with paraquat, on the sub= sequent establishment of overseeded pasture species.

Procedure

The experiment was started in November 1965, on the "Clovelly" block, when the nitrogenous fertilizer was applied for the first time to veld which had been mown in September. The paraquat was applied and seeding was carried out in December 1966. The experi= ment consisted of a 5 x 2 x 2 factorial design in ran= domised blocks with three replicates. The treatments are described in the following paragraphs.

Five preseeding treatments were applied. The first treatment was not treated prior to seeding (con= trol). The second treatment was fertilized with 300 lb (136 kg) N (as limestone ammonium nitrate - 21% N), 50 lb (23 kg) P (as superphosphate - 8.3% P), 200 lb (92 kg) K (as KCl- 50% K) and 600 lb (272 kg) agricultu= ral lime per morgen (0.8565 ha) applied to the veld in the year prior to overseeding. The third treatment was the same as the second except that the amount of nitrogenous fertilizer applied was doubled. The fourth and fifth treatments consisted of one and two pounds per morgen (0.53 and 1.06 kg/ha) respectively of paraquat sprayed on the veld the day before seeding.

The veld canopy was in two conditions at seeding. It was either mown just prior to seeding or was left uncut (i.e. two to three months spring growth on the plots).

The seed was applied at two rates. It was ap=plied at 100 lb (45.4 kg) P. dilatatum, 6 lb (2.7 kg) T. repens (Ladino) and 16 lb (7.3 kg) T. pratense per morgen (0.8565 ha) and at double these rates.

The nitrogenous fertilizer was applied in two equal dressings, one at the end of November 1965 and one during January 1966. The phosphate, potash and lime were also applied during November 1965. Para=quat was sprayed onto the veld by means of a knapsack spray in December 1966. The paraquat was mixed with water, at the rate of 100 gallons (455 litre) per mor=gen, and "Agrol 90" (a non-ionic wetting agent) at the rate of 16 fluid ounces (454 cc) per morgen. The seed of the pasture species was broadcast over each plot separately, on moist soil one day after spray=ing with paraquat in December 1966. The legume seeds were inoculated with appropriate strains of Rhizobium bacteria. At establishment all the plots were fer=tilized with 600 lb (272 kg) superphosphate, 400 lb (182 kg) KC1, 2 ton (908 kg) agricultural lime and 250 lb (114 kg) limestone ammonium nitrate per morgen. In the spring of the 1967/68 season the plots were all fertilized with a further 600 lb superphosphate and 400 lb KCl per morgen.

The herbage yield of the plots was determined from two strips (each of 2 x 10 yd — 1.8 x 9.1 m) which were cut from each 7 x 12 yd (6.4 x 10.9 m) gross plot.

After seeding, sample strips of herbage were separated into the sown components and the veld component. Prior to seeding, during the 1965/66 season, all the plots were cut twice, the mown treatment was applied to half the plots in November 1966, and the first post-seeding cut was applied in January 1967. (For purposes of statistical analyses the yields of these last two cuts were combined). The contribution of the sown species, to yield, is apparent only in the last cut of the 1966/67 season and in all three cuts of the 1967/68 season.

The basal cover and species composition of the veld were recorded, by means of a point bridge containing three points spaced ten inches apart, during December 1965 and again in November 1966. One hundred and eighty points were recorded on each plot at each analysis - this amounted to 2160 points on each of the five pre-seeding treatments, as the mowing and seeding rate treatments had not yet been applied. The two para=quat treatments, which had not been applied, were con=sidered as additional control treatments.

The pattern or arrangement of a grassland sward may affect the success obtained with the establishment of oversown species. Individual plants in the field are rarely systematic or random in distribution and, in fact, the commonest situation is that plants tend to be more or less gregarious and are clumped in patches of varying size and density within an area (Greig-Smith, 1957). When this happens the mean density of plants per unit area gives a misleading impression of the mean distance apart of individuals, and so of their effective density (Harper, 1959). The mean density, therefore, also gives a misleading impression of the size of the open spaces between tufts. The size, pattern and frequency of tufts and of bare spaces in veld determines the number of "safe microsites" for establishment, which according to Harper, Williams and Sogar (1965) determines the early establishment of oversown species. Because the nitrogen fertilizer treatments may have resulted in a change in the horizontal spacial arrange= ment or pattern of the grass tufts, it was decided to attempt to record any such changes. The presence or absence of basal cover at points along two transects, parallel to one another and 40 cm apart, was recorded in March and again in November 1966. The March ana= lysis, although carried out three months after the ap= plication of fertilizer, should give a fairly good re= flection of the pre-treatment condition of the veld as obvious changes in basal cover had not yet taken place. The presence or absence of cover was recorded at every centimetre along the 640 cm length of each transect. This data was then examined and the size of the bare spaces and tufts was recorded. (The possibility of a bare space or tuft, smaller than one centimeter, between two adjacent recordings was ig= nored. This practice probably resulted in an over= estimation of cover, as bare spaces of less than one centimetre in diameter could be expected more frequent= ly than small tufts of this size on this type of sward). Only total cover, and not species composition, was re= corded.

Table 65

The effect of nitrogen fertilizer and paraquat pre-seeding treatments on herbage yields
(Yields of Dry material in ton/morgen) (1 ton/morgen = 1059 kg/ha)

Treatment	1965/66			1966/67				Total of 3 cuts 1967/68			
	20/12/65	9/3/66	Total	17/11/67 & 17/1/67	9/3/67	Total	9/3/67 Clover	Clover	P.dilatatum	Veld	Total
Pre-seeding treatment											
No treatment	0.77	0.77	1.54	1.69	0.59	2.28	0.003	0.118	0.031	3.976	4.125
300 lb N/morgen	1.01	4.26	5.28	4.86	1.16	6.01	0.014	0.540	0.075	4.540	5.155
600 lb N/morgen	1.10	5.39	6.49	6.02	1.87	7.90	0.020	1.331	0.170	5.349	6.850
1 lb paraquat/morgen	0.89	0.78	1.67	1.00	0.54	1.52	0.008	0.462	0.176	3.304	3.942
2 lb paraquat/morgen	0.89	0.87	1.78	1.02	0.53	1.55	0.008	0.481	0.200	3.454	4.135
Mean	0.93	2.41	3.35	2.91	0.94	3.85	0.011	0.586	0.130	4.125	4.841
L.S.D. P = 0.05	N.S.	0.77	0.95	0.73	0.29	0.69	N.S.	0.356	0.103	0.777	0.706
P = 0.01		1.19	1.39	0.99	0.39	0.93		0.480	0.138	1.047	0.951
Condition of veld											
Mown	-	-	-	2.87	0.98	3.86	0.011	0.615	0.112	4.170	4.897
Unmown	-	-	-	2.95	0.90	3.85	0.010	0.559	0.150	4.082	4.791
L.S.D. P = 0.05	-	-	-	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P = 0.01											
Seeding rate											
Low	-	-	-	2.31	0.93	3.74	0.011	0.404	0.122	4.436	4.962
High	-	-	-	3.01	0.95	3.96	0.010	0.770	0.139	3.816	4.725
L.S.D. P = 0.05	-	-	-	N.S.	N.S.	N.S.	N.S.	0.225	N.S.	0.492	N.S.
P = 0.01	-	-	-					0.304		0.662	
Coefficient of variation	19.35	16.95	15.10	30.14	38.47	21.48	172.62	72.88	94.40	22.60	17.50

Results and Discussion

(a) Herbage yields

The yields of herbage harvested from the plots during the pre-establishment, the establishment and during one post-establishment season are given in table 65.

The yield of the veld was increased considerably by the application of nitrogenous fertilizer. During the pre-establishment period the yield of the first cut, taken within one month of the first fertilizer application, was not affected by the treatments. How= ever, in the second cut of that season, which was har= vested three months later during March, there was a very marked response to the application of nitrogenous fer= tilizer. The application of 300 lb N per morgen re= sulted in a five fold increase of yield compared with the control plots, while 600 lb N per morgen produced a further significant increase in yield. During the establishment season (1966/67) the yield of herbage from the fertilized plots was also much greater than that of the unfertilized plots. (This also reflected the response of the veld as the sown species made only a very small contribution to the yield during this season). In all, from the time of the first fertili= zer application (November, 1965) until the end of the establishment season in March 1967 (a period of sixteen months), the unfertilized plots yielded 3.82 tons (4045 kg/ha) the 300 lb N per morgen treatment 11.29 tons (11,956 kg/ha) and the 600 lb N per morgen treat= ment 14.39 tons (15,239 kg/ha) dry material per morgen.

If the costs of the fertilizer applied (based on lime= stone ammonium nitrate (26% N) at R40.95 per ton (908 kg), superphosphate R23.60 per ton, muriate of potash R34.70 per ton and lime R2.00 per ton) on the treat= ments is compared with the increased value of the hay produced (valued at R15 per ton or R16.50 per ton of dry material) then the treatments appear to yield a handsome profit. At the 300 lb N per morgen level the profit is R85 per morgen and at 600 lb N per morgen it is R112.50 per morgen. Slightly higher hay making costs per morgen should be offset against these figures but other costs such as depreciation and interest on implements, and on land capital would be unaffected by the increased yields. Thus all factors considered, the costs of seed-bed preparation involved in this technique should be amply repaid by the pre-establish= ment yields of veld.

The application of both levels of paraquat sig= nificantly reduced the yield of the veld during the establishment season (1966/67). Mowing the veld prior to seeding and the two seeding rates did not influence the herbage yields during this season. However, the interaction between the preseeding treat= ments, the condition of the veld at seeding and the seeding rates was statistically significant in the total yield. The 600 lb N per morgen pre-seeding treatment on unmown vled at the high seeding rate gave a higher yield than it did at the low seeding rate, while the yield of all the other pre-seeding treatments, irrespective of the condition of the veld, was unaffected by the seeding rate. At this level of nitrogen fertilization the mown plots (at seeding) outyielded the unmown plots at the low seeding rate but the reverse was apparent at the high seeding rate. As these tendencies were not apparent in the yields of the third cut or in the yield of clover material, the cause for them is obscure.

The yield of clover, in the first season after establishment (1967/68), increased as a result of the pre-seeding treatments. Both the 300 lb N and the 600 lb N per morgen pre-treatments resulted in a sig= nificant increase in the yield of clover when compared with the control treatment, while the plots of the 600 lb N per morgen treatment yielded significantly more clover than did all other treatments. The yield of clover on the plots sprayed with 2 lb paraquat per morgen was significantly greater than on the con= trol plots, while the increase in clover at 1 lb para= quat per morgen just failed to reach significance (P=0.05). The mowing of the veld prior to seeding did not affect the yield of clover, but the seeding rate did. The yield of clover was significantly greater at the high seeding rate than at the low rate. The interaction of the seeding rate and the pre-seeding treatments was significant for the yield of clover du= ring this season. The high seeding rate produced an increased yield of clover at 600 lb N per morgen but was no better than the low seeding rate on the other pre-seeding treatments. The yield of clover at the low seeding rate was the same on all pre-seeding treat= ments (except that the control was less than the 600 lb N) but at the high seeding rate the 600 lb N per mor= gen pre-treatment produced more clover than did all the other treatments.

The yield of P. *dilatatum* was increased signifi= cantly by the application of 600 lb N per morgen and by the application of both rates of paraquat. The high level of paraquat (2 lb/morgen) also resulted in a greater yield of P. *dilatatum* than did the applica= tion of 300 lb N per morgen. The condition of the veld at seeding and the seeding rates did not affect the yield of P. *dilatatum*.

The yield of veld was greater, in the year after seeding, on the 600 lb N per morgen pre-treatment than on all other treatments, while at 300 lb N per morgen (pre-treatment) the veld outyielded that on the plots which had been sprayed with paraquat. The mowing of the veld just prior to overseeding did not affect the yield of the veld, but its yield was depressed by the high seeding rate. The interaction of the seeding rate and the pre-seeding treatments for the yield of veld was significant during this season. The high seeding rate resulted in a significant increase in the yield of the veld on both N treatments and at two lb paraquat per morgen, at one pound of paraquat per mor= gen seeding rate had no effect on veld yields, but on the control treatment the high seeding rate depressed the yield of the veld. The veld at 600 lb N per morgen, at the low seeding rate, outyielded all other pre-seeding treatments, but at the high seeding rate both nitrogen pre-seeding treatments outyielded both paraquat treatments.

In the first year after seeding the total yield of herbage was greatest on the 600 lb N per morgen pre-seeding treatment. The 300 lb N per morgen pre-seeding

Table 66

Percentage basal cover of plant famalies before and after nitrogen fertilization

Category	PRESENT BASAL COVER															
	1965								1966							
	Control	300 N	600 N	*Control	*Control	Mean	L.S.D. P=0.05	L.S.D. P=0.01	Control	300 N	600 N	*Control	*Control	Mean	L.S.D. P=0.05	L.S.D. P=0.01
Desirable species	6.62	6.66	6.53	9.68	8.15	7.53	1.61	2.17	11.25	7.18	5.32	10.14	11.02	8.98	1.24	1.74
Undesirable species	6.16	5.23	4.77	5.93	6.90	5.80	1.40	1.88	2.73	5.79	5.65	4.86	4.25	4.66	1.64	2.21
Total Cover	12.78	11.89	11.30	15.61	15.05	13.33	1.86	2.63	13.98	12.46	10.97	15.00	15.28	13.64	1.86	2.51
Arundinelleae	3.24	3.56	2.87	4.21	3.56	3.49	-	-	5.93	4.95	3.66	5.37	5.65	5.11	1.13	1.52
Andropogoneae	3.61	3.80	3.47	4.35	4.90	4.03	-	-	4.72	1.94	1.20	4.31	5.09	3.45	1.33	1.74
Paniceae	2.04	1.67	2.36	2.59	2.04	2.14	-	-	1.85	1.62	0.79	2.22	1.99	1.69	0.95	1.27
Chlorideae	1.16	0.97	0.88	1.39	1.71	1.20	-	-	0.83	1.76	2.18	1.25	0.83	1.37	0.76	1.02
Eragrosteae	2.13	1.39	1.06	2.04	1.94	1.72	-	-	0.37	1.34	1.90	1.16	1.34	1.22	0.95	1.27
Compositeae	0.32	0.14	0.09	0.28	0.55	0.28	-	-	0.19	0.88	0.88	0.32	0.23	0.50	0.62	-
Other	0.28	0.37	0.55	0.83	0.28	0.46	-	-	0.09	0.46	0.37	0.37	0.14	0.29	-	-

*Later treated with paraquat.

treatment also outyielded the other three treatments. The condition of the veld at over-seeding and the seeding rates did not affect the total herbage yields.

These results indicate that the pre-seeding treat= ments which were applied aided in the establishment of the oversown species. The nitrogen treatments had a further advantage of increasing by a considerable amount, the total yield of herbage during the whole period of the trial.

(b) The botanical composition of the herbage

The percentage basal cover of the various plant families in December 1965 (i.e. just after the first application of N fertilizer), and in November 1966 are given in table 66.

The categories and families were represented by the following genera and species.

Undesirable species

Alloteropsis semialata, Andropogon filifolius, Aristida junciformis, Elyonurus argenteus, Eragrostis species (chiefly E. curvula and E. plana), Festuca species, Harpechloa capensis, Helictrotrichon turgidulum, Koe= leria cristata, Michrochloa caffra and all other non-gramineaceous species.

Desirable species

Bracharia serrata, Digitaria tricholaenoides, D. seti= folia, Eulalia villosa, Heteropogon contortus, Hyparrhenia hirta, Monocymbium ceresiiforme, Panicum ecklonii, Themeda triandra, Trachypogon spicatus and Tristachya hispida.

Andropogoneae

Andropogon filifolius, *Elyonurus argenteus*, *Eulalia villosa*, *Heteropogon contortus*, *Hyparrhenia hirta*, *Monocymbium ceresiiforme*, *Themeda triandra* and *Trachypogon spicatus*.

Arundinelleae

Tristachya hispida

Chlorideae

Harpechloa capensis and *Microchloa caffra*

Compositae

Eragrosteae

Eragrostis plana and *E. curvula*

Paniceae

Alloteropsis semialata, *Bracharia serrata*, *Digitaria tricholaenoides*, *D. setifolia* and *Panicum ecklonii*

Other

Aristida junciformis, *Cyperaceae*, *Festuca* species, *Helictrotrichon turgidulum* and *Koelaria cristata*.

The 1965 analysis

The plots of the two treatments which were to be treated with paraquat, had a greater total basal cover than did the other treatments at the start of the experiment. This is unfortunate and is obviously due to variation within the experimental area. Both these treatments had more cover of desirable species than did the other three treatments. There were also some differences in the cover of undesirable species between these two treatments and the other treatments. Due to these initial differences in cover these two treat= ments (which were at this stage virtually "dummies"), were excluded from further comparisons between the treatments.

Thre were no significant differences in any of the various categories of cover between the first three treatments at this stage.

The 1966 analysis

The application of 600 lb N per morgen resulted in a significant reduction in the total basal cover when compared with the control treatment. The appli= cation of nitrogenous fertilizer (at both levels) re= sulted in an increase in the basal cover of undesirable species and a reduction in that of desirable species. There was also less basal cover of desirable species at the high level (600 lb N per morgen) of nitrogen application than at the low level (300 lb N/morgen). The effects of the fertilizer treatments on the various grass families is summarised as follows:

Arundinelleae

Nitrogenous fertilizer resulted in a reduction in the basal cover of this "climax grass" family. The reduction was most marked at the high level of application of nitrogen.

Andropogoneae

The application of nitrogenous fertilizer also resulted in a reduction of the basal cover of this "climax grass" family.

Paniceae

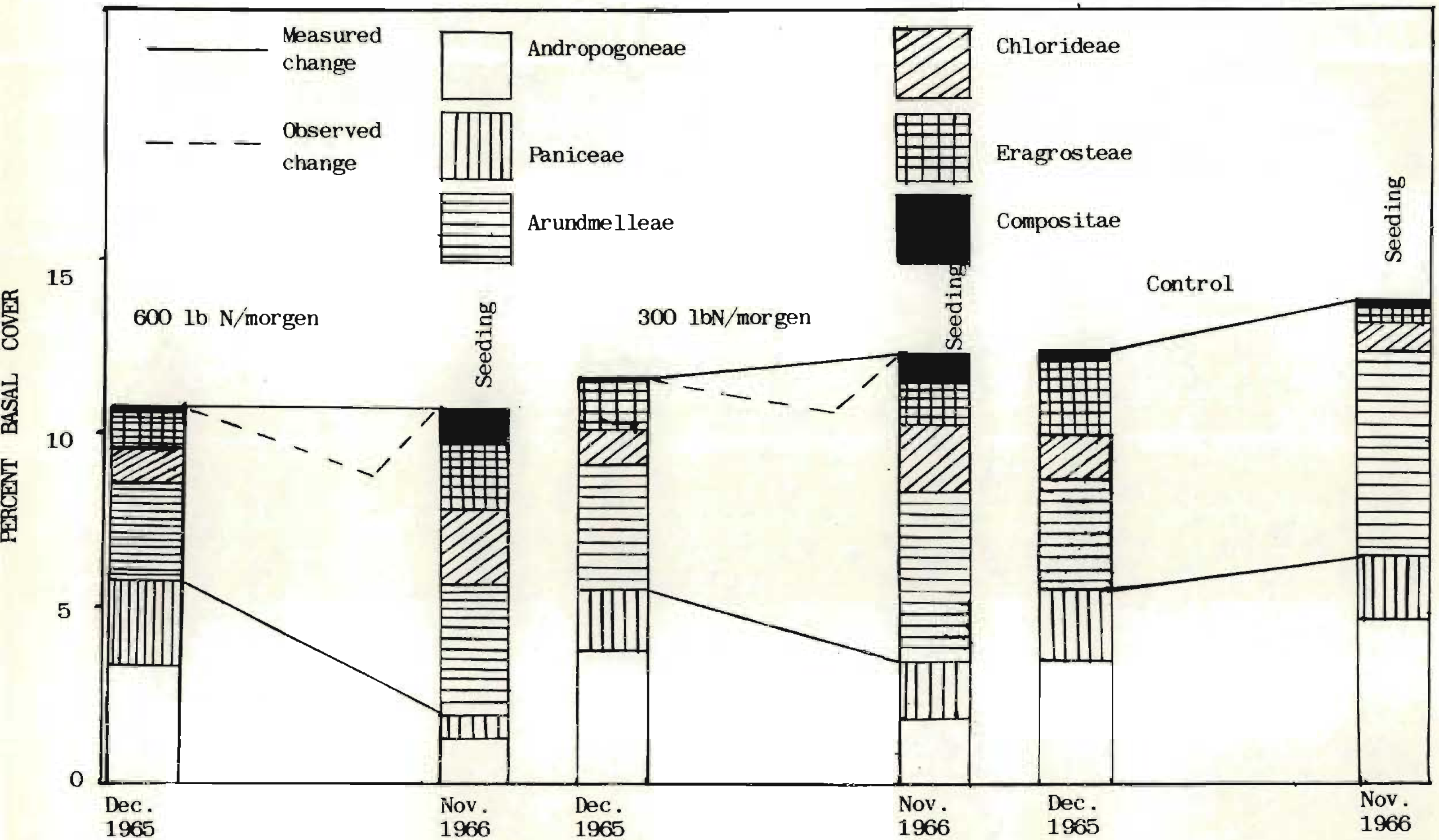
The basal cover of this family was also reduced as a result of the application of the high level of nitro= genous fertilizer. The low level of fertilizer ap= parently had no effect on the basal cover.

Chlorideae, Eragrosteae and compositae

The basal cover of these three families increased as a result of the application of nitrogenous fertili= zer. The latter two families comprise the main pio= neer plant species in this veld type.

The rapidity with which the changes in basal cover took place was perhaps the most significant feature. Observations indicated that the change took place over winter, between the first frosts in April 1966 and the spring of 1966. The changes, predicted in the hypothe= sis on which the treatments were based, occurred so rapidly that the experimenter was unprepared, and con= sequently the overseeding and the second botanical ana= lysis were carried out later than they should have been. At the time of seeding (and botanical analysis), the invading indigenous pioneer species had already begun to colonise the space formerly occupied by the "climax grass" species which had died. Thus earlier seeding, in spring, may have produced better results as the overseeded species were observed

FIGURE 10. CHANGE IN SPESIES COMPOSITION RESULTING FROM NITROGEN FERTILIZATION (1 lb/morgen = 1059 kg/ha)



to suffer from the competition of the indigenous pioneers. The charges in cover, in relation to seed= ing are illustrated in figure 10.

Louw (1967) reporting on the effect of fertili= zation of the veld with sulphate of ammonia, on the red loams of the Transvaal Springbok flats, also ob= served a decline in the basal cover of Andropogoneae due to fertilization. Three of the species (T. triandra, H. contortus and E. argenteus) in this family are com= mon to the veld of his experiment and to the Highland sourveld. He also noted that the basal cover of the Eragrosteae remained more or less unaltered as a re= sult of nitrogen fertilization. He ascribed this to the varied reaction of the Eragrostis species. E. curvula which responded to nitrogen fertilization in the Highland sourveld was apparently not present in the Springbok flats, but on the basis of Ranwell's (1964) work at Potchefstroom such a response might indeed be expected. Louw (1967) notes that the basal cover of B. serrata increased as a result of nitrogen fertilization, but at Tabamhlope the basal cover of this species tended to decrease (this obser= vation is very tentative due to the sparcity of this species at Tabamhlope).

Although it is generally accepted that the Andro= pogoneae decrease and the Eragrosteae increase as a result of nitrogen fertilization, there appears to be scope for further investigation of the behaviour of individual species and their ecotypes. It is con= cievable that there may be ecotypes of normally sus= ceptible species which are adapted to a high level of nitrogen. (e.g. T. triandra on the black turf soils of the Themeda veld - Acocks veld type 52 - on which annual crops show a poor response to nitrogen ferti= lization). The practical value of such investigations may also lie in determining the genetic yield limita= tions of the ecotypes. Tolerance to nitrogen ferti= lization in such an ecotype may be coupled with a low genetic potential for yield. Such a condition could seriously limit the response of the veld to fertiliza= tion because pioneer species, with a higher yield po= tential, may be unable to obtain a foothold.

(c) The size of tufts and bare spaces

The mean diameter of the grass tufts and of the bare spaces between tufts on the treatments in March and in November 1966 is given in table 67.

The mean diameter of the grass tufts did not vary between treatments at either of the periods of measure= ment. However, the mean diameter of all tufts appeared to be greater in March than in November. During March there was no difference in the mean diameter of the bare spaces between tufts on the various treatments. However, eight months later (November), and one year after the first application of fertilizer, there were significant differences between the diameter of the bare spaces on the various treatments. The diameter of the bare spaces on the two treatments which had been fertilized was greater than that on the control treatment. The diameter of the bare spaces was also greater at the high level (600 lb N/morgen) of ferti= lization than at the low level (300 lb N/morgen).

FIGURE 11. THE EFFECT OF NITROGEN FERTILIZATION ON PLANT NUMBERS IN TUFT SIZE CATEGORIES

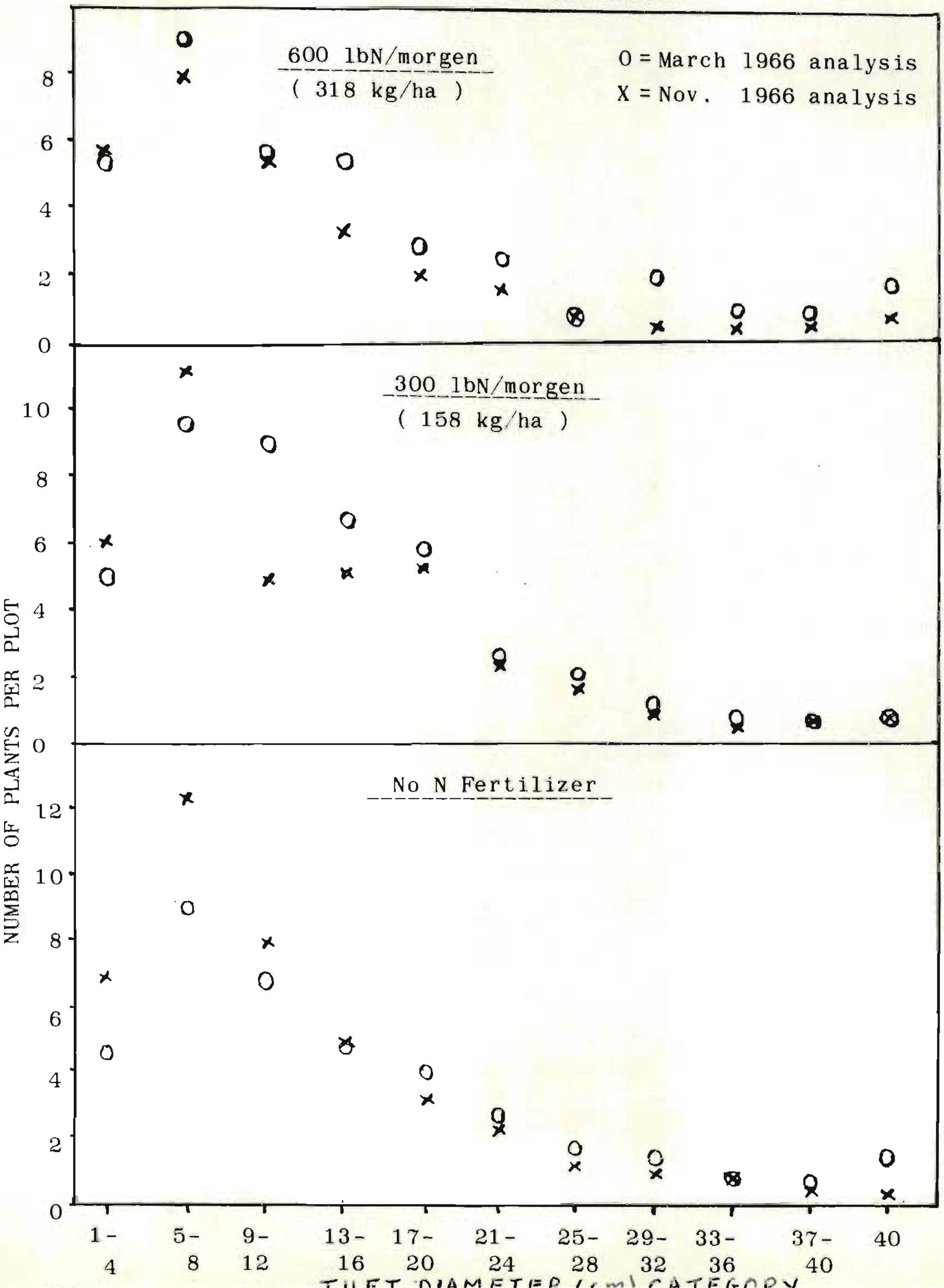


FIGURE 12. THE EFFECT OF NITROGEN FERTILIZATION ON THE NUMBER OF BARE SPACES IN SPACE SIZE CATEGORIES

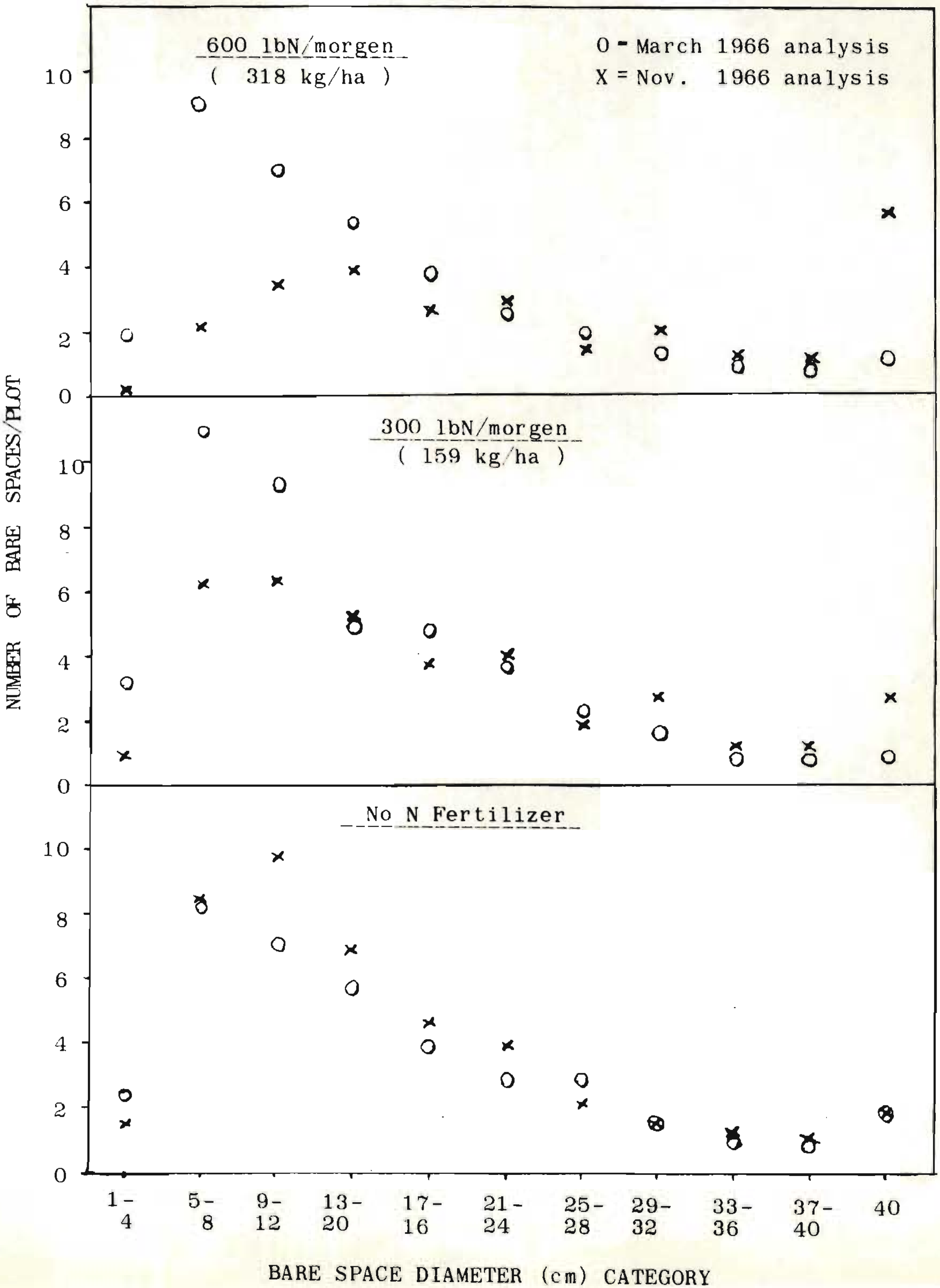


Table 67.

Mean diameters of tufts and of bare spaces as affected by nitrogen fertilization.
(1 lb = 0.454 kg; 1 morgen = 0.8565 ha)

Treatment	Mean size of tufts (cm)			Mean size of bare spaces (cm)		
	March 1966	Nov. 1966	Change	March 1966	Nov. 1966	Change
Control	16.97	12.26	-4.71	17.95	17.77	-0.18
300 lb N/morgen	14.98	13.12	-1.86	15.35	20.82	+5.47
600 lb N/morgen	18.36	12.63	-5.73	17.31	33.40	+16.09
*"Control"	15.47	12.30	-3.17	17.84	17.10	- 0.74
*"Control"	18.53	12.06	-6.47	19.19	16.91	- 2.72
Mean	16.86	12.47	-3.39	17.53	21.20	+ 3.67
L.S.D. P = 0.05	N.S.	N.S.	-	N.S.	3.93	-
P = 0.01			-		5.29	-
Coefficient of Variation	28.87	15.88	-	20.79	22.21	-
Mean of 3 controls	16.99	12.21	-4.78	18.33	17.26	- 1.07

*Later sprayed with paraquat.

The number of tufts, and bare spaces, also varied depending on the treatment applied. Between March and November the number of tufts on the control plots increased from an average of 36.6 to 41.4 per 1280 cm, however, at 300 lb N per morgen they decreased from 42.1 to 37.0 and at 600 lb N per morgen from 34.6 to 26.1. As might be expected similar changes were also apparent in the number of bare spaces. The number of bare spaces increased on the control plots and decreased on the fertilized plots.

In order to facilitate comparisons between the size of the tufts, and the bare spaces, on the various treatments, the plants and bare spaces were grouped into categories based on their diameter. The number of plants, and of bare spaces, occurring in each cate= gory on each treatment are represented in figures 11 and 12.

The number of small (<12 cm diameter) plants in= creased on the unfertilized plots between March and November. However, at 300 lb N per morgen the number of very small (<8 cm diameter) plants increased while the number of slightly larger (9-16 cm diameter) plants decreased over the same period. At 600 lb N per morgen the number of plants in most categories de= creased between March and November. These changes may be indicative of a change in the botanical composition of the veld, as different grass species might have different peaks on the tuft size and number Unfortunately, the staff available for these recordings was not trained in species identification and this ad= ditional data was, therefore, not recorded.

Changes in the number of bare spaces in the vari= ous categories were also apparent between March and November. The number of bare spaces with a diameter of between 9 and 24 centimetres increased on the con= trol plots between March and November. However, where nitrogenous fertilizer had been applied the number of small (<20 cm diameter) bare spaces decreased while the number of large (>40 cm diameter) bare spaces increased over the same period. These effects were more marked at 600 lb N than at 300 lb N per morgen. This data indicates that the application of heavy dressings of nitrogenous fertilizer to the Highland sourveld re= sults in a rapid change in the size and frequency of bare spaces and thus probably in the pattern of the vegetation. It results in less bare spaces which, however, tend to be larger than on unfertilized veld. Such large bare spaces might be expected to provide favourable micro-sites for the establishment of over= seeded pasture species.

The application of the method

The use of heavy dressings of nitrogenous fertili= zer as a pre-treatment to aid in the establishment of overseeded pasture species was successful. Not only did it result in a ten-fold increase in the her= bage yield of the sown species in the year following seeding, but there was also a 3.8 fold increase in the herbage yield of the veld during the two and a half seasons following the fertilizer application. The returns from such treatment appear to be very profitable.

The method appears to be most suited for use on rough terrain where tractors and implements can not be used. Spreading the fertilizer from the air has ob= vious attractions, and urea because of its N concen= tration appears to be well suited to this method of application. However, due to the rapid returns rela= tive to other methods of pasture establishment; this technique might also find favour on more accessible terrain.

The success of the method was probably due to the drop in basal cover, and to the development of many large bare spaces which followed the application of large amounts of nitrogenous fertilizer. These ad= vantages apparently overshadowed the effects of increas= ed competition of the veld grasses (as evidenced by their increased yields) resulting from fertilization. Further study of the most suitable stage for over- seeding in relation to the basal cover changes, of the most suitable sources of nitrogenous fertilizer and of the possible use of herbicides to control broad- leaf weeds just prior to seeding are some aspects which warrant attention. The post-establishment management of such pastures will also require considerable atten= tion.

3.5.3.5 Trampling with livestock as a means of es= tablishment (N-Ec 17/5)

The fourth method which was tested for use in the establishment of overseeded species in grassland, was the concentration of livestock on re= latively small areas to trample the seed into the soil. (The other three methods were minimum tillage, herbicides and nitrogen fertilization).

Crampton (1960) and Davies and Jones (1963) sug= gest that "Hoof cultivation" after over-seeding should give sufficient soil consolidation and seed covering for establishment, on areas where mechanical cultiva= tion is difficult. However, the Japanese appear to be the only ones who have utilized the effects of con= centrated trampling by livestock, to prepare a seed bed as well as to cover the seed in the oversowing of grassland (Yamane, Iizumi, Kurosaki, Saito and Suga= wana, 1962). A further example of the use of this method in the Highland Sourveld of Natal has been re= ported by Edwards (1966). In the latter instance 200 sheep were concentrated on $^1/3$ acre for 14 days after seeding to Paspalum dilatatum. The sheep were used to manure the soil, cultivate and destroy existing vegetation and to trample the P. dilatatum seed into the soil. The results of this treatment was the al= most complete replacement of Eragrostis plana with P. dilatatum on old lands.

Because of these results it was considered that this technique might prove suitable for the establish= ment of overseeded pasture species in the Highland sourveld of Natal.

Objective

The object of this experiment was to determine the effect of concentrated trampling of the veld with cattle on the establishment of over-seeded pasture species.

Procedure

The experiment was started in November 1966 on the Clovelly block at the Tabamhlope Research Station. It consisted of a randomised block design with four whole-plot treatments and two split-plot treatments in five replications. The whole plot treatments of hoof cultivation were as follows:

(1) No hoof cultivation
(2) The equivalent of 150 head of cattle per morgen (0.86 ha) for six days.
(3) The equivalent of 300 head of cattle per morgen for six days.
(4) The equivalent of 450 head of cattle per morgen for six days.

Split-plot treatments comprising the following two seeding rates were applied:

(1) One hundred lb (45.4 kg) _P. dilatatum_ + 6 lb (2.7kg) _T. repens_ (Ladino) + 16 lb (48 kg) _T. pratense_ (Kenland) per morgen;
(2) double the above seeding rates.

The whole plots were ten yards (9.1 m) wide and twenty-seven yards (24.6 m) long, and they were split down their length (i.e. 5 x 27 yd – 4.5 x 24.6 m – sub-plots). The whole plots were fenced and the trampling treatments were applied over both sub-plots. The experimental area was burnt in July, prior to the application of the treatments, in an attempt to reduce the vigour of the veld. Seeding, was carried out, on a moist soil, in November 1966, and after seeding all the plots were fertilized with the equivalent of 600 lb (272 kg) superphosphate (8.3% P), 400 lb (182 kg) KCl (50% K), 400 lb limestone ammonium nitrate (26% N) and 2 ton (1816 kg) agricultural lime per morgen. The day after seeding and fertilization the cattle were introduced into the plots. Steers of the pasture research herd were used to trample the seed into the soil and to graze and muck the veld. Twelve, eight, four and no steers per plot were used respectively on

Table 68

The effect of trampling on the dry matter yields of herbage (ton/morgen) 1966/67

(1 ton/morgen = 1059 kg/ha)

Treatment	Cuts 2 + 3 (28.2.67, 25.4.67)				Cut 1 (8.1.67) All herbage	Total 1+2+3 All herbage
	Clover	Paspalum	Veld	All Herbage		
<u>Hoof cultivation</u>						
Nil	0.048	0.022	1.305	1.375	2.301	3.676
150 steer/morgen	0.679	0.095	1.582	2.357	1.486	3.843
300 steer/morgen	1.007	0.166	2.295	3.469	1.253	4.722
450 steer/morgen	1.374	0.783	2.069	4.226	0.848	5.076
Mean	0.777	0.266	1.813	2.857	1.472	4.329
L.S.D. P = 0.05	0.424	0.420	0.496	0.526	0.488	0.778
P = 0.01	0.594	0.589	0.695	0.737	0.685	1.090
<u>Seeding rate</u>						
Low	0.627	0.257	1.885	2.769	1.467	4.236
High	0.928	0.276	1.741	2.945	1.477	4.422
L.S.D. P = 0.05	0.227					
P = 0.01	0.410	N.S.	N.S.	N.S.	N.S.	N.S.
Coefficient of variation	43.56%	46.75%	27.54%	25.79%	18.81%	17.98%

the 450, 300, 150 and nil steer per morgen treatments, and they were confined to their plots, except when they were watered, for a period of six days. As there was insufficient feed available on the plots, E. curvula hay was provided at the rate of 20 lb (9.1 kg) per animal per day. The hay was spread along the line dividing the sub-plots and in order to minimise its effect the remnants were raked up after the grazing period.

Subsequent to the application of the treatments the sward was mown three times during the 1966/67 season, and it was also mown three times in the 1967/68 season. The dry matter yields of the veld, and of the planted species, was recorded at each of these cuts on a strip of 2 x 20 yds (1.8 x 18 m) on each sub-plot.

In the spring of 1967 the plots were fertilized with a further 600 lb superphosphate and 400 lb KCl per morgen.

Results and Discussion

The yields obtained during the establishment season (1966/67) are given in table 68.

In the first cut of this season, practically no herbage of the sown species was harvested, and the yields of the veld reflected the intensity of stocking after seeding. The most herbage was harvested from the control plots and the least from the plots which had been grazed with an equivalent of 450 MLU per morgen.

Thus it is apparent that the trampling treatments were successful in reducing the regrowth, and thus the canopy competition for the overseeded species. As might be expected the seeding rate did not affect the herbage yields at this stage.

In the second and third cuts of the establishment season the total yield of herbage increased with in= creasing intensity of hoof cultivation. The most herbage was harvested on the plots stocked at 450 MLU per morgen and the least on the control plots. The total yield was not affected by the seeding rates during this period. The yield of clover also increas= ed with increasing stocking rates, and the proportion of clover in the herbage was 3.5% on the control plots, 28.8% at 150 MLU per morgen, 29.1% at 300 MLU per mor= gen and 32.5% at 450 MLU per morgen. There was thus little difference in the percentage of clover in the herbage at the three stocking rates, inspite of in= creased clover yields. The yield of clover was sig= nificantly greater at the high seeding rate than at the low. The yield of P. dilatatum was significantly grea= ter at 450 MLU per morgen than on any of the other treat= ments, while the yield of veld alone was greater at 450 and 300 MLU per morgen than on the other two treat= ments. The increase in the yield of the grasses, in particular the veld, at the high stocking rates may have been due to the additional nitrogen from the extra dung and urine deposited on these treatments. The seeding rates did not affect the yield of P. dila= tatum or of the veld. The total yield of herbage during the establishment season was greatest on the 450 and 300 MLU per morgen stocking rates.

Table 69.

The effect of trampling on the dry matter yields of herbage (ton/morgen) 1967/68 (1 ton/morgen = 1059 kg/ha)

Treatment	Clover	Paspalum	Veld	Total
Hoof cultivation				
Nil	0.958	0.049	3.099	4.106
150 steers/morgen	1.966	0.214	2.522	4.702
300 steers/morgen	2.382	0.515	1.801	4.698
450 steers/morgen	2.428	0.851	1.664	4.942
Mean	1.933	0.407	2.271	4.612
L.S.D. P = 0.05	0.621	0.125	0.681	0.527
P = 0.01	0.870	0.175	0.954	0.739
Seeding Rate				
Low	1.771	0.388	2.519	4.678
High	2.096	0.426	2.024	4.546
L.S.D. P = 0.05	N.S.	N.S.	0.415	N.S.
P = 0.01			0.572	
Coefficient of variation	27.99%	127.65%	27.24%	10.75%

During the first season after establishment (1967/68) the total yield of herbage was greater on the plots which had been trapled than on the treat= ment which was not trampled (See table 69).

During this season the yield of clover was also greater on the plots which had been trampled than on the control plots. There were no significant diffe= rences due to the intensity of trampling. However, the yield of P. dilatatum increased with each increase in stocking rate. The yield of the veld, during this season, was less at the two highest stocking rates than at the low stocking rate and on the control plots. The yield of the veld was lower at the high seeding rate than at the low seeding rate, but this treatment did not affect the yields of either the clover or _P. dilatatum._ The sown species contributed 25% on the control treatment, 46% at 150 MLU per morgen, 62% at 300 MLU per morgen and 66% at 450 MLU per morgen to the total yield during this season.

The application of the method

Trampling with livestock proved to be successful as a method of aiding the establishment of oversown pasture seeds in the Highland sourveld of Natal. Of all the techniques applied it is the only one which makes provision for the covering of the seed, and be= cause of this may prove more successful over a wider climatic range than the other methods. However, tramp= ling may cause puddling of the soil if it is too wet and if the soil is heavy (high clay content). The covering of the seed when added to the organic ferti= lization and reduction of competition provided by the technique all ensure its success. A further practi= cal advantage of the technique is its low initial cost.

The method, as it was applied in the experiment, might be criticised because impracticably large num= bers of animals were required. This problem could be overcome by lengthening the period of trampling, which should prove successful on dry soil. (In the present experiment it was originally intended to main= tain the stocking rates for ten days - not six-, but germination of the clover seeds on the fifth day ne=cessitated the curtailment of the period.) In the Highland sourveld, where most farmers "kraal" and feed all their livestock in winter, the concentration of large numbers of animals on small areas presents few problems. With a little forethought, hay stacks and even portable bunker silos could be placed stratigi=cally over the veld when the fodder is harvested in the summer. These supplies could then be used in winter and early spring to concentrate the animals on seeded areas. The effects of seeding during winter and of prolonged trampling after seeding require investigation.

This technique appears to be well suited to areas where tractors and implements can not be used (i.e. steep slopes, stony areas and vleis when they are not too wet). The method is cheap and apparently effec=tive, and should be well within the resources of every farmer in the area.

3.6 Discussion

The vegetation and environment of the High=land Sourveld indicate that it should be well suited to radical veld improvement. The summers are tem=perate and the rainfall is high and reliable. These are conditions which, despite cold and relatively dry winters and a short growing season, appear to provide favourable conditions for the growth of many temperate legumes and grasses as well as for a number of impor=tant tropical grasses. The vegetation when protected from fire and grazing, tends towards forest margin plants – generally a good indicator of a high grassland potential. Due to the limitations of topography large portions of this veld type are unsuited to annual crop= ping, and it is probable that their full potential for food production can be realized only under grassland. The soils are poor but this problem can be remedied by the application of fertilizers.

The experimental trials conducted at the Tabam= hlope Research station have confirmed that the Highland Sourveld has a high potential for grassland production. Nitrogen fertilization of the veld, when combined with the application of other major plant nutrient elements which are deficient in these soils, results in a marked increase in herbage yields in the short term. (Results of long term experiments and yields of animal products are unfortunately not availeble, but it is thought that they probably would agree with the short term re= sults.) Grassland species, when fertilized, thrive in the area provided the correct slections of adapted species are planted. The yields of some of these spe= cies, when grown under dry land conditions, approach the best in the world. (Dry material yields of nearly 20 tons per morgen – 21,180 kg/ha – from E. curvula and between five and six tons per morgen – 5295 and 6354 kg/ ha – from T. repens were obtained annually.) The nu= trient deficiencies of the soil which limit plant growth can, in this area, be corrected simply by the application of fertilizers containing the major plant nutrient elements N, P and K (and Ca for legumes) in the correct proportions. Marginal trace element defi= ciencies may limit production at high levels of fer= tilizer application - particularly in the absence of the grazing animal e.g. with hay and ensilage making.

However, such deficiencies, once identified, are usually easy to remedy.

Using selected plant species and a suitably balanced fertilizer regime the successful establishment of improved grassland can be achieved over almost the whole of the Highland Sourveld. On the bottom lands or vleis (3.4% of this veld type) observation on farms has indicated that improved plant species can be introduced by seeding mole hills (which are frequent) or dung pads, by light soil disturbance and in extreme cases by controlled drainage and cultivation. The flat lands (40.4% of the veld type) presents no problems for the establishment of pastures, provided a fine seed-bed is prepared. These flat lands are, however, probably more profitably used for annual food crops than for pastures. On the moderate slopes (21% of the veld type), where complete removal of the vegetation by cultivation is hazardous because of soil erosion, various techniques of minimum tillage have proved successful for seed-bed preparation. The steep slopes (35.3% of the veld type) and stony areas, where implements cannot operate, can be seeded successfully with pre-treatments such as heavy dressings of nitrogenous fertilizer, heavy concentrations of grazing animals, and possibly the use of herbicides. This latter technique (herbicides) requires further investigation before it can be advocated in practice in South Africa. On these steep and stony areas aeroplanes may yet prove to be profitable aids to overseeding and fertilization.

There is a lack of information on the management and utilization of improved grasslands in this area.

This deficiency is greatest in the sphere where only partial replacement (reinforcement) of the veld is achieved. The best grazing management practices to encourage the spread of oversown species are not known. The most profitable way of utilizing such improved grassland has not been determined locally, nor is it known what the optimum (economic) proportions of improved to unimproved veld are. Work in Scotland, as reported by Fisher (1963) has shown that small areas of improved pasture within a large unimproved paddock, provided benefits, to livestock, out of all proportion to their area and herbage yield. At this stage it is not possible to predict the effect of large scale radical veld improvement in this area on water supplies. Thus, although some information has been gained there is still an urgent need for further investigations into the intensification of grassland in the Highland Sourveld of Natal.

4. GENERAL DISCUSSION

The rapid rate of increase in the population of the Republic of South Africa, and consequently in= creased demand for food, will necessitate that all the arable land in the country be used to produce food as efficiently as is possible. This means the production of food directly from plant sources which is considerably more efficient than the conversion of plant crops to animal products for human consumption. However, as the amount of arable land is limited (estimated to be less than 15% of the area), and has been developed to near its potential, increased production from this source does not seem likely to fulfil the demand for additional food. It is also apparent that the 20% of the Republic, which enjoys a favourable rainfall and which is not suited to arable cropping, is the most promising sector from which to produce food to elimi= nate this shortfall.

Sufficient data are available to indicate that this high rainfall area has a high potential for grass= land production, and that radical veld improvement can be applied to achieve this potential. However, such improvement presents many prob lems which have yet to be solved. The data which are available are scanty, and an intensive effort on the part of research and extension workers, and possibly even radical social changes, are necessary before the full potential of the area can be exploited.

Grassland research, the results of which depend largely on the yield of animal products obtained from the utilization of the herbage of perennial grassland species, is usually a long process. Experience in= dicate that the process of acceptance and application of such results by the farming community is an even longer process. If the demand for food at the turn of the century (only thirty years hence) is to be sa= tisfied, it is imperative that a well planned and ex= tensive research programme be instituted immediately to ensure the rapid development of radical veld improve= ment in the high rainfall areas. The urgency of this matter requires a crash programme of research as out= lined in the section which follows.

The research programme should be implemented by the establishment of temporary research units in the high rainfall areas. The siting of these research units, and the number required, could be determined from a priority list formulated on the basis of the subdivision of the country into grassland units, which is contained in the first part of this thesis. Using the potential for development and the area of the grass= land units as a means of determining priorities a list of the sites might read as follows: (The list does not take into consideration existing research stations which might be used as bases for the research.)

(1) Summer rainfall region, frosty zone, veld re= placement unit. (See 3.1.3).

(2) Summer rainfall region, frost free zone, veld replacement unit. (See 3.2.3) (Due to the large proportion of this area, which is at present occupied by high profit crops such as sugar cane, it might be dropped lower in the list of priorities.)

(3) Winter rainfall region, veld replacement unit (See 1.3)

(4) All-year rainfall region, veld replacement unit (See 2.3)

(5) Summer rainfall region, frosty zone, veld reinforcement unit (See 3.1.2)

(6) Summer rainfall region, frost free zone, veld reinforcement unit (See 3.2.2)

(7) All-year rainfall region, veld reinforcement unit (See 2.2)

(8) Winter rainfall region, veld reinforcement unit (See 1.2)

These priorities should be amended in the light of more detailed surveys of the arable areas in each unit.

The initial objective of each research unit would be to investigate practical ways and means of developing rapidly, the full grassland potential of non-arable land for food production within the specific grassland unit. In order to achieve this objective it is neces= sary, however abhorrent it is to research workers, to stipulate a time schedule for each phase of the research programme. Lack of such a schedule frequently induces procrastination and deviation from the aim. Both the aim and the time schedule should be strictly ad= hered to, and when the task is completed a new aim should be adequately motivated or the unit should be disbanded.

The terrain selected for each unit must be representative of the area which it is to serve with respect to climate, grassland and physiography. It must be in close proximity (within ten miles) of a town which can provide adequate accommodation for the staff, and which has satisfactory schooling facilities. Electricity and water should be available (or easily obtainable) on the site. This selected terrain should be leased, and all offices, laboratories and farm buildings would be pre-fabricated structures which are easily removalbe. It is essential that all the facilities required for research (buildings, drying ovens, tractors and implements), and also adequate funds, be available when the research staff take occupation. These requirements for each unit would be the same basically, and could be provided well in advance.

Basic research and the development of experimental techniques would not be the function of the units. A central institute, or some other organisation, should cated for this and would also provide analytical services for soil and herbage samples. In the analysis of herbage emphasis should be placed on the determination of energy values and digestibility rather than on the chemical composition.

The research workers selected for the task should work as a unit and should not be encumbered with other sectional obligations and allegiances. All would be stationed at the unit. The research staff might consist of three pasture workers (including the unit leader), one animal nutritionist, one plant nutritionist and one rhizobium microbiologist each of whom would be supported by as many as three technicians. Specialist advice in biometry, economics and other fields could be pro= vided by visits to or by specialists consultants. One qualified clerk, with the aid of female assistants, should be able to take care of the routine administra= tion of the unit. A farm foreman and labour would al= so be required.

As a result of pre-planning it should be possible to implement the first phase of the research programme within the first year of occupation. The unit should be fully staffed from the start and this complement should be maintained until the prescribed aim is achieved or abandoned. New units would not be developed until these requirements could be met. The research pro= gramme would depend on the requirements of the grass= land unit under investigation, and upon the advances already made within the area. It might include spe= cies and cultivar trials, investigations into nutrient deficiencies of the soils for the growth of plants (and Rhizobium) and deficiencies of the plants for animal nutrition, Rhizobium adaption and pasture establishment studies and the management and utilization of pastures.

Co-operative research on farms in the grassland unit, if required as a result of inadequacies of the selected site, should be streamlined to make use of easily portable equipment.

When reasonable progress has been made with the research programme, one of the research staff should be relieved of his research duties and given the task of specialist extension in grassland improvement for the unit. He would remain in the area after the rest of the unit had dispersed, and would also establish demonstrations. Economic assessment of the results obtained would also be part of his task.

Such an intensive research and extension pro= gramme should greatly facilitate the development of our high rainfall grasslands within an acceptable period of time.

5. SUMMARY

Due to the rapidly expanding population of the Republic of South Africa, and due to the increasing standard of living of its inhabitants, the demand for human food may be expected to increase rapidly during the next thirty years. It has been estimated that the population will more than treble to a figure of some 54 million by the year 2000, and that the demand for food may quadruple during this same period. This trend will continue until the relatively low death rate is balanced, and not exceeded as at present, by the birth rate.

At present South Africa exports relatively small amounts of foodstuffs but also imports those of which local production is indadequate – there are no large consistent surpluses except perhaps of fruit. Land suited to annual cropping is limited, by physiography and climate, to a maximum of 15% of the area of the country, and the greatest and most productive portion of this has already been developed. It is thus un= likely that improved technology and increased areas of annual crops will be able to meet the increasing de= mand for food. Therefore, it is important that the full potential of the remaining 85% of the country be thoroughly investigated and developed. This area is at present under grassland and indigenous vegetation and must be retained under a dense perennial cover if soil erosion is to be controlled.

As a preliminary step towards the investigation of the grassland potential of the Republic, an attempt has been made to subdivide and map it according to this potential. The Republic has been divided into three regions on a basis of the time of the year at which the rain falls viz. the winter rainfall region (11.12% of the area), the all-year rainfall region (9.71% of the area), and the summer rainfall region (79.16% of the area). The latter region is divided into a frosty zone (70.72% of the Republic) and a frost free zone (8.44 % of the Republic). Each of these regions and zones has been further subdivided, on the basis of rainfall and evaporation, into three grassland poten=tial units. The first unit comprises areas in which the potential is limited to veld management and its utilization (65.00% of the Republic), while the second unit is suited to veld reinforcement (22.93% of the Republic) and the third unit can be used for veld re=placement (12.06% of the Republic). Because the produc=tion of the veld management units (65% of the area) is not likely to increase greatly, any notable increase in grassland production must come from the high rain=fall radical veld improvement units. These units re=present 35% of the area of the country, and as nearly 15% of this is arable land, the reamining 20% which is grassland must be developed to supply via the animal, at least some of, the increasing demand for human food. This grassland appears to have a high potential for food production and its development will provide many benefits, but also presents a number of problems.

The Highland sourveld of Natal, which has a high potential for grassland improvement, was selected as an example of such areas, and the results of a series of experiments designed to evaluate this potential are described. The warm and wet summers of this veld type, which has large areas unsuited to annual cropping, provide a favourable situation for grassland improvement, despite the cold and dry winters. The climate, vegetation and physiography of the area are described in relation to the potential for grassland improvement.

The greater portion of the research programme in the Highland Sourveld was carried out on a site typical of the physiography (soils and topography) which would be available for grassland improvement. The layout of the experimental area, and the techniques used in experimentation were adapted to the needs of grassland improvement and greatly facilitated the research work.

Nitrogen fertilization appears to be a very practicalbe and profitable means of reinforcing the veld. Unfortunately long term results and animal production figures are not available for the area.

A series of species and cultivar trials indicated that a number of grasses (*E. curvula* and *P. dilatatum* being among the most successful) and selected cultivars of two legumes (*T. repens* and *T. pratense*) were well adapted to and high yielding in this area. These trials also emphasised the importance of selecting the best cultivar within single species of grassland plants. It was apparent that the selection of suitable cultivars is a prerequisite to successful pasture production, and that there is considerable scope for the breeding and selection of new adapted plants.

Three fertilizer experiments, each with a diffe= rent pasture plant, indicated that nitrogen was the main plant nutrient deficiency for grasses on the highly leached Farningham soil series. However, once this deficiency was remedied adequate amounts of phos= phatic and potassic fertilizer were necessary for op= timum utilization of the applied nitrogen and conse= quently maximum production. Even on these acid soils little benefit was apparent in the production of gras= ses due to the addition of calcium in the form of agri= cultural lime. Red clover (T. pratense) showed a good response to phosphatic and potassic fertilizer applications, and probably benefited from the use of lime. It is apparent, from the results of these trials, that balanced fertilization (in respect of each soil type and each plant species requirements) is necessary on these soils if optimum production is to be achieved.

A number of trials were carried out in an attempt to determine the most suitable methods of establishing over-seeded pasture species for veld reinforcement. Trials on minature (one square yard) plots produced the following results:

(a) A considerable proportion (as much as 30%) of oversown seed is intercepted by the canopy of an unmown grassland sward. Much of this seed probably does not germinate. The per= centage of seed intercepted by the canopy de= pends on the type of seed sown, the species composition of the sward and its density.

(b) A cover of dead grass tufts, such as might be produced by the application of herbicides, can be both detrimental and beneficial to the establishment of overseeded pasture species. The nature of the effect depends on the density of the cover, which when present in reasonable amounts provides some shade an benefits the seedlings. However, when the amount of cover is excessive it appears to prevent sufficient light for optimum growth from reaching the seedlings.

(c) Living grass tufts appear to have similar effects, on the establishment of oversown seeds, to those of dead tufts. Under conditions where soil moisture limits establishment the effects of living tufts might be expected to be less favourable than those of dead tufts.

(d) The pattern on arrangement of the grass tufts had no obvious effects on the establishment of oversown seeds.

It may be concluded from these trials that, in the Highland Sourveld, a thinning of the basal cover and a reduction of the canopy cover will benefit the establishment of overseeded species. This observation may not, however, apply to all veld types. In some areas with a poorer basal cover the elimination of the cover, as distinct from soil distrubance, may not be of benefit.

In a comparison of the use of various tillage implements for the preparation of a seed-bed for pasture species it was found that a fine well-prepared seed-bed had no peer. However, when complete soil dis=turbance was not practicable, due to the hazard of soil erosion or for other reasons, the rough seed-bed created by a heavy tined impliment (soilmaster) produced ex=cellent results when overseeded with pasture species. In a small-plot trial it was found that the early es=tablishment of oversown clovers was positively related to the roughness of the seed-bed. It is suggested that a rugged micro-topography provided more favourable micro-climatic conditions for the establishment of the seedlings.

Paraquat, when used as a means of seed-bed pre=paration in an overseeding trial, did benefit the es=tablishment of overseeded pasture species. However, it is doubtful if these benefits are sufficient to allow this method of seed-bed preparation to compete with other more successful techniques at this stage. More information on the effects of this herbicide in combination with other techniques is necessary. It is suggested that dalapon, which has a more severe herbicidal effect, might be more effective in this veld type than was paraquat. Dalapon has apparently a short ($\pm$ 8 weeks) residual effect, while paraquat has practically no residual effect. The commoner grass species of the Highland Sourveld have a varied susceptibility to paraquat. Some, like A. filifolius are very susceptible (although by no means completely killed) while M. ceresiiforme is apparently unaffected by the herbicide. The sensitivity of the species to dalapon also varies with A. filifolius being rather insensitive to this herbicide, and *T. hispida* and *E. curvula* being susceptible.

Heavy applications of nitrogenous fertilizer (up to 600 lb - 272 kg - N per morgen - 0.86 ha - applied in two dressings), apart from resulting in increased herbage yields, also provided a seed-bed which favoured the establishment of overseeded pasture species. This technique is profitable and is ideally suited for use in steep and stony areas. A second technique which showed promise on rough terrain, was that of trampling oversown seeds into the soil with large concentrations of livestock.

The Highland Sourveld is well suited to intensive grassland production, and pasture plants and techniques for their establishment are available for almost all physiographic conditions in this veld type. However, much is still to be learned about the grazing management of the improved veld, particularly when the replacement of the original vegetation is incomplete.

The establishment of temporary, intensive grass= land research units within each of the eight radical veld improvement grassland units is suggested. These research units, which would be subjected to a clearly defined research programme and a strict time schedule, would greatly facilitate the development of the 20% of the area of the Republic which has a high rainfall but which is not arable.

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Appendix Table 1.

Total yields of herbage from "in cuts" of fertilizer experiment (NP 17/6): Interaction of nitrogenous and "other fertilizer".

Treatment	Herbage yields ton/morgen (1059 kg/ha)			
	No N	300 lb N/ morgen	600 lb N/ morgen	Mean
No "other fertilizer"	3.268	4.411	5.278	4.319
100 lb P, 200 lb K & 265 lb Ca/morgen	3.415	5.326	7.230	5.323
Mean	3.342	4.868	6.254	4.821

L.S.D. body of table: P = 0.05 = 0.743 ton/morgen

P = 0.01 = 1.028 ton/morgen

(1 lb = 0.454 kg & 1 morgen = 0.8565 ha)

Appendix Table 2.

The interaction between nitrogen and phosphate in the fertilization of "lands grass." Five year average (ton oven dry material/morgen/annum). (1 ton/morgen = 1059 kg/ha).

P applied (lb/morgen/annum)	N applied (lb/morgen/annum)					
	Nil		600		1200	Mean
Nil	2.11	<**	5.46	>*	4.68	4.08
	NS		∧ **		∧ **	∧ **
133	1.92	<**	7.98	NS	7.62	5.84
	NS		NS		∧ **	∧ **
266	2.32	<**	8.12	<*	8.86	6.43
Mean	2.12	<**	7.19	NS	7.05	5.45

Body of table : SE 0.25 ton/m

LSD P = 0.05 = 0.74 ton/m (*)
P = 0.01 = 1.00 ton/m (**)

Mean: SE 0.15 ton/m

LSD P = 0.05 = 0.43 ton/m (*)
P = 0.01 = [illegible]

Appendix Table 3.

The interaction between nitrogen and potash in the fertilization of "lands grass". Five year average (ton oven dry material/morgen/annum). (1 ton/morgen = 1059 kg/ha).

K applied (lb/morgen/annum)	N applied (lb/morgen/annum)					
	Nil		600		1200	Mean
Nil	1.80	<**	3.97	NS	4.04	3.27
	NS		**		∧ **	∧ **
375	2.13	<**	8.68	NS	8.24	6.35
	NS		NS		NS	NS
750	2.44	<**	8.93	NS	8.88	6.75
Mean	2.12	<**	7.19	NS	7.05	5.45

Body of table: SE = 0.25 ton/m
LSD P = 0.05 = 0.74 ton/m (*)
P = 0.01 = 1.00 ton/m (**)

Mean : SE = 0.15 ton/m
LSD P = 0.05 = 0.43 ton/m (*)
P = 0.01 = 0.58 ton/m (**)

Appendix Table 4.

The interaction between phosphate and potash in the fertilization of "lands grass." Five years average (ton oven dry material/morgen/annum) (1 ton/morgen = 1059 kg/ha)

K applied (lb/morgen/annum)	P applied (lb/morgen/annum)					
	Nil		133		266	Mean
Nil	2.75	<*	3.51	NS	3.53	3.27
	∧ **		∧ **		∧ **	∧ **
375	4.69	<**	6.75	<*	7.61	6.35
	NS		NS		NS	NS
750	4.81	<**	7.27	<*	8.16	6.75
Mean	4.08	<**	5.84	<**	6.43	5.45

Body of table : SE = 0.25 ton/m
LSD P = 0.05 = 0.74 ton/m (*)
P = 0.01 = 1.00 ton/m (**)

Mean: SE = 0.15 ton/m
LSD P = 0.05 = 0.43 ton/m (*)

Appendix Table 5.

The interaction between nitrogen and phosphate in the fertilization of *E. curvula*. Five year average, (ton oven dry material/morgen/annum). (1 ton/morgen = 1059 kg/ha)

P applied (lb/m/annum)	N applied (lb/m/annum)					
	80		830		1580	Mean
44	7.40	<	15.06	N.S.	14.86	12.44
	N.S.		^		^	^
175	8.20	<	16.83	N.S.	16.91	14.00
	N.S.		N.S.		N.S.	N.S.
306	7.73	<	17.51	N.S.	17.64	14.29
Mean	7.78	<	16.49	N.S.	16.47	13.58

Body of table : SE = 0.28 ton/m
LSD P = 0.05 = 0.81 ton/m
P = 0.01 = 1.10 ton/m
Mean SE = 0.16 ton/m
LSD P = 0.05 = 0.47 ton/m
P = 0.01 = 0.63 ton/m

Appendix Table 6.

The interaction between nitrogen and potash in the fertilization of *E. curvula*. Five year average (ton oven dry material/morgen/annum). (1 ton/morgen = 1059 kg/ha)

K applied (lb/m/annum)	N applied (lb/m/annum)					
	80		830		1580	Mean
100	8.30	<	14.57	N.S.	13.79	12.22
	N.S.		^		^	^
411	7.69	<	17.42	N.S.	17.86	14.32
	N.S.		N.S.		N.S.	N.S.
722	7.34	<	17.47	N.S.	17.76	14.19
Mean	7.78	<	16.49	N.S.	16.47	13.58

Body of table : SE = 0.28 ton/m
LSD P = 0.05 = 0.81 ton/m
P = 0.01 = 1.10 ton/m

Mean : SE = 0.16 ton/m
LSD P = 0.05 = 0.47 ton/m
P = 0.01 = 0.63 ton/m

Appendix Table 7.

The interaction between phosphate and potash in the fertilization of <u>E. curvula</u>. Five year average (ton oven dry material/morgen/annum). (1 ton/morgen = 1059 kg/ha)

P applied (lb/m/annum)	K applied (lb/m/annum) 100		411		722	Mean
44	11.64	<	13.08	N.S.	12.60	12.44
	∧		∧		∧	∧
175	12.58	<	14.62	N.S.	14.80	14.00
	N.S.		N.S.		N.S.	N.S.
306	12.44	<	15.27	N.S.	15.18	14.29
Mean	12.22	<	14.32	N.S.	14.19	13.58

Body of table : SE = 0.28 ton/m
LSD P = 0.05 = 0.81 ton/m
P = 0.01 = 1.10 ton/m

Mean : SE = 0.16 ton/m
LSD P = 0.05 = 0.47 ton/m
P = 0.01 = 0.63 ton/m

Appendix Table 8.

The interaction between phosphatic and potassic fertilizer on the yield of clover + weed (ton oven dry material/morgen). (1 ton/morgen = 1059 kg/ha)

K applied (lb/m/annum)	P applied (lb/m/annum) 44		96		149		201	Mean
100	6.66	NS	6.81	NS	6.99	NS	6.74	6.80
	NS		∧		∧		∧	∧
274	7.25	NS	7.86	NS	8.08	NS	7.70	7.72
	NS		NS		NS		∧	NS
449	7.67	NS	7.76	NS	7.75		8.60	7.95
	NS		NS		∧		NS	NS
623	7.36	NS	7.91	NS	8.57	NS	8.27	8.03
Mean	7.24	NS	7.59	NS	7.85	NS	7.83	7.63

Body of table : LSD P = 0.05 = 0.72 ton/m
P = 0.01 = 0.97 ton/m

Mean : LSD P = 0.05 = 0.36 ton/m
P = 0.01 = 0.48 ton/m

Appendix Table 9.

The interaction between phosphatic and potassic fertilizer on the clover content in the material harvested (clover as a percentage of oven dry weight and then transformed by angular transformation, underlined – re-transformed data not underlined).

K applied (lb/m/annum)	P applied (lb/m/annum)							Mean
	44		96		149		201	
100	23.70	NS	30.08	NS	27.32	NS	24.09	26.30
	16.16		25.12		21.07		16.66	19.65
	NS		NS		NS		NS	NS
274	29.14	NS	31.53	NS	23.58	NS	28.89	28.29
	23.62		27.34		16.00		23.30	22.46
	NS		NS		NS		NS	NS
449	34.71	NS	30.75	NS	29.33	NS	31.48	31.57
	32.37		26.14		24.00		27.26	27.41
	NS		NS		NS		NS	NS
623	30.19	NS	29.04	NS	36.98	NS	31.10	31.83
	25.29		23.49		36.18		26.68	27.81
Mean	29.44	NS	30.35	NS	20.30	NS	28.89	29.50
	24.16		25.53		24.95		23.34	24.25

Body of table: LSD P = 0.05 = 8.17
P = 0.01 = 11.01

Mean : LSD P = 0.05 = 4.09
P = 0.01 = 5.51

Appendix Table 10.

The interaction between phosphatic and nitrogenous fertilizer on the yield of clover + weed (ton oven dry material/morgen).
(1 ton/morgen = 1059 kg/ha).

K applied (lb/m/annum)	P applied (lb/morgen/annum)							Mean
	44		96		149		201	
0	7.05	NS	6.97	NS	7.41	NS	7.15	7.14
	NS							
105	7.41	<	8.21	NS	8.29	NS	8.50	8.10
Mean	7.24	NS	7.59	NS	7.85	NS	7.83	7.62

Body of table : LSD P = 0.05 = 0.51 ton/m
P = 0.01 = 0.69 ton/m

Mean : LSD P = 0.05 = 0.36 ton/m
P = 0.01 = 0.48 ton/m

Appendix Table 11.

Percentage seed intercepted by tufts:
Interaction between subject species and seeded species

Seed sown	Subject species			
	T.hispida	E.curvula	A.filifolius	Mean
P.dilatatum	29.75%	12.88%	17.63%	20.08%
T.repens	25.54%	14.04%	18.83%	19.47%
T.pratense	17.58%	11.21%	23.00%	17.26%
Mean	24.29%	12.71%	19.82%	18.94%

L.S.D. Body of table P = 0.05 = 7.30%
P = 0.01 = 9.89%

Appendix Table 12.

The percentage seed intercepted by tufts:
Interaction between subject species and seeded species (4% cover x4)

Seed sown	Subject species			
	T.hispida	E.curvula	A.filifolius	Mean
P.dilatatum	45.88%	20.88%	26.13%	29.71%
T.repens	37.92%	24.79%	32.71%	31.81%
T.pratense	27.83%	18.83%	37.50%	28.06%
Mean	35.96%	21.50%	32.11%	29.86%

L.S.D. Body of table P = 0.05 = 7.30%
P = 0.01 = 9.89%

Appendix Table 13.

The percentage seed intercepted by tufts:
Interaction between subject species and density of cover.

Density.	Subject species			
	T.hispida	E.curvula	A.filifolius	Mean
4%	7.78%	5.86%	8.19%	7.28%
16%	40.81%	19.55%	31.45%	30.60%
Mean	24.29%	12.71%	19.82%	18.94%

L.S.D. Body of table P = 0.05 = 4.65%
P = 0.01 = 6.52%

Appendix Table 14.

Percentage seed intercepted by tufts:
Interaction between subject species and density of cover (4% cover X4)

Density	T.hispida	E.curvula	A.filifolius	Mean
4% x 4	31.11%	23.44%	32.78%	29.12%
16%	40.81%	19.55%	31.45%	30.60%
Mean	35.96%	21.50%	32.11%	29.86%

L.S.D. Body of table P = 0.05 = 5.40%
P = 0.01 = 7.56%

Appendix Table 15.

Results of seed tests.

Category	Species of seed			
	P.dilatatum(S)*	P.dilatatum(O)*	T.repens	T.pratense
Pure seed	63.9%	31.3%	99.5%	99.4%
Inert matter	35.9%	68.1%	0.1%	0.4%
Foreign seed	0.2%	0.6%	0.4%	0.2%
Mean	100.0%	100.0%	100.0%	100.0%
Live seed content	36.4%	21.0%	81.6%	80.5%

S = Seed separated by flotation in benzene.
0 = Ordinary seed.

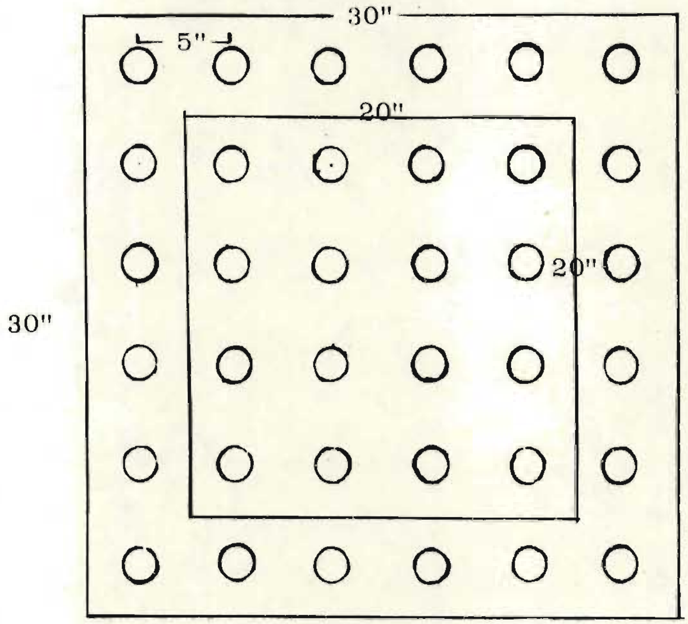
APPENDIX PLAN 1. SPACING OF TUFTS

(N-Ec 7,8 & 9) (1" = 2.54 cm)

PLAN 1a

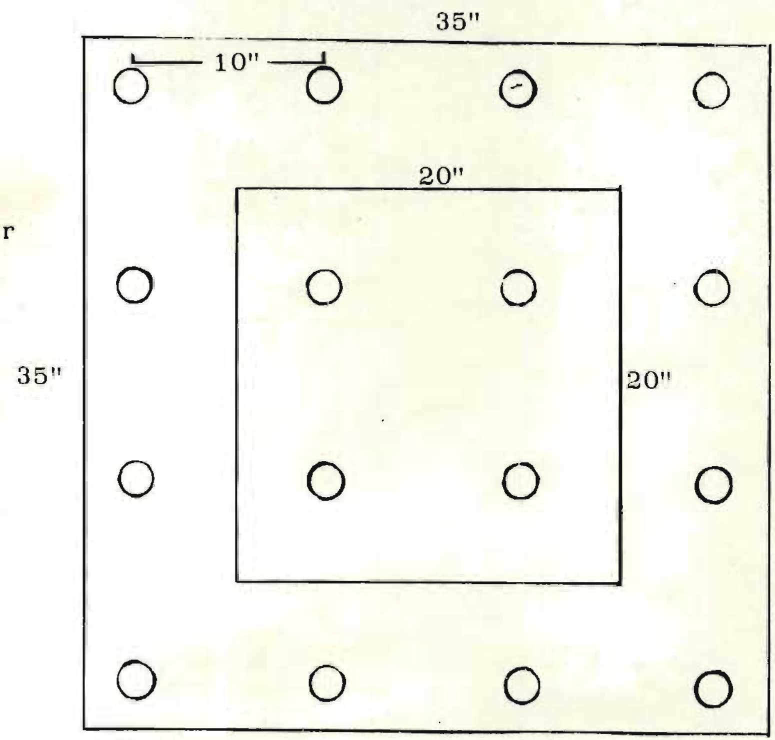
16% Basal cover

O = Grasstuft of 4sq in basal cover



Plan 1b

4 % basal cover



Scale 1/10" = 1"