

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

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

by

James M. M. Munro.

Thesis presented in partial fulfilment of the
requirements for the degree of M.Agric.Sci.

Massey Agricultural College,
University of New Zealand.

December 1961.

C O N T E N T S.

<u>Section.</u>	<u>Page.</u>
1. <u>Introduction. Plant Breeding and the improvement of hill pastures in North Island.</u>	1
2. <u>The Ecological Tolerance of Yorkshire Fog and its Agricultural Significance.</u>	5
The geographical distribution of Yorkshire fog.	6
Climatic tolerance.	8
Edaphic tolerance.	8
Biotic tolerance.	9
The agricultural potential of Yorkshire fog.	10
The improvement of the agronomic value of Yorkshire fog.	13
Conclusion.	14
3. <u>The Utilization of Ecotypic Variation in New Zealand Populations of Yorkshire Fog.</u>	15
4. <u>The Selection of Parent Material for a Synthetic Variety of Yorkshire Fog.</u>	20
The Massey College selection programme - 1953-61.	20
Review of literature.	21
Experimental area, layout and establishment.	23
Recording and sampling procedures.	24
Experimental results.	26
The selection of parent material for the synthetic variety.	32
Proposals for further evaluation.	34
5. <u>The Agronomic Potential of the Synthetic Variety.</u>	35
Introduction.	35
Review of literature.	35
Experimental area, layout and establishment.	38
Sampling Procedure.	40
Experimental results.	42
Discussion.	49
6. <u>Conclusions. The Future of Breeding for the Hill Environment.</u>	53
- <u>Summary.</u>	56
- <u>Bibliography.</u>	57
- <u>Appendices.</u>	-

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 country 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

MARGINAL FARMING AREAS
OF
NEW ZEALAND



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° and 85°F, with an optimum in the region of 62°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).

Biotic tolerance.

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°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.

The Agricultural Potential of Yorkshire Fog.

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, 1953; 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; Cowlshaw 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 (Puccinia coronata),
- 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 than 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 disposed 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 compatibility 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.