A Study of the growth form and behaviour of Yorkshire fog (*Holcus lanatus*) and of its dry matter production compared with perennial rye-grass (*Lolium perenne*), both with and without fertilizers.

by

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Being thesis presented in partial fulfilment of the requirements for the degree of M.Agric.Sc.

Massey Agricultural College
University of New Zealand

February, 1957.

TABLE OF CONTENTS

TABLE OF CONTENTS (Contd.)

TABLE OF CONTENTS (Contd.)

TABLE OF CONTENTS (Contd.)

SECTION I

INTRODUCTION

New Zealand is a land of pastures and the greatest reliance is placed on them by farmers for the maintenance of their live-stock, which is the main source of national income. She is favoured by an equable climate and well distributed rainfall, which tends to keep her predominantly a grassland country. Every farmer should accept the aim expressed by Swift (1) to make "Two blades of grass to grow upon a spot of ground where only one grew before."

Hill country pasture development is of paramount importance in New Zealand and must be extended if we are to maintain the present standard of living of an increasing population. Calder (2) said that farm production must increase greatly in the next 20 years. "We will have three-million people for whom we must provide not only food, but also additional overseas exchange to maintain the standard of living of increasing population." High pasture production can only be maintained if suitable species of grasses are grown according to the soil fertility gradient. It is not uncommon for the high producing pasture species to lose their producing power where fertility falls below a certain level or where practices inimical to their best growth are followed. On poor hill-country, the presence of low fertility demanding species is felt, due to the fact that they provide feed for the stock where the high fertility demanding species cannot maintain themselves.

Yorkshire fog (Holcus lanatus) being suitable for a wide range of soil conditions, though generally regarded as a weed, is so widespread that it must of necessity provide a considerable amount of feed to the cattle and sheep grazing on pastures. It is said, and probably with some degree of truth, that a considerable amount of butter fat comes from Yorkshire fog in New Zealand, especially from some of the low-lying meadow-type pastures in the Waikato.

It is unquestionably a valuable grass under two conditions. Firstly in the grassing of drained peat swamps, Yorkshire fog is of great importance as a pioneer grass. The main prerequisite of this type of country (peat swamps) is consolidation, which is greatly facilitated by Yorkshire fog with its ease in establishment and due to its rapid binding effect and mat forming habit. It permits cattle to be run on this country with a consequent increase in consolidation and fertility.

Secondly it establishes well in low fertility country. On most of the poor hills with fair rainfall it is often well represented, especially on shady faces. Although it cannot be claimed as one of our highest producing species, nevertheless its contribution in the low yielding sward is valuable. Spillman (3) comments that in the vicinity of the Pacific Coast it forms a first-class meadowgrass on soils that consists of nearly pure sand.

Evidence from various sources would suggest that 'fog' is one of the few grasses to remain green and produce grazing during the winter, particularly in low fertility tussock country. In this type of country its winter production is well appreciated (Levy (4); Sandy (5)). The most interesting thing to note is that this grass continues to grow and produce throughout the year. Bearing in mind that Yorkshire fog tends to spread under lower fertility soil conditions, it is not surprising that total pasture production declines when this grass increases. The reason, most probably, lies in the management pactices which encourage its spread and not altogether with the productive potential of the grass itself.

Levy (4) ranks Yorkshire fog in his ecological requirement gradation tables as a moderate to low fertility demanding plant. It can grow under variable moisture conditions (swamp and water-logged conditions to an average soil moisture), and it can tolerate the light gradation from dense shade to open and sunny situations.

New Zealand has progressed a long way in grassland research. The progress can to some extent be credited to the wide range of trials conducted by the Department of Agriculture and the Grassland Division of the Division of Scientific and Industrial Research, particularly over the last quarter century. Most of the environmental re-

quirements of individual pasture species have been resolved and farming practice aims to provide the most suitable conditions for the maximum production from the grass and clover species.

Yorkshire fog has also attracted some attention from the Research Workers, Plant Research Division, New Zealand (6) recommends that a good deal of preliminary testing of growth form, freedom from woolliness and dead bottom, palatability, rust resistance, persistency, etc. is necessary. Corkill (8), says that 'Grasslands' have examined Yorkshire fog collected from Te Awa, to determine the range of variation present, should work be undertaken on this species in future.

In view of the widespread distribution of Yorkshire fog throughout the grasslands of New Zealand, and the ignorance of Grassland workers regarding its behaviour it was felt that some investigation was warranted. A collection of 168 samples from North Island, South Island, Chatham Island and machine-dressed seed (from South Canterbury) was made through District Agricultural Instructors. Plants derived from the seeds were observed under the single plant spacing method. A study of the growth-forms and their behaviour in these plants constitutes the subject matter of this thesis. Selection work on the outstanding plants is at present carried out by the staff of the Field Husbandry Department, Massey Agricultural College.

In addition, a comparative yield trial was laid down to compare the productive capacity of Yorkshire fog with that of perennial rye grass.

SECTION II

REVIEW OF LITERATURE

PART I

(A) YORKSHIRE FOG, ITS DESCRIPTION AND AGRICULTURAL VALUE

Holcus lanatus is distributed through all parts of the British Isles, also throughout Europe, temperate Asia and N.W. Africa. It was introduced to various parts of U.S.A. from England with other seeds, Americans call it meadow soft-grass, velvet grass, salem grass, white Timothy and Velvet mesquit grass. In England it is known as "Yorkshire fog". The word 'fog' in this connection means 'the winter growth on meadows', and is possibly derived from the fact that in dull light the herbage assumes a greyish green appearance and owing to its hairy nature, holds moisture. It is most probable that it found its way to New Zealand through seed impurities or the early settlers with the experience of it in the permanent meadow of England might have brought it with an idea of growing it for hay.

(a) Botanical features

Yorkshire fog (Fig. 1) is a loosely to compactly tufted, soft, hairy perennial plant, growing 20 - 100 cm high. In all cases hairiness is a prominent feature. The sheaths and leaves normally are densely covered with soft hairs giving the plant a velvety touch. The sheath is split and has a slight keel. The veins of the sheaths are pink and contrast strongly with the white portions between. Ligules (L), are from 1 - 4 cm long, membranous and distinct, blunt and hairy and the free edge is frilled. Auricules are absent. Leaf blades become narrowed to a fine point, 4 - 20 cm long and are flat and vary from 3 - 10 mm wide. Panicles are lanceolate to oblong or ovate, very dense to rather loose, erect or nodding, whitish, pale green, pinkish or with a tinge of purple, 3 - 20 cm long. (Hubbard (9); Ward (10)).

(b) Floral behaviour and Seed Character

The spikelets (S) are oblong to elliptic or compressed, 4 to 6 mm long, falling entire at maturity. There are two flowers (FS) per spikelet, the lower one is bi-

sexual (FL) and the upper one staminate only (ST). The glumes (G1 G2) are almost equal in length, or sometimes the upper one is longer and broader. Both the glumes are sharply keeled, with stiff hairs on the keels. The lower glume is narrowly lanceolate or oblong and one-nerved, the upper one is ovate to eliptic, usually tipped with an awn-like point up to 1 mm long and is three-nerved. The lower lemma (LL) is boat-shaped, blunt and awnless and there is an equally long palea (P_1). The upper lemma (L_2) is narrower, awned on the back near the tip, the awn being up to 2 mm long and becoming recurved upon itself when dry. The palea (P_2) is shorter than the lemma.

The "Seed" (C.H) The term "seed" in grasses is applied to the caryopsis and the attached glumes. Flowering glumes enfold the seed and the colour of the "seed" varies from dark brown to yellowish brown. Frequently the caryopsis comes free from the glumes and is a silvery grey colour. (Hubbard (9), Ward (10)). See Fig. 1.

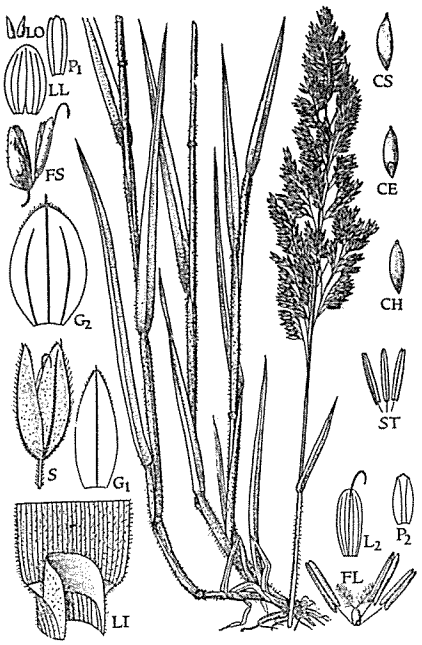
(c) Comparison with Holcus mollis

(i) Botanical Make-up

The only other common plant belonging to Holcus spp in New Zealand is creeping soft grass or creeping fog (Holcus mollis). (Fig. 2). Both are perennials and flower about the same time. H. mollis grows 20 - 100 cm high with tough creeping rhizomes, forming compact tufts or loose mats. Unlike Yorkshire fog it is able to spread below ground in addition to its ability, shared by Yorkshire fog, of being able to spread by stolons which root at the nodes. It is loosely to densely bearded at the nodes and the hairs on the sheath and blade are shorter and more dense. Other points of difference in florestic character from Yorkshire fog are (1) both its glumes are acute at the top and rather larger, (2) the lateral nerves of the upper glumes are closer to the keel than to the margin and (3) the awn of the upper flower which is more dorsally situated is longer and is rough throughout the entire length.

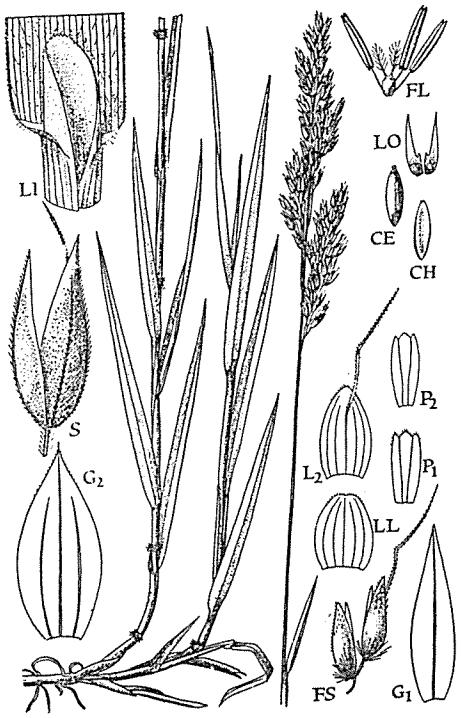
(ii) Difference in habitat of growth and use

H. mollis ((9) (11)) is less common and is generally found in shady places. It occurs under beech but is less common in ashwood. It can be found in other situations where the soil is shallow and liable to dry out. It forms one of the most



Holcus lanatus. Very common; grassland.

Fig. 1. YORKSHIREFOG (After Hubbard; 331)



Holcus mollis. Common; shaded places and arable land.

Fig. 2. ~~YORKSHIREFOG~~ Creeping Fog (After Hubbard; 332)

common weeds of sandy arable land. In comparison, fog can grow on a wide range of soils (preferably in wet conditions), and is of better feeding value. Being a rhizomatous plant mollis has become a troublesome weed in sandy fields. Its eradication is extremely difficult. It is apparent that its ability to survive by means of its underground stem, to endure shade and also to grow to some height if mixed with other tall growing vegetation, enables it to compete very successfully with other plants.

Hubbard (9) states that investigations have shown that a sq. foot of infested sandy soil within 6" of the surface may contain up to 110 ft. of its rhizomes, the weight of which has been estimated at over $7\frac{1}{2}$ tons per acre.

Fenton (11) states that Holcus mollis may become a noxious weed but there are ways and means of holding it in check, as indicated by its absence in the field where cultivated root crops (potatoes, swedes) were grown or in the vicinity of rabbit burrows.

(d) Character of growth including leaf and colour

Turesson (12) has shown "by making collections of representatives of a particular species from devious and characteristic habitats and growing the plants thus collected as spaced individuals under one and the same set of uniform garden conditions, very striking differences in growth form and frequently also in more intimate morphological characteristics as between the representatives of various habitat are revealed." The variation in growth form, leaf character and colour arising out of the genotypical response of an ecospecies to a particular habitat are dealt with in more detail in the experimental findings of this thesis.

(e) Palatability

It is extremely soft and velvety and becomes conspicuous in a sward of darker-leaved grasses and it is logical that farmers should come to know it and be interested in its grazing value. It is still questionable whether it is worthy of cultivation anywhere or not? There is no doubt that this grass is unpalatable at certain times and stages of growth and it is also certain that it tends to be avoided where other palatable grasses are available.

Hilgendorf (13) states "Fog is eaten to a considerable extent, and it probably

provides more fodder than it is usually credited with".

Percival (14) states that almost all hairy grasses are refused by stock and Yorkshire fog is in no way an exception to this. Stapledon (15) also supported this view that very hairy plants are not usually palatable, and it is this defect which probably more than any other, renders Yorkshire fog, relatively unpalatable to stock.

Beal (16) gives evidence that Yorkshire fog is undoubtedly unpalatable and in most of the old pastures of New England other species are kept closely cropped, whereas Yorkshire fog plants are often seen going to seed.

Thomas (17) states that plants such as Yorkshire fog and tall fescue, are unpalatable despite the fact that they may be highly productive and persistent with satisfactory chemical composition which would theoretically make them valuable components of seed mixtures.

From the above it would appear that Yorkshire fog is relatively unpalatable due to its hairiness. Evidences from various sources would suggest that it becomes as palatable as any other palatable species under certain circumstances. Percival (14) states that the hairiness in Yorkshire fog is more or less governed by the soil moisture content. In some parts of Holland and Eastern England, on damp soils, fog is less hairy than when grown in drier soils. Under this condition the grass is palatable and many cattle thrive upon it. A report from the Welsh Plant Breeding Station (18) shows that an interesting strain (S152) of Holcus lanatus, which shows remarkable paucity of hair has been selected. It is probable that however a glabrous form of Yorkshire fog through breeding could be developed, but further comment on this aspect is beyond the scope of this thesis.

There is evidence which points to the fact that even cocksfoot becomes unpalatable, even when young, where the water table is too high. Under such condition, Yorkshire fog was preferred to cocksfoot and observed to be cleanly grazed.
(Schneider-Kleeberg, K (19); Leiose (20)).

Leiose (20) states that in North Sweden and Finland the effect of sunlight on palatability is well illustrated, where during the summer months, Holcus lanatus, normally unpalatable, is grazed as clean as "good" grasses. It is believed that the

intensive sunlight of the North produced a higher sugar content which made the grass palatable.

Davies (21) says "when we go into the finer points of palatability, however, there are differences between the palatability of one species and another at any particular time, but these are more frequently to be correlated with stage and rate of growth." Blackman (22) observed Festuca ovina, Agrostis species and Holcus lanatus being preferred by the sheep only in their early stages of growth.

Some of the grassland workers support the view that Yorkshire fog would be more palatable under certain climatic conditions. Leiese (20) studied the influence of climate upon the sward of the pastures and meadows of the Island of Rugen in Germany. He observed that the climate seemed to affect palatability, in the case of some poorer herbage plants. There is some evidence to lead one to believe that the palatability of Yorkshire fog plants was increased by the use of phosphatic and nitrogenous fertilisers. (Hall etal (23)).

(f) Agricultural Value (Overseas Review)

Yorkshire fog commands a prominent place in pastures, particularly those in rundown hills, poor soils and acidic peat soils. Many workers are of the opinion that Yorkshire fog can be successfully introduced to the hill country and bring about an increased carrying capacity. Hubbard (9) comments that Yorkshire fog has some value, especially on poor soils in England where better grass would not grow.

Stapledon (24) commenting about Yorkshire fog for the improvement of hill grazings showed it to be remarkable both for the rapidity of its establishment and for the speed with which it grows away under proper manurial treatment. Armstrong (25) says that as pasture plants, the indigenous forms have some agricultural value, particularly in the poorer or upland areas in the moist districts of Britain. Robinson (26) says that although Yorkshire fog is considered as a weed in low-land grassland it is sometimes used successfully as a pioneer plant in the reclamation of very poor hill grazings. Stapledon (27) considers that Holcus lanatus, Anthoxanthum odoratum and Festuca rubra are useful species and can be successfully introduced up to 1,500' above sea level to improve the hill lands of Wales. A report from the Edinburgh and East of Scotland College of Agriculture (28) shows that the growth of Yorkshire fog in a cultivated area in Boghall Glen was remarkable and, due to its high-yielding capacity, it could be useful for reclaiming this type of land. O'Connell (29) commented that in most of the hills in Kerry, so-called good grasses such as Festuca ovinatensis often never establish themselves on poor soils, whilst those described as useless, such as Holcus lanatus produce valuable fodder and good quality cattle live almost entirely on "poor" grass herbage. The suitability to poorer soils of Holcus lanatus and Trifolium repens was outstanding.

The comment from American workers is that Holcus lanatus has little forage value but it does better than any other grasses on poor soils (Hitchcock (30)). Roseveare (31) states that Holcus lanatus is cultivated in the mountains of Latin America, where it provides some green feed to the cattle.

Most of the workers have reported that Yorkshire fog is useful in the moist rather than in drier regions and is undoubtedly a good winter producer. Long (32) comments that on damp and poor land Yorkshire fog is readily eaten by cattle and they thrive upon it. It remains green during winter and can be of some value for winter grazing. Stapledon etal, (35) also commented that plants such as Yorkshire fog are decidedly winter green and provide a certain amount of green feed for sheep during the dead season. Mundy (34) reports that in the preliminary investigations with the object of establishment with other species on the wet veli soils, Yorkshire fog has yielded hopeful results. Hall etal (35) concluded, from observations on pasture trials in the Union of South Africa, that Yorkshire fog is one of the most promising winter grasses for the Eastern high veld. Heddle etal (36) classified the pastures of Boghall, Midlothian, into different types under the following headings (1) Moist flush pastures (2) Wet flush pasture (3) Short dry grass (4) Short grass with Baleberry (5) Nardus Baleberry, (6) Nardus with Baleberry and (7) Nardus with under grass. Holcus lanatus falls into type (1) and they comment that it constitutes the most valuable herbage for sheep grazing in the Glen.

Some of the workers have credited Yorkshire fog with valuable features as a temporary expedient on peat land (Ogg, etal (37)). Hansen (38) classified the pastures of the North Sea coast of Schleswig-Holstein after studying soil, water table, climate and botanical composition. He puts Holcus lanatus in (C) group (moist condition) as a dominant young cattle-fattening species.

Stapledon, etal (39) conducted a test on the potentiality of production of different species under varying soil conditions. Yorkshire fog did very well under pond-field conditions (poor medium, stony loam, with a tendency to be heavier and wetter towards the bottom third of the area.) The conclusion drawn from this test shows that Yorkshire fog must evidently be ranked as a potentially high producing species. Jones (40) groups species under two classes, (a) those which thrive best in the ab-

sence of the grazing animal and, (b) those which thrive best under the influence of grazing. Holcus lanatus falls in the (b). Baron Hay (41) says that Yorkshire fog, along with other species and Lotsus major have given good results in the reclamation and grazing of Kangaroo grassland in Western Australia.

Conclusion

It is clear from the above review that Yorkshire fog has some value, especially on the poor land. It is endowed with the power of remaining productive during winter. It does well under moist conditions. It can be safely grown in those areas where water table is too high for most of the high-producing species. It appears to be persistent enough and maintains a steady production throughout the seasons.

(g) Agricultural Value (New Zealand Review)

It is possible that Yorkshire fog has a bright future for the development of the hill country in New Zealand. The Report of the Royal Commission into New Zealand Sheep Industry (42), recommends research into the development of better, more palatable and more nutritive strains of such poor grasses as . . . Yorkshire fog . . . , which will thrive under the dry and less fertile conditions which prevail in much of the hill country. King (43) says that the deterioration of the tussock country in New Zealand, caused by the indiscriminate burning, overstocking and overabundance of rabbits was more or less compensated for by the introduction of plants such as Yorkshire fog, sorrel, etc. Levy (4) says that Yorkshire fog has got greater value in the development of steep unploughable forested country owing to both its quick establishing and deep rooting nature.

Most of the workers have emphasised the inclusion of Yorkshire fog in the seed mixture intended for sowing hill country. Stainton (44) recommends the inclusion of Yorkshire fog in seed mixtures for hill country sowing after second growth burns. 4 lbs. of Yorkshire fog seed per acre could be included in the seed mixture as a pioneer establishing crop.

There is evidence to support that Yorkshire fog has good feeding value in New Zealand. Sanby (5) says that all New Zealand's milk and meat is not produced from the best pastures of rye grass and white clover alone. There are many thousands of pasture which contain high proportions of other grasses including Yorkshire fog, which produce considerable amounts of livestock-products.

Yorkshire fog acts as a pioneer crop for the consolidation of peat areas, due to its quick establishing, deep rooting and sod-forming nature. Allan (45) says that Yorkshire fog is a valuable grass in the early stages of reclaiming swamp lands, especially those of peaty nature. Hilgendorf (13) is also of the opinion, "it is a useful grass to sow to help to consolidate swamps."

That Yorkshire fog is an acid-tolerant grass is substantiated from the tables given by Davies (47). Adams (46), reasons as follows, "Let us consider an extreme

case first - a very acid peat with a pH of 4. A good pasture can be established with 2 tons of lime per acre disced approximately 3 in. deep and another application of 2 cwt. per acre before sowing down. But one should not aim for a rye grass-white clover sward, because the pH of the top layer would be still slightly under 5, which is too acid for rye grass. Very good production can be obtained from a fog-white clover seed mixture. With the application of 3 cwt. of superphosphate and one of potash, a firm turf can be established and there is little danger that this sward will revert to fern or manuka.

If two tons of lime per acre is applied to an initial pH of 4 and a rye grass-white clover seed mixture sown, a good proportion rye grass grows in the winter, but its production is very low. Where the pH is suitable for rye grass, bad drainage might still hinder growth, due to lack of oxygen and nitrogen."

Though Yorkshire fog is not grown for seeds production, its seeds are available from cleanings from machine dressing. Figures supplied by the Census and Statistics Department, Wellington (49), show that the seed dressing centres of Christchurch and Timaru firms and Dunedin, Gore and Invercargill dressing plants accounted for 8,873 lbs. and 22,599 lbs. respectively. Information for exports is available since 1949, as the classification of grass-seed exports, prior to then, was restricted to 6 or 7 main varieties, no account being kept for minor varieties. No information is available on how these seeds are being used locally.

The figures for export are:-

Calendar Year	Weight (cwt.)	Value (£)
1949	565	915
1950	571	695
1951	321	675
1952	110	328
1953	198	621

(h) Summary of the Questionnaire

In view of the fact that Yorkshire fog has such a wide range and distribution in New Zealand pastures from first-class dairying pastures to poor hill-country past-

ures, and is regarded as a valuable species under certain conditions, it is felt that a study of the ecology of this species would be a valuable contribution to pasture research.

The first stage in such a study is the collection of seeds from as wide a coverage of the country as possible, followed by the growing of the plants resulting from this seed in an area for recording of plant characteristics.

Requests have been made to Instructors in Agriculture throughout the country to send seed heads of Yorkshire fog, together with details of locality and soil type from which collections were made. Opinions of individual Agricultural Instructors on fog as a pasture grass in the various districts were sought. Through a questionnaire, it was made possible to gather all the information that was needed.

A summary of the questionnaire pertaining to the opinions of Agricultural Instructors on Yorkshire fog as a pasture grass, is presented below and the details of information is provided in Appendix I.

The Summary is presented District-wise.

Manawatu

Fog has a limited value in flat country. Under heavy rainfall it is useful, provided it is kept under reasonably good grazing control. It carries much stock on hill country.

Wanganui

Very wide range of utility, and has got no value on farms where rye grass and white clover predominates.

Taranaki

It is useless under high fertility conditions, but contributes some feed on poor paddocks. It provides a fair amount of feed in Spring but becomes unpalatable in Summer. On many poor farms, most of the livestock products come from fog.

Waikato/Bay of Plenty

In most of the flat country, high producing species tend to dominate and York-

shire fog is a useless weed. In heavy rainfall areas it is a dominant feature in run out pastures and plays an important part under good management. It also contributes a great amount to Autumn-saved pastures but would prefer it not to be present.

Gisborne

It has no value in Gisborne areas.

Northern Hawkes' Bay

It has got some value as pasture, particularly in damp areas.

Southern Hawkes' Bay

Its value is limited and land should carry ryegrass and white clover high-producing pastures.

Wairarapa

Fog appears in damp and wet areas, cattle graze it better than sheep. The early Spring growth seems to be palatable.

Horowhenua

In high-fertility conditions, fog is useless and has a smothering effect on clovers. Under such conditions, its presence is generally an indication of run out swards. However, it provides a certain amount of cover and grazing in rush-dominant flats.

Ashburton

It has got limited value.

South Canterbury

On the better class of land it is regarded as a weed. Under South Canterbury conditions, it is unpalatable and is definitely a weed grass of little value. However, it is recognised to be the best of the weed grasses and no doubt contributes useful feed. It has got no value in most of the Canterbury seed-producing farms and can be a troublesome weed.

Waimate

Fog has little value. It seems to be quite palatable in its early Spring growth.

Cocksfoot

It is a weed grass and appears after the depletion of good species and has some value.

Danthonia

It is a useful grass in early Spring. It has got much value as a pioneer plant in reclamation of tussock and unploughable hill country. On peaty soil it is dominant and has both economic value and a value in a development programme.

South Otago

It tends to dominate on run-out pastures and has got some value.

Southland

There is quite an appreciable amount of fog in Southland pastures, particularly in the older swards. It is grazed cleanly and can, therefore, be said to be a useful grass under these conditions. Its importance is felt on poorly-drained areas, and provides a certain amount of rough feed.

(B) REVIEW OF STUDIES ON "GROWTH FORM"

(a) Ecotype Concept

In cross fertilised pasture plants, very distinct variations in growth form with definite adaptation to particular environmental conditions are apparent. These variations in growth form are believed to be due to climate, soil, and the influence of man and his grazing animals (biotic factors) and therefore given rise to the terms, "climatic ecotype", Edaphic ecotype" and "Biotic ecotype."

This ecotype concept was proposed by Turesson (12) and was an attack on the species problem from an ecological stand-point. He states that purely genetical side of the "Species problem" is well understood, but no experiment has been done to delimit the differentiation caused by ecological factors. Thus he aims at an understanding of the Linnean species from an ecological point of view. Heretofore, the term ecotype proposed by him (12) is "an ecological unit to cover the product arising as a result of the genotypical response of an ecospecies to a particular habitat". This definition clearly delimits the species and ecospecies problem as "the ecotypes are the ecological sub-units of the ecospecies, while genotypes are purely Mendelian sub-units of the genespecies".

The ecotype concept as proposed by Turesson is universally accepted with slight modification in the terminology. Turrill (49) proposes "ecotype to cover the ecological sub-unit of the ecospecies arising as a result of the differentiation of the species-population in response to a particular habitat condition". Gregor etal (30) interpret Turesson's definition and define "the ecotype as a population distinguished by morphological and physiological characters most frequently of a quantitative nature; interfertile with other ecotypes of the ecospecies, but prevented from freely exchanging genes by ecological barriers. Spatially widely separated ecotypes may exhibit characters determined by genes restricted to the geographical regions in which they occur."

Gregor (51) in his publication on 'The Ecotype' argues on the basis of Mayr's (52) species definition 'species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups' and further states that there is no biologically significant reason in adhering to Turesson's eco-prefix and why not call it a species as Mayr has done? However, he justifies Turesson's eco-prefix concept, apparently due to the fact that it does indicate a species which has been taxonomically delimited as a result of experimentation.

Cain (53) refers to the work of Danser (54) who also tried to delimit groups of individual as follows:-

'Danser Concept'	'Turesson Concept'
Connexivum - possibility of hybridization but the products are sterile or fertile.	Coenospecies
Commixtum - can successfully exchange genes.	Ecospecies
Convivium - which is a population differentiated within the commixtum and isolated by geographical influences.	Ecotype

Danser did not attempt to co-ordinate his conception with taxonomic usage and is not popular with taxonomists. However, on this concept Cain defines 'an ecotype as a convivium caused by ecological factors.'

Clausen (55) defines the ecotype as 'an ecological race, usually composed of considerable number of variable local populations existing within a given ecological zone.'

Other terms are also proposed, including cline concept. Huxley (56) defines the

cline as an 'auxiliary taxonomic principle' or in other words 'character gradient.' Ecocline is defined as 'a cline apparently correlated with an observable ecological gradient' and on the basis of this concept ecotype is defined as a 'particular range on an ecocline.'

It is to be noted, however, cline and ecotype are not mutually exclusive concepts but merely express different ways of approaching the same problem. Gregor (57) emphasizes that both of these concepts are valuable aids to an understanding of the variation within species.