A STUDY IN THE BREEDING AND SELECTION OF YORKSHIRE FOG (*Holcus lanatus* L.) for Hill Land Conditions in New Zealand.

by

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C O N T E N T S.

Section One.

INTRODUCTION.

Plant Breeding and the Improvement of Hill Pastures in North Island.

> 'New Zealand is essentially a land of pasture, and the endeavour of its farmers is to grass every type of county from the seashore to the line of perpetual snow'.
>
> – E. Bruce Levy, 1922.
> Principles of Pasture Establishment.

In a few simple words, written many years ago, we see the objectives which have become fundamental not only to the foundation of New Zealand's farming industry but to the whole economic wellbeing of the nation. In no other country has continued economic survival become so closely associated with pasture development and the progress of grassland and animal research.

Since these words were first written, New Zealand has entered into an era of achievement, an era in which the vision has come near to reality. Few new areas have been cleared of their native vegetation and the achievement has been realized by the checking of reversion and the increasing of production on the existing land. In little over thirty years, the total animal production from New Zealand's grassland has almost doubled, yet this accomplishment provides little room for complacency since the future of the nation depends on the continuation and even acceleration of this rate of progress.

New Zealand is essentially an upland country, with only a quarter of its surface below 650 ft. contour. The topography is rugged and 28 million acres or 64 per cent of the farming land available is said to be too steep to permit cultivation by present day methods (Scott, 1956).

In North Island alone there are almost 8 million acres, originally covered by native bush and scrub before being reclaimed at the beginning of the century by burning and surface sowing with European grasses and clovers, which now produce a large proportion of New Zealand's beef cattle and store lambs. Until very recently, much of this important area was in the stranglehold of the three scourges of hill farming – economic marginality, declining fertility and steadily diminishing carrying

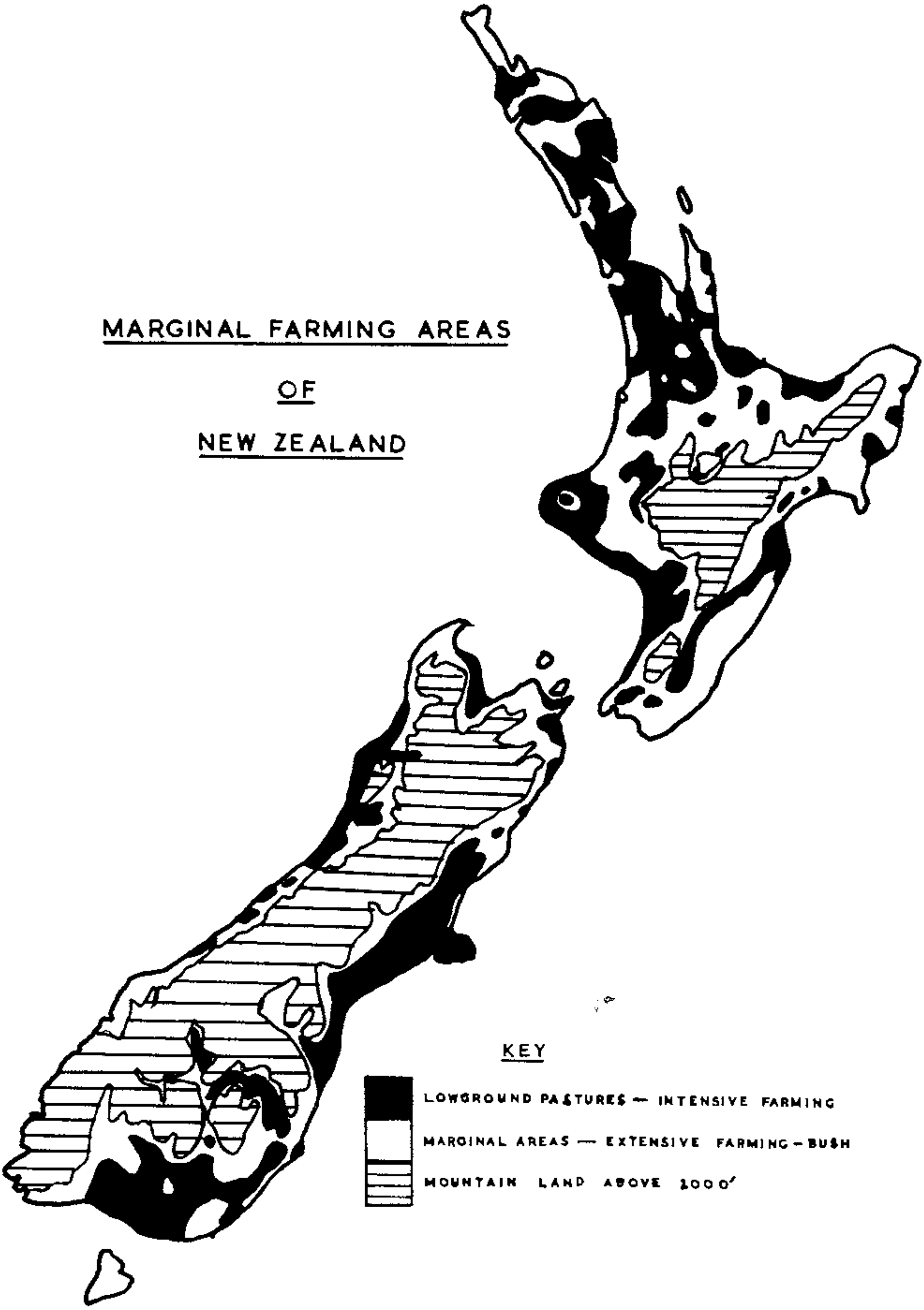

Fig. 1. The Marginal Grasslands of New Zealand.

capacity. It is easy to understand, therefore, why the major proportion of grassland research in this country has shown a tendency to concentrate on solving the problems of the more fertile and productive lowland dairying and fat lamb farms.

Recent discoveries, however, have highlighted a hidden potential in the hill pastures of North Island, especially in the more humid western regions. There is little doubt that their improvement, by aerial top-dressing, better pasture management, more subdivision and the reincorporation of legumes and high fertility grasses will provide the nucleus for increased production in many other parts of New Zealand (Campbell, 1952; Suckling, 1954, 1959).

Even when these pastures reach an advanced stage of improvement, however, a considerable proportion of their production will continue to come from the species already existing there e.g. _Danthonia pilosa_, _Agrostis tenuis_, _Holcus lanatus_, _Cynosurus cristatus_, and _Anthoxanthum odoratum_. There is, therefore, an urgent requirement for more information on both the agronomic potential and genetic variation in these species which show adaptation to the hill environment (Royal Commission on the Sheep Farming Industry, 1949). The ultimate prospect is the development of more nutritious and palatable grass varieties with unique characteristics, the capacity to survive in farming systems of low intensity and at the same time retain the ability to respond to improved management and fertility.

In 1953, the Field Husbandry Department at Massey Agricultural College started an investigation into Yorkshire fog (_Holcus lanatus_), one of the most widespread and adaptable of all the introduced western European grasses (Basnyat, 1957). There has been, and still is, considerable prejudice against the use of this grass as a sown species, even on marginal lowland and hill areas. However, it is now a major constituent of some 8 million acres of grassland in the North Island (Madden, 1940, 1960), 5 million acres being in the wetter hill country of the west. Thus, as a volunteer, it contrives to produce much of New Zealand's production of wool, lamb, beef and even butter fat (Saxby, 1956; Mitchell and Glenday, 1958; McMeekan, 1960).

The investigation commenced with the collection of a wide range of seed samples, representing local populations of species in most major areas of the North and South Islands (Basnyat, 1957; Jacques and Schwass, 1959). Since 1953, continuous examination and selection has been carried out on this material and, in 1959 and 1960, final selection was made in order to form a synthetic variety which, it was hoped, would incorporate the important characteristics of production and survival with improved palatability and animal return. In this thesis it is proposed to discuss the progeny testing of potential parent plants for this variety and then investigate the agronomic value of the final product.

Section Two.

The Ecological Tolerance of Yorkshire Fog and its Agricultural Importance.

'Farming is not a question of whim but of the alignment of agricultural practices to ecological conditions, governed firstly by the climate, and then by the soil itself.'

- E. Bruce Levy, 1955.
Grasslands of New Zealand.

The most important prerequisite of progress in research is a thorough understanding of the ultimate objective. Though the reiteration of this statement seems a mere platitude, it is appropriate to give it emphasis at the beginning of a discussion on pasture plant breeding, a science in which progress has been retarded for some time by the lack of adequate understanding of the environment and appreciation of its requirements.

In many instances it has not been possible for the breeder to improve on the products derived from primary selection, the phase in which surveys were made of the range of adaptive variation in the species. The certification and multiplication of those ecotypes or land races with the greatest agricultural potential, has, in fact, provided the basis for most of the improvement programmes carried out both in New Zealand and overseas (Levy and Davies, 1930; Corkill, 1957).

Despite the application of modern breeding methods and selection indices, it is hardly possible to improve on the products of natural selection without a fuller understanding of the relationship between the plant and its environment. This is particularly true in the context of breeding for hill pastures, because, under the extensive farming systems typical of these areas, man's control over the environment is at a minimum and natural selection is allowed to exert its full influence (Frankel, 1954, 1957, 1958).

Although precise definition of the hill environment in North Island is difficult, its general description corresponds closely to that of other marginal lands in the temperate regions of the world. Its outstanding characteristic is variability - in climate, soil and management - for, despite the popular vision of New Zealand as a uniform grassland Utopia, the country encompasses more climatic differences in relation to its area than any other pastoral region in the world (Madden, 1940; Garnier, 1958).

In the major areas of hill land development, below an altitude of 2000 ft., temperatures remain within a relatively narrow range throughout the year. Over the whole region, mean annual surface temperatures are within the range 50° - 55°F while maximum and minimum monthly temperatures are only separated by 15° - 20°F.

Because of the wide variation in the topography of the hill slopes, however, considerable differences are noted in the micro-climate within relatively short distances. Recordings made on the hill research station at Te Awa (altitude 1050 ft) show a difference of approximately 4°F in the mean annual 4 in. earth temperatures of sunny and shady faces. Although the mean monthly 4 in temperatures rise to only 55° - 65°F in the summer, maximum temperatures on the surface regularly exceed 70°F and have been recorded up to 120°F (Suckling, 1954, 1959).

However, the variability of rainfall and soil moisture rather than temperature, typify the hill lands of North Island. In the wetter western areas, annual rainfall generally exceeds 60 in. while in the east, in Hawke's Bay, it is between 30 and 40 in. The rainfall, in addition, is more variable in the east and summer drought is of frequent occurrence.

The conformation of the land again exerts a major influence within any particular region and soil moisture and fertility gradients are everywhere apparent.

In considering the potential value of Yorkshire fog in the hill areas therefore major emphasis will be placed on its tolerance of variation in the environment and its adaptation to extensive systems of agriculture.

The geographical distribution of Yorkshire fog.

In his survey of the geographical distribution of flowering plants, Good (1947) drew particular attention to the overall supremacy of the grass family in their capacity for colonisation of a wide range of habitats. Within the family, however, the western European grasses occupy a special position through their contribution to pastoral farming in all the temperate regions of the world (Hartley and Williams, 1956). Yorkshire fog is no exception for, although seldom used as a sown species, its efficient means of seed dispersal and tolerance of habitat variation make it one of the most cosmopolitan of all grasses.

Yorkshire fog probably has its centre of origin in the Iberian Peninsula (Vinall and Hein, 1937) but, as a result of continued colonization since the end of the Ice Age, is now found throughout Europe from the limits of Northern Scandinavia and Iceland to the Caucasus mountains and north west Africa (Beddows, 1961; Hulten, 1950; Bocher and Larsen, 1958). Under the influence of human pastoral activities the species has spread to all of the more recently developed farming areas in the temperate regions of the Americas, South Africa and Australia (fig. 2a).

Yorkshire fog was introduced into New Zealand, either as a seed impurity or, more objectively, for use as a hay grass, by the settlers as recently as the 1860's. Due to its aggressiveness and capacity for seed production it has spread throughout both Islands of the mainland and even to the more remote Chatham and Auckland Islands (Cheeseman, 1923; Stapledon, 1928). Under the equable climatic conditions in this country, its colonization limits probably exceed those observed in the British Isles, where the species is established in every district over a wide altitude range (Beddows, 1961).

The prewar pasture surveys of the North and South Islands (Madden, 1940; Hilgendorf, 1935) record the association of Yorkshire fog with many major grassland communities, particularly those which are typical of the more humid and less fertile regions. It is a major component of much of the North Island hill country where declining fertility has led to the dominance of browntop (Agrostis tenuis). Yorkshire fog also contributes in no small way to the total production of many lowground dairy pastures, particularly in the Waikato (McMeekan, 1960).

In the South Island and the more easterly hill regions of Hawke's Bay, the absence of adequate rainfall precludes the dominance of fog in any major community. It does however contribute valuable sheep grazing on some of the better tussock grass zones, particularly during the winter months. Plant material has been obtained from altitudes of over 2300 ft. on Mt. Somers in Canterbury (R. H. M. Langer). It is important on the poorly drained infertile soils of coastal Westland and can become a menace to seed production in the arable areas of the Canterbury Plains (Basnyat, 1957).

Climatic tolerance.

Yorkshire fog exhibits the wide tolerance of temperature regimes which is characteristic of the important western European grasses (Mitchell, 1956; Mitchell and Lucanus, 1960). In controlled environment studies at Grassland Division, the growth of seedling plants showed general similarity to that of perennial and short rotation ryegrass, cocksfoot and browntop.

The rate of growth of foliage on an individual tiller, the most valid estimate of production under sward conditions, remained high at all temperatures between 55^{o} and 85^{o}F, with an optimum in the region of 62^{o}F. In temperature tolerance, therefore, Yorkshire fog occupies an intermediate position between perennial ryegrass and cocksfoot. The former shows a tendency to suffer from the high temperature and light intensity regime prevalent during the summer in many parts of New Zealand, whereas cocksfoot seldom experiences adequate temperatures for optimal growth (Mitchell, 1959).

Although the production of Yorkshire fog is considerably affected by the reduction of temperatures and, to a lesser extent, by the limited light available during the winter months in the North Island, growth and new tiller formation continues. Close study of the seasonal growth rhythms in a wide range of species (Lynch, 1949; Suckling, 1960) does, in fact, show a remarkable constancy of production in this reputedly undesirable species.

Edaphic tolerance.

Concerning its value in marginal areas, one of its most important features is an almost complete absence of edaphic specialization (Levy, 1955; Beddows, 1961). Yorkshire fog is capable of growing on a wide range of soil types, varying from sand to heavy loam and derived from such diverse parent materials as pumice and volcanic ash, limestone, sandstone and papa, greywacke and organic peats. Although the optimum soil reaction for growth is considered to be within pH 5.0 - 7.5 (Spurway, 1941; Davies, 1944), this grass is a notable colonist on areas of much higher acidity.

Although Yorkshire fog grows on areas varying in soil moisture content from waterlogged to average and in fertility from moderately high to low (Levy, loc. cit) there is little apparent effect on grass growth. It is difficult to specify the exact physiological basis of these wide tolerances but three factors may be of importance in assisting the plant in supplying its nutrient requirements under seemingly adverse conditions.

The first important feature is the adaptation of the root system to the absorption of nutrients in the surface layers of soil (Boggie et al, 1958; Beddows, 1961). The anatomy of the root incorporates a radial cortex and many small irregular air spaces, structures which may increase the efficiency of nutrient uptake when the soil water level is high and aeration is restricted (Soper, 1959).

Studies of the cation-exchange capacity of the root systems of various grass and clover species (Mouat, 1959; Jackman, 1959) tend to suggest that Yorkshire fog has a high competitive ability for phosphate, nitrogen and potash where their deficiency is a major factor limiting the growth of plants of higher ecological succession. Even when grown on soils extremely deficient in calcium and phosphorus (Davies, 1952) the herbage produced showed average levels of these minerals.

In certain soils, it has been reported that the roots of Yorkshire fog become extensively infected by endotrophic mycorrhiza (Nicholson, 1960). A symbiosis of this nature may have some ecological significance because of the possible fixation of small but critical quantities of atmospheric nitrogen (Stevenson, 1959).

<u>Biotic tolerance.</u>

Although Yorkshire fog will persist under a wide range of management regimes, its general growth habit and system of vegetative reproduction are most suited to a lenient system of defoliation and the maintenance of a certain amount of herbage cover (Levy, 1955; Beddows, 1961). The species is generally propagated by wind or human dispersal of seed yet it does spread considerably, once it has become established in a pasture, by the formation of a dense mat of runners and developing new nodal roots and shoots.

Controlled environment studies elaborate the existing evidence that this grass is intermediate between cocksfoot and perennial ryegrass in its tolerance of grazing (Mitchell, 1956). In the sward, the growth of the Yorkshire fog plant is centred on leaf expansion on a moderate number of large tillers, whereas in ryegrass and browntop it is on a large number of small tillers. Thus, at a constant temperature of 65^{O}F, equivalent growth is obtained from 50 tillers of fog or cocksfoot, 80 tillers of short rotation ryegrass, 100 tillers of perennial ryegrass or 350 tillers of browntop.

The differences between cocksfoot and fog are related to the formation of leaf tissues. Although the daily rate of increase in leaf length is lower in the latter, the leaf blade shows a greater average width. This suggests that recovery from close grazing will be greater in Yorkshire fog, a smaller proportion of the total photosynthetic surface being removed.

From these considerations it can be readily deduced that fog is not adapted to the close grazing, heavy treading or very high fertility of the most productive lowground sheep pastures. It is however, ideally suited to survival under the less intensive systems typical of many dairy pastures and upland sheep farms.

<u>The Agricultural Potential of Yorkshire Fog.</u>

It has been mentioned previously that, despite its observed ecological tolerance, Yorkshire fog is rarely incorporated in seeds mixtures, although it has shown great value in the pioneer stages of hill land and peat bog improvement (Adam, 1953; Stapledon, 1933; Davies, 1952). The reasons for this apparent oversight are not connected with any shortcoming in growth rhythm or production. It is more probable that the reputation of this grass has suffered because of its association with areas of low fertility and insufficient environmental control (Basnyat, 1957). This connexion may have some importance when the removal of these conditions is economically feasible; it is of little consequence in the context of the hill farm.

The information presented up to this stage has tended to stress the valuable characteristics of Yorkshire fog. There are several features, however, which, although of ecological significance, are important drawbacks to its usefulness as a pasture grass.

The value of a grass is determined by the ultimate animal return and factors such as nutritive value, palatability and digestibility can be of more importance than high dry matter production.

One of the major shortcomings of Yorkshire fog is its low relative palatability at certain stages of growth (Davies, 1925). The early spring growth is rapidly consumed by all animals and it is almost certain that a rapid decline in palatability is associated with the onset of heading and the general reduction in nutritive value characteristic of most grasses at this time. In the case of Yorkshire fog, this appears to be more pronounced because of the presence of velvet-like pubescence on the foliage (Stapledon, 1927; Cowlishaw and Alder, 1960).

The differences between fog and certain other grasses are most noticeable when palatability is assessed by making a large number of species available to the animal, often when they are at different stages of growth. Where fog is grazed alone and is not allowed to become rank, little difficulty is experienced in consuming the herbage throughout most of the year (Watkin, 1960).

The possibility of improving the relative palatability by selection and breeding within the species is quite high, however. Studies of the grazing preference of sheep on spaced plant material of Yorkshire fog (Jacques and Schwass, 1959; Basnyat, 1957) has revealed a relationship between low palatability and the following features:-

(a) prolific heading during the flower period,
(b) severe infection by crown rust (<u>Puccinia coronata</u>),
and
(c) a prostrate habit of growth.

Recorded observations on the grazing utilization of Yorkshire fog herbage in the sward closely tie up with this information. In many cases there is a tendency for the animal to graze out the plant centres alone, leaving the peripheral tillers to become rank and form flowering heads. Selection towards a more semi-prostrate or semi-erect habit may reduce the difficulty of managing the sward to prevent heading.

In certain years, when conditions favour the spread of the pathogen, Yorkshire fog can become severely infected by crown rust (Puccinia coronata Cords var. holci) which is responsible for a considerable reduction in palatability (Corkill, 1956; Ivins, 1952).

The digestibility of the herbage is equivalent to that of many of the so called 'better' grasses (Raymond, 1958). Examination of the anatomical structure of the leaves in relation to the presence of indigestible cell formations shows a low proportion of either sclerenchymatous tissue or collateral vascular bundles (Regal, 1960).

In their classic study of the chemical composition of swards, Fagan and Milton (1931) found that growth stage was more important that species in determining nutritive value. The physiological processes associated with floral emergence result in both a decline in the proportion of crude protein and a rise in the fibre content of the dry matter. In Yorkshire fog, crude protein dropped from 13.5 per cent at the beginning of panicle emergence to 4.6 per cent at the time of cutting for hay. At the same time the fibre content rose from 22.9 to 34.6 per cent.

It has been noted earlier that Yorkshire fog has the capacity to maintain an average mineral content in the foliage even under conditions of extreme soil deficiency. There seems little need for improvement in this aspect as even in fertile areas the content is comparable with that in more highly regarded grasses (Thomas and Thomson, 1948). Similar lack of discrepancy has also been shown in relation to the proportion of nitrogenous compounds, sugars, ash, fructosans and organic acids present (Bathurst and Mitchell, 1958).

Several writers have postulated the presence of hydrocyanic glucosides or oestrogens but this has subsequently been disproved on further investigation (Beddows, 1961; Pope et al, 1959). If a considerable amount of dead basal tissue is allowed to accumulate in the pasture, however, it may form a medium for the growth of Pythomyces chartarum, the causal organism of facial eczema (Barclay and Wong, 1961).

The Improvement of the Agronomic Value of Yorkshire Fog.

In considering the present status of pasture plant breeding as a whole, emphasis was placed on the necessity for better definition in the objectives of selection. An improvement of this nature can only come about from a better understanding of the relationship between the plant and its environment.

Yorkshire fog has shown, both by its widespread presence in the area, and by its observed ecological tolerance limits that it has a potential in the hill areas of North Island. Since the grass readily establishes itself as a volunteer, however, its inclusion in the initial seeds mixture seems to be dependent on the isolation of a source of genetic material which possess superior characteristics to many of the commercial seed lines available in New Zealand today.

The major objectives of a Yorkshire fog improvement programme will be those associated with improving the utilization and palatability of the grass. A task of this nature cannot be solved by selection on a single plane, however. Five features seem to require concurrent improvement (Jacques, 1959), namely:-

i. the habit of growth,
ii. the extent of leaf pubescence,
iii. the proportion of dead basal tissue,
iv. resistance to crown rust, and
v. compatibility with legumes in the sward.

The utilization of Yorkshire fog in the pasture through the grazing animal is considerably affected by the incidence of flowering and selection towards the development of a variety which shows limited tendency to head is extremely important. Preliminary studies carried out by Basnyat (1957) suggest that plants adopting a semi-prostrate growth form with adequate growth on the crown will prove to be the best agronomic type.

Early breeding work in this grass at Aberystwyth (Beddows, 1961a) resulted in the development of a glabrescent variety. Completely glabrous types are unknown but differences have been noted in the proportion of hairs in plants from various parts of New Zealand and selection seems possible (Jacques, 1959).

In the initial studies of spaced plants of Yorkshire fog at the Plant Research Station (1932), attention was drawn to the need for selection towards freedom from dead basal tissue, which results in the formation of a surface mat in the pasture. No marked differences were noted between lines in these characters and it was suggested that screening would have to take place within the populations.

The improvement of resistance to rust infection is a relatively simple procedure, giving rapid response to selection (Corkill, 1956).

The final consideration, that of compatability with other species in the sward, is particularly important in the hill pasture where the essential nitrogen must be supplied by legumes such as white clover and Lotus uliginosus. Yorkshire fog has a reputation as a smothering plant because of the formation of a thick surface mat. Although persistence is generally regarded as an important character in any perennial grass it may well be that too much emphasis should not be placed on it in this context (Beddows, 1961a). The fog will gradually be replaced by species such as ryegrass as fertility is increased through the grazing animal and it must allow the survival of the other grasses during the intermediate stages of improvement.

Conclusion.

The available information on the ecological tolerance of Yorkshire fog gives emphasis to the desirability of its inclusion in North Island hill pastures. The next logical phase in the selection of an improved variety is to study the influence which the New Zealand environment has had on genetic variation in the species and then assess the probable location of the most desirable genotypes.

SECTION THREE.

THE UTILIZATION OF ECOTYPIC VARIATION IN NEW ZEALAND POPULATIONS OF YORKSHIRE FOG.

'Natural selection is so simple in its application and yet so forceful in its results that no serious consideration should be given to methods for the improvement of a particular forage species that do not utilize the benefits already achieved in nature.'

J. M. Poehlman, 1959
Breeding Field Crops.

The extent and rapidity of the adaptation of introduced pasture plants to the New Zealand environment is primarily governed by the nature of their breeding systems (Baker, 1953; Frankel, 1954). Despite the relatively recent development of this country's grassland resources considerable ecotypic development has been shown in the major outbreeding species e.g. perennial ryegrass (Levy and Davies, 1930) cocksfoot (Calder, 1955) and timothy (Gorman, 1950).

Genetic variation in outbreeding plants is essentially of a continuous nature, being under the control of a large number of polygenic systems (Mather, 1953; Clausen and Hiesey, 1958, 1960). Variability is contained both within and between the constituent plants and populations of the species and, despite a certain amount of coherence in major adaptive features, it is possible to maintain the ability to respond rapidly to new selective pressures.

Yorkshire fog is almost certainly outbreeding throughout most of its distribution area (Beddows, 1931). On the continent of Europe, recent investigations have shown the extensive formation of ecotypes or, more correctly, ecolinal variation (Huxley, 1938; Gregor, 1939) in adaptive features such as growth form, extent of flowering, time of flowering and perenniality (Bocher and Larsen, 1958). The variation pattern in this region, the centre of distribution of the species, strongly reflects the recurrence of certain climatic, edaphic and biotic sequences, each characteristic being closely associated with the length of the active growing period, the temperature regime, the incidence of seasonal moisture stress (McMillan, 1959), exposure to wind and the influence of the grazing animal (Stapledon, 1928).

As the district of origin of the material became more northerly and mean annual and midwinter temperatures declined, there was an increasing tendency to delay head formation until the summer after the year of sowing. Floral induction in Yorkshire fog is primarily controlled by a low temperature requirement (Cooper, 1960) which is probably closely correlated with the average temperature of the coldest month (Ketellapper, 1960). Other ecoclines recorded were those of growth habit and time of flowering, which are related to the strong selective pressures of moisture availability, exposure and the grazing animal. Plants from coastal areas formed flat leaf cushions and had slender ascending culmus whereas those native to continental districts were tall, erect and mostly early flowering.

Despite the rather limited period in which Yorkshire fog has been subjected to the New Zealand environment, natural selection has taken place to such an extent that the varirbility expressed is in many ways equivalent to that found in the centre of distribution. As the original nucleus of the species in this country probably came from a limited amount of English seed, new variation must have been released through recombination. New Zealand has, in fact, become a new centre of diversity of the species (Darlington, 1956; Hutchinson, 1958).

The substantiating evidence for this statement is derived from the initial study of variation in New Zealand material carried out by Basnyat (1957) and Jacques and Schwass. In 1954, 118 seed samples were received from areas in both Islands of the mainland and the adjacent Chatham Islands (Fig. 3). No seed was included from Westland, but otherwise the collection was regarded as a typical cross-section of breeding populations of Yorkshire fog in this country.

Although the preliminary analysis of variation was concerned with the relationship between growth form and the time of flowering, leaf morphology, plant colour, rust infection and recovery after grazing, it is perhaps more appropriate to classify these characteristics on a regional and climatic basis.

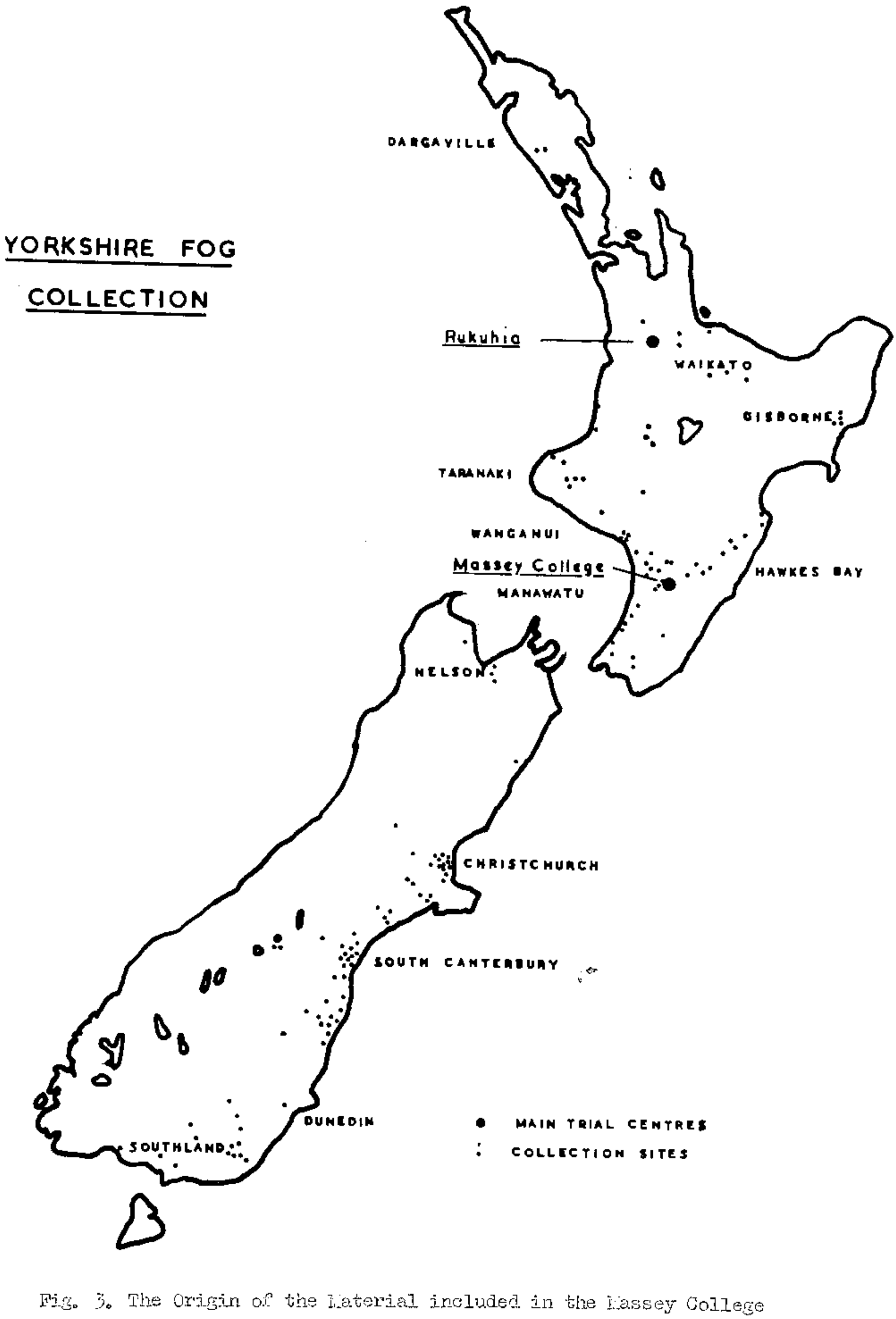

Fig. 3. The Origin of the Material included in the Massey College Collection (1953-54).

The most suitable climatic divisions for this purpose are those adopted by Garnier (1958) and Taylor (1954). In the latter case the main criterion used was that of the monthly potential evapotranspiration in each region; as this measurement is closely related to the assimilation of the plant the divisions have a strong ecological significance.

The length of the growing season is under thermal control and is considered to be the number of months in which evapotranspiration is in excess of 1 in (Fig. 4a). In North Auckland growth continues all the year round, whereas in the interior of North Island and throughout most of South Island, low temperatures limit evapotranspiration to below the critical level for three months or more.

On the other hand the control of evapotranspiration by moisture governs growth during the warmer months (Fig. 4b). The incidence of the period of moisture deficiency is based on the exhaustion of the soil reserve (estimated as 1 in. rainfall). Growth is then subject to the amount of rainfall in the following months. Most northern and western regions in both Islands experience no major drought period but on the east coast of South Island there is a deficiency for up to five months in the year.

Statistics are available for the regional frequency of growth form groups, time of flowering, flowering during the year of sowing, plant recovery after grazing and average rust infection. A summary of this information is presented in Table 1, the main regions concerned being shown in Figure 4c.

Although there is extensive variation within the populations in each region the mean phenotype demonstrates the intimate relationship of each character to a growth rhythm essential to survival and reproduction. The proportion of erect and semi-erect plants gradually diminishes with the shortening of the active growing season from north to south. In western North Island, the combined groups (erect and semi-erect) generally exceed 15 per cent of all plants examined under the nursery conditions at Palmerston North. Material derived from South Island, however, was more prostrate in nature, only up to 5 per cent of the plants being erect or semi-erect.

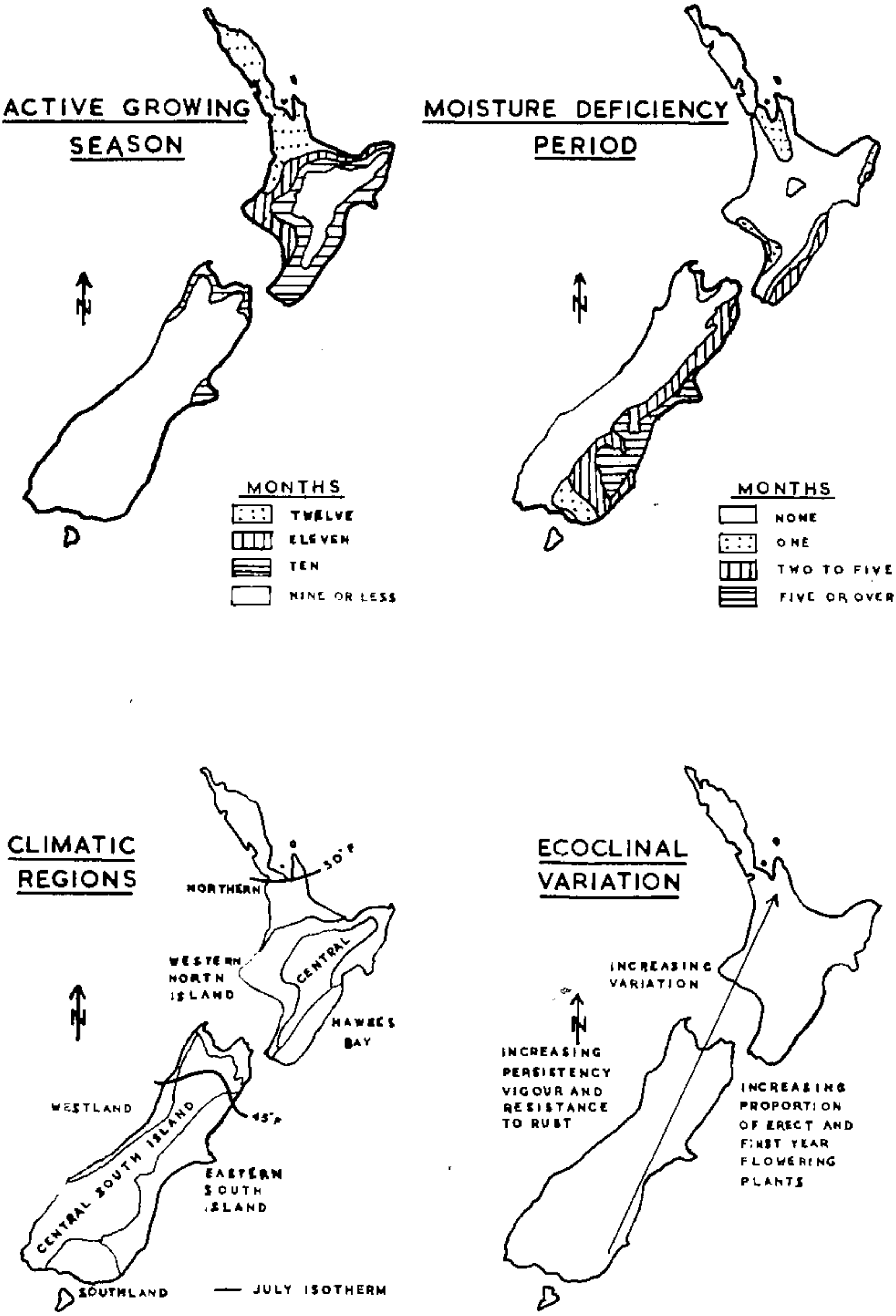

Fig. 4. a b The Relationship between the Climate of New Zealand
c d and Ecoclinal Variation in Yorkshire Fog Populations.

TABLE I. The Regional Characteristics of New Zealand Populations of Yorkshire Fog

CLIMATIC REGION	Climatic Characteristics		Growth Form (% age of all spaced plants)				Flowering (% age)		RUST SCORE [3] (0 - 5)
	Growing Season (Months)	Moisture Deficit (Months)	Erect	Semi-Erect	Semi-Prostrate	Prostrate	First [1]* year	Early [2]	
Northern*	12	0	0	7	23	70	100	28	3.89
Waikato-Bay of Plenty	12-11	0-1	6	13	29	52	80	65	4.23
Taranaki	11	0	5	14	31	50	75	36	3.93
Wanganui	11	1	4	10	21	65	33	36	4.52
Manawatu	11	3	7	14	36	43	10	34	3.37
Gisborne	11	1-2	2	13	25	60	50	68	3.91
Hawke's Bay	10	1-4	2	10	22	66	44	24	4.40
Nelson	9-10	1-2	1	5	29	65	33	83	4.28
Christchurch	10	2-5	1	4	17	78	14	85	4.57
S.Canterbury	9	2-5	0	3	28	69	10	46	4.65
Dunedin	9	2	0	2	33	65	0	37	4.67
S.Otago-Southland	9	0	0	5	30	65	0	47	4.62

1. Percentage of lines in which at least one plant flowered following a spring sowing in August, 1954
2. Percentage of all plants flowering before 22nd November in second year
3. Mean of all plants

* Small sample

The time of flowering is a feature considerably influenced by local micro-habitat conditions e.g. grazing pressure, soil moisture and exposure (McMillan, 1959; Cooper, 1954, 1959). In several regions the high proportion of early flowering plants may, however, be associated with the recurrence of an annual period of moisture stress e.g. in Waikato - Bay of Plenty, Gisborne, Nelson and Christchurch. Although certain areas may be regarded as drier e.g. Hawke's Bay and South Canterbury, rainfall is more adequate for growth at a later period in the spring and summer.

The proportion of first year flowering plants in each line included in the collection was recorded by Schwass (1954). As in the European Yorkshire fog types examined by Bocher and Larsen (1958) there was strong positive correlation with the mean temperature of the coldest month. The July isotherms of 50°F and 45°F are shown in Figure 4c. Cooper (1957) has specified the mean mid-winter temperature of 50°F as an approximate threshold for vernalization response. It is, therefore, interesting to note that the highest proportion of first-year flowering plants was recorded in the two lines collected at Dargaville, north of this isotherm. The proportion gradually decreases to the south and east, only one plant flowering in all the lines from Dunedin and Southland.

Little information is available as to the relative vigour of regrowth in plants from each region. There was a tendency however for different seasonal growth patterns, depending on the length of the active growing period in the district of origin. South Island plants showed lower vigour over most of the year, particularly in the winter and spring. The only occasion on which they recovered from grazing more quickly than the North Island material was almost concurrent with the period of flowering (Basnyat, loc. cit.).

The prevalence of mortality in the ecotypes derived from arable areas of South Island suggests that there is a tendency for plants to be of an annual or pauciennial type, with a high proportion of flowering tillers in relation to vegetative tillers. Rust infection observations reflect a lack of vigour in these plants following flowering. Although rust resistance varies greatly even within lines the frequency of low infection is greatest in plants from the wetter western regions of North Island.

In searching for a nucleus of breeding material with a high potential value for use in the hills of North Island it is apparent from the above information that the most useful genetic pool will be found among the local ecotype populations of Waikato, Taranaki, Wanganui and Manawatu. In reality this has actually taken place, for although selection at Massey College has been on a phenotypic analysis of each spaced plant, the final isolations are all derived from these areas.

After the first cycle of selection, 118 plants were selected from the initial collection of 4,214 plants. These represent 118 lines collected from all over New Zealand and 33 from the Massey College area. Of these 118 plants, only 8 came from South Island and none from the East Coast of North Island. In 1958, 32 plants were selected for progeny testing by the polycross method; all were derived from western North Island.

Although selection within the western region is advisable from the point of view of general adaptation alone, the greatest variation in plant characteristics is also observed in this area. The extent of variation is related to the intensity of selection by the environment (McMillan, 1959); it is lowest in the dry upland regions of South Island and highest in the diverse habitats and more equable climatic conditions found in the North Island.

Conclusion.

Preliminary examination of Yorkshire fog populations in New Zealand indicates considerable adaptive variation both between and within individual lines. The most suitable material for inclusion in the development of a variety for hill areas is found in western North Island. In this region major differences are observed within the individual plants from a population rather than between populations.

Differences in rust susceptibility, vigour, growth form, extent of flowering and palatability indicate considerable potential response to secondary selection.

SECTION FOUR.

THE SELECTION OF THE PARENT MATERIAL FOR A SYNTHETIC VARIETY OF YORKSHIRE FOG.

The Massey College Selection Programme - 1953-61.

The selection procedures discussed in this section were carried out during 1959 and 1960. They form the final stage of a complete programme briefly considered in previous sections. Basically, this closely follows the standard method for the development of a synthetic variety using a polycross progeny test (Schaepman, 1952). Four main stages have been involved.

1. Collection of a wide range of adapted material - 1953-56.

One hundred and fifty-one seed samples were received, 33 from the vicinity of Massey College and 118 from other parts of New Zealand. Twenty-nine spaced single plants derived from each sample were examined under nursery conditions at the College during the period from September, 1954 to September, 1956 (Basnyat, 1957).

2. Examination of clonal lines - 1956-58.

One hundred and eighteen plants were selected from the nursery on a phenotype basis and propagated clonally to form rows of 18 single plants. Overall observations were made on vigour, the extent of flowering, growth form, rust incidence and palatability (Jacques and Schwass, 1959).

3. Selection of parental material for progeny testing - 1958-59.

In April 1958, 32 plants were selected for genetic study by means of progeny testing. The plants were grouped into two categories and separate polycross isolation areas were established, one comprising 20 prostrate and semi-prostrate types and the other the remaining erect and semi-erect types. Seed was harvested from these areas in January, 1959.

4. Progeny testing and the formation of a synthetic variety - 1959-61.

The progeny of the 32 potential parent plants were examined at two main centres, on loam at Massey College and on peat land at Rukuhia Soil Research Station, Hamilton. The information reported here deals with the testing of this material under spaced plant, row and sward conditions at the College, leading to the final selection of eight superior plants for combination in a synthetic variety. Data from Rukuhia (van der Elst and Corby, 1960) was used to determine the potential range of adaptability of all parent plants.

Review of Literature.

Although it is possible to achieve considerable progress in the improvement of a pasture species in the early stages through simple mass selection on phenotype alone, further advance necessitates greater knowledge of the genotypic structure of potential parent material. This is effected through progeny testing and the study of the combining ability of individual plants.

In outbreeding grass species such as Yorkshire fog the most valuable assessment is that of general combining ability, the relative performance of each plant when crossed with a broad base of heterozygous genetic material (Sprague and Tatum, 1942; Johnson, 1952; Breese, 1960). Selection on this basis, rather than that of the specific combining ability with individual plants, makes it possible to maintain the high performance of the synthetic variety through the various stages of seed multiplication. (Kalton and Leffel, 1955; Tofrie, 1957).

Of all the methods of crossing prior to maternal line selection, the polycross system has evoked most interest in recent years. Frandsen (1940) and Tysdal et al (1942) were the first to suggest replicated and randomized plantings of clonal material in a manner which would allow the collection and bulk mixing of seed from each propagule for progeny testing.

The theoretical basis of the polycross test is discussed by Wellensiek (1952). In testing for general combining ability, the selection of plants is towards those which are approaching homozygosity for the desired characteristics and will give a high degree of true breeding in mixtures of their genotypes. Selection, is, therefore, based on the highest relative frequency of the desirable feature in the progeny.

Following the progeny test, the decision on the number of parental lines to be incorporated in the synthetic variety is dependent on two factors, the relative losses from inbreeding depression and from the lowering of the average combining ability (Corkill, 1956). In perennial ryegrass Corkill (loc. cit.) found that there was no significant difference in the yield of the syn. 2 generation once the number of plants incorporated rose to six. The optimum number, however, is likely to vary with the species and parent material used (Beddows, 1958, 1960).

Genetic drift in synthetic varieties is generally acknowledged (Gorman, 1940; Beard and Hollowell, 1952) but is unlikely to become serious unless a large number of multiplication stages are involved or where the variety is made inherently unstable through the use of parental lines differing widely in heading dates.

Although the selection of plant material should ideally be carried out in the sward under the influence of the grazing animal, the limited amount of seed available at this intra-breeding state necessitates the use of single spaced plants. The reliability of assessments based on these plants in terms of sward performance is a major topic of discussion in pasture plant breeding. Several investigators have compared the results obtained under spaced plant, row and broadcast sward conditions (Lazenby, 1957).

Spaced plant nurseries give a satisfactory comparison when the characters show high heritability e.g. date of inflorescence emergence, resistance to disease and leaf-stem ratio. Contrasting results can be obtained however, where competition effects the expression of the character and where a factor limiting growth is not of equal importance in swards and spaced plants e.g. drought (Knight, 1960).

Until recently, the importance of genotype-environment interaction has been largely neglected in plant breeding (Fejer, 1955). In New Zealand, testing has been carried out in high fertility environments, with the assumption that the superior plants selected under these conditions would also be the most productive in more marginal areas (Levy, 1955). In selecting for these marginal areas, however, more emphasis must be placed on adaptability to a wide range of fertility levels (Frankel, 1958).

Experimental Area, Layout and Establishment.

(i) Experimental area and layout.

Three sites were selected for the progeny testing of polycross material. Two areas were established by the New Zealand Department of Agriculture on newly developed peat at Lake Cameron and Moanatuatua, near the Rukuhia Soil Research Station, Hamilton (pH 5.3 and pH 4.4 respectively). Results obtained from these areas were used to substantiate the findings made at the main centre at Massey College (van der Elst and Corby, 1960).

This latter centre was established on Block Four of the Field of Husbandry Department Demonstration Area on an ~~Ohea~~ Ohakea loam soil (New Zealand Soil Bureau, 1954; Pollok, 1960). The soil was formed from deposition on an intermediate river terrace and was comprised of a thin layer of fairly heavy silt loam overlying a clay loam subsoil and gravel. Before liming the area had a pH value of 5.4 - 5.7 (Jacks, 1959).

During the preceding year the block, which is 0.75 acres in extent, was sown in two drill widths of various cereal and legume crops. Because of the likelihood of nutritional differences in the soil, therefore, the progeny test was laid down in a randomized block layout, the replicates conforming as much as possible to the orientation of the previous strips.

Figures available from spaced plant studies of Yorkshire fog suggested that the coefficient of variation of such material would be of the order of 10 per cent. By using five replications, therefore, it was possible to detect differences of 14 per cent and above by statistical analysis (Cochrane and Cox, 1957).

In the spaced plant study, each replicate (Blocks I, II, III, IV, V; Figure 5) was composed of 320 plants, spaced at 30 in. x 30 in. intervals, i.e. 10 plants of each of the 32 progenies. The parental clones were planted nearby in a similar position but without replication.

In an adjacent strip, duplicate randomized rows of the progeny, each 12 ft. in length with 30 in. intervals between, were established, and unreplicate sward plots (10 ft. x 3 ft.) were sown to check on the performance of the lines in conjunction with clover.

PROGENY TEST OF POLYCROSS MATERIAL

MASSEY COLLEGE 1959-60

I	II	III	IV	V	I Guard	II Guard	
					6-5	1-22	
4-7	3-9	4-18	2-11	1-1	2-6	6-5	1-22
5-12	6-15	1-22	2-22	5-2	4-16	2-11	2-22
4-18	5-12	3-13	4-3	1-4	5-12	1-4	5-2
2-11	2-16	6-3	3-13	3-22	5-9	3-15	3-13
5-9	6-5	5-2	5-15	1-22	3-9	3-9	2-6
5-11	3-5	2-21	6-5	2-11	5-11	5-2	4-16
3-12	6-3	2-6	2-19	2-16	4-22	4-7	5-11
6-15	4-3	2-11	4-22	4-7	1-22	5-9	3-22
1-1	3-15	2-19	4-16	6-5	4-18	5-8	1-19
5-8	4-22	4-22	2-16	5-9	5-8	3-13	4-22
4-16	1-22	3-12	6-15	4-3	4-4	3-22	4-3
3-13	5-2	4-7	4-1	6-3	4-3	4-4	2-19
5-2	2-22	3-15	5-11	3-12	3-12	2-6	2-11
6-3	3-12	4-16	1-4	2-19	3-13	5-11	5-12
3-15	1-1	5-9	4-4	5-12	3-15	6-15	5-9
3-22	3-13	3-9	3-22	5-8	1-1	2-16	2-21
5-15	4-4	6-5	3-15	3-9	2-21	5-12	5-8
1-4	1-19	2-22	5-9	3-15	2-11	3-5	6-15
2-22	5-11	2-16	1-1	3-13	3-22	4-3	4-1
2-21	5-8	6-15	3-9	6-15	6-3	2-19	6-3
2-19	2-11	1-4	4-18	4-22	4-1	2-22	3-9
6-5	4-1	4-1	2-21	4-4	5-2	4-16	4-7
2-16	1-4	5-15	3-12	2-22	2-22	4-22	1-4
3-5	5-9	1-19	2-6	2-21	2-16	6-3	2-16
2-6	5-15	4-4	5-8	5-11	2-19	2-21	3-12
4-3	2-19	3-22	5-2	4-16	4-7	1-1	5-15
3-9	2-6	5-8	3-5	5-15	6-15	5-15	3-15
1-19	2-21	5-12	1-19	2-6	1-19	1-19	3-5
1-22	4-7	5-11	1-22	4-18	3-5	3-12	1-1
4-22	3-22	1-1	5-12	3-5	5-15	4-1	4-18
4-1	4-16	4-3	6-3	1-19	1-4	4-18	4-4
4-4	4-18	3-5	4-7	4-1	Guard	Guard	6-5
SPACED PLANTS					ROWS		PARENTS

Fig. 5. The Layout of Spaced Plant, Row and Parent Material in the Progeny Test.

(ii) Establishment and routine care.

After the removal of the previous crop residues, the area was rotary cultivated, harrowed and levelled to provide a firm planting medium. The seedling plants were raised in boxes in a greenhouse and transplanted into their final positions be ween the 17th and 19th June, 1959. General soil moisture conditions were adequate, the growth of the seedlings showed little check and few replacements were needed.

The row trial was planted during the last two weeks of August, 1959, seedlings being transplanted at 4 inch intervals to form rows 12 ft. long. The weather after planting was very dry and irrigation was required. The broadcast plots were sown on to a roller-drilled surface on 13th October, 1959, the seed rate used being 10 lb. per acre of each Yorkshire fog line plus 2 lb. of white clover.

The whole of Block Four was given an application of 1 ton of ground limestone per acre before cultivation and a topdressing of 2 cwt. of superphosphate and 1 cwt. nitroline per acre was given to the spaced plants, rows and plots, following transplanting and sowing.

Because of a severe infestation of twincress (Coronopus-didymus), dock (Rumex obtusifolium), black nightshade (Solanum nigrum), and annual meadow grass (Poa annua), preliminary weed control was carried out by hand. On all subsequent occasions, however, a 20 in. rotary hoe was used in eradicating weed growth.

Following the first series of observations on the 25th September, 1959 the spaced plants were trimmed with hand shears. After flowering, the area was cut with a tractor mower; thereafter all defoliation was carried out by the grazing sheep. No trimming was necessary on the row area as all the herbage was harvested during sampling.

Recording and Sampling Procedures.

A. Spaced plants.

On the single plant area regular recordings were made of the following features:-

(i) vigour and recovery after grazing,
(ii) the extent and time of heading, and
(iii) infection from rust (Puccinia coronata).

(i) Vigour was determined on an individual plant basis, giving a mean value for each parental line in the five replicates. The scale adopted ranged from 0-10 and was related to the leaf material produced since the previous grazing, 0 being the lower limit of growth.

Observations were made on the following occasions during September, 1959 - August, 1960:

25th September	21st March
1st January	29th May
6th February	26th August.

(ii) The extent and time of heading. It was originally intended to record the actual date on which each spaced plant commenced to head i.e. when the third inflorescence emerged from its sheath (Bedsows, 1954). This proved to be too great a task, however, and the relative time of flowering, based on the proportion of plants flowering on three occasions, was used in its place. An assessment of the extent of flowering was derived from the number of flowering tillers on each plant at the three dates:

23rd November 2nd December 7th February.

(iii) The incidence of rust. Following the termination of flowering and the arrival of moist conditions after an extremely dry summer there was a noticeable increase in the incidence of crown rust lesions on the spaced plants. Observations were taken on three occasions, at the commencement, the zenith and the end of the major infection period i.e. on the following dates -

7th February 23rd March 30th May

The scoring method utilized was adapted from that recommended for cereals by Peterson et al (1948). A scale of 0-5 gave adequate separation of the individual categories, 0 being the score given when no lesions were noted on the plant and 5 when almost all of the leaf surface was affected by the pathogen.

B. Progeny rows.

(i) Yield. At each harvest a 10 ft. length of row was sampled by cutting the herbage with hand shears to a height of 1 in. above the soil surface. The green material was weighed and the percentage of dry matter present subsequently determined by drying sub-samples for 12 hours in an electric oven maintained at a temperature of 100°C.

Dates of yield determinations on rows.

8th December.	25th February
12th January	20th April.

(ii) Flowering and growth habit. To augment the information obtained from the single plant area, observations were made on the growth form of each row at the early heading stage, on 7th December, 1959. The categories adopted are described by Basnyat (1957) and are:

erect; semi-erect; semi-prostrate; prostrate.

On the same date a count was made of the number of inflorescences in each row of replicate I in order to give an estimate of the possible extent of heading in the sward.

C. Progeny swards.

Because of the lack of replication and the uneven nature of irrigation during the dry summer period no observations were made on the sward plots during 1959 and 1960.

Experimental Results.

In the final selection of parent material particular attention was paid to three aspects of growth in progeny:

(i) vigour, i.e. the maintenance of leaf production throughout the year without any serious decline either in the summer months following flowering or during the winter.

(ii) a low proportion of flowering tillers, leading to the maintenance of palatability and nutritive value during the heading period; and

(iii) resistance to severe infection by crown rust.

In presenting the results the lines will be referred to on the basis of the code system first allocated when the parent material was examined in clonal form following the initial selection. The code numbers given to the 32 lines are as follows: further details of the origin are recorded in Appendix I.

Code Numbers of the 32 Parent Plants.

Prostrate Group.

1-1	1-4	2-11	2-16
2-21	3-5	3-9	3-12
3-15	4-1	4-4	4-7
4-18	5-8	5-9	5-12
5-15	6-3	6-5	6-15

Erect Group.

1-19	1-22	2-6	2-19
2-22	3-13	3-22	4-3
4-16	4-22	5-2	5-11

Although provision was made for the statistical treatment of results by an analysis of variance and the application of multiple range test (Duncan, 1955), the relative ranking of each line at the time of each observation was regarded as the most important criterion in selection (Finney, 1958).

Vigour.

A summary of the vigour rankings of the 32 lines is given in Table II while the actual scores used in classification can be found in Appendix I.

The progeny of each parental line was more variable with regard to vigour and recovery after grazing than in any other feature. As a consequence, differences between lines were more difficult to establish than was the case with the parental clones. Very few progenies retained a high ranking throughout the whole season, vigour being subject to the varied influences of climatic and soil conditions, flowering and disease.

Spring and early summer. During the spring early summer, vigour recordings were made on the Massey College spaced plant material on only one occasion, in late September. Additional information was, however, available from Rukuhia regarding growth in late October and early December.

In the period immediately following transplanting, considerable uniformity was noted within each progeny line, with a tendency to reflect the main maternal characteristics. Following the first defoliation, however, the intra-progeny variation became more evident, yet despite this feature there was a noteworthy range in the mean values accorded to each progeny. Certain lines were prominent in the level of their performance above and

TABLE II. Summary of Vigour and Yield Ratings

LINE	SPRING - EARLY SUMMER				SUMMER				AUTUMN-WINTER		ROW
NO.	a	b	c	d	e	f	g	h	i	j	k
Prostrate											
* 1-1	23	23	22	13	13	16	4	18	1	5	22
* 1-4	12	13	12	26	4	9	8	5	11	16	31
* 2-11	6	13	17	26	19	9	3	17	4	30	27
2-16	28	32	27	21	1	11	13	30	25	31	29
2-21	24	25	22	19	27	3	5	25	25	28	3
* 3-5	16	29	27	19	4	1	5	19	15	18	2
3-9	3	25	15	29	27	22	18	21	11	25	20
3-12	26	25	27	21	10	16	16	22	31	14	25
3-15	20	29	30	21	25	6	21	6	24	20	18
4-1	9	12	7	16	2	11	3	7	9	1	8
4-4	5	25	30	18	23	26	29	27	11	25	6
* 4-7	14	20	12	7	16	7	32	12	8	29	7
* 4-18	1	8	10	2	16	4	11	24	5	3	26
5-8	13	23	17	31	19	20	30	4	20	16	17
5-9	24	20	17	21	26	28	28	9	27	32	19
5-12	2	15	26	10	25	5	11	16	6	7	4
5-15	30	8	15	30	2	2	15	10	9	13	32
* 6-3	7	5	5	5	8	8	1	2	15	8	13
6-5	17	25	30	26	19	11	14	13	18	9	14
6-15	15	20	22	8	8	15	16	28	27	23	9
Erect											
1-19	20	15	2	21	19	22	25	8	17	4	24
1-22	27	15	5	32	10	27	18	3	29	21	30
2-6	10	3	7	13	6	11	18	31	14	15	28
2-19	28	8	2	16	31	32	26	32	30	27	5
2-22	32	29	17	13	6	19	24	29	20	26	21
* 3-13	22	4	10	4	13	24	9	13	3	6	23
3-22	18	5	2	6	26	31	21	20	28	32	10
* 4-3	18	15	22	10	23	18	2	1	1	10	1
4-16	10	5	17	3	32	29	26	23	22	11	12
4-22	25	8	7	9	10	21	21	26	22	19	16
* 5-2	4	1	1	1	13	30	10	5	7	2	10
5-11	8	2	12	10	16	25	31	11	32	24	15

NOTE: * Final selections.

Spaced plants

a. Massey - 25 Sept.59
b. L.Cameron - 22 Oct. 59.
c. do 8 Dec. 59
d. Moanatuatua - 8 Dec.59
e. Massey - 1 Jan.60
f. Massey - 6 Feb.60
g. do - 22 Mar.60
h. L.Cameron-29 Mar.60
i. Massey - 29 May,60
j. do - 26 Aug.60

Rows

K. mean total D.M. prodn.

below the overall mean. Few minor discrepancies occurred between the rankings at the Massey College and Rukuhia centres but in general performance was similar.

The following lines were outstanding in their production capacity in the spring and early summer of the first harvest year:

5-2	3-33	5-11
4-18	2-6	4-16
6-6	3-13	4-1

Of these nine lines, the light coloured erect line 5-2 was perhaps the best individual producer, performing well at both main centres.

Summer. In the post-heading period the spaced plants were subjected to very dry conditions. According to meteorological data collected at Grasslands Division, Palmerston North (1 mile from Massey College), the year 1959-1960 was very abnormal as regards rainfall, only 29.47 in. falling between September 1959 and August 1960 inclusive (Appendix III). This was 9.83 in. below the mean for the years 1928-1956 and o.77 in. below the previous lowest recorded year, 1924.

Under the spaced plant conditions growth was less restricted than in the rows and swards and observations were made on the regrowth following grazing at Massey College. The exhaustive influence of flowering severely affected some of the lines which were previously high yielding e.g. 4-16 and 3-22 while others such as 6-3, 4-18, 4-1, 2-6 and 3-13 retained their positions.

When more moist conditions appeared in February and March, several lines were severely infected by rust. This was probably a reflection of low vigour rather than the reverse effect.

Based on observations made in February and March, nine lines appeared to be capable of high production in the late summer.

6-3	1-4	4-3
4-1	5-12	6-5
3-5	5-15	4-18

Autumn and winter. By May, 1960, the mean monthly 4 in. soil temperature had fallen to 50.3°F and there was a considerable reduction in the rate of growth. Thus the maximum progeny mean score was 4.98 on the 29th May compared with 8.12 on 6th February. A second recording was made at Massey on 27th August, and relates to growth during the two coldest months in the year.

There was little change in the ranking of the lines between the two periods and eleven progenies showed a strong potential for winter production.

1-1	5-12	1-19	4-3
4-1	5-15	2-6	5-2
4-18	6-3	3-13	

Row Yield Determinations.

Because of the limited replication used in the row trial and the disturbing influence of uneven irrigation during the dry period, it was necessary to exercise considerable caution in the interpretation of yield data obtained. In general, therefore, evidence from this trial was merely used to substantiate the findings under spaced conditions.

Following four yield determinations between November, 1959 and April, 1960 the total production for each line was calculated, giving the relative ratings shown in Table II. In most cases these ratings reflected performance under spaced plant conditions. Where there was strong contrast, as in lines 1-4, there was a likelihood of uneven irrigation leading to a considerable difference in the yields of the two replicate rows.

It is interesting to note, however, that the poorest yielding rows 5-11, 2-16, 3-12, 1-22 and 2-19 were amongst the poorest as spaced plants.

Flowering.

Although flowering was observed in the original collection from the 4th October to the end of December (Basnyat, 1957) the influence of selection considerably narrowed the range of heading dates in the parental material under examination.

Three major observations were made on the flowering behaviour of the progeny lines under spaced plant conditions. On 23rd November few plants had commenced emergence, only 23 out of the overall total of 1600. Fourteen of these plants came from line 2-6 and 4 from line 4-7. In the case of emergence, there was much less intra-line variation than had been in regard to vigour.

TABLE III. Summary of Growth Form, Flowering and Rust Ratings

LINE NO.	GROWTH FORM	FLOWERING		RUST RESISTANCE		
		PERIOD	EXTENT	FEB.	MAR.	MAY
Prostrate						
* 1-1	SP	L	R	20	9	8
* 1-4	SE	E	R	4	10	7
* 2-11	SP	E	R	6	1	16
2-16	SP	L	R	28	23	20
2-21	SP	L	R	11	7	1
* 3-5	SP	L	R	8	15	2
3-9	SP	L	P	19	26	11
3-12	SE	L	R	2	4	3
3-15	SP	L	R	3	14	15
4-1	E	E	P	30	30	25
4-4	SP	L	R	26	24	12
* 4-7	SE	E	P	27	6	10
* 4-18	SP	L	P	32	18	19
5-8	SP	E	R	5	2	4
5-9	SE	E	R	15	13	1[illegible]
5-12	SE	L	R	24	21	30
5-15	SE	L	R	17	16	27
* 6-3	SE	L	R	29	29	26
6-5	SP	L	R	12	19	4
6-15	SE	L	P	21	28	32
Erect						
1-19	E	E	P	10	17	21
1-22	E	E	P	16	20	17
2-6	E	E	R	31	31	29
2-19	E	L	R	23	32	31
2-22	SE	E	P	22	22	9
* 3-13	SE	L	R	14	11	14
3-22	E	E	P	32	27	23
* 4-3	SE	L	P	13	8	6
4-16	SE	L	P	9	5	3
4-22	E	E	P	25	25	28
* 5-2	E	E	P	7	12	5
5-11	SE	E	P	1	3	27

NOTE: * Final selections

Growth form - Rubu[illegible] and Massey
E - erect
SE - semi-erect
SP - semi-prostrate

Rust resistance - Massey

Flowering :
E - early L - late
R - restricted
P - profuse

By 2nd December, 584 plants were heading. On this date 40 of the 50 plants in line 2-6 were heading profusely whereas in lines 5-15 and 2-21 no plants had reached the emergence stage.

After this recording, almost all the spaced plants came into head and the whole area was mown and grazed. Observations on the extent of heading in the aftermath growth were made on 7th February, 1960. Sixty-five of the plants in the area bore more than 20 inflorescences. In general, only one or two of these plants were noted among the 50 individuals in each progeny but in the instance of lines 4-16 (9 plants); 6-15 (9 plants), 2-16 (7 plants) and 4-18 (6 plants) they were more frequent.

From these observations it was possible to differentiate the progenies into early and late flowering lines i.e. lines where the bulk of flowering came before or after the recording made on 10th December. The extent of head formation was assessed by counting the number of inflorescences in the spaced plants and in the 10 ft. sample strip of each progeny row.

Details of the relative ratings of each line are incorporated in Table III. The thirty-two progenies fall into four major categories, namely:-

(i) early flowering, profuse heading,
(ii) early flowering restricted heading,
(iii) late flowering, restricted heading, and
(iv) late flowering, profuse heading.

The two major categories were (i) and (iii), which indicated a general correlation between earliness and the extent of heading. All parent plants from the erect polycross block had a predominantly erect or semi-erect progeny, which in most cases was early and profusely flowering. Of the progenies derived from the prostrate polycross area only line 4-1 was not semi-erect or semi-prostrate and most plants showed late flowering, with the formation of a limited number of heads.

Classification of Flowering Characteristics.

i. early flowering - profuse heading

1-19 1-22 2-22 3-33 4-1 4-7 4-22 5-2 5-11.

ii. early flowering - restricted heading.

1-4 2-6 2-11 5-8 5-9

iii. late flowering - restricted heading.

1-1 2-16 2-19 2-21 3-5 3-12 3-13

3-15 4-4 5-12 5-15 6-3 6-5

iv. late flowering - profuse heading.

3-9 4-3 4-16 4-18 6-15

This grouping is almost exactly comparable with that which would be given on the basis of records made on the parent material during the years 1956-1958 (Jacques and Schwass, 1959). Aspects of flowering behaviour show high heritability and respond rapidly to selection (Cooper, 1959).

Rust Infection.

As in the case of heading, there was a strong correlation between the parental material and their progeny in their susceptibility to crown rust. In general the situation was one of increasing infection from the beginning of February until late May.

On the 7th February, 1960, observations were made on the incidence of lesions on each individual plant at Massey College. Approximately 50 per cent of all plants showed some symptoms of infection, the mean overall score being 0.91, on 0-5 basis. There was considerable variation both within and between lines, however, the extreme progeny means varying from 0.24 to 1.60.

By the 23rd March, more humid conditions following the dry summer led to a further increase in the spread of infection, particularly in replicates I and II. At the same time, the mean score per plant over the whole area rose to 1.41, with extreme progeny means ranging from 0.66 to 2.26.

A final record was taken on 30th May when all plants in the area were showing the presence of lesions. The mean infection score was 2.36 and the extreme means were 2.02 and 2.84.

Statistical analysis of the results by means of Duncan's range test shows that the differences between progenies were significant on each occasion. Separation of the treatment means was greater than in the case of vigour.

The individual placing at successive observations remained relatively constant and classification proved to be a simple procedure (Appendix I).

<u>Lines showing high resistance to crown rust.</u>

1-1	2-21	3-15	5-2
1-4	3-5	4-3	5-8
1-19	3-12	4-7	5-11
2-11	3-13	4-16	6-5

<u>Lines showing low resistance to crown rust.</u>

1-22	2-22	4-4	5-12
2-6	3-9	4-18	5-15
2-16	3-22	4-22	6-3
2-19	4-1	5-9	6-15.

There was no apparent association between rust incidence and the growth form, time of flowering or extent of flowering. Neither was there evidence of superior rust resistance in parental material derived from particular regions of western North Island. Certain lines originated from the same original seed sample e.g. 1-1, 1-22, 3-15, 4-3 and 4-4 and yet show different susceptibility.

<u>Growth form.</u>

Growth form was recorded at the initial heading stage on the spaced plants at Rukuhia and the progeny rows at Massey College. The rating awarded was in nearly every case identical with that used in dividing the parent material into the polycross blocks. All progenies of the erect group were erect or semi-erect, and all progenies of the prostrate group were semi-erect or semi-prostrate, except for line 4-1 which was wrongly placed in the initial grouping (Jacques and Schwass, 1959).

<u>The Selection of Parent Material for the Synthetic Variety.</u>

In making the final decision as to which lines would be included in the synthetic variety bred for the wetter hill areas of North Island, constant reference was made to several important factors. It has been stressed earlier in this discussion, that, above all, a variety of this nature must have adaptability to a wide range of climate, edaphic and biotic conditions.

At this preliminary stage, it was only feasible to test all the lines as spaced plants at three centres, at Massey College and on the two peat areas at Rukuhia. Selection was dependent on satisfactory rating on each area.

The second important factor in selection was that of general growth cycle, the maintenance of production during the critical periods of winter, early spring and the dry conditions which often prevail during the summer months.

When several potential parents had been selected on this basis, attention was then directed to the examination of plant characteristics which, it was thought, would influence the conversion of the herbage by the grazing animal. Earlier studies in the Yorkshire fog collection (Jacques and Schwass , 1959) Basnyat, 1957) had revealed a relationship between low palatability and

i. prolific heading during the flowering period,
ii. the presence of rust lesions, and
iii. a prostrate habit of growth.

Thus despite overall changes in palatability associated with the stage of growth it was concluded that certain plants had a higher inherent value than others in this respect. Ten lines looked particularly promising from all or some of these aspects and were retained for final consideration.

<u>Lines with a High Potential as Parent Plants.</u>

1-1	2-11	3-13	4-4	5-2
1-4	3-5	4-3	4-18	6-3

In the formation of synthetic varieties it is essential to maintain a uniformity of heading time within the parental material, thus preventing the possibility of considerable genetic drift during seed multiplication. Most of these ten lines were late flowering but there were four which showed a tendency towards earlier flowering, namely 1-4, 2-11, 4-7 and 5-2.

When the first synthetic was compounded in 1960 eight lines were incorporated.

<u>Selected Parents for the 1960 Synthetic Variety.</u>

1-1	2-11	3-13	4-7
1-4	3-5	4-3	5-2.

While this selection contains a high level of adaptability the variation in heading performance and growth form may prove to be a hazard in seed multiplication. It is proposed therefore that two further varieties should be formed and subjected to full agronomic testing.

The more important variety, composed of late flowering plants with a semi-erect or semi-prosprate habit of growth, would incorporate the following lines.

<u>Proposed Late-Flowering Variety</u>.

1-1	3-13	4-18
3-5	4-3	6-3

The second variety would include earlier flowering, more erect lines with a high performance.

<u>Proposed Early-Flowering Variety</u>.

1-4	4-7
2-11	5-2.

<u>Proposals for Further Evaluation</u>.

The ultimate criterion of the value of any variety of pasture grass can only be determined under actual farming conditions. The most pressing requirement in the Yorkshire fog breeding programme will be for more adequate information on the animal utilization of the improved material in comparison with that of the South Island commercial lines obtained from cocksfoot and ryegrass seed cleanings.

Although selection has been based on spaced plant data information has been received from Rukuhia on the sward performance of six of the polycross progenies with white clover as a companion species (van der Elst and Corby, 1960). The seasonal yields and total production of these lines, 1-19, 2-6, 2-11, 2-22, 3-13 and 5-11 shows general agreement with their performance as speced plants at Massey College and Rukuhia. Over the period 27th April, 1959 to 7th June, 1960, the yields obtained from the mowing trials at Lake Cameron ranged from 6262 lb. dry matter per acre in progeny 1-19 to 7370 lb. in progeny 5-11.

Line 5-11 was not included in the final selection because of its low production in the winter months. Lines 3-13 and 2-11, however, were the next highest yielding and gave a winter growth closely following that of perennial ryegrass. Both these parents were included in the proposed new varieties.

SECTION FIVE.

THE AGRONOMIC POTENTIAL OF THE SYNTHETIC VARIETY.

In recent years, one of the most controversial topics of agricultural science has been that centred on the methods to be adopted in the testing of a grass or legume variety. The final criterion of success in a breeding programme is undoubtedly that of animal production and the ultimate aim must always be that of a full scale grazing trial before the release of the material to the hill farmer.

At the intra-breeding level, however, the quantity of seed available will not allow tests of this nature and recourse must be made to small plot trials incorporating systems of simulated grazing.

In this section it is proposed to discuss a preliminary pasture comparison between selected Yorkshire fog material, a typical commercial line and five other species.

It was decided to make the comparison under conditions appropriate to the environment in which the Yorkshire fog would be used, namely those of moderate fertility and stocking intensity. The conditions were simulated through three techniques, the use of limited fertilizers during the establishment period, mowing to a pattern similar to rotational sheep grazing and the return of nutrients to the individual swards in relation to the amount of dry matter produced in the preceding period (McNeur, 1953). Fertilizer return on the more normal uniform basis would have given a material advantage to those species which required high levels of fertility to give optimum production.

Review of Literature.

In a previous section, a certain amount of emphasis has been placed on the broad ecological tolerance of Yorkshire fog. Tolerance of the range of climatic conditions in western North Island results in the maintenance of relatively uniform production throughout most of the year (Levy, 1955; Lynch, 1949; Suckling, 1960). Yorkshire fog is important in many areas through its contribution to pasture production in the critical winter and early spring months (Basnyat, 1957).

In a grazing trial carried out at Grassland Division (Goodall, 1943) the production of a Yorkshire fog-white clover sward was compared with that of several other important species under systems of full grazing utilization and more lenient defoliation. The performance of Yorkshire fog, a normal commercial line was greatest under the latter method of grazing, and in many aspects resembled the overall production of cocksfoot. When yield was calculated in terms of grazing-days the Yorkshire fog maintained its relative position despite the fact that it has a lower relative palatability than perennial ryegrass, cocksfoot and timothy.

The total annual production of the fog - white clover pasture was approximately 16,500 lb. d.m. per acre compared with 17,900 lb. from perennial ryegrass-white clover. Under full utilization the production of the two swards was reduced to 14,200 lb. and 15,700 lb. respectively.

In the more leniently grazed area, Yorkshire fog produced approximately 4,700 lb. d.m. during the critical winter months of May, June, July and August, 25 per cent more than the perennial ryegrass. This winter growth attribute of the Yorkshire fog makes it extremely important under conditions of the autumn sowing of pastures (McMeekan, 1960).

Growth studies carried out by Watkin (1960) at the Lincoln substation of Grassland Division show that this grass is also more tolerant of high summer temperatures and soil moisture stress than the currently available varieties of short-rotation and perennial ryegrass. This situation was shown both in replicated spaced plants and in swards subjected to rotational grazing. During the winter months, prairie grass and tall fescue were undoubtedly the outstanding species but, on the other hand, Yorkshire fog produced as much as short rotation ryegrass and considerably outyielded such highly regarded species as cocksfoot and perennial ryegrass.

All these studies have been carried out under lowground conditions and there is a considerable lack of information on the relative performance of a wide range of species in the hill areas of New Zealand, especially under the existing management systems. Recent investigations under high fertility conditions have been carried out with 27 pasture species on high rainfall hill country at Te Awa (Suckling, 1960) to investigate the maximum climatic potential of a range of grass legumes and weeds.

The total annual yield over three years for some of the species is shown below.

Annual Productivity of Grass Species at Te Awa (mean of three years).

Species.	Dry matter production (lb. per acre).	Index.
	High fertility grasses.	
Perennial ryegrass	23,770	100
Short rotation ryegrass	20,180	85
Cocksfoot	19,650	83
	Medium fertility grasses.	
Yorkshire fog	14,140	59
Danthonia spp.	10,150	43
Browntop	7,580	32

Yorkshire fog was the highest producing of the 'lower fertility' grasses, yielding 59 per cent of the annual production of perennial ryegrass. This discrepancy is perhaps not so important as it appears, however, as the main difference was obtained from growth in the summer and autumn.

In winter and spring, however, as indicated in the seasonal production table below, Yorkshire fog produced almost as much herbage as the perennial ryegrass.

Seasonal Productivity of Grass Species at Te Awa (mean of three years).

Species.	Spring.	Summer.	Autumn.	Winter.
Perennial ryegrass	5,720	10,450	4,880	2,700
Short rotation ryegrass	6,330	7,790	2,070	3,000
Cocksfoot	5,360	7,970	4,740	1,580
Yorkshire fog	4,530	4,760	[illegible]	2,150
Danthonia spp.	3,150	[illegible]	1,200	1,490
Browntop	2,860	1,400	2,230	1,090

The pattern of seasonal growth varies considerably between the different species and was very similar to that noted in the experiments in the lowlands of North Island (Lynch, 1949). Cocksfoot and browntop were notable for their autumn production, yielding 24 and 29 per cent of their annual yield respectively during March, April and May. Yorkshire fog reached its peak of production in the latter part of the spring (October and November) but at the same time maintained a certain consistency of yield throughout the year, producing 81 per cent of the growth obtained from perennial ryegrass in the winter.

The Yorkshire fog used in these trials was again derived from South Island commercial material. Early studies at the Plant Research Station (Levy and Davies, 1930) noted that ryegrass plants from this region were lacking in persistency and showed a tendency to early and prolific flowering. In these false perennial types the vegetative tillers died off in the autumn at the same time as their flowering counterparts whereas, in later and less profusely flowering plants, non-flowering tillers remained alive into the winter and spring (Soper, 1958; Lucanus et al, 1960). One of the major side effects of flowering is that noted on the root system of the plant. In heavily flowering plants, there is considerable sloughing of the cortical tissue and consequently the efficiency of uptake of water and nutrients is restricted. This is extremely important in governing plant survival during a dry summer period.

The daily rate of pasture growth is affected by fluctuation in both temperature and light regimes as well as by the frequency of defoliation (Brougham, 1959). The average diurnal increment obtained from a short-rotation ryegrass-white clover pasture ranged from 10 lb. d.m. per acre in mid-winter to 12 lb. per acre in early summer in sward growth studies at Palmerston North.

<u>Experimental Area, Layout and Establishment.</u>

The study of the agronomic potential of the selected Yorkshire fog material was carried out at Massey College on an area adjoining the progeny trial. A bred Yorkshire fog variety was produced by compounding the seed remaining from the polycross blocks after the requirements of the progeny trials had been met. The major contributing lines were:-

1-1	2-26	3-5	3-13	5-8	
1-19	2-19	3-9	4-3	5-11	6-15
2-11	2-21	3-12	5-2	5-15	

The production characteristics of the variety were compared with those of a typical commercial line from South Island and five other species, the main Grassland bred materials and the winter-growing prairie grass (<u>Bromus</u>

PRODUCTIVITY TRIAL

PLOT LAYOUT

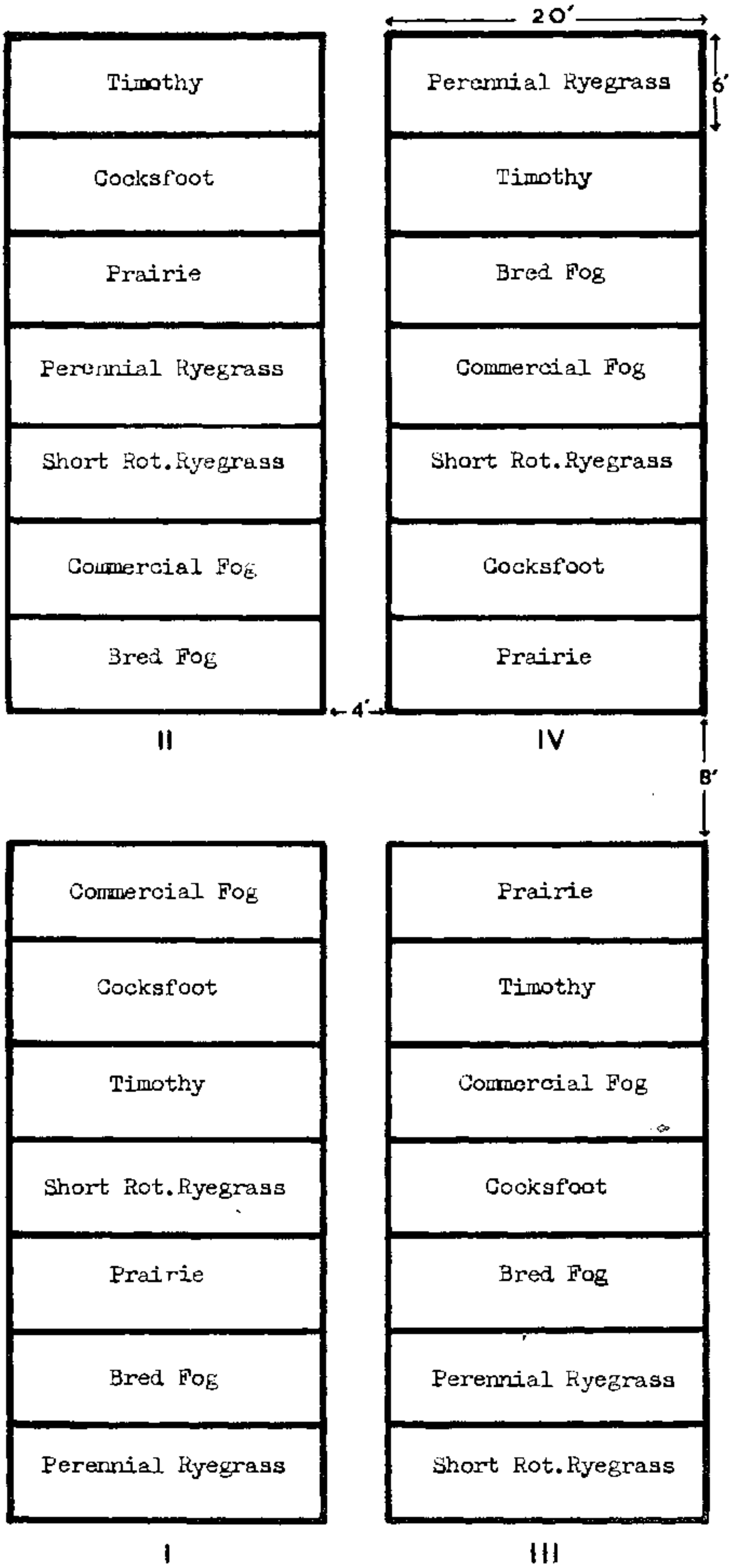

Fig. 6. Productivity Trial Plot Layout.

catharticus). Each grass was sown at the recommended seeding rate for the species in conjunction with 2 lb. white clover per acre.

Table IV. Seeding Rates in the Productivity Trial.

Species and Source.	Final Germination.	1000 Seed Weight.	Seed Rate.	
	per cent.	gm.	per acre. lb.	per plot. gm.
Bred Yorkshire fog-Massey College	88	302	10	15.6
Commercial Yorkshire fog-Ashburton	72	244	10	26.0
Perennial ryegrass-Grasslands Ra136	86	1807	20	32.0
Short rotation ryegrass-Grasslands Cg 121	53	1944	20	51.9
Cocksfoot-Grasslands Bc 747	76	765	15	27.1
Timothy - Bd 340	79	305	10	17.4
Prairie grass - Commercial	93	11490	30	44.3
White Clover - Ac 143	94	689	2	2.9

The experiment was laid down in a randomized block design using four replications. Each individual plot had dimensions of 20 ft. x 6 ft., the size being determined by the availability of seed and the width of cut of the motor mower used in sampling and trimming the area. A guard area composed of a commercial Yorkshire fog and white clover sward was maintained around the perimeter of each block.

The plots were sown on 13th October 1959, following preliminary rotary cultivation and levelling. An initial dressing of 3 cwt. serpentine superphosphate per acre was applied by roller drill then the seed was broadcast on the surface produced by this operation and covered by a light harrowing.

The emergence of seedlings was relatively uniform within the replicates of each species. Rain fell 2 days after sowing and by 27th October seedlings of short rotation ryegrass, perennial ryegrass and bred Yorkshire fog were clearly visible. Clover growth, on the other hand, was not evident until a much later date.

Following emergence, the area was consolidated with a flat roller. Weed competition proved to be serious and it was necessary to apply 0.5 cwt.

nitrolime per acre to stimulate grass and clover growth. All subsequent fertilizer dressings, however, were given on the basis of the dry matter produced in the previous growth period.

Because of the excessive drought during the summer the area was irrigated for a short period during January 1960.

Sampling ~~Research~~ Procedure.

To estimate production, cuts were taken by using a 20 in. reel Lawnmaster motor mower on which the front roller had been replaced by a pair of wheels, allowing adjustment to different cutting heights (M. W. Cross). Sampling of all plots took place when a yield of approximately 1000 lb. d.m. per acre had been attained by the most productive species. Generally this involved mowing the herbage from 4-6 in. to a standard height of 1 in.

After removing a mower width of herbage from each end of the plot, two 20 in. strips, each 16 ft. 5 in. long (0.456 of the total area of each ploy) were harvested and their green weight determined to the nearest 0.1 lb. on a tripod-mounted spring balance.

A 500 gm. sample of this herbage was retained for further analysis. From this, duplicate sub-samples of approximately 100 gm. each were dried in a 'Wilco' electric-oven at 100°C for 12 hours, to estimate the percentage dry matter of the material harvested from each plot. A further subsample was used for botanical dissection into grass, clover and weed fractions.

Herbage left standing in the field was removed immediately by mowing to the standard height.

During the period under consideration a total of nine harvests was made.

16th December	8th February	13th May
29th December	2nd March	24th June
15th January	5th April	7th August.

Return of Nutrients.

After each harvest, the dry matter production of each plot was determined and a fertiliser mixture returned on a proportionate basis. The compound used was that proposed by McNeur (1953) following a thorough study of the composition of the dung and urine produced by sheep. On a standard sward composed of 70 per cent ryegrass and 25 per cent white clover, (producing 14,000 lb. d.m.

per acre per annum) sheep returned an annual equivalent of 630 lb. N_2, 154 lb. CaO, 154 lb. P_2O_5, 547 lb. K_2O and 2520 lb. organic matter.

The fertilizers were mixed in the following proportions:

Fertilizer Compound.

Compact Material.	Proportion in 1 lb. mixture.
Blood and bone	0.130
Dried blood	0.273
Superphosphate	0.026
Muriate of potash	0.126
Sulphate of ammonia	0.185
Limestone	0.260
	1.000

For each 1 lb. herbage dry matter produced by the respective plots 250 gm. of fertilizer was returned. In the case of the harvests carried out on 29th December and 15 January a combined dressing was given.

Statistical Analysis.

The main methods of statistical treatment used in comparing the seven grasses were those of the analysis of variance and the multiple range test (Duncan, 1955). The range test provides information on the significance of differences between the species means, as regards yield, etc. and is more simple and powerful in its application than the more widely used least significant difference test.

Mean values were determined on nine occasions for the dry matter production of all herbage on each of the seven grass swards. In interpreting the significance of differences between these values comparisons were made with the shorest significant range (P = 0.05) computed from the appropriate standard error.

It was necessary to compile missing plot values for each of four areas, the prairie grass, cocksfoot and timothy plots in Replicate II and the short rotation ryegrass plot in Replicate III. The botanical analysis of the first three areas was markedly different from that in the other replicates, a direct result of uneven fertility and soil moisture status and the presence of severe weed infestation in one particular corner of the trial during the establishment phase. In the fourth instance, that of the short-rotation ryegrass plot, extensive damage resulted from the preliminary rolling operations. The treatment of this area as a missing plot was continued until the sixth harvest on 5th April, 1960.

Experimental Results.

i. Presentation of results.

Complete tables of the production data from the nine harvests are included in Appendix II along with the relevant statistical analyses and a summary of the botanical and dry matter composition of the herbage.

Because of the variation in the length of each harvest period, however, most of the results quoted in the main body of this discussion have been converted to a common basis, that of the mean daily dry matter increment (lb. per acre per day).

A summary of these results is given in Figure VIII along with the soil temperature and rainfall data for the year 1959-60. Opposite each harvest period an indication is given of the shortest significant range required between any two herbage production means. Estimates of the contribution of the sown grass, clover and weed fractions to the total yield were prepared from the average botanical analysis of each pasture. As no information was available regarding the composition of the herbage at the second and third harvests (29th December and 15th January), extrapolated values were used.

ii. Meteorological data.

Although records were not available on the exact site of the experiment, meteorological data were obtained from the adjacent weather station at Grasslands Division (1 mile distant). A summary is given in Appendix III of the monthly temperature, rainfall, evaporation and sunshine statistics for the period September, 1959-August, 1960. Comparative figures are also given for the 27 years between 1928 and 1956.

The year was to a certain extent abnormal, particularly with regard to rainfall. The total precipitation was well below average, 29.47 in. compared with a mean of 39.30 in. The most marked deficiency occurred during the months of December and January, when the dry spell was equivalent to a partial drought of 41 days (an absolute drought of 19 days), the longest on record at the station.

Temperatures, on the whole, showed less variation from previous years than the rainfall, although conditions were warmer than average during the early summer months (November to January).

iii. Total production.

The total herbage yields for each of the seven grass swards are given below (Table V and Figure VII), covering a period from establishment, arbitrarily standardised at 16th November, to the early part of August, a total of 265 days.

Table V. Total Dry Matter Production

(lb. d.m. per acre).

Species.	Total Herbage.	Component Production. Grass.	Clover.	Weed.
Short Rotation Ryegrass	7990	7310	530	150
Perennial Ryegrass	6570	5270	970	330
Bred Yorkshire Fog	7680	6130	1000	550
Commercial Yorkshire Fog	6920	4850	1380	690
Prairie Grass	7400	4310	1810	1280
Cocksfoot	7220	4210	1670	1340
Timothy	6320	2560	2270	1590

Despite a certain compensating relationship between grass and clover production there were considerable differences in the herbage yields of the seven grass swards. The highest production (7990 lb. d.m.) was obtained from the short-rotation ryegrass and the lowest (6320 lb. d.m.) from timothy. The selected Yorkshire fog line (7680 lb.) produced 760 lb. more than the commercial material and gave the second highest yield of all the grass varieties. By comparison, perennial ryegrass had a comparatively low performance under the prevailing conditions and occupied an intermediate position between cocksfoot and timothy.

Reference to the contributions of the sown grass, clover and weed species, however, shows more distinct variation in performance. Although total grass production follows a similar order to that of all herbage, the range encountered was considerably greater, from 7310 lb. d.m. in the case of short rotation ryegrass to only 2560 lb. from timothy.

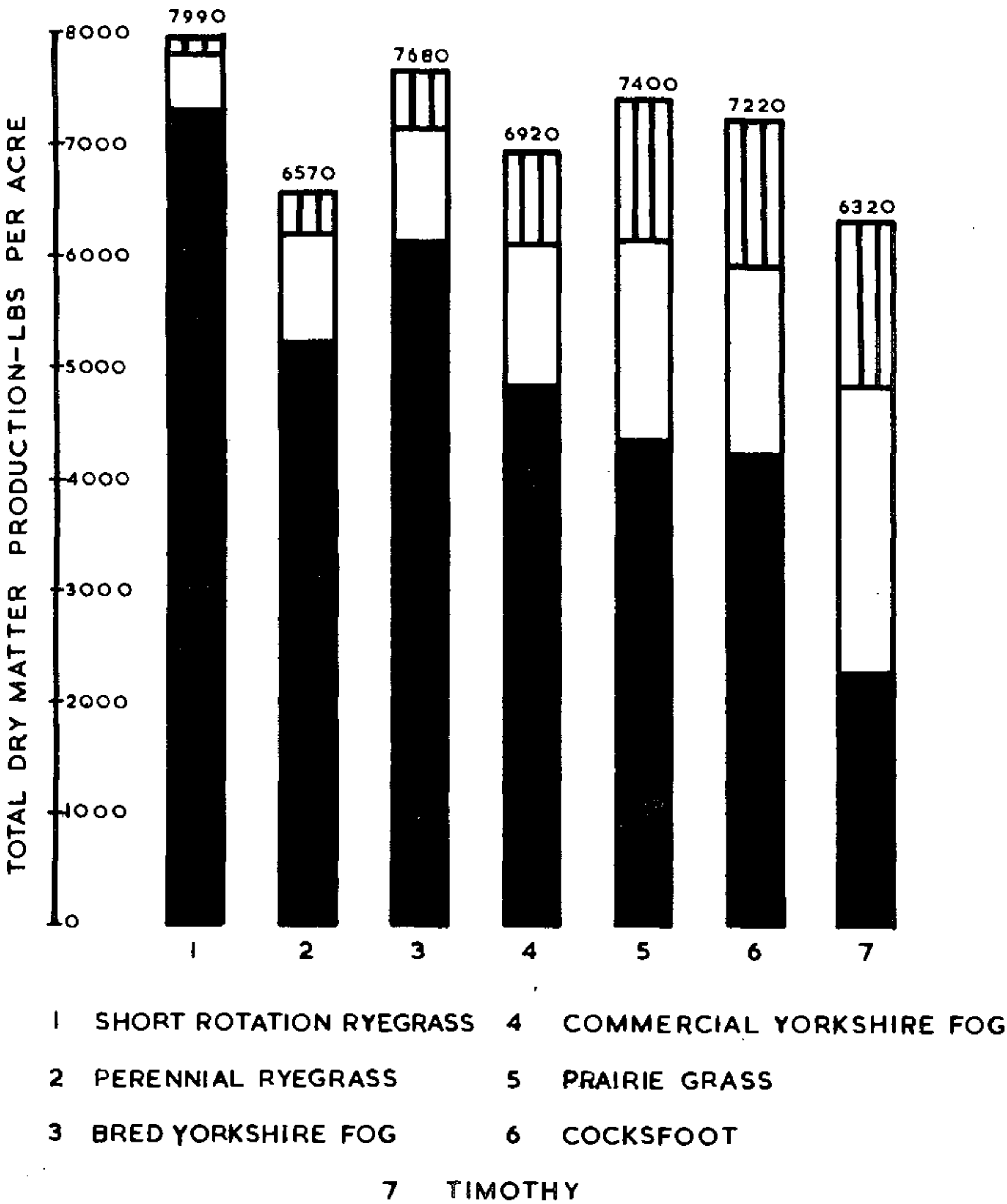

Fig. 7. Total Dry Matter Production -- 16 Nov. - 7 Aug.

As stated previously, the contribution of the clover and weed components of each sward was inversely proportional to the vigour of the sown grass. Thus in the short-rotation ryegrass pasture, where approximately 90 per cent of the herbage was from the grass, clover production was only 530 lb. d.m. per acre over the whole period. In comparison, a clover yield of 2270 lb. per acre was harvested from the timothy area. Annual meadow grass (Poa annua) and dicotyledonous weeds such as redshank (Polygonum persicaria) dock (Rumex spp.) and twin-cress (Coronopus didymus) contributed over 1000 lb. d.m. in the more slowly establishing prairie grass, cocksfoot and timothy swards. They were quickly suppressed by the more vigorous ryegrass and Yorkshire fog varieties, however.

iv. Seasonal production and growth cycle.

Daily dry matter production means for each of the nine growth periods are presented in Table VI and Figure VII, along with the shortest significant ranges between means.

Table VI. Seasonal Dry Matter Production - Total Herbage (lb. per acre per day).

Species	PERIOD 1	2	3	4	5	6	7	8	9	Mean
Short Rotation Ryegrass	32.3	39.8	32.5	30.4	32.8	40.9	27.5	23.0	24.9	32.6
Perennial Ryegrass	30.5	27.0	19.6	28.0	29.2	36.7	28.8	18.4	11.8	26.8
Bred Yorkshire Fog	21.3	30.1	32.3	45.5	37.4	39.8	26.1	20.6	21.7	31.3
Commercial Yorkshire Fog	23.0	31.4	31.5	44.1	30.4	32.7	20.6	17.2	21.3	28.1
Prairie Grass	21.2	38.7	38.0	48.1	29.6	30.6	23.3	20.1	23.4	30.2
Cocksfoot	20.0	28.6	32.5	46.0	38.6	37.7	20.6	16.3	19.6	29.4
Timothy	23.5	27.8	35.6	47.4	33.4	31.3	18.5	10.0	12.9	25.8
Shortest Significant range 2 (Means)	2.7	5.9	6.3	7.6	5.9	4.8	3.0	3.5	3.1	

Period 1 - 16 Nov. - 16 Dec.
2 - 16 Dec. - 29 Dec.
3 - 29 Dec. - 15 Jan.
4 - 15 Jan. - 8 Feb.
5 - 8 Feb. - 2 Mar.

Period 6 - 2 Mar. - 5 Apr.
7 - 5 Apr. - 13 May
8 - 13 May - 26 Jun
9 - 26 Jun. - 7 Aug.

When the yields are expressed in terms of the rate of production a close association is observed with the temperature regime during the different periods of the year. The highest rate of total herbage production was recorded

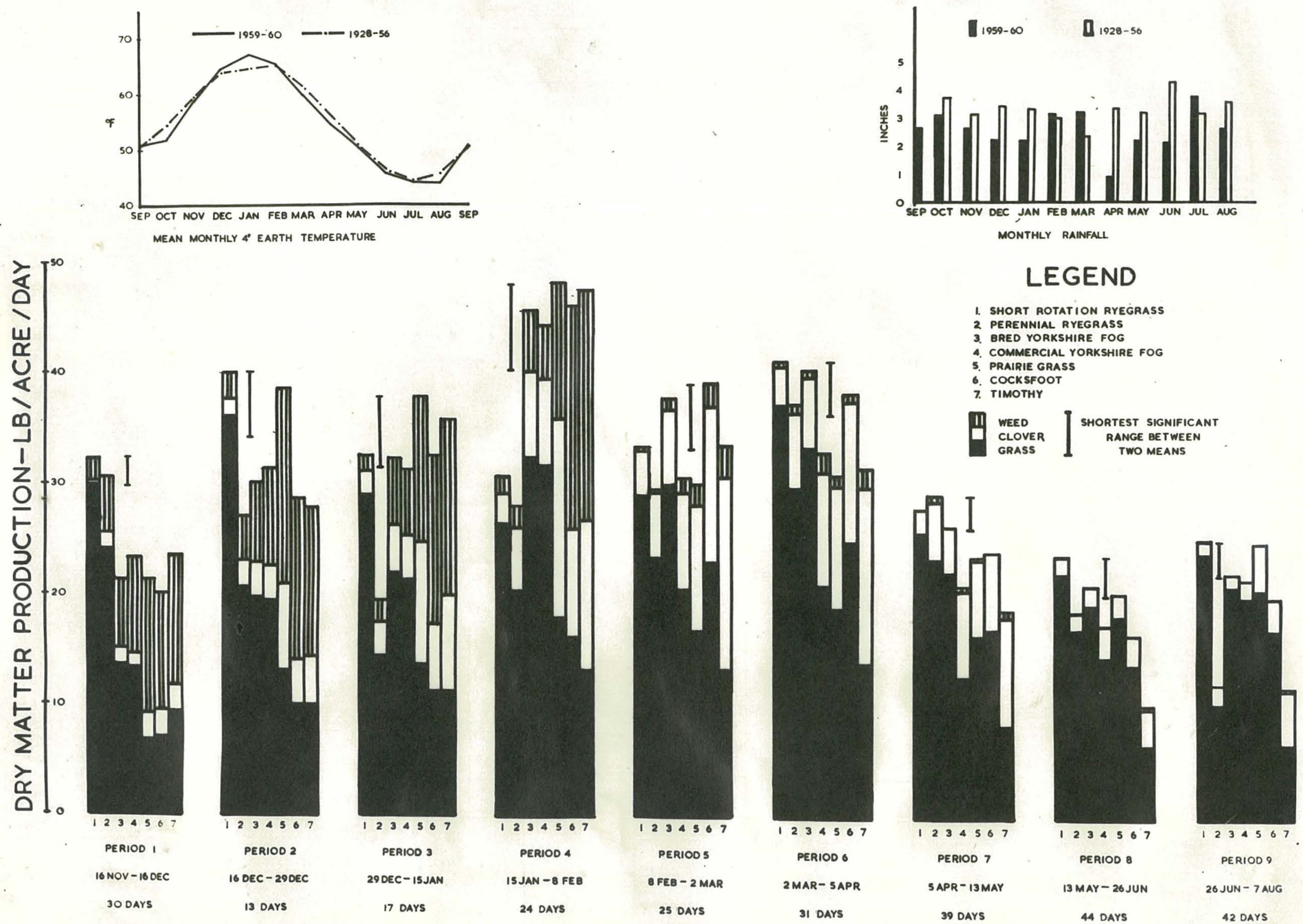

Fig. 8. Seasonal Dry Matter Production for Nine Periods between 16 Nov., 1959 and 7 Aug., 1960.

in late January and early February when temperatures at the 4 in soil level averaged over 65°F. During this period the daily herbage increment averaged over 40 lb. d.m. per day on all except the ryegrass areas. By May and June, however, the mean temperature had fallen below 50°F and production was reduced to around 20 lb. per day.

Within the overall pattern of summer production peak and winter trough certain distinct differences were noted in growth rhythm between the seven grasses. In considering these differences reference will be made first of all to the total herbage production in each period and then to the relative contributions of the sown grass, clover and weed species.

(a) Total Herbage production. Reference has already been made to the overall supremacy of short rotation ryegrass during the 245 days under consideration. This was mainly due to vigorous growth in the periods following establishment and in the cooler months of the autumn and winter (Periods 1 and 2 and 6 to 9). Under the conditions prevalent during this particular summer the short-rotation ryegrass sward was considerably reduced in production through the combined influences of high temperature, soil moisture deficiency and rust infection.

Although the herbage yield was significantly lower than in five of the other swards during late January (Period 4) the decline was much less serious than in the case of perennial ryegrass, where rust infection was more extensive and vigour was very low throughout most of December and January. During the 17 day period from 29th December - 15th January mean daily production was less than 20 lb. d.m. from the perennial ryegrass whereas that on all other areas exceeded 30 lb. d.m. per acre.

In the latter part of the summer and early autumn (Periods 5 and 6) there was less variation between the areas than at other seasons, nearly all swards producing between 30 and 40 lb. d.m. per day. The best production, however, came from the bred Yorkshire fog, short-rotation ryegrass and cocksfoot. With the onset of winter in the latter part of May and early June (Period 8) a rapid decline was noted in the growth of perennial ryegrass and timothy, the most productive swards being those of short-rotation ryegrass, prairie grass and the Yorkshire fog varieties.

Differences between the herbage production of the bred and commercial Yorkshire fog materials were not significant (P = 0.05) until the latter part of the summer (Periods 5, 6 and 7). During the dry weather the commercial variety showed evidence of plant mortality, the pasture thinned noticeably and the foliage showed infection from rust (although not to the same extent as on the ryegrass areas). A few lesions were noted on the bred variety but on the other hand, there was no sign of lack of persistency in the sward, growth remaining vigorous throughout the whole of the period recorded. In early winter there were no significant differences in the productivity of the two varieties and the commercial sward became noticeably denser.

(b) Grass production. Daily grass production means for each of the nine growth periods are presented in Table VII and Figure VII.

Table VII. Seasonal Dry Matter Production - Grass alone.
(lb. per acre per day).

Species	PERIOD 1	2	3	4	5	6	7	8	9	Mean
Short duration Ryegrass	30.1	36.2	28.9	26.1	28.7	36.8	25.3	22.0	23.7	24.8
Perennial Ryegrass	24.1	20.5	14.5	20.2	23.1	29.4	23.0	16.7	10.2	21.5
Bred Yorkshire Fog	13.6	19.9	22.0	32.3	29.6	33.0	21.7	19.1	20.6	25.0
Commercial Yorkshire Fog	15.4	19.7	21.4	31.8	20.4	20.9	12.6	14.3	18.7	19.8
Prairie Grass	6.8	13.2	13.7	17.8	16.6	18.7	16.3	18.0	20.3	17.6
Cocksfoot	7.0	10.0	11.4	16.2	22.8	24.5	16.9	13.5	16.8	17.2
Timothy	9.4	10.0	11.4	13.3	13.0	15.8	8.0	6.5	6.7	10.4

Period 1 - 16 Nov. - 16 Dec.
2 - 16 Dec. - 29 Dec.
3 - 29 Dec. - 15 Jan.
4 - 15 Jan. - 3 Feb.
5 - 8 Feb. - 2 Mar.

Period 6 - 2 Mar. - 5 Apr.
7 - 5 Apr. - 13 May
8 - 13 May - 26 June
9 - 26 June - 7 Aug.

These data highlight the differences in growth rhythm and vigour between the seven varieties to a much greater extent that the total herbage results. The general situation is closely similar to that described earlier in reference to total production over the whole experimental period, clover and weed growth compensating for the grass in the sward. This was particularly true during the height of the summer (Periods 3 and 4), at the time when conditions were most suitable for clover growth. Although the grass production of the prairie grass, cocksfoot and timothy swards was only in the region of 15 lb. d.m. per acre per day, clover and and weed growth raised the total to over 45 lb. The early vigorous growth of the short-rotation ryegrass had resulted in the suppression of clover in the pasture and although the grass yield was above 25 lb. d.m. per day the total herbage yield only slightly exceeded 30 lb. per day.

In the case of the more vigorous grasses such as the Yorkshire fog and the ryegrasses the trends in grass yield closely follow those already mentioned in regard to total herbage. The growth pattern of the short rotation ryegrass was very uniform throughout the experiment except for the slight decline in summer and winter. The daily increment remained within a range of from 22.0 lb. d.m. to 36.2 lb. d.m. during the period recorded.

The perennial ryegrass was generally less productive and only compared closely in the late autumn and early winter months (Periods 7 and 8). Variation in seasonal production was perhaps more apparent than in any other grass under examination.

The timothy, prairie grass and cocksfoot areas showed slow growth in the early stages of the trial (Periods 1, 2, 3 and 4) but were interesting from several points of view.

Whereas the selected material maintained a relatively level plateau of growth between 20 lb. and 40 lb. d.m. per day, the commercial line had a more pronounced peak of production in summer followed by a sharp decline until late winter and early spring.

(c) Dry matter content of the green herbage. A summary of the percentage dry matter in the herbage of the seven swards is given in Appendix II. In every case there is a seasonal trend similar to that encountered from total herbage production. The highest dry matter contents, over 20 per cent in the case of the ryegrasses and prairie grass, are associated with the warm summer conditions in January and February (Period 3, 4 and 5). Certain differences are almost maintained between the individual species throughout the duration of the experiment. Perennial and short-rotation ryegrass showed considerable similarity until late autumn and winter, being generally higher in dry matter content that the other species, at least during the summer months.

Both Yorkshire fog varieties demonstrated a tendency towards lower dry matter percentage throughout the year than most of the other grasses. The main disparity between the two lines coincided with their divergent performance during the latter part of the summer. While herbage production from the commercial material was much below that of the bred variety the dry matter content was between 0.7 and 1.5 per cent higher. Thus differences which appeared considerable when viewed in terms of green herbage were reduced to a certain extent on conversion to a dry matter basis.

One general trend was established from all the observations, however. The dry matter content of the herbage in each grass sward appeared to be inversely proportional to the vigour of growth. Thus, although the short rotation ryegrass and timothy had mean dry matter contents of 20.24 and 17.90 per cent in Period 5, by Period 8 and 9 the latter was approximately 2.5 per cent higher (18.04 and 20.75 per cent; 15.99 and 18.58 per cent).

(d) Botanical composition. Data concerning the botanical composition of the swards at each of the nine harvest dates are summarised in Appendix II. As mentioned previously, the composition during the second and third periods was extrapolated from the nearest available recordings.

On a percentage composition basis, the clover and grass contents of the seven pastures appear to vary widely. To a certain extent, however, these differences are diminished when actual productivity is considered. Although the percentage clover contribution to the commercial Yorkshire fog sward seems to be considerably greater than in the selected material during late summer, the clover yield differs very little. In Period 6, the comparative proportions of clover in the bred and commercial swards were 16 and 30 per cent. The rate of clover production per day, however, was much closer, 6.4 lb. d.m. per acre in comparison with 9.8 lb.

Under the management system adopted, the short-rotation ryegrass areas contained a very low proportion of clover and weed. Perennial ryegrass exhibited similar aggressive traits at the commencement of the trial but allowed more incursion of clover during the dry summer months. In the autumn and winter this sward contained approximately the same amount of clover as that of the bred Yorkshire fog, between 4 and 14 per cent.

The cocksfoot, timothy and prairie grass areas contained a high proportion of clover and weed until the end of January. By Period 4 most of the annual weeds had been eradicated by the frequent defoliation and little difference remained between the grasses in this respect. The major differences in clover percentage remained, however; at the end of the recording period the timothy areas had 47 per cent of their production in the form of clover and only 52 per cent as grass. On the short-rotation ryegrass areas at the same time only 5 per cent of the herbage was derived from clover.

Visual assessments of the quality and density of the pastures tend to favour the short-rotation ryegrass, bred Yorkshire fog and cocksfoot areas. Cocksfoot was perhaps the grass most suited to combination with clover under the rotational management system and would seem to be a suitable companion for prairie grass in the production of both summer and winter growth. The prairie grass-clover sward tended to allow considerable weed incursion during the summer and at the same time produced flowering heads over a long period.

Discussion.

Agronomic assessment trials, despite seemingly minute attention to detail, require considerable caution in their translation into farming terms. Before entering into discussion on the results of this comparison of Yorkshire fog and other grass species, it is important to re-emphasise the limited duration of the recording period under consideration. Much more information would be required from early spring production and performance over a period of years before final conclusions can be given as to the merits of the individual grasses.

Certain conclusions are, however, immediately apparent from the present experiment. The first concerns the high production potential of Yorkshire fog as a species in comparison with even the best of the existing grasses developed by breeding and selection. Its maximum rate of growth was approximately equal to that of the short rotation ryegrass (35.0 lb. d.m. and 36.8 lb. d.m. per day respectively during Period 6) and showed less susceptibility to decline under dry summer conditions. Although this information substantiates the previous findings of Watkin (1960) in the Canterbury Plains, it would not be correct to place too much emphasis on drought resistance as an all-important factor in deciding on the usefulness of a grass in the hill country of western North Island. The year in consideration was undoubtedly abnormal in regard to rainfall and although the ryegrasses have been observed to suffer to some extent in the summer it is unlikely that they would do so to the degree recorded in 1960. In the trials carried out by Suckling (1960) in high rainfall country at Te Awa, the highest summer production was attained in a perennial ryegrass sward, 10,450 lb. d.m. being produced between the beginning of November and the end of January to comparison to 4,760 lb. d.m. from Yorkshire fog.

The seasonal growth rhythms of each species were closely related to those observed in many previous trials, the autumn production of cocksfoot and the winter growth of prairie grass being outstanding characteristics of the two grasses. One of the most interesting features, however, was the effect of selection on the persistency and seasonal growth pattern of the Yorkshire fog. The commercial material exhibited similar responses to those observed on spaced plants derived from the arable areas of South Island (Basnyat, 1957). In late spring, growth was slightly more vigorous than in the bred variety, probably because of the physiological changes associated with earlier and more prolific flowering. The commercial line certainly demonstrated a greater tendency to head in the sward and it is probably for this reason, more than any other, that tiller mortality occurred during the late summer, resulting in a considerable decline in production.

The overall excellence of the bred Yorkshire fog substantiated the reliance placed on spaced plant selection in the improvement of the species. Although the material used only represented a cross-section of the 32 perennial lines being subjected to progeny testing, there was every evidence of the efficiency of selection towards restricted heading, sustained vigour throughout the year, and a high resistance to infection from crown rust.

Perhaps the only feature which immediately requires further investigation is the extent of suppression of the clover in the sward by the bred Yorkshire fog. It may be that, under grazing, the sward will become more open than it was under the mowing system and more clover will enter the pasture. There was, however, a higher proportion of clover than in the ryegrass swards and there seems less likelihood of the marked swing in the balance of grass and clover which often occurs in ryegrass pastures.

The overall seasonal trend in dry matter content, with a mid summer peak and a trough in winter and spring, was similar to that recorded by Suckling (1960) in twelve grasses under hill conditions. The figures recorded in this experiment are not exactly comparable, being the mean values for the total herbage rather than the grass alone. Yorkshire fog, however, was one of the species with a low average dry matter content in both trials. This attribute appears to show inverse correlation with the vigour of growth in the species, being highest in grasses such as danthonia, browntop and chewing's fescue, the lower producing but predominant hill grasses.

No crude protein determinations were carried out during the trial but, on the other hand, studies made at Te Awa (Suckling, loc. cit.) demonstrate the improbability of any deficiency in Yorkshire fog in this respect. Over a two-year period, the average crude protein content of this species was 19.5 per cent, in comparison with 17.6 and 18.2 per cent in the case of short rotation and perennial ryegrass.

Thus, in reviewing the experimental evidence obtained from the agronomic study of Yorkshire fog and five other species, there is little to detract from previous conclusions as to the overall suitability of this grass to marginal and more intensive farming conditions alike. Under regimes where soil fertility and soil moisture content is adequate the ryegrasses obviously have a higher potential both in regard to production and tolerance of intensive stocking.

The exact delimitation of the border between the two categories, however, will require considerably more fundamental knowledge of the agronomy and physiology of the individual grasses. In particular, attention must be given to the efficiency of the conversion of nutrients into herbage.

SECTION SIX.

CONCLUSIONS.

The Future of Breeding for the Hill Environment.

In the development of this discussion on the agronomic and genetic potential of Yorkshire fog as a pasture grass for marginal areas, considerable emphasis has been placed on the need to make more adequate appraisal of the environment in pasture plant breeding and selection.

Although plant breeders in New Zealand have not adopted the extreme policy of developing a new grass variety and then commencing to search for a suitable agricultural niche for the result of their endeavours, there has been a tendency to breed with high fertility conditions in mind. Concentration has been placed on a limited range of species, mainly the ryegrasses, to fill the requirements of North and South Island, fertile and less fertile land, lowland and hill alike.

This policy was undeniably correct in the early stages of plant breeding in this country, when the demands of the more productive lowlands necessitated the concentration of the limited resources available. In future years, however, the continued economic survival of the nation will become more and more dependent on the intensification of farming on the large areas of marginal land existing in both the North and South Islands.

This development will require the full cooperation of the plant breeder in producing material capable of survival under systems of low intensity yet possessingthe ability to respond rapidly when conditions are improved through aerial topdressing, increased stocking and greater subdivision of the land. One possible source of such genetic material will be found in the grasses with medium fertility requirements such as Yorkshire fog.

It has been shown by an analysis of the range of adaptive variation that this grass has become conditioned to the natural selection pressures of the New Zealand environment. As an outbreeding species it has responded to the wide range of climatic sequence encountered in this country, producing an adequate nucleus of variable material to warrant a full selection programme.

On the basis of the existing knowledge of the species, the most suitable gene source for breeding towards a variety for the more humid hill areas is that located in the western part of North Island. The populations observed in this region have developed inherent characteristics of persistency, sustained production, and resistence to rust infection to a much greater extent than the local ecotypes from eastern North Island and the arable areas of South Island.

At present, selection has mainly centred on material derived from the Manawatu area and there is need for a closer investigation of populations in other parts of western North Island. If even greater winter growth is required, for instance, attention might be paid to Yorkshire fog populations from the sub-tropical areas of North Auckland rather than introducing material from Spain or Portugal (Barclay, 1960; Morrill, 1961).

Response to the selection towards an improved agronomic type of Yorkshire fog has proved to be extremely rapid, probably because the material was at the primary stage of selection. The greatest overall improvement was undoubtedly that obtained in the reduction of heading and susceptibility to crown rust and the attainment of a semi-prostrate habit of growth.

Despite a concentration on selection under spaced plant conditions, however, the vigour of the improved material is markedly superior to that observed in commercial material, particularly in the period following flowering. Future selection for increased yield, on the other hand, will most certainly require greater knowledge of the physiological processes involved. In particular, it will be essential to obtain more information on the hill environment and such features as the utilisation of soil and fertiliser nutrients by different genotypes.

The close agreement between the performance of the species in the agronomic trial and predictions made from controlled environment studies suggests that phytotron investigations would prove invaluable in selection for the hill environment. In an improved variety, adaptability is essential and screening would be carried out most expediently by this method.

Work at Grasslands Division (Moust, 1959; Jackman, 1960) has already shown the possibility of selection for high nutrient utilisation on the basis of root cation exchange capacity and this approach should be fully investigated.

In conclusion, it may be stated that a suitable case has been presented for the study of the genetic potential of other grasses such as *Danthonia pilosa* and *Agrostis tenuis*. Despite the fact that the introduction of new species is in vogue all over the world, it is unlikely that grasses which are not already established in the hills of New Zealand will have any greater potential. The material is present and waiting, waiting for utilisation.

SUMMARY.

Following a study of the potential value of Yorkshire fog (*Holcus lanatus*) as a pasture grass in the more marginal farming areas of New Zealand, selection was carried out in an extensive collection of material adapted to different local environments.

In the development of a synthetic variety of this grass for the wetter hill areas of North Island the most suitable genetic material was found to be located in the districts of Manawatu, Waikato, Taranaki and Wanganui.

Populations from these regions exhibited persistency, sustained vigour throughout the year and high resistance to leaf damage from crown rust (*Puccinia coronata*). Plants from drier areas in eastern North Island and the arable areas of South Island were frequently of a shorted lived nature and demonstrated a tendency towards undesirable characteristics such as prostrate growth habit, prolific heading and strongly pubescent foliage.

The progeny testing of 32 potential parent plants during 1959 and 1960 at Massey College resulted in the selection of 10 lines showing high general combining ability for maintained production, adaptability to three different soil types, limited heading and rust resistance.

Selected material was compared with a commercial line and five other species in a sward productivity trial conducted under simulated conditions of medium fertility and rotational sheep grazing. The bred variety compared favourably with perennial ryegrass in growth during dry summer conditions and the low temperatures of winter.

The selected material also showed considerable improvement over the characteristics of the commercial line in production in the period following heading.

The need is stressed for further investigation into the potentialities of other medium fertility species in New Zealand.

Plate I. General view of the Field Husbandry Demonstration

Plate II. Spaced plant material - Yorkshire Fog Progeny Test.

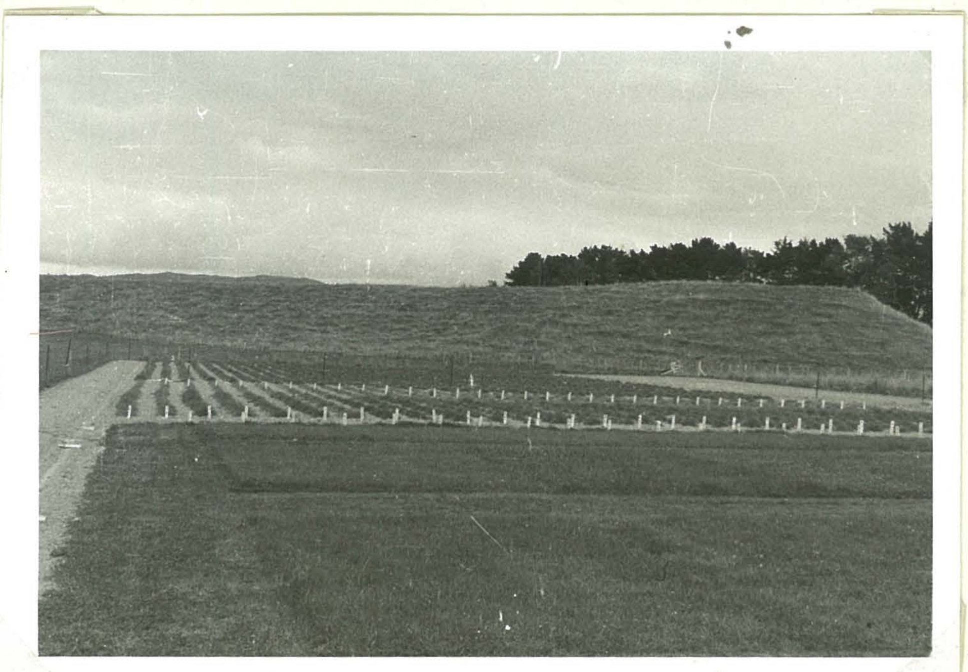

Plate III. General view from the Producti

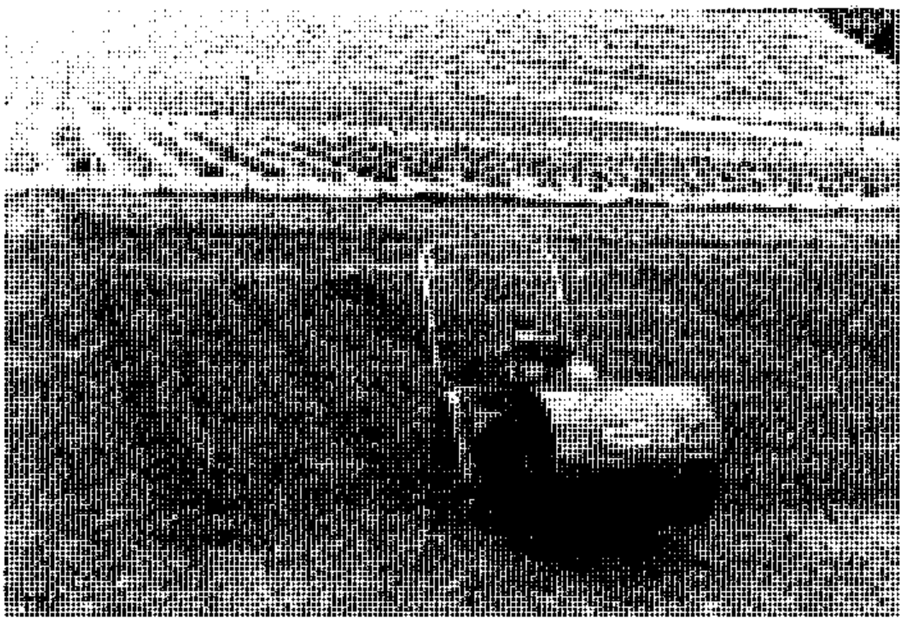

Plate IV. Sampling procedure - two mower-widths per plot.

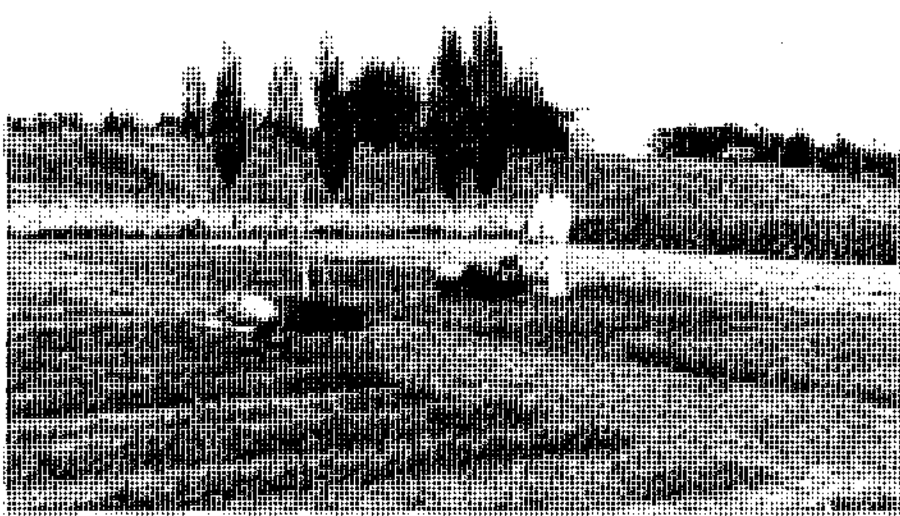

Plate V. Sampling procedure - sample and path areas cleared.

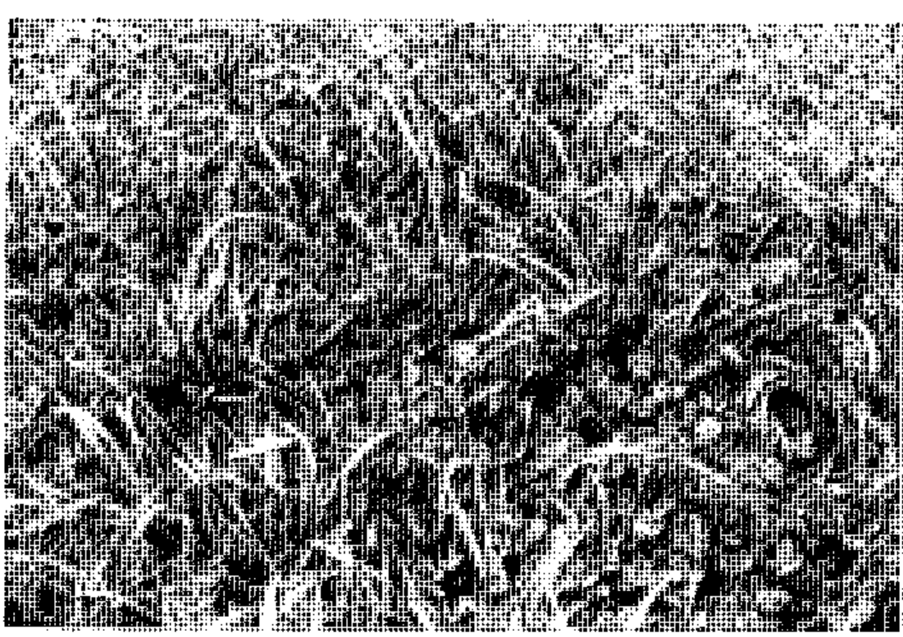

Plate VI. Productivity trial - Prairie grass and white clover

Productivity Trial - Sward Composition in March.

Plate VII. Short rotation ryegrass and white clover.

Plate VIII. Perennial ryegrass and white clover.

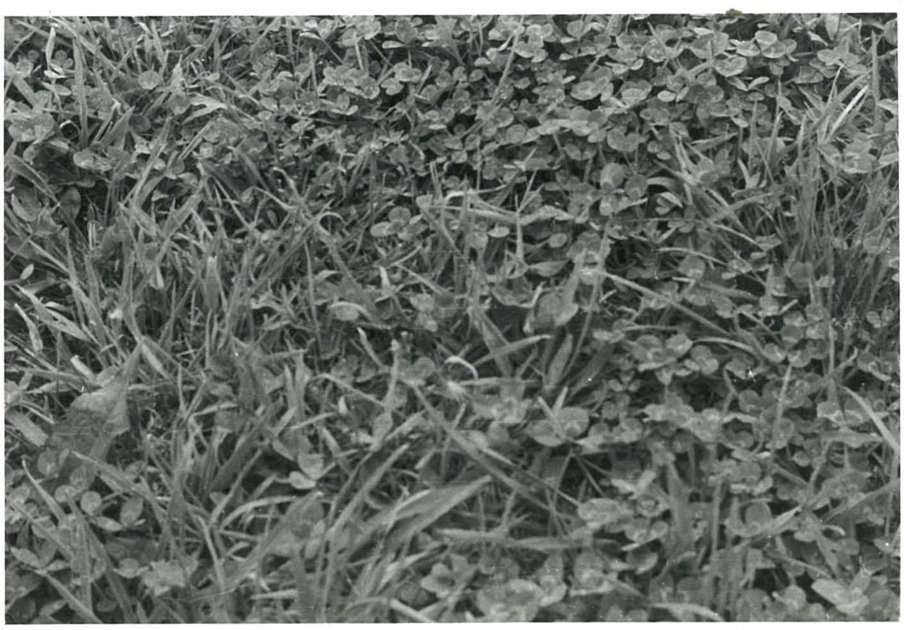

Plate IX. Timothy and white clover.

Productivity Trial — Sward Composition in March.

Plate X. Bred Yorkshire fog and clover.

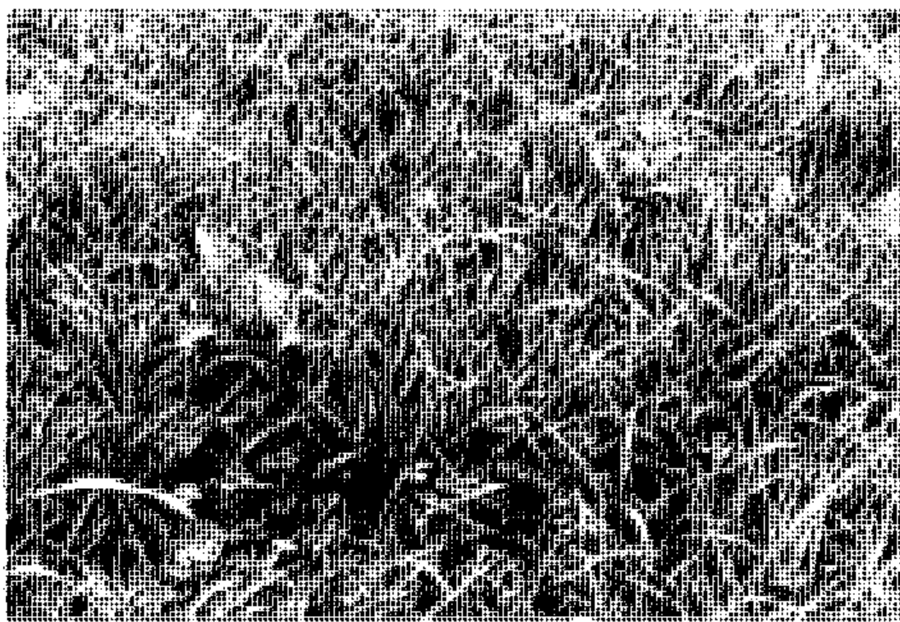

Plate XI. Commercial Yorkshire fog and clover.

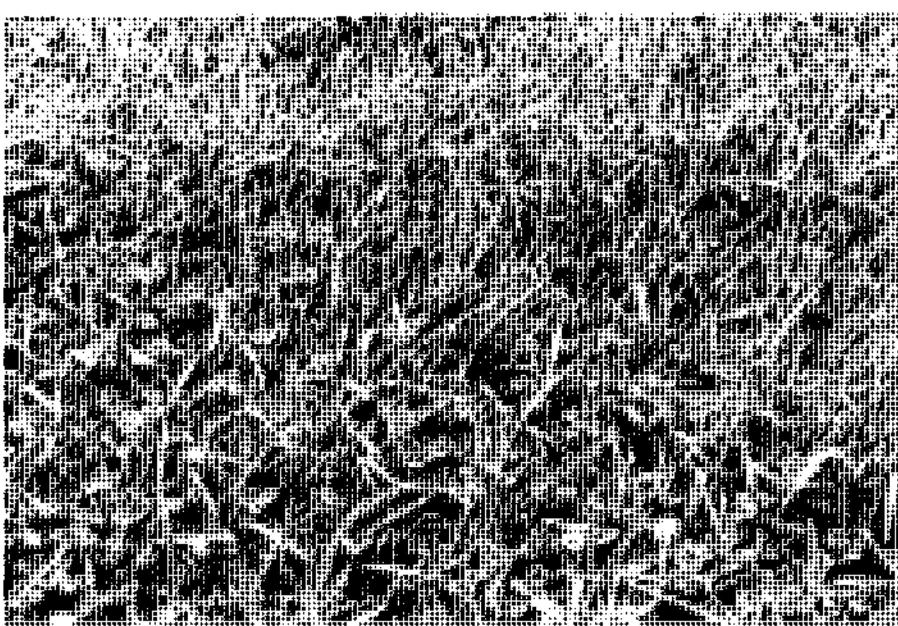

Plate XII. Cocksfoot and white clover.

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James M. M. Munro.

APPENDICES.

APPENDIX I

Yorkshire Fog Polycross Progeny Test

Origin of Maternal Plants

Maternal Line No.	Introduction No. 1953-54.	District of Origin
Prostrate		
* 1-1	2-1	Massey College
* 1-4	3-19	Panatahanui
* 2-11	1-4	Massey College
2-16	3-16	Otaki
2-21	1-26	Massey College
* 3-5	1-20	Massey College
3-9	5-22	Dargaville
3-12	1-15	Massey College
3-15	2-1	Massey College
4-1	1-18	Massey College
4-4	2-1	Massey College
* 4-7	1-11	Massey College
* 4-18	2-28	Matamata
5-8	1-28	Massey College
5-9	2-21	Tongapurutu
5-12	1-5	Massey College
5-15	2-2	Palmerston N.
* 6-3	2-11	Tokomaru
6-5	2-22	Palmerston N.
6-15	2-17	Wanganui
Erect		
1-19	1-16	Massey College
1-22	2-1	Massey College
2-6	3-13	Masterton
2-19	2-28	Matamata
2-22	1-23	Massey College
* 3-13	2-28	Matamata
3-22	1-6	Massey College
* 4-3	2-1	Massey College
4-16	1-21	Massey College
4-22	1-16	Massey College
* 5-2	1-6	Massey College
5-11	1-5	Massey College

Note * Final Selections.

APPENDIX I

Spaced Plant Vigour Scores 0-10
Mean of 10 plants

TABLE 1. First Observation - 25th September, 1959

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	4-18	7.7	7.6	7.8	8.2	6.0	7.46
2	5-12	6.5	7.0	7.9	7.4	7.0	7.16
3	3- 9	5.3	7.4	6.9	8.2	7.7	7.10
4	5- 2	4.8	6.4	8.0	8.4	7.3	6.98
5	4- 4	6.5	7.4	6.5	7.2	6.5	6.82
6	2-11	5.5	7.4	6.8	7.5	6.5	6.74
7	6- 3	5.2	6.6	8.2	6.9	6.3	6.64
8	5-11	5.5	6.8	6.6	7.8	6.3	6.60
9	4- 1	7.1	7.4	5.8	6.5	6.1	6.58
10	4-16	5.1	7.0	6.8	7.9	5.5	6.46
10	2- 6	5.0	6.6	6.8	7.6	6.3	6.46
12	1- 4	4.7	6.6	7.4	7.4	6.0	6.42
13	5- 8	5.2	6.3	6.4	7.2	6.5	6.32
14	4- 7	4.9	5.9	6.7	6.6	6.8	6.18
15	6-15	4.8	6.4	6.4	7.3	5.9	6.16
16	5- 5	5.2	6.7	6.1	7.3	5.4	6.14
17	6- 5	5.2	6.7	6.3	6.0	6.3	6.10
18	4- 3	5.9	5.6	4.8	6.7	6.2	6.04
18	3-22	5.0	6.7	5.7	7.3	5.5	6.04
20	3-15	4.9	5.7	5.8	7.7	6.0	6.02
20	1-19	5.9	6.6	5.5	7.9	4.2	6.02
22	3-13	5.2	6.3	6.5	5.6	5.9	5.90
23	1- 1	5.1	6.1	4.9	6.4	6.1	5.72
24	2-21	4.9	6.3	5.9	5.7	5.3	5.62
24	5- 9	4.8	6.3	5.0	6.7	5.3	5.62
26	4-22	6.0	6.1	4.8	6.7	4.3	5.58
27	3-12	3.8	5.6	5.6	7.1	5.7	5.56
28	1-22	4.3	4.9	5.3	7.0	5.5	5.40
29	2-16	3.6	6.1	6.0	5.8	5.4	5.38
30	5-15	3.7	6.0	5.6	5.5	5.8	5.32
31	2-19	4.2	6.2	5.1	5.8	5.0	5.26
32	2-22	3.9	5.9	6.3	4.7	4.7	5.10

APPENDIX I

Spaced Plant Vigour Scores 0-10
Mean of 10 plants

TABLE 2. Second Observation - 2nd January, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	2-16	6	4	7	7	4	5.6
2	5-15	5	4	7	5	4	5.0
2	4- 1	4	3	7	6	5*	5.0
4	1- 4	4	4	5	6	5	4.8
4	3- 5	4	6	10*	4	5	4.8 †
6	2-22	4	6	6	3	3	4.4
6	2- 6	7	5	4	3	3	4.4
8	6- 3	5	4	5	3	3	4.0
8	6-15	3	6	5	3	3	4.0
10	4-22	5	4	4	3	3	3.8
10	1-22	4	3	6	3	3	3.8
10	3-12	5	6	3	2	3	3.8
13	3-13	3	3	6	4	2	3.6
13	5- 2	4	3	5	1	5	3.6
13	1- 1	4	6	3	2	8*	3.6 †
16	4- 7	9*	4	3	6*	3	3.4 †
16	4-18	3	10*	7*	3	4	3.4 †
16	5-11	4	3	4	4	2	3.4
19	5- 8	4	4	5	2	1	3.2
19	2-11	4	3	4	5*	2	3.2 †
19	6- 5	3	4	6	2	1	3.2
19	1-19	2	3	5	3	3	3.2
23	4- 3	3	4	2	3	3	3.0
23	4- 4	5*	3	4	3	2	3.0 †
25	3-15	4	3	4	1	2	2.8
25	5-12	3	4	2	3	2	2.8
27	5- 9	2	3	3	2	2	2.4
27	3-22	3	3	2	1	3	2.4
29	2-21	2	2	3	2	2	2.2
29	3- 9	2	5*	4	2	1	2.2 †
31	2-19	2	1	2	2	2	1.8
32	4-16	2	2	2	1	1	1.6

* Inflated value due to border effects

† Adjusted mean

APPENDIX I

Spaced Plant Vigour Scores 0-10
Mean of 10 plants

TABLE 3. Third Observation - 6th February, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	3- 5	8.0	8.5	8.1	7.3	8.7	8.12
2	5-15	7.3	8.4	8.7	7.7	8.2	8.06
3	2-21	8.7	7.8	8.3	7.7	7.5	8.00
4	4-18	8.2	8.0	8.6	7.4	7.2	7.88
5	5-12	9.1	7.1	7.5	7.8	7.2	7.74
6	3-15	7.8	8.5	8.3	6.8	7.4	7.72
7	4- 7	7.9	7.5	7.4	8.1	7.4	7.66
8	6- 5	7.4	7.8	8.0	7.5	7.5	7.64
9	1- 4	8.7	8.3	7.3	6.4	7.2	7.58
9	2-11	7.9	7.4	[illegible]	7.5	7.1	7.58
11	6- 5	8.3	8.0	7.9	6.5	7.0	7.56
11	4- 1	7.2	7.9	7.9	6.8	8.0	7.56
11	2-16	8.2	7.7	8.0	7.3	6.5	7.56
11	2- 6	6.0	7.6	7.2	7.5	7.5	7.56
15	6-15	7.6	7.4	7.7	7.5	7.5	7.54
16	3-12	7.3	8.0	7.9	7.1	7.3	7.52
16	1- 1	7.5	7.3	7.6	7.3	7.9	7.52
18	4- 3	7.7	8.2	7.1	7.0	7.5	7.50
19	2-22	7.9	7.4	8.1	7.0	7.0	7.48
20	5- 8	7.9	8.2	7.2	6.9	7.0	7.44
21	4-22	7.5	8.0	8.2	6.9	6.5	7.42
22	3- 9	7.1	8.3	7.7	6.5	7.3	7.38
22	1-19	6.8	7.5	8.0	7.3	7.3	7.38
24	3-13	7.9	6.5	6.4	7.1	6.9	7.36
25	5-11	8.3	7.7	6.5	6.5	7.4	7.28
26	4- 4	7.6	7.1	7.1	6.8	7.4	7.20
27	1-22	7.3	7.6	7.1	7.1	6.7	7.16
28	5- 9	7.1	7.2	7.6	6.8	7.0	7.08
29	4-16	7.3	7.1	7.4	6.6	7.0	7.08
30	5- 2	6.3	7.1	8.3	6.9	6.2	6.96
31	3-22	7.5	7.9	6.9	5.8	6.5	6.92
32	2-19	7.3	6.7	6.4	6.2	6.9	6.70

APPENDIX I

Spaced Plant Vigour Scores 0-10
Mean of 10 plants

TABLE 4. Fourth Observation - 22nd March, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	6- 3	6.5	6.5	6.3	7.0	7.0	6.66
2	4- 3	6.4	6.8	6.1	6.9	7.0	6.64
3	2-11	6.4	5.8	6.7	6.8	7.0	6.54
4	1-*1	6.3	5.4	6.2	6.8	7.8	6.50
5	4- 1	6.2	6.5	6.5	5.5	7.5	6.44
5	3- 5	5.8	6.7	6.9	6.1	6.7	6.44
5	2-21	6.6	6.0	6.7	6.7	6.2	6.44
8	1- 4	6.7	6.0	6.5	5.9	6.9	6.40
9	3-13	6.5	6.0	6.8	6.7	5.9	6.38
10	5- 2	5.7	6.4	6.8	6.6	6.1	6.32
11	5-12	6.6	5.4	6.5	6.9	6.1	6.30
11	4-18	6.1	6.3	5.7	6.8	6.6	6.30
13	2-16	5.9	6.3	6.5	6.3	6.3	6.26
14	6- 5	6.1	6.0	6.7	6.0	6.4	6.24
15	3-15	5.7	6.3	6.5	6.4	6.2	6.22
15	5-15	5.0	6.7	6.7	6.7	6.0	6.22
17	3-12	5.9	6.1	5.9	6.7	6.4	6.20
17	6-15	6.2	5.5	6.7	6.4	6.2	6.20
19	1-22	5.9	6.0	6.7	6.6	5.7	6.18
19	2- 6	6.1	6.5	5.1	6.6	6.6	6.18
19	3- 9	6.0	6.0	6.6	6.4	5.9	6.18
22	3-22	5.6	6.2	6.0	6.4	6.6	6.16
22	4-22	6.4	6.1	6.7	6.2	5.4	6.16
24	2-22	5.4	6.1	6.9	6.6	5.6	6.12
25	1-19	5.6	6.3	6.0	6.7	5.9	6.10
26	4-16	6.0	5.8	6.5	5.7	6.1	6.02
26	2-19	5.6	6.1	5.7	6.0	6.7	6.02
28	5- 9	5.6	5.3	6.4	6.4	6.3	6.00
29	4- 4	6.3	5.8	5.6	6.5	5.7	5.98
30	5- 8	6.1	5.9	5.9	5.5	6.2	5.92
31	5-11	6.2	5.9	5.7	5.6	5.8	5.84
32	4- 7	5.0	5.1	5.7	6.4	6.2	5.68

APPENDIX I

Spaced Plant Vigour Score 0-10
Mean of 10 plants

TABLE 5. Fifth Observation - 29th May, 1960

Rank	Code No	REPLICATE 1	2	3	4	5	Mean Score
1	1- 1	5.2	4.3	4.9	4.5	6.0	4.98
1	4- 3	5.1	4.7	4.5	4.7	5.9	4.98
3	3-13	4.5	4.6	5.0	5.4	4.6	4.82
4	2-11	4.3	4.3	4.5	5.7	5.2	4.80
5	4-18	4.8	5.2	5.0	4.4	4.5	4.78
6	5-12	5.3	3.8	4.9	4.9	4.9	4.76
7	5- 2	4.2	4.5	5.0	5.1	4.6	4.68
8	4- 7	4.7	4.3	4.3	4.9	5.1	4.66
9	5-15	4.6	4.4	4.5	5.3	4.3	4.62
9	4- 1	4.7	4.4	4.5	4.2	5.3	4.62
11	3- 9	5.2	4.4	4.5	4.3	4.5	4.58
11	1- 4	4.9	4.4	4.6	4.3	4.7	4.58
11	4- 4	5.0	4.6	4.2	5.0	4.1	4.58
14	2- 6	4.4	4.7	4.5	4.8	4.4	4.56
15	6- 3	4.2	4.1	4.6	4.8	5.0	4.54
15	3- 5	4.4	4.4	5.3	4.0	4.6	4.54
17	1-19	4.9	4.6	4.5	4.2	4.4	4.52
18	6- 5	4.4	4.2	4.1	4.7	5.1	4.50
19	2-22	4.4	4.0	4.5	5.0	4.4	4.46
19	5- 8	4.6	4.6	4.2	4.0	4.9	4.46
21	4-16	4.5	4.4	4.6	4.3	4.4	4.44
21	4-22	4.9	4.2	4.8	4.4	3.9	4.44
23	3-15	4.1	4.4	4.7	4.3	4.6	4.42
24	2-21	4.5	4.6	4.9	4.0	4.0	4.40
24	2-16	4.5	4.2	4.3	4.8	4.2	4.40
26	5- 9	4.0	4.3	4.5	4.1	4.9	4.36
26	6-15	4.4	4.4	4.7	4.1	4.2	4.36
28	3-22	4.1	4.6	4.2	4.0	4.6	4.30
29	1-22	4.7	4.0	4.3	4.3	4.1	4.28
30	2-19	4.1	4.5	3.8	4.1	4.8	4.26
31	3-12	4.1	3.7	4.1	3.9	5.2	4.20
32	5-11	4.3	4.2	4.1	3.9	4.4	4.18

Spaced Plant Vigour Scores 0-10
Mean of 10 plants

TABLE 6. Sixth Observation - 26th August, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	4-1	5.2	3.2	3.2	3.2	4.2	3.80
2	5-2	2.9	3.8	4.7	3.7	3.8	3.78
3	4-18	3.9	4.0	4.1	2.7	3.4	3.62
4	1-19	4.0	3.8	3.0	3.4	3.7	3.58
5	1-1	4.2	3.2	3.4	2.6	4.4	3.56
6	3-13	3.3	4.0	3.9	2.9	3.4	3.50
7	5-12	3.6	3.1	3.8	3.6	3.1	3.44
8	6-5	3.9	3.2	3.5	2.7	3.5	3.36
8	6-3	3.1	3.7	3.5	3.9	2.6	3.36
10	4-3	3.6	3.6	3.6	3.2	2.5	3.30
11	4-16	3.7	3.6	3.3	3.0	2.7	3.26
12	3-9	3.7	3.3	3.2	2.8	3.1	3.22
12	5-15	2.5	3.5	3.6	3.1	3.4	3.22
12	3-12	3.1	3.2	3.5	3.3	3.0	3.22
12	2-6	2.5	3.5	3.9	3.0	3.2	3.22
16	4-22	4.2	3.4	3.4	2.3	2.7	3.20
16	3-5	3.3	3.0	3.6	2.7	3.4	3.20
16	3-15	3.1	3.4	3.5	3.0	3.0	3.20
16	1-4	3.4	3.2	3.1	2.4	3.9	3.20
20	1-22	4.1	2.7	3.2	3.3	2.6	3.18
20	3-22	3.0	4.0	3.3	2.6	3.0	3.18
22	5-8	2.8	3.4	3.5	3.0	2.8	3.10
23	6-15	2.9	2.9	3.2	3.2	3.0	3.04
24	5-11	2.0	3.7	3.3	2.7	3.3	3.00
25	4-4	3.2	3.2	2.7	2.6	3.1	2.96
26	2-22	2.9	3.2	2.9	2.6	3.1	2.94
26	2-19	2.5	3.1	3.7	2.4	3.0	2.94
28	2-21	2.6	2.5	3.8	2.8	2.8	2.90
29	4-7	3.0	3.1	2.9	3.0	2.4	2.88
30	2-11	2.2	2.6	3.1	3.0	2.8	2.74
31	2-16	3.4	2.1	2.8	2.4	2.4	2.62
32	5-9	1.7	2.8	3.2	3.0	2.3	2.60

APPENDIX I

Spaced Plants Rust Scores 0-5
Mean of 10 plants

TABLE 7. First Observation - 7th February, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	5-11	0.3	0.5	0.0	0.1	0.3	.24
2	3-12	0.6	1.7	0.0	0.0	0.0	.46
3	3-15	1.9	0.3	0.2	0.0	0.0	.48
4	1-14	0.3	0.8	0.1	0.8	0.5	.50
5	5-8	0.3	0.7	0.5	0.9	0.3	.52
6	2-11	0.2	0.6	0.9	0.9	0.2	.56
7	5-2	0.9	0.5	0.7	0.3	0.6	.60
8	3-5	1.9	0.3	0.9	0.7	0.3	.64
9	4-16	0.5	1.5	0.3	0.9	0.5	.74
9	1-19	0.3	0.8	0.6	0.6	1.4	.74
11	2-21	1.4	0.3	0.4	0.5	1.2	.76
12	6-5	1.2	0.7	0.9	0.8	0.3	.78
13	4-3	0.3	0.6	1.3	1.3	0.5	.80
14	3-13	0.5	0.6	0.9	1.3	0.9	.84
15	5-9	1.5	1.6	0.2	0.3	0.7	.86
16	1-22	1.4	0.2	1.0	1.4	0.4	.88
17	5-15	1.4	1.0	0.2	1.0	1.1	.94
17	3-22	0.7	1.4	1.0	0.4	1.2	.94
19	3-9	0.6	1.3	0.9	1.4	0.6	.96
20	1-1	0.8	1.7	0.3	0.7	1.6	1.02
21	6-15	0.5	1.3	0.6	1.2	1.6	1.04
22	2-22	0.9	1.1	1.0	1.5	0.8	1.06
22	2-19	0.9	1.0	0.8	1.2	1.4	1.06
24	5-12	0.5	1.6	0.3	2.5	0.5	1.08
25	4-22	1.4	0.5	0.7	1.8	1.3	1.14
25	4-4	1.6	0.3	1.7	0.6	1.5	1.14
27	4-7	2.7	1.3	0.1	0.6	1.4	1.22
28	2-16	1.7	1.5	1.2	0.6	1.3	1.26
29	6-3	0.8	0.9	1.9	2.0	0.9	1.30
29	4-1	1.4	1.3	1.1	1.4	1.3	1.30
31	2-6	2.[illegible]	0.9	0.7	2.0	1.1	1.42
32	4-18	0.9	1.4	2.2	1.4	2.1	1.60

APPENDIX I

Spaced Plants Rust Scores 0-5
Mean of 10 plants

TABLE 8. Second Observation-23rd March, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	2-11	0.2	1.0	1.5	0.4	0.2	.66
2	5- 8	0.8	0.6	0.6	1.0	0.7	.74
3	5-11	1.2	1.4	0.1	0.9	0.2	.76
4	3-12	1.2	1.1	0.3	0.6	0.8	.80
5	4-16	0.8	1.8	0.9	0.7	0.5	.94
5	4- 7	1.4	1.1	0.9	0.4	1.0	.96
7	2-21	2.2	0.5	0.8	0.5	0.9	.98
8	4- 3	0.8	1.0	1.8	1.3	0.1	1.00
9	1- 1	1.8	1.6	0.4	0.5	0.8	1.02
10	1- 4	1.4	1.4	0.7	1.4	0.6	1.10
11	3-13	1.2	1.0	0.7	2.0	0.7	1.12
12	5- 2	2.1	1.4	1.1	0.8	0.4	1.16
13	5- 9	2.4	1.7	0.7	0.5	0.6	1.18
14	3-15	3.0	1.1	0.9	0.4	0.7	1.22
15	3- 5	1.3	2.4	1.4	0.9	0.3	1.26
15	5-15	2.7	1.2	0.6	0.9	0.9	1.26
17	1-19	1.8	2.2	0.7	0.5	1.7	1.38
18	4-18	1.0	1.5	1.2	1.1	2.5	1.46
19	6- 5	2.5	2.0	1.5	1.2	0.5	1.54
19	1-22	2.8	1.8	1.1	1.2	0.8	1.54
21	5-12	0.4	3.7	1.1	1.8	1.1	1.62
22	2-22	2.3	1.8	1.8	1.6	0.7	1.64
23	2-16	2.4	2.7	1.9	0.3	1.4	1.74
24	4- 4	2.7	1.5	1.8	1.8	1.2	1.80
25	4-22	2.5	2.4	0.8	1.8	1.8	1.86
26	3- 9	1.4	2.8	2.2	2.2	0.8	1.88
26	3-22	2.4	1.9	1.9	1.4	1.8	1.88
28	6-15	1.7	2.2	2.1	1.8	2.4	2.04
29	6- 3	1.7	2.9	1.9	2.4	1.4	2.06
30	4- 1	2.9	3.0	1.9	1.6	1.3	2.14
31	2- 6	2.9	1.9	1.9	2.4	2.1	2.24
32	2-19	3.0	2.4	1.0	1.9	3.0	2.26

APPENDIX I

Spaced Plants Rust Scores 0-5
Mean of 10 plants

TABLE 9. Third Observation - 30th May, 1960

Rank	Code No.	REPLICATE 1	2	3	4	5	Mean Score
1	2-21	2.3	2.3	1.4	1.8	2.3	2.02
2	3- 5	2.3	1.8	2.2	2.3	2.0	2.12
2	3-12	2.4	1.8	2.3	2.1	2.0	2.12
4	6- 5	1.9	2.1	2.3	2.2	2.2	2.14
4	5- 2	2.6	2.3	1.9	2.1	1.8	2.14
6	4- 3	1.7	2.1	2.8	2.4	1.8	2.16
6	1- 4	1.5	2.4	2.3	2.5	2.1	2.16
8	1- 1	2.1	2.4	2.5	1.9	2.0	2.18
9	2-22	1.7	2.5	2.4	2.2	2.4	2.24
9	4- 7	2.7	2.5	2.0	1.9	2.1	2.24
9	3- 9	1.8	2.5	2.3	2.3	2.3	.24
12	4- 4	2.1	2.1	2.6	2.1	2.4	2.26
12	4-16	2.6	2.0	2.1	2.3	2.3	2.26
14	3-13	3.0	2.0	2.0	2.3	2.1	2.28
14	3-15	3.2	1.9	2.1	2.1	2.1	2.28
14	2-11	2.5	2.6	2.4	1.8	2.1	2.28
14	1-22	2.4	2.2	1.9	2.5	2.4	2.28
18	5- 9	3.5	2.6	2.1	2.0	1.9	2.42
19	4-18	2.9	2.2	1.8	2.6	2.7	2.44
20	2-16	2.4	2.8	2.1	2.3	2.7	2.46
20	1-19	2.3	2.3	2.7	2.5	2.5	2.46
22	5-15	3.0	2.3	2.4	2.1	2.6	2.48
23	3-22	2.5	2.4	2.4	2.5	2.7	2.50
24	5- 8	2.6	2.4	2.6	2.6	2.5	2.54
25	4- 1	2.4	3.0	2.5	2.4	2.5	2.56
26	6- 3	2.3	3.0	2.6	2.6	2.4	2.58
26	5-11	3.2	2.3	2.5	2.7	2.2	2.58
28	4-22	2.9	2.5	2.1	2.7	2.8	2.60
29	2- 6	2.8	2.5	2.2	2.7	2.9	2.62
30	5-12	2.4	3.2	2.7	2.7	2.5	2.70
31	2-19	2.7	3.0	2.5	2.5	2.9	2.72
32	6-15	3.0	2.8	2.6	3.0	2.8	2.84

APPENDIX I.

Observations on Heading in the Polycross Progeny

Maternal Line No.	SPACED PLANTS Total No. in head (out of 50)			ROWS. No. Heads (Rep.II)
	23.11.59	2.12.59	7.2.60	10.12.59
Prostrate				
* 1-1	-	8	4	140
* 1-4	-	34	-	110
* 2-11	-	19	1	65
2-16	-	4	7	75
2-21	-	-	1	200
* 3-5	-	11	-	150
3-9	-	8	4	140
3-12	-	9	1	110
3-15	-	2	2	110
4-1	1	23	2	170
4-4	-	9	-	80
* 4-7	4	43	1	200
* 4-18	1	36	6	90
5-8	-	16	7	110
5-9	-	19	1	150
5-12	-	10	-	140
5-15	-	-	1	25
* 6-3	-	6	1	140
6-5	-	8	4	40
6-15	-	5	9	140
Erect				
1-19	1	34	-	160
1-22	-	35	-	200
2-6	14	49	2	35
2-19	-	21	1	150
2-22	-	36	3	260
* 3-13	-	14	1	125
3-22	-	24	-	185
* 4-3	-	7	3	200
4-16	-	13	9	200
4-22	-	31	1	230
* 5-2	2	21	3	180
5-11	-	35	2	270

Note * Final selections.

APPENDIX II

Productivity Trial **First Harvest** **16th December, 1959**

Dry Matter Yields (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTALS
Short Rotation Ryegrass	1.15	1.29	1.18	1.25	4.87
Perennial ryegrass	1.08	1.18	1.14	1.19	4.59
Bred Yorkshire Fog	0.80	0.85	0.72	0.84	3.21
Commercial Yorkshire Fog	0.79	0.84	0.96	0.88	3.47
Prairie Grass	0.71	0.78	0.77	0.94	3.20
Cocksfoot	0.66	0.75	0.73	0.92	3.06
Timothy	0.67	0.86	1.02	0.99	3.54
REPLICATE TOTALS	5.86	6.55	6.52	7.01	25.94

Analysis of Variance

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.0959	0.0320	4.92^x
Species	6	0.7847	0.1308	20.12^xxx
Error	14	0.0914	0.0065	
TOTAL	23	0.9720		

Comparison of Species Means

$$Sm = \sqrt{\frac{0.0065}{6}} = \sqrt{0.0011} = 033166$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)
Significant studentised range:	3.03	3.18	3.27	3.33	3.37	3.37
Shortest significant range:	.100	.105	.108	.110	.112	.112

Species means:

SRR	PRG	TIM	CYF	BYF	PRA	COC
1.218	1.148	0.885	0.868	0.803	0.800	0.752

Dry matter yield/acre: 969 914 704 691 639 637 599

NOTE: Any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different.

APPENDIX II

Productivity Trial Second Harvest 29th December, 1959

Dry Matter Yields (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTALS
Short Rotation Ryegrass	.563	.629	.718	.691	2.601
Perennial Ryegrass	.362	.464	.500	.450	1.776
Bred Yorkshire Fog	.514	.493	.611	.348	1.966
Commercial Yorkshire Fog	.520	.525	.594	.410	2.052
Prairie Grass	.521	.602	.790	.614	2.527
Cocksfoot	.432	.442	.488	.506	1.868
Timothy	.480	.427	.608	.295	1.810
REPLICATE TOTALS	3.392	3.585	4.309	3.314	14.600

Analysis of Variance

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.0882	0.0291	4.93^{X}
Species	6	0.1737	0.0289	4.89^{XX}
Error	14	0.0820	0.0059	
TOTAL	23	0.3439		

Comparison of Species Means

$$Sm = \sqrt{\frac{0.0059}{6}} = \sqrt{0.0010} = 0.031623$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)	
Significant studentised range:	3.03	3.18	3.27	3.33	3.37	3.39	
Shortest significant range:	.096	.100	.103	.105	.106	.107	
Species means:	SRR	PRA	CYF	BYF	COC	TIM	PRG
	0.650	0.632	0.513	0.492	0.467	0.453	0.444

Dry matter yield/acre:

517	503	408	392	372	361	353

APPENDIX II

Productivity Trial **Third Harvest** **15th January, 1960**

DRY MATTER YIELDS (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTALS
Short Rotation Ryegrass	.709	.633	.857	.575	2.774
Perennial Ryegrass	.468	.453	.467	.285	1.673
Bred Yorkshire Fog	.703	.477	.823	.753	2.761
Commercial Yorkshire Fog	.604	.533	.968	.586	2.691
Prairie Grass	.902	.676	1.629	.640	3.247
Cocksfoot	.842	.561	.889	.481	2.773
Timothy	.742	.625	1.068	.606	3.041
BLOCK TOTALS	4.975	3.958	6.101	3.926	18.960

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.4546	0.1515	12.95 XXX
Species	6	0.3711	0.0619	5.29 XX
Error	14	0.1636	0.0117	
TOTAL	23	0.9893		

COMPARISON OF SPECIES MEANS

$$Sm = \sqrt{\frac{0.0117}{6}} = \sqrt{0.0020} = 0.044721$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)
Significant studentised range:	3.03	3.18	3.27	3.33	3.37	3.39
Shortest significant range:	.135	.142	.146	.149	.151	.152

Species means:

PRA	TIM	COC	SPR	BYF	CYF	PRG
0.811	0.760	0.693	0.694	0.690	0.673	0.418

Dry matter yield/acre:

646	605	552	552	549	536	333

APPENDIX II

Productivity Trial **Fourth Harvest** **8th February, 1960**

DRY MATTER YIELDS (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTAL
Short Rotation Ryegrass	.851	.903	.850	1.061	3.665
Perennial Ryegrass	.885	.959	.712	.827	3.381
Bred Yorkshire Fog	1.487	1.212	1.178	1.607	5.484
Commercial Yorkshire Fog	1.191	1.409	1.339	1.378	5.317
Prairie Grass	1.731	1.370	1.540	1.163	5.804
Cocksfoot	1.644	1.310	1.451	1.146	5.551
Timothy	1.497	1.349	1.406	1.467	5.719
REPLICATE TOTALS	9.284	8.512	8.476	8.649	34.921

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.0608	0.0203	
Species	6	1.5511	0.2585	7.48XXX
Error	14	0.4840	0.03457	
TOTAL	23	2.0959		

COMPARISON OF SPECIES MEANS

$$Sm = \sqrt{\frac{0.3457}{6}} = \sqrt{0.00576} = 0.075895$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)	
Significant studentised range:	3.03	3.18	3.27	3.33	3.37	3.39	
Shortest significant range:	.230	.241	.248	.253	.256	.257	
Species means:	PRA	TIM	COC	BYF	CYF	SRB	PRG
	1.451	1.430	1.388	1.371	1.329	0.916	0.845
Dry Matter yield/acre:	1155	1138	1105	1091	1058	729	673

APPENDIX II

Productivity Trial   Fifth Harvest   2nd March, 1960

DRY MATTER YIELDS (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTALS
Short Rotation Ryegrass	1.170	.852	1.046	1.053	4.121
Perennial Ryegrass	.838	1.169	.859	.800	3.666
Bred Yorkshire Fog	1.172	1.209	1.247	1.076	4.704
Commercial Yorkshire Fog	.787	.732	1.008	1.086	3.813
Prairie Grass	.934	.857	1.082	0.838	3.711
Cocksfoot	1.293	1.123	1.195	1.245	4.856
Timothy	1.203	0.963	1.197	0.828	4.191
REPLICATE TOTALS	7.597	6.905	7.634	6.926	29.062

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.070	0.023	1.00 NS
Species	6	0.337	0.0562	2.532 N.S.
Error	14	0.311	0.0222	
TOTAL	23	0.718		

COMPARISON OF SPECIES MEANS

$$Sm = \sqrt{\frac{0.0222}{6}} = \sqrt{0.0037} = 0.060828$$

no. of Means:	(2)	(3)	(4)	(5)	(6)	(7)	
Significant studentised range:	3.03	3.18	3.27	3.33	3.37	3.39	
Shortest significant range:	.185	.194	.199	.203	.205	.206	
Species means:	COC	BYF	TIM	SRR	CYF	PRA	PRG
	1.214	1.176	1.048	1.030	0.953	0.928	0.917
Dry matter yield/acre:	966	936	834	820	759	739	730

APPENDIX II

Productivity Trial   Sixth Harvest.   5th April, 1960

DRY MATTER YIELDS (lb)

SPECIES	REPLICATES				SPECIES TOTALS
	1	2	3	4	
Short Rotation Ryegrass	1.663	1.408	1.555	1.748	6.374
Perennial Ryegrass	1.486	1.430	1.542	1.264	5.722
Bred Yorkshire Fog	1.608	1.507	1.579	1.502	6.196
Commercial Yorkshire Fog	1.244	1.019	1.620	1.211	5.094
Prairie Grass	1.240	1.006	1.379	1.141	4.766
Cocksfoot	1.508	1.273	1.465	1.459	5.875
Timothy	1.480	1.051	1.436	0.923	4.878
REPLICATE TOTALS	10.309	8.674	10.576	9.338	38.897

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.3313	0.1104	4.779[X]
Species	6	0.6290	0.1048	4.537[XX]
Error	15	0.3461	0.0231	
TOTAL	24	1.3064		

COMPARISON OF SPECIES

$$Sm = \sqrt{\frac{0.0231}{6}} = \sqrt{0.00385} = 0.062048$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)
Significant studentised range:	3.01	3.16	3.25	3.31	3.36	3.38
Shortest significant range:	.187	.196	.202	.205	.208	.210

Species means:

SRR	BYF	COC	PRG	CYF	TIM	PRA
1.594	1.549	1.469	1.431	1.274	1.218	1.192

Dry matter yields/acre: 1269 1233 1169 1139 1014 970 949

APPENDIX II

Productivity Trial — Seventh Harvest — 13th May 1960

DRY MATTER YIELDS (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTALS
Short Rotation Ryegrass	1.156	1.110	1.448	1.320	5.394
Perennial Ryegrass	1.580	1.321	1.687	1.065	5.653
Bred Yorkshire Fog	1.258	1.225	1.533	1.109	5.125
Commercial Yorkshire Fog	0.984	0.985	1.152	0.921	4.042
Prairie Grass	1.093	0.977	1.338	1.154	4.562
Cocksfoot	1.127	0.998	1.317	1.159	4.601
Timothy	1.056	0.754	1.095	0.728	3.633
REPLICATE TOTALS	8.614	7.370	9.570	7.456	33.010

ANALYSIS OF VARIANCE

Source of Variation	d.f.	S.S.	M.S.	'F' value
Replicates	3	0.4686	0.1562	10.70^xxx
Species	6	0.7923	0.1321	9.05^xxx
Error	15	0.2185	0.0146	
TOTAL	24	1.4794		

COMPARISON OF SPECIES MEANS

$$Sm = \sqrt{\frac{0.0146}{6}} = \sqrt{0.00243} = 0.4993$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)	
Significant studentised range:	3.01	3.16	3.25	3.31	3.36	3.38	
Shortest significant range:	.148	.155	.160	.163	.165	.166	
Species means:	PRG 1.413	SRR 1.349	BYF 1.281	COC 1.1502	PRA 1.1405	CYF 1.010	TIM .9083
Dry matter yields/acre	1125	1074	1020	916	908	805	723

APPENDIX II

Productivity Trials   Eighth Harvest   26th June, 1960

DRY MATTER YIELD (lb)

SPECIES	REPLICATES 1	2	3	4	SPECIES TOTAL
Short Rotation Ryegrass	1.228	1.118	1.352	1.400	5.098
Perennial Ryegrass	1.329	0.820	1.229	0.699	4.077
Bred Yorkshire Fog	1.049	1.078	1.117	1.304	4.548
Commercial Yorkshire Fog	0.812	0.967	0.920	1.105	3.804
Prairie Grass	0.899	0.957	1.305	1.281	4.442
Cocksfoot	0.884	0.754	1.004	0.955	3.597
Timothy	0.522	0.416	0.626	0.634	2.198
REPLICATE TOTALS	6.723	6.110	7.553	7.378	27.764

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value	
Replicates	3	0.234	0.078	3.059	N.S.
Species	6	1.287	0.215	8.431	XXX
Error	15	.382	0.0255		
TOTAL	24	1.903			

COMPARISON OF SPECIES MEANS

$$S_m = \sqrt{\frac{0.0255}{6}} = \sqrt{0.00425} = 0.065192$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)
Significant studentised range:	3.01	3.16	3.25	3.31	3.36	3.38
Shortest significant range:	.196	.206	.212	.216	.219	.220

Species means:	SRR	BYF	PRA	PRG	CYF	COC	TIM
	1.2745	1.1370	1.1105	1.0192	0.951	0.899	0.550
Dry matter yields/acre:	1015	905	884	811	757	716	438

APPENDIX II

Productivity Trial *Ninth Harvest* *7th August, 1961*

DRY MATTER YIELD (lb)

SPECIES	REPLICATES				SPECIES TOTALS
	1	2	3	4	
Short Rotation Ryegrass	1.244	1.208	1.345	1.460	5.257
Perennial Ryegrass	0.678	0.600	0.755	0.453	2.486
Bred Yorkshire Fog	1.056	1.094	1.338	1.097	4.585
Commercial Yorkshire Fog	0.996	1.151	1.183	1.175	4.505
Prairie Grass	1.022	1.027	1.392	1.494	4.935
Cocksfoot	0.953	0.920	1.093	1.178	4.144
Timothy	0.848	0.576	0.664	0.637	2.725
REPLICATE TOTALS	6.797	6.576	7.770	7.494	28.637

ANALYSIS OF VARIANCE

Source of Variation	d.f.	s.s.	m.s.	'F' value
Replicates	3	0.1366	0.0455	2.514 N.S.
Species	6	1.7330	0.2888	15.956 XXX
Error	16	0.2902	0.0181	
TOTAL	25	2.1598		

COMPARISON OF SPECIES

$$Sm = \sqrt{0.0181} = \sqrt{0.00302} = 0.054955$$

No. of means:	(2)	(3)	(4)	(5)	(6)	(7)
Significant studentised range:	3.00	3.15	3.23	3.30	3.34	3.37
Shortest significant range:	.165	.173	.178	.181	.184	.185

Species means:	SRR	PRA	BYF	CYF	COC	TIM	PRG
	1.314	1.234	1.146	1.126	1.036	0.681	0.622
Dry Matter yields/acre	1046	982	912	896	825	542	495

APPENDIX II.

Summary of Herbage Dry Matter Analyses.

SPECIES HARVEST	SRR	PRG	BYF	CYF	PRA	COC	TIM
1. 16 Dec.	16.17	17.41	1559	15.04	15.61	14.99	15.34
2. 29 Dec.	22.61	24.61	22.22	22.09	22.26	22.15	23.70
3. 15 Jan.	19.82	22.82	19.65	19.51	21.64	19.19	18.49
4. 8 Feb.	21.24	24.32	18.17	19.27	21.80	19.61.	17.64
5. 2 Mar.	20.24	21.29	18.51	19.49	20.98	18.93	17.90
6. 5 Apr.	18.18	18.03	15.72	16.78	17.67	16.62	16.68
7. 13 May.	19.44	19.98	17.01	17.74	18.97	19.37	19.60
8. 26 Jun.	18.04	19.76	15.76	17.29	17.19	19.05	20.75
9. 7 Aug.	15.99	19.59	14.27	14.78	15.43	17.01	18.58
MEAN VALUE.	19.08	20.87	17.43	18.80	19.06	18.55	18.74

APPENDIX II.

Summary of Botanical Analyses. 9 Harvests.

Mean Percentage Composition - 4 Replicates.

1st Harvest. 16th December, 1959.

	Grass	Clover	Weed
S.R.R.	93	1	6
P.R.G.	79	4	17
B.Y.F.	64	7	29
C.Y.F.	58	5	37
P R A.	32	11	57
C O C.	35	10	55
T I M.	40	10	50

2nd Harvest. Extrapolated Values. 29 th December, 1959.

	Grass	Clover	Weed
S.R.R.	91	4	5
P.R.G.	76	9	15
B.Y.F.	66	10	24
C.Y.F.	63	9	28
P R A.	34	20	46
C O C.	35	14	51
T I M.	36	16	48

3rd. Harvest. Extrapolated Values. 15th January, 1960.

	Grass	Clover	Weed
S.R.R.	89	7	4
P.R.G.	74	15	11
B.Y.F.	68	13	19
C.Y. F.	68	13	19
P R A.	36	29	35
C O C.	35	18	45
T I M.	32	24	44

APPENDIX II.

Summary of Botanical Analyses - 9 Harvests.

Mean Percentage Composition - 4 Replicates.

4th Harvest. 8th February, 1960.

	Grass	Clover	Weed
S. R. R.	86	10	4
P. R. G.	72	20	8
B. Y. F.	71	17	12
C. Y. F.	72	17	11
P R A.	37	~~21~~37	~~44~~26
C O G.	35	21	44
TiM M.	28	29	43

5th Harvest. 2nd March, 1960.

	Grass	Clover	Weed
S. R. R.	88	11	1
P. R. G.	79	20	1
B. Y. F.	79	19	2
C. Y. F.	67	29	4
P R A.	56	38	6
C O G.	59	36	5
T I M.	39	52	9

6th Harvest. 5th April, 1960.

	Grass	Clover	Weed
S. R. R.	90	9	1
P. R. G.	80	18	2
B. Y. F.	83	16	1
C. Y. F.	64	30	6
P R A.	61	36	3
C O G.	65	33	2
T I M.	44	50	6

APPENDIX II.

Summary of Botanical Analyses - 9 Harvests.

Mean Percentage Composition - 4 Replicates.

7th Harvest. 13th May, 1960.

	Grass	Clover	Weed
S.R.R.	92	8	0
P.R.G.	80	20	0
R.Y.F.	83	17	0
C.Y.F.	61	37	2
P R A.	70	29	1
C O C.	72	28	0
T I M.	43	54	3

8th Harvest. 26th June, 1960.

	Grass	Clover	Weed
S.R.R.	96	4	0
P.R.G.	91	9	0
R.Y.F.	93	7	0
C.Y.F.	83	17	0
P RRA.	90	10	0
C O C.	83	17	0
T I M.	65	33	2

9th Harvest. 7th August, 1960.

	Grass	Clover	Weed
S.R.R.	95	5	0
P.R.G.	86	14	0
R.Y.F.	95	5	0
C.Y.F.	88	12	0
P R A.	87	13	0
C O C.	86	14	0
T I M.	52	47	1

APPENDIX III

Meteorological Observations - Grasslands Division

Palmerston North - 40°23'S: 175°57'E: 110ft. altitude

Monthly Temperature, Rainfall, Evaporation and Sunshine Records for the period September, 1959 - August, 1960 and the years 1928-56.

RECORD	SPRING			SUMMER			AUTUMN			WINTER		
	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.
Temperature												
Maximum	60.7	59.6	65.7	71.6	73.2	70.6	67.6	64.0	60.9	56.1	54.9	56.2
	59.6	62.1	65.7	69.1	71.3	72.5	70.1	66.7	60.2	55.1	54.2	55.9
Minimum	45.1	45.3	49.5	55.0	55.7	55.8	51.6	47.7	44.0	40.1	36.5	38.2
	43.7	46.8	49.6	52.1	53.7	54.0	52.5	49.4	44.8	40.8	37.8	40.8
Mean	57.9	52.4	57.6	63.3	64.5	63.2	59.6	55.8	52.4	48.1	45.7	47.2
	50.4	53.9	56.8	60.6	62.5	62.6	60.7	57.0	51.0	47.1	46.1	47.7
Grass Min.	38.0	39.2	43.8	48.7	50.5	50.5	46.2	41.4	37.6	33.1	28.9	30.8
	36.7	40.3	43.5	45.9	47.5	47.5	44.3	43.8	36.9	33.5	32.3	33.5
Earth 4 in.	50.7	52.0	59.0	64.6	66.6	65.3	60.0	54.5	50.3	45.7	43.4	44.0
	50.3	54.9	59.8	63.7	64.7	65.2	61.7	56.2	50.9	46.4	44.4	45.9
RAINFALL	2.69	3.19	2.84	1.27	1.22	3.18	3.29	0.95	2.25	2.14	3.81	2.64
	2.67	3.66	3.20	3.44	3.28	3.02	2.37	3.33	3.25	4.27	3.24	3.57
RAIN DAYS	16	13	16	7	7	13	13	12	14	16	16	13
EVAPORATION	2.25	2.93	3.53	5.16	5.30	4.66	4.09	2.17	1.15	1.47	0.70	1.55
	1.97	2.71	3.75	4.43	4.93	4.14	3.39	1.92	1.60	1.11	1.08	1.48
SUNSHINE HOURS	131	147	117	180	164	175	162	149	103	108	84	170
	140	157	179	198	206	178	173	134	122	97	110	132
GROUND FROSTS	5	3	1	-	-	-	3	-	7	13	18	17
DRY SPELLS				17d.	18d.		15d.					

Note. Upper figures : records for 1959-60

Lower figures : temperature - 1946-57

rainfall - 1930-56

evaporation - 1947-58

sunshine - 1928-56

The most suitable climatic divisions for this purpose are those adopted by Garnier (1958) and Taylor (1954). In the latter case the main criterion used was that of the monthly potential evapotranspiration in each region; as this measurement is closely related to the assimilation of the plant the divisions have a strong ecological significance.

The length of the growing season is under thermal control and is considered to be the number of months in which evapotranspiration is in excess of 1 in (Fig. 4a). In North Auckland growth continues all the year round, whereas in the interior of North Island and throughout most of South Island, low temperatures limit evapotranspiration to below the critical level for three months or more.

On the other hand the control of evapotranspiration by moisture governs growth during the warmer months (Fig. 4b). The incidence of the period of moisture deficiency is based on the exhaustion of the soil reserve (estimated as 1 in. rainfall). Growth is then subject to the amount of rainfall in the following months. Most northern and western regions in both Islands experience no major drought period but on the east coast of South Island there is a deficiency for up to five months in the year.

Statistics are available for the regional frequency of growth form groups, time of flowering, flowering during the year of sowing, plant recovery after grazing and average rust infection. A summary of this information is presented in Table 1, the main regions concerned being shown in Figure 4c.

Although there is extensive variation within the populations in each region the mean phenotype demonstrates the intimate relationship of each character to a growth rhythm essential to survival and reproduction. The proportion of erect and semi-erect plants gradually diminishes with the shortening of the active growing season from north to south. In western North Island, the combined groups (erect and semi-erect) generally exceed 15 per cent of all plants examined under the nursery conditions at Palmerston North. Material derived from South Island, however, was more prostrate in nature, only up to 5 per cent of the plants being erect or semi-erect.