ECOLOGY AND AGRONOMY OF TUSSAC GRASS

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by

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Cover:- Experimental plot of Tussac grass established and thriving on previously burnt, eroded, infertile peat overlying clay at Robinson's Point, Keppel Island.

CONTENTS

Note:- Terminology. Throughout this report the original, local Falkland Island word "Tussac" is used in preference to Tussock when referring to the species itself. "Tussac grass" has been used synonimously with "Tussac" and individual Tussac grass plants have been described as "Tussacs". The terms "tussock" or "tussock-forming" are used to describe individual plants where special reference is being made to their growth habit.

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SUMMARY

The area of Tussac grass in the Falkland Islands has declined considerably since the introduction of grazing stock over a century ago. With recent radical changes in the agricultural infrastructure and an increasing concern for the conservation of wildlife there is an interest in the re-introduction of this nutritious and relatively highly productive grass. A programme of research carried out at three locations into some factors affecting the establishment and early growth of Tussac grass is reported.

From field work on South Georgia, the ecology and physiology of natural, grazed and ungrazed stands of Tussac grass was investigated. The adaption of Tussac grass to a sub-antarctic environment is discussed and the effect of grazing pressure on canopy structure outlined. Leaf growth was lower from South Georgia than from the Falkland Islands. A list of fungi isolated from Tussac grass leaves is presented.

Aspects of the establishment of Tussac grass were investigated on the Falkland Islands. Plants were successfully established on sites which ranged from coastal, 'Tussac' peat to inland, rotavated 'whitegrass' peat. The 3-tiller group is the minimum size recommended to plant and planting density is dependent on factors such as achievement of rapid ground cover and availability of planting material. Establishment was unaffected by fertiliser application; a response to fertiliser only being measured on established, adult plants.

Rust can be a serious problem on Tussac grass in certain seasons and, although an effective fungicide control programme was found, spraying is hardly likely to be economically or ecologically desirable in all

but a few specific situations [e.g. in the initial stages of establishment of a large area of Tussac]. The effects of stem-boring insects on plant growth and health were clearly demonstrated and give potentially more cause for concern than rust attacks. Studies on adult plants of leaf production and growth showed that Tussac produces, on average, 14 leaves per year. Such studies provide a foundation for a more scientific approach to a study of the grazing ecology of Tussac grass.

An experimental approach was adopted for a programme conducted in Northern Ireland. Tussac grass plants were successfully raised from seed though the quality of the resultant plants can be greatly affected by site and time of seed collection, seed bed fertility, application of plant growth hormone (which considerably improved seed germination) and adherence to certain selection criteria for seedling and young plant vigour.

Provided pests are controlled, Tussac established well at field sites in N. Ireland and, at the coastal site, indicated potential for very high levels of production of digestible forage. Tussac grew well at low temperatures and may have potential as an out of season forage resource on farms in the British Isles though further field experimentation would be required to confirm this. Detailed observations on the development of the tiller structure were related to the ability of plants to withstand initial grazing. Unless plants have attained a critical size before grazing damage, particularly through tiller uprooting, will be severe. Plant recovery was better after winter grazing than summer grazing.

Following on from the work reported, a series of recommendations for further research on all aspects of Tussac grass establishment, growth and management, are presented.

1. INTRODUCTION

1.1 Tussac grass

The natural vegetation of the Falkland Islands is closely related to plant communities in southern Patagonia and Tierra del Fuego. It is a complex mixture of dwarf shrubs, ferns, herbs and grasses with very similar growth forms being shown by quite unrelated species. With less than 170 native species in the flora and many of these quite restricted in their distributions, relatively few species dominate the five major community types.

It is believed that Tussac grass (*Parodiochloa flabellata* (Lam.) C.E. Hubbard = *Poa flabellata* (Lam.) Hook. f) (Groves, 1981) originally formed a coastal fringe around much of the archipelago. Indeed, when the islands were first visited, voyagers mistook the grass for coastal woodland. The grass can form almost pure stands and, where heavily manured by seals or birds, can grow up to three metres high with a closed canopy of leaves between individual plants.

In the Flora of the Falkland Islands, Moore (1968) provides a detailed botanical description of the species:

> "Perennial, forming dense tufts up to 2.5 m; stems aggregating to form stool up to 70(-100) cm high, up to 100 cm or more in diameter and crowned by the somewhat spreading leaves. Leaves 30-70 cm, 5-15 mm wide; lamina linear, acute, narrowly channelled and scabrid on upper surface; sheath somewhat keeled, smooth; ligule *c.* 5 mm, obtuse, usually torn, membranous. Culms (30-)50-150 cm, 2-3 mm in

diameter, erect, rather compressed, glabrous. Panicle 8-21 x 1-4 cm, spike-like, dense, cylindrical or ovoid-cylindrical, yellowish green, spikelets 7-9 mm, 3- to 4-flowered. Glumes unequal, the upper slightly the longer, *c.* two-thirds as long as spikelet, ovate-lanceolate, acute to acuminate, ciliolate on margins and keel, with hyaline margins, the lower 1-nerved. Lemma 5.0-6.5 mm, ovate-lanceolate, acuminate or subobtuse, with short, terminal, scabrid awn, keeled, scabrid on nerves, with ciliolate scarious margins; palea almost equalling to two-thirds as long as lemma, ciliolate, scabrid on nerves. Anthers *c.*2.8-4.0 mm, 6-7 times as long as wide. Fl. IX-XI(-XII)."

Tussac grass is found on South Georgia, Tierra del Fuego, Isla de los Estados and Gough Island in the Southern Cool Temperate Zone as well as in the Falkland Islands. Whenever it is subjected to unrestricted grazing - e.g. in the Falkland Islands and on South Georgia - it is quickly exterminated and this has been the fate of many of the original Tussac stands on the Falkland Islands.

All the agronomic investigations conducted on species in the Falkland Islands flora have recognized the potential of Tussac grass as a winter feed for animals - a point first made by Governor Moody in 1843 - but little has been done to protect the communities from uncontrolled sheep grazing. More recently, conservationists have identified Tussac grassland as a key environment for many Falkland Island birds (Strange, 1987).

1.2 History of Tussac usage

The individual plants produce a fibrous pedestal which can reach more than 2 metres in circumference. Called "bogs" in the Falkland Islands the largest of these tussocks are likely to be many decades or possibly more than a century old. Originally used for grazing by wild cattle, the early settlers found them useful also for thatching the first huts.

In the 19th century farmers would cut and dry Tussac leaves as winter feed for horses and dairy cows. This continued into the 20th century at Stanley where the Tussac Islands in the outer harbour provided winter fodder for the Stanley dairy.

The stem bases have even been used as food. Shipwrecked sealers subsisted on them for many months (e.g. Barnard in 1814, recorded in Dodge, 1979) whilst even today naturalist Ian Strange (1987) remarks on their palatability in salads.

Whilst most of the Tussac grass communities have undoubtedly disappeared because of overgrazing by sheep, some have been burnt out by fire. In some instances these have been fires started by sailors to attract attention after a shipwreck but in other cases they appear to be due to lightning. The fires can go underground into the peat and burn for many months, completely devastating the community. Evidence of earlier fires can be seen in ash layers in many parts of the Islands.

1.3 Present distribution and usage

At present Tussac grass makes little contribution to output on all but a few farms. This is largely because the original area of Tussac has been severely depleted and its correct management is now poorly understood, rather than from a lack of awareness of the value of the grass amongst farmers. The current extent of Tussac grass has been summarised in a report by the Falkland Islands Foundation (Strange, Parry, Parry and Woods, 1988), which documents independent surveys by Strange and Woods. The Woods survey was based on a photogrammetric technique utilising a series of photographs taken in 1956 (by Hunting Aerosurveys) and photographs taken in 1979 and 1983 (by the Royal Air Force). The Strange survey is based on the author's site inspections, comprehensive local knowledge and detailed records.

Woods (in Strange *et al.*, 1988) estimated that in 1956 there were approximately 10 776 ha of Tussac in total, 8 014 ha on smaller, uninhabited islands, 1 609 ha on the larger islands (905-21 850 ha in size) and only 1 153 ha on East and West Falkland. The more recent air photographs (1983) did not provide comprehensive coverage and, where comparisons could be made with the 1956 coverage, it was found that from a subsample of 49 islands (approx 24 000 ha in total) 'dense' Tussac cover had decreased by 41.7% where these were stocked. Where stock had been removed prior to 1983 (using information from Strange, in the same report) the reduction in area was 3.9% and dense cover on unstocked islands remained virtually unaltered. The increase in cover defined as 'scattered' in 1956, (largely at the expense of 'dense' cover) was 97% where the Tussac was stocked, 21.8% where stock was removed previously and little changed where the islands were unstocked.

Hence, it was estimated that, overall, total Tussac cover on these 49 islands had declined by 10.9% where stocked, increased by 3.8% where stock had been removed before 1983 and was unchanged where unstocked. If this percentage loss was extrapolated to the total estimated area in 1956 (10 776 ha) then approximately 8 686 ha of Tussac remain on the Falkland Islands. From the 1983 partial survey 62% of this i.e. 5 385 ha could be classed as 'dense' Tussac.

Early reports e.g. Moody (1843) infer that the most of the coastline of the Falkland Islands once had a fringe of Tussac grass. From other early documentary evidence and from a study of aerial photographs of eroded areas, Strange (in Strange *et al.*, 1988) considers that Tussac was not so widespread as once thought. He has calculated that, before the Falkland Islands were settled and stocked (i.e. early in the 19th century), there were 5 668 ha, 4 251 ha and 8 642 ha of Tussac grass on East Falkland, West Falkland and the scattered islands respectively. This represented a total area of 22 181 ha or approximately 2.3% of the total land area. Strange estimated that there was now only 16 ha and 49 ha of Tussac remaining on East Falkland and West Falkland respectively in 1987. With 4 094 ha remaining on the scattered islands (stocked and unstocked) Strange estimates a total of 4 159 ha of Tussac remaining in the Falkland Islands. He has also included a detailed inventory of those islands, islets and stacks with Tussac grass communities (Strange *et al.*, 1988).

If this estimate of Strange's is accepted, the *c* 22 000 ha of Tussac grass in the Falkland Islands before the introduction of grazing stock had declined by the mid 1950's to 10 800 ha. Strange's present estimate of almost 4 200 ha represents a considerable decline since the

1956 survey to only *c* 20% of the original area and is probably more complete than the recent (1983) aerial photogrammetric survey though, as the two surveys incorporated different methods of assessment, direct comparisons are not possible.

During the summers of 1986 and 1988 a survey of the status of Tussac grass on islands in the Weddell Island and Beaver Island groups was carried out (Poncet, Poncet and McAdam, 1989). Estimates were made of the extent of Tussac grass cover and of the area of eroded ground which apparently had previous Tussac cover.

The estimated area of Tussac grass from the Woods survey and the Strange survey (Strange *et al.*, 1988) and the Poncet *et al.* (1989) survey on the 22 islands in the Weddell Island and Beaver Island groups are presented (where comparable) in Table 1. The photogrammetric survey data quoted (Woods), was based on estimates from a 1983 set of aerial photographs. Only seven islands (Penn, Barclay, Fox, Quaker, Hill, Staats and Tea) were common to all three surveys. The estimated total areas of Tussac grass from these were 495, 221 and 320 ha from the Woods, Strange and the Poncet *et al.* studies respectively. The main discrepancy between the first two surveys for this group of islands was in the assessment of Tussac cover on Staats and Tea Islands. It is relatively meaningless to compare the values for different classes of Tussac as these are heavily subjective.

Strange includes almost all the islands in the Poncet *et al.* (1989) survey in his survey (in Strange *et al.*, 1988) and his total area of Tussac cover for 21 of the 22 islands is estimated at 373 ha compared to 502 ha from the same 21 islands in the Poncet *et al.* survey. Poncet *et al.* (1989) also estimated a total area of eroded Tussac ground ('black ground') from these islands at 401 ha. In view of the nature of such surveys involving field visits, visual appraisal and subjective estimates such differences are to be expected. Strange (in Strange *et al.*, 1988) estimated that, from historical and visual evidence, the total area of Tussac grass on Governor, Staats, Barclay, Fox and Quaker Islands had declined from 397 ha before stock introduction in the last century to 161 ha at the present day (1986). The Poncet *et al.* (1989) survey estimates 157 ha for these islands with 103.5 ha of 'black ground', which obviously was once Tussac covered. Hence the total area can be reliably assumed to have declined by over half. Woods (Strange *et al.*, 1988) estimates that in 1956 the total Tussac area on the islands common to all 3 surveys (see list earlier) was 527.5 ha. Recent estimates of the total Tussac cover on these islands range from 221-495 ha (Table 1). Hence, depending on the methodology accepted, the decline in Tussac from these islands may have been considerable.

The decline can be largely attributed to over-grazing, although accidental fires have also played a part.

Only three island farms at present actively manage Tussac. Strange (in Strange *et al.*, 1988) has estimated that the total area under such management on these farms is 294 ha (164 ha, 81 ha and 49 ha on Sealion Island, Carcass Island and West Point Island respectively). The total area of Tussac on these islands estimated from the 1983 photographs was 317 ha, 170 ha and 114 ha respectively, i.e. considerably more than Strange's estimate (Woods, in Strange *et al.*, 1988).

Other small uninhabited islands are intermittently stocked and the area of Tussac is very small on mainland farms. Neither of these sources constitute usage on a scale which makes any significant contribution to output on the farms in question. The conservation and wildlife value of Tussac has been recognised by the Falkland Islands Government in its designation of reserve status for some islands and, although difficult to quantify, must also be taken into consideration as a source of revenue for farms. At present it is largely those farms with the highest Tussac cover which manage and utilise the grass to fulfil both objectives of agriculture and wildlife conservation.

1.4 Need for research into Tussac grass establishment, growth and utilisation

It is clear that the extent, distribution and current status of Tussac grass is lower than at any time in the Island's documented history. It is also apparent that, for a variety of reasons, there is a desire to recover from this unacceptable condition and to extend the area of Tussac grass. Most farmers and all conservationists recognise the value of Tussac grass and consider that there is an urgent need to investigate means of planting and establishing Tussac under a range of conditions.

Agriculture in the Falkland Islands is at present in a period of fundamental and radical change. Over the past eight years an ambitious programme of sub-division has been undertaken and the number of individual farms has increased from under 30 to over 80 (FIG, 1988), most of these farms passing into private sector ownership. There are now more farmers who are interested in farm improvement and increasing output from natural grasslands. A more intensive and personal interest in land management is both possible and necessary in these smaller farms. Concomitant with this change has been an extensive programme of government funding, in the form of grant aid for farm developments such as fencing and grassland renovation. Hence, the current economic situation is favourable for investment in land improvement and the motivation is present for programmes of investment. The planting of Tussac grass is one such improvement and although many of the landowners are convinced of its value (Carter, 1988), planting techniques and early management are poorly researched and advisers are unable to offer a tried and tested suite of techniques to suit a range of sites and situations. Such questions are also posed by conservationists who are equally concerned with issues of establishment and early management of Tussac.

If Tussac grass is to be planted on a more widespread scale than at present then research must be carried out on establishment of the plant. Conventionally Tussac grass has been planted in winter, when sheep work is not so demanding, using relatively large tiller clumps (sets) cut from mature plants. This technique is time consuming, relatively wasteful on the use of material and dependent on the proximity of an existing, mature Tussac stand. There is a need for research into the reliability of tiller survival, site selection, time of planting, planting methodology and propagation material in relation to success of establishment. The constraints on establishment and growth imposed by 'rust' disease and insect pests and their likely interaction within and between plants is as yet almost completely unknown.

Despite this lack of scientific knowledge, there is evidence of cases where individual farmers have had consistent success in establishing and maintaining Tussac. These successes have, however, often lacked repeatability on other sites and there is a need for controlled and replicated experimentation to determine general principles of establishment. Although the facilities to carry out such experimentation exist in the UK, many of the aspects of the general ecology and agronomy of Tussac needed investigation within the plants' natural range on the Falkland Islands and South Georgia.

A broad summary of the research work undertaken within the present programme on the ecology and agronomy of Tussac grass is presented in the following report. The report also contains an account of Tussac grass research carried out by the Agricultural Research Centre, Stanley, Falkland Islands and a brief introduction to a wide range of other data on Tussac grass collected previously by British Antarctic Survey. Special emphasis has been laid on factors likely to affect establishment.

2. SOUTH GEORGIA

2.1 General ecology

On South Georgia Tussac grassland is the dominant vegetation on all coastal sites (Smith and Walton, 1975). It grows on a variety of substrates from peat to scree, and over an altitudinal range from sea level to at least 200 m (on north-facing slopes). Individual tussocks vary greatly in size and form, from small yellowish plants growing in dry scree or on mineral soils to large, bright green plants on wet peat near sea level with considerable animal manuring.

Individual tussocks can reach over 1 m in basal diameter of the stool and up to 2 m in height at the most favourable beach sites (Plate Ia). Mature, individual plants cast a heavy shade which allows few other species to grow between the tussocks. This "closed" Tussac community is always associated with animal activities, especially burrowing petrels which nest in the peaty bases of the stools. These birds, together with surface nesting albatrosses, provide a considerable input of nutrients into many of the Tussac communities; those most heavily manured by bird guano appear much brighter green, due apparently, to an enhanced chlorophyll content.

The beach Tussac communities are favourite areas for seals and penguins. Constant movement of these animals not only suppresses plant growth between the tussocks but often erodes the peaty subsoil. Thus plants can be found with healthy canopies growing from the top of a pedestal apparently rooted in the pebbles of a raised beach. The plants benefit from nutrient input from the animals but where seal populations are high, as on Bird Island, the disturbance can be too great and plants are killed. Fur seal populations in particular are now causing increased Tussac death in some areas of South Georgia. Elephant seal groups routinely cause local and limited death of Tussac by lying on the grass during their extended moulting period. In both cases, offer the departure of the animals, the wet and slimy Tussac bases are immediately colonised by a green alga (*Prasiola crispa*), followed by the germination of Tussac grass seeds.

Flowering is annual and widespread. To ensure that viable seed is set and dispersed every year the panicle (flowering head) is initiated in January and completes most of its development before May, whilst still completely covered by the leaf bases (Walton, 1982). Final development occurs during the winter and in September elongation of the culm begins, pushing the panicle clear of the leaf canopy. In many winters the panicle is pushed up through the snow. Flowering begins in October and pollen liberation is completed at most sites by mid-December. Aspect has a considerable influence on the rate of development of the flowers with all pollen shed in north-facing sites by early November, whilst in some south-facing sites flowers do not open until December. Seeds are usually ripe by late January and shed during February and March.

Tussac grass is the principal food for the introduced reindeer (Leader-Williams, Scott and Pratt, 1981; Leader-Williams, 1988). In some areas it has been so severely overgrazed that Tussac communities have been replaced by the more grazing tolerant alien species *Poa annua* (Annual Meadow grass). Reindeer population size is largely controlled by the quality and quantity of winter grazing and it is here

a. Typical Tussac stand with individual plants *c.* 1 m.

b. Section through Tussac plant showing canopy structure, arrangement of standing dead material and peaty pedestal.

Plate I Typical Tussac grass communities on South Georgia.

c. Grazed area showing regeneration within fenced area (photo: R.I.L. Smith).

d. Heavily over-grazed area in Moltke harbour (photo: R.I.L. Smith).

Plate I (continued) Typical Tussac grass communities on South Georgia.

that Tussac grass has proved so important. The tussocks protrude through winter snow and are easily found by the reindeer. In addition the storage of carbohydrate as fructans makes it a more readily assimilatable energy source than starch.

Observations have been made over a period of 12 years to assess the potential for the recovery of native plant communities from various degrees of grazing (Leader-Williams, Smith and Rothery, 1987). It appears that moderately damaged Tussac grass plants quickly regenerate when grazing ceases and seedling germination is widespread. However, where the crown of the stool has been removed by grazing and mosses or Annual Meadow grass are well established, recolonisation by Tussac grass is very slow.

2.2 Biomass

Published estimates of green biomass give a maximum above ground value of up to 15 kg m^{-2}; this is derived from a large, mature, heavily manured individual plant and not the community as a whole. More typically for the grass community as a whole are values of 7.5 kg m^{-2} green leaves, 5 kg m^{-2} dead leaves, 5 kg m^{-2} root biomass (Smith and Walton, 1975). These biomass data all relate to a very limited study on ungrazed mature grassland and need to be used with caution. The present project has focused on providing more reliable biomass data for both ungrazed and grazed Tussac sites as well as characterising the canopy structure of a natural community.

The biomass estimates quoted above are exceptionally high when compared with published grassland data from temperate sites, and are more comparable with data for large tropical grasses. If they are correct then it would be necessary to assume that Tussac grass was exceptionally efficient at photosynthesis under subantarctic conditions. Information on how the biomass is produced - as leaves, daughter tillers, reproductive tissues and roots - is also very important in understanding the growth strategy of this species.

2.2.1 Effects of grazing

Data for above ground biomass in Table 2 are based on the harvesting of four complete tussocks at four locations - two ungrazed sites of high (PR) or low (NF) fertility and two infertile areas grazed either lightly (LG) or heavily (HG) (Plate Ic and d). Each sample taken was 1 metre square centred on a tussock, and the material inside and outside the square was collected separately. Thus the table shows biomass per unit area (ie. per m^2) from within the square and biomass per tussock which includes the material outside the square.

At the fertile site almost half the biomass (46%) was outside the square whilst at the infertile site only 33% was outside the square. This correlates well with a greater leaf length at the fertile site. Grazing produces a considerable effect on the spread of the leaf canopy with only 22% at the light grazed site and 27% at the hard grazed site outside the square.

The biomass per unit area was very much less than the values reported earlier. Even for the best Tussac grass plant at the fertile site the dry matter was only 1479 g m^{-2}. This does not mean the earlier values were necessarily incorrect but that they must only apply to mature, heavily manured stands where the plants are 1.5-2.0 m high. The stands sampled in the present study barely reached 1 m high but are more typical of the Tussac grass community as a whole on South Georgia than the tall stands.

2.2.2 Leaf canopy structure

Grazing obviously affects the structure of a plant. The removal of the leaves by the grazing animal can stimulate leaf growth, increase the rate of tiller production, change the growth form of individual plants or even exhaust the plant to the extent of causing death. Tussac plants were examined at four sites to assess the effects of grazing on the vertical distribution of dry matter in the form of leaves. To provide this data each tussock was clipped horizontally in 10 cm layers. A measurement of the area covered by the leaf canopy at each level was also made.

Figure 1 compares the patterns of distribution of dry matter in individual tussocks from the four grazed and ungrazed sites. As would be expected both grazed sites had smaller tussocks than ungrazed sites and the ungrazed sites showed the highest biomass around ground level. By contrast, the highest biomass for ungrazed tussocks was 10-20 cm above the ground and consisted largely of a skirt of dead leaves. This skirt seemed to be missing at the grazed site, either because the dead leaves were broken off by animal trampling or because the tussocks were grazed down to that level so that the skirt did not develop.

Measurements of the pattern of cover shown by the leaf canopy are less clear than the biomass data. Figure 2 attempts to show typical patterns of leaf spread as seen in a vertical section through the Tussac grass canopy.

2.2.3 Below ground biomass

Although Gunn (1976) provided an estimate of 10 kg m^{-2} for the below ground biomass of roots in a mature stand of Tussac, he made no estimate of the living proportion and sampled only from the largest tussocks available. To produce such a considerable biomass he estimated that below ground production could be as high as 2 kg m^{-2} yr^{-1}.

Limited data on biomass were obtained from cores taken at both grazed and ungrazed sites in the present investigations. Above:below ground ratios varied considerably from 4.8 - 3.7 at the site fertilised by penguins, 8.2 - 5.6 at the infertile site, 2.8 - 2.5 at the light grazed site and 8.0 - 2.2 at the hard grazed site. These data suggest considerable spatial variability in root biomass which must be investigated further.

In an experiment growing tillers and seedlings of Tussac in various soil types and at different sites on South Georgia Smith (1985) showed a strong growth response to added nutrients. Almost regardless of soil type and site the above:below ground biomass ratio for seedlings changed little after the addition of nutrients, suggesting that at least at the earliest stages of growth root and shoot benefit equally. With tillers the pattern was different, the nutrients stimulating much more shoot than root growth. A density experiment demonstrated that, even under non-limiting nutrient conditions, competition for water and space resulted in a steady decline in production with a change in the above:below ground ratio from three to over five at the highest densities.

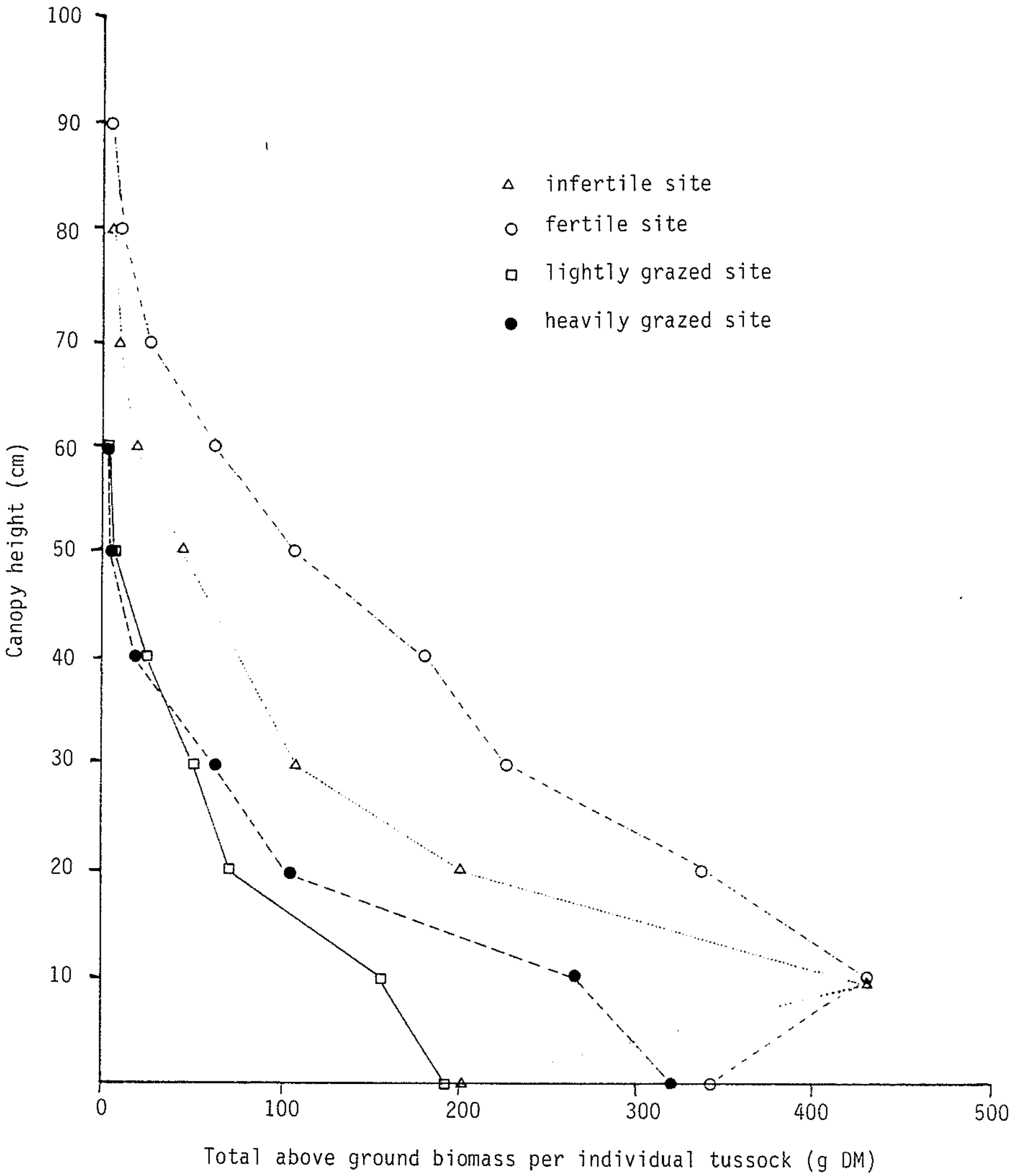


Figure 1. Patterns of distribution of leaf dry matter in a vertical profile through individual tussocks from four sites on South Georgia.

○- fertile site, △- infertile site, □- lightly grazed site, ●- heavily grazed site.

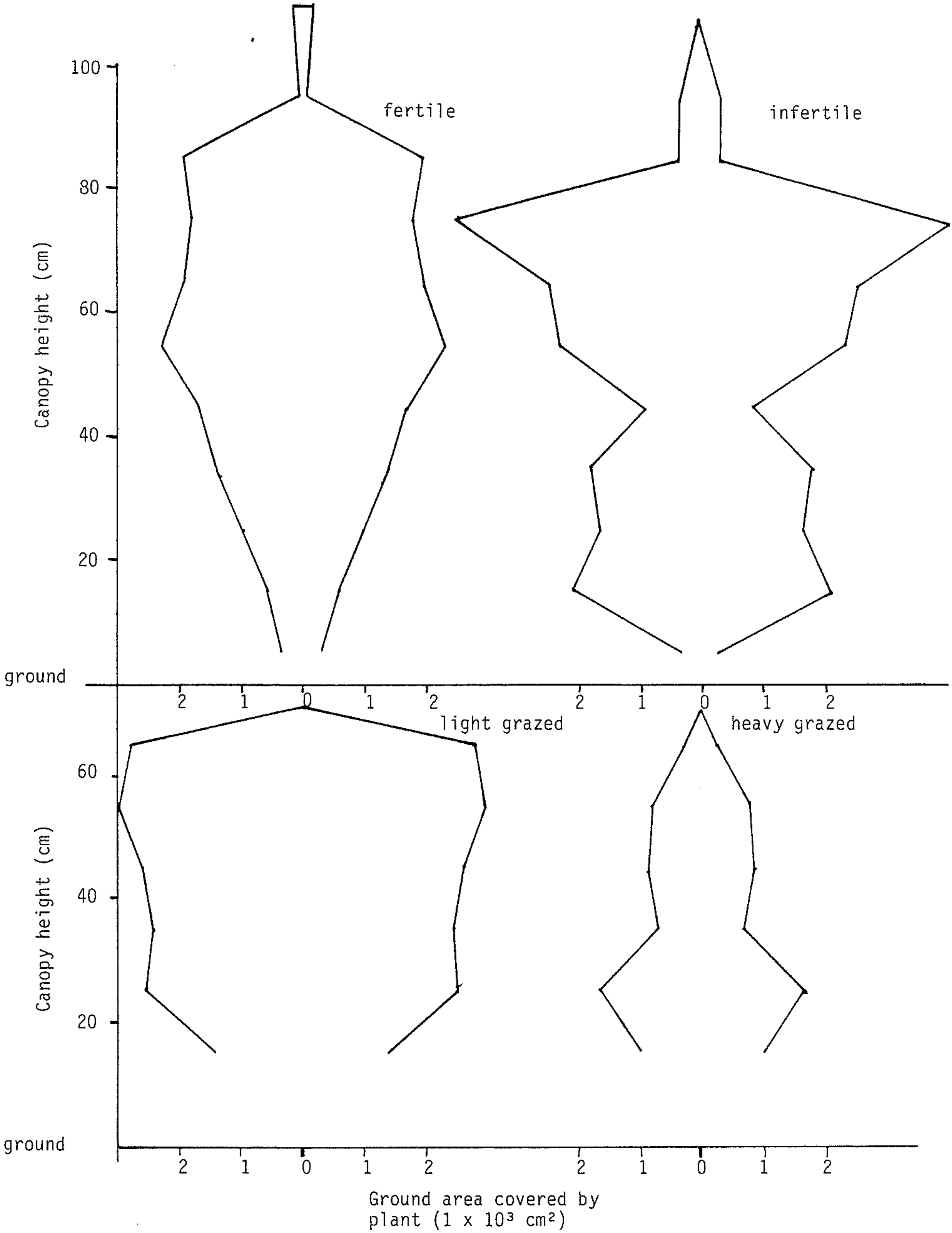


Figure 2. The shape of tussocks (presented as distribution of canopy area) from a fertile, infertile, light grazed and heavy grazed site.

2.3 Translocation studies

The growth of a Tussac grass plant clearly necessitates the movement or translocation of carbohydrates from the most actively photosynthesising leaves to leaves just beginning to expand, to roots and to flowering stems. The patterns of translocation change with season and with the age of the plant. In addition, defoliation by damage or grazing can seriously disturb the normal pattern of movement.

Preliminary experiments have been conducted to establish the normal relationships between leaves of different ages (the sources) and other parts of the plant (the sinks). It is clear from the elongation of the flowering culm through the snow in September that translocation is active at subzero temperatures. Photosynthesis has also been measured at subzero temperatures and for this to continue, some movement of carbohydrates away from the leaf is likely to be essential.

Work by Gunn (1976) established a number of basic features:-

(i) mature leaves do not import carbohydrates;

(ii) young tillers are at first supported by their subtending leaf, then by the parent tiller and finally by a number of nearby tillers;

(iii) flowering tillers appear to be independent of any carbohydrate suply from vegetative tillers.

(iv) dying leaves move carbohydrates to a range of other sinks;

(v) leaf bases of apparently "dead leaves" are used for temporary storage of carbohydrates;

(vi) the roots do not appear to be major sinks for carbohydrates.

2.4 Complementary studies

In the recent past BAS have undertaken a number of botanical studies on South Georgia which focused, at least in part, on Tussac grass. These data, of which much remains to be published, can contribute towards the understanding of the ecology and general physiology of the grass in the Falkland Islands and are therefore summarized here.

2.4.1 Photosynthesis

Studies on young Tussac plants at King Edward Point were carried out during two summers using a portable infra-red gas analysis system (D.W.H. Walton and P.M. Harrison, unpublished data). Due to restrictions on the length of the leaf chamber only leaves up to 50 cm long could be measured and these were all from young plants not exceeding 50 cm in height. Leaves of several different ages were measured over a range of temperatures and light conditions. Preliminary data are shown in Figure 3 for the youngest expanded leaf on a non-flowering tiller.

There is considerable scatter since the individual measurements were made at a wide range of temperatures but a clear trend can be seen from the fitted regression line. Light compensation point (the level of light below which the respiration exceeds photosynthesis) was determined as 52 mol m^{-2} s^{-1}. This is certainly low but not as low as that found for another subantarctic tussock-forming grass, *Poa cookii*, on Marion Island. Light saturation (the level above which photosynthesis no longer increases) was *c.* 1000 mol m^{-2} s^{-1}. This means that on South Georgia, especially on the north coast, photosynthesis of Tussac grass is unlikely to be significantly light-limited during the summer.

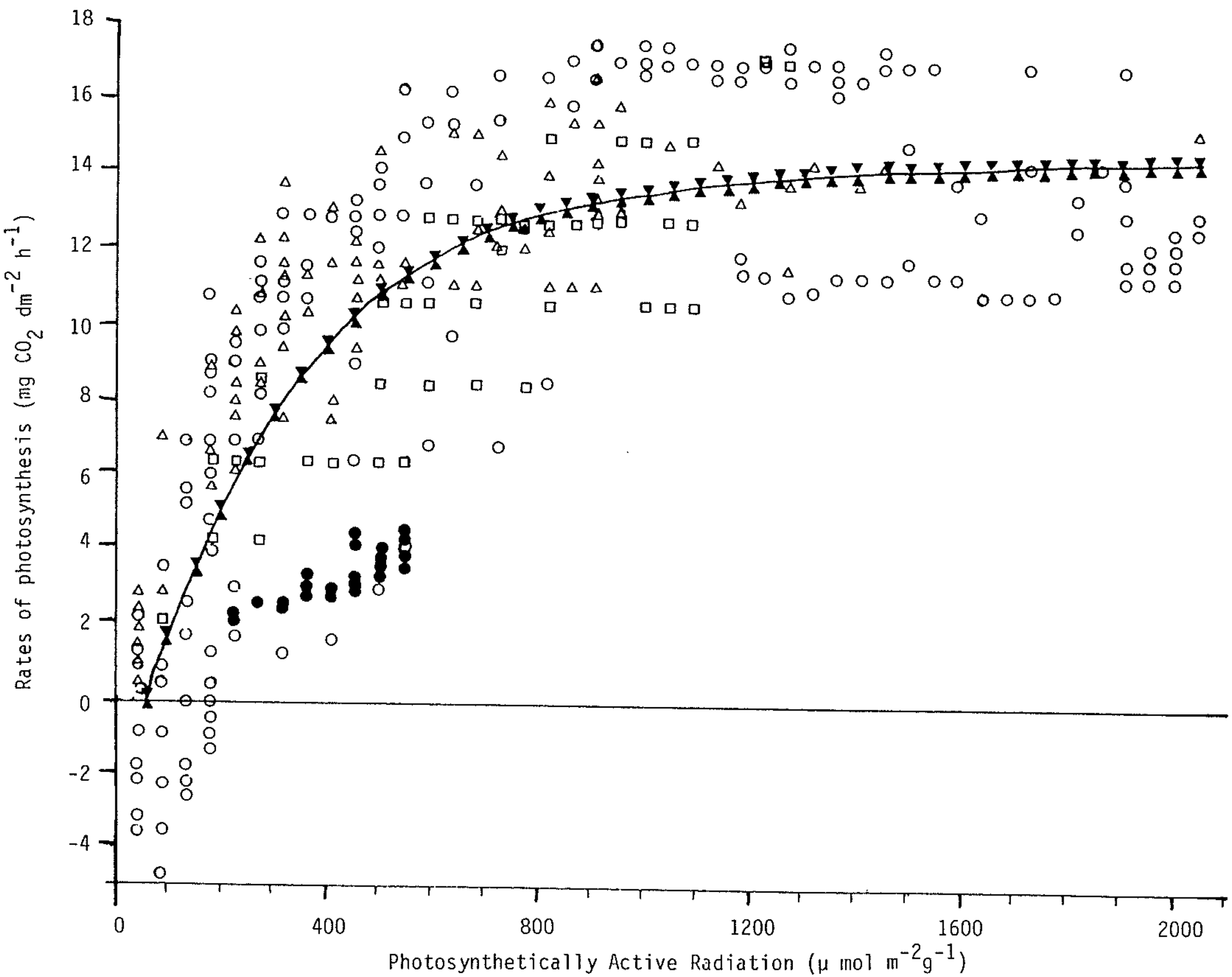


Figure 3. Mean net photosynthetic response of young, expanding leaves of Tussac grass at a range of temperatures and light levels.

Observations on South Georgia during cold summer days have established that photosynthesis continues below 0° C but the lowest limit for activity has not yet been determined.

Measurements of chloroplast size in Tussac grass leaves from both seal fertilized and scree sites (Jellings *et al.*, 1983) have very clearly shown that much larger chloroplasts were present at the fertilized site. The greater chloroplast to leaf area index in the presence of seal excreta may be sufficient to account for the greater size of these plants.

2.4.2 Microclimate

Measurements of the microclimate around and within Tussac plants were made in a pure stand of the grass at King Edward Point (D.W.H. Walton, unpublished data). The data comprise information on air, soil and plant temperatures, soil heat flux, solar radiation (incoming and nett), and wind speed, over a period of 15 months. A descriptive account of the environment within this Tussac grass community is being prepared at present but Figure 4 shows some sample data for sunny and overcast days. On the sunny day the temperature in the dead leaf litter around the base of the Tussac reached almost 22° C at noon, whilst in amongst the green leaves over 20° C was attained by 1500 hrs. On the overcast day the leaf litter was again warmer than the green leaves but the highest temperatures were achieved in the soil. A full evaluation of these microclimatic data will be important in understanding photosynthetic response, leaf production and decomposition, and the conditions under which fungal pests can spread.

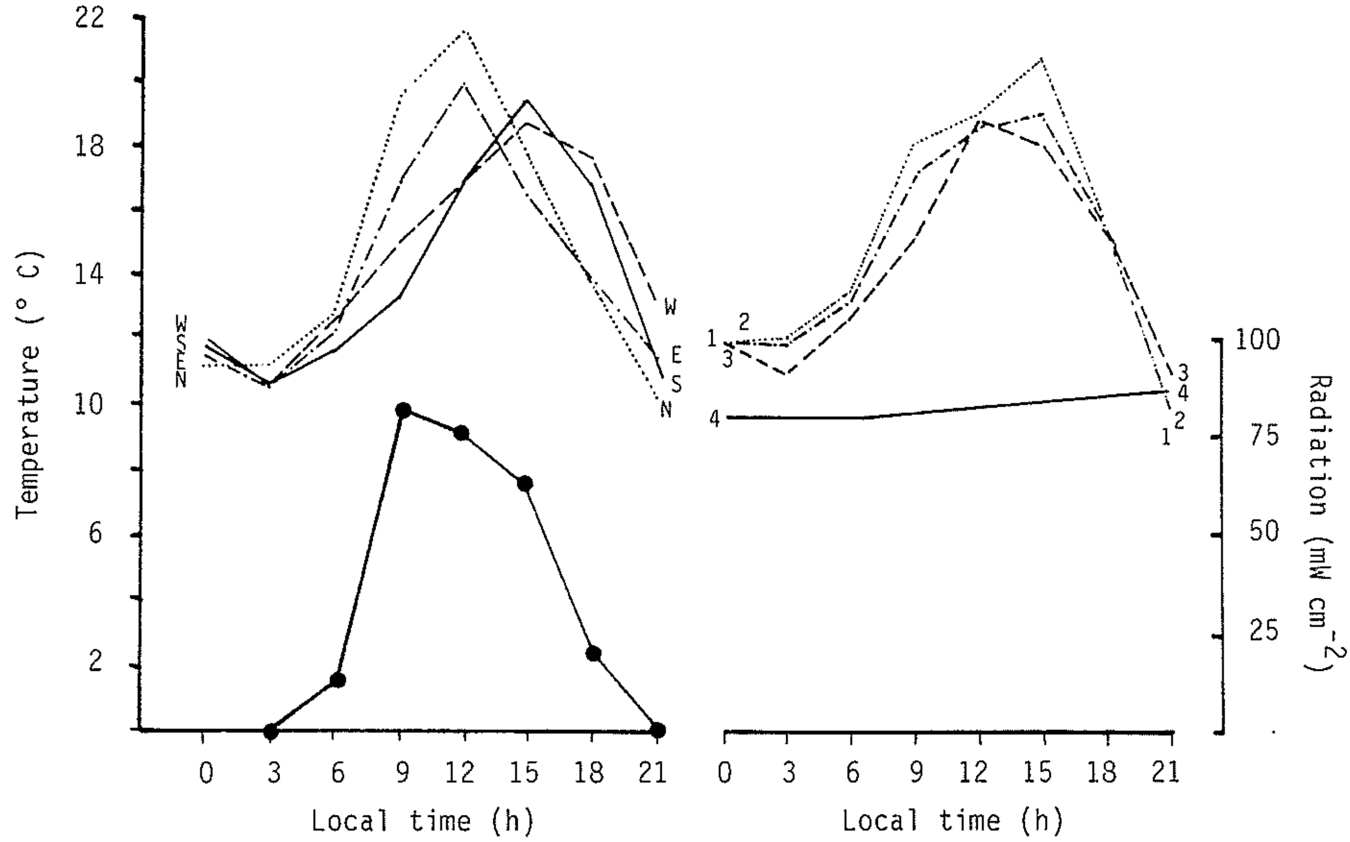
2.4.3 Anatomy and histochemistry

As part of a detailed survey of the anatomy and histochemistry of all South Georgian flowering plants Tussac grass has been examined in detail (D.W.H. Walton and L. Barber, unpublished data).

Anatomically the leaves resemble those of other grasses growing in the more arid Patagonian region. The construction is similar to that of *Poa cookii* (found on other subantarctic islands Berjack, 1979) and is illustrated in Plate II. The massive strands of strengthening tissue are essential if such a long leaf is to avoid destruction in a windy environment. This type of construction and the tendency of leaves to remain attached to the plant and to be held above the ground even when dead, means that decomposition of dead leaves is very slow.

The surface of the Tussac leaves (Plate III) is channelled and rough, offering a good place for fungal spores to lodge and germinate. Sections through rust-infected leaves indicate that multiple infection is the rule, with the mycelium spreading rapidly in the mesophyll tissue. Despite a thick and waxy epidermis the fungal hyphae are apparently able to penetrate with ease, so that attack is not restricted to stomatal openings.

Carbohydrate storage in the grass is in the form of fructans of variable chain length and not as starch. The concentrations of fructans vary considerably both between parts of the plant and seasonally within a particular organ. The base of leaves is a preferential storage site and there up to 50% of the dry weight can be attributed to fructans (Gunn and Walton, 1985).



Key: aspect of leaf litter - N, north-facing; S, south-facing; E, east-facing; W, west-facing. Profile through tussock - 1(-·-·-), 70 cm in air amongst leaves; 2( ), 55 cm in air amongst leaves; 3(---), 45 cm in air amongst leaf bases; 4(——), ground level, amongst humus. - , temperature (° C); ●—●, radiation (mW cm^{-2}).

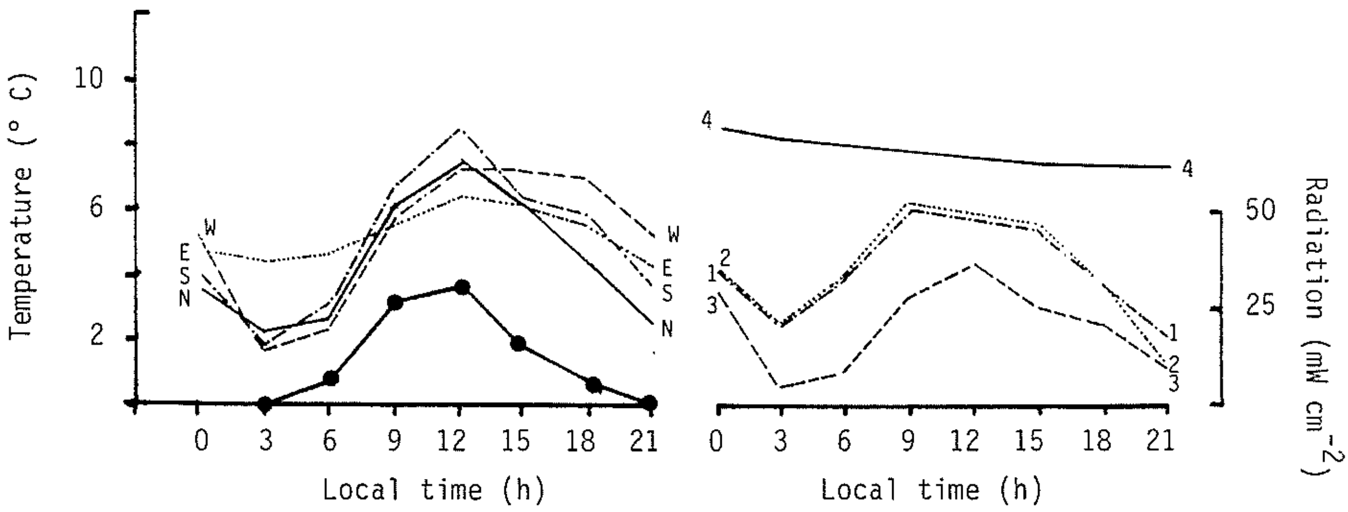


Figure 4. Temperatures and radiant energy levels within and around a Tussac grass plant during summer. All measurements made with Gulton 32TD25 thermistors on a digital multimeter; accuracy of data points ± 0.5° C.

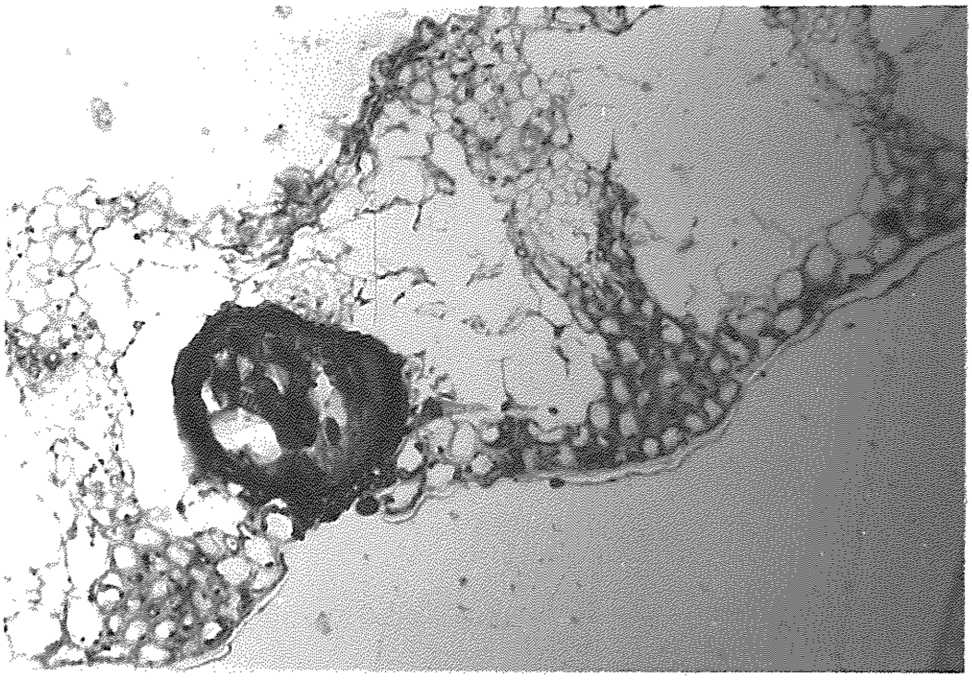


Plate II Transverse section illustrating the anatomy of a typical Tussac leaf. Note the "girder like" construction and the ascus with fungal spores embedded in the leaf.

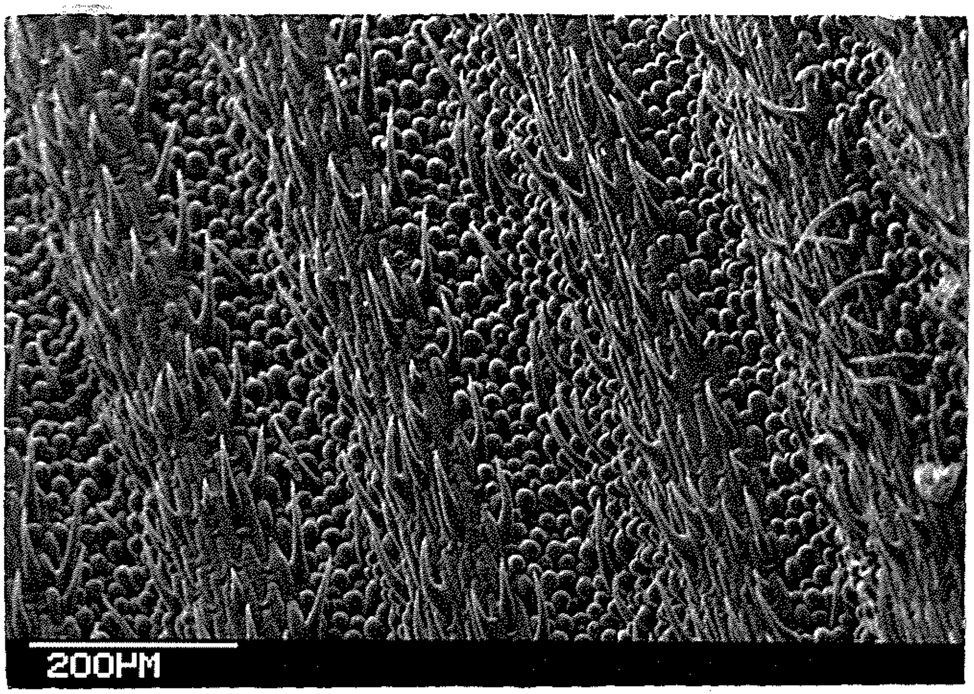


Plate III Scanning electron micrograph showing the surface of a Tussac leaf. Note the trichomes along the leaf veins and the papillionate form of the epidermal cells.

2.4.4 Leaf elongation and production

Marking experiments have shown that about nine leaves are generally produced per year on South Georgia, with leaves growing to over 50 cm long at all but the most infertile sites (D.W.H. Walton, unpublished data). Elongation is most rapid in the period December to February but some growth occurs as late as April. Death of the leaf tip generally begins before elongation is complete. Several green leaves overwinter, ensuring a rapid start to photosynthesis in spring. Tussac grass can grow at sub-zero temperatures and leaf elongation begins before snow melt. The typical pattern of elongation is shown in Figure 5; rates of elongation of over 10 mm day^{-1} have been measured for young leaves in December and January.

The life of a leaf depends on when it was initiated, and this also affects its final length. A typical leaf spectrum established by measuring the length of each leaf (starting with the youngest at the growing tip) is shown in Figure 6. The troughs correspond to shorter leaves which overwintered soon after emerging and only had a short growth period. The peaks are of the principal summer leaves which emerge in spring and have a long growing season. The retention of dead leaves for long periods allows these long-term patterns of growth to be established from a single harvest. Section 3.5.2 gives similar data for plants in the Falkland Islands.

Analysis of the relationship between the length of mature leaves and their dry weight shows a good predictive model (Figure 7). Thus it is possible to obtain estimates of leaf biomass from different plants and different sites without destructive harvesting. Indeed, Figure 8 demonstrates how the weight of green leaf tissue on a shoot can be calculated for each section from length measurements on the leaves.

2.4.5 Nutrients

Analysis of Tussac grass plants has provided considerable data on inorganic and organic constituents (Walton and Smith, 1980; Pratt and Smith, 1982; Gunn and Walton, 1985). In general, in bird-manured sites Tussac leaves have higher levels of nitrogen and phosphorus than in non-enriched sites. Comparisons between plants from the margin of elephant seal wallows and those from nearby scree slopes showed the fertilized plants contained three times the amount of calcium, nearly twice the amount of magnesium and over twice the amount of phosphorus and nitrogen.

Tussac grass has lower levels of elements in its foliage than many other species but shows the same general trends - total sodium, potassium, phosphorus and nitrogen decreasing through the growing season while calcium and magnesium increase. An earlier trial on South Georgia to assess the effects of soil type and nutrients on the growth of Tussac tillers (Smith, 1985) showed that fertilizer always improved growth (principally by increasing leaf area) and growth was generally better in organic soils than in mineral soils.

Despite the propensity of this species for near-shore sites no final data are available yet to provide an unequivocal assessment of salt tolerance. Initial trials have suggested that the species is tolerant of salt (D. Roberts, ARC unpublished data) but does not require high salt levels for growth. It may be a lack of tolerance on the part of

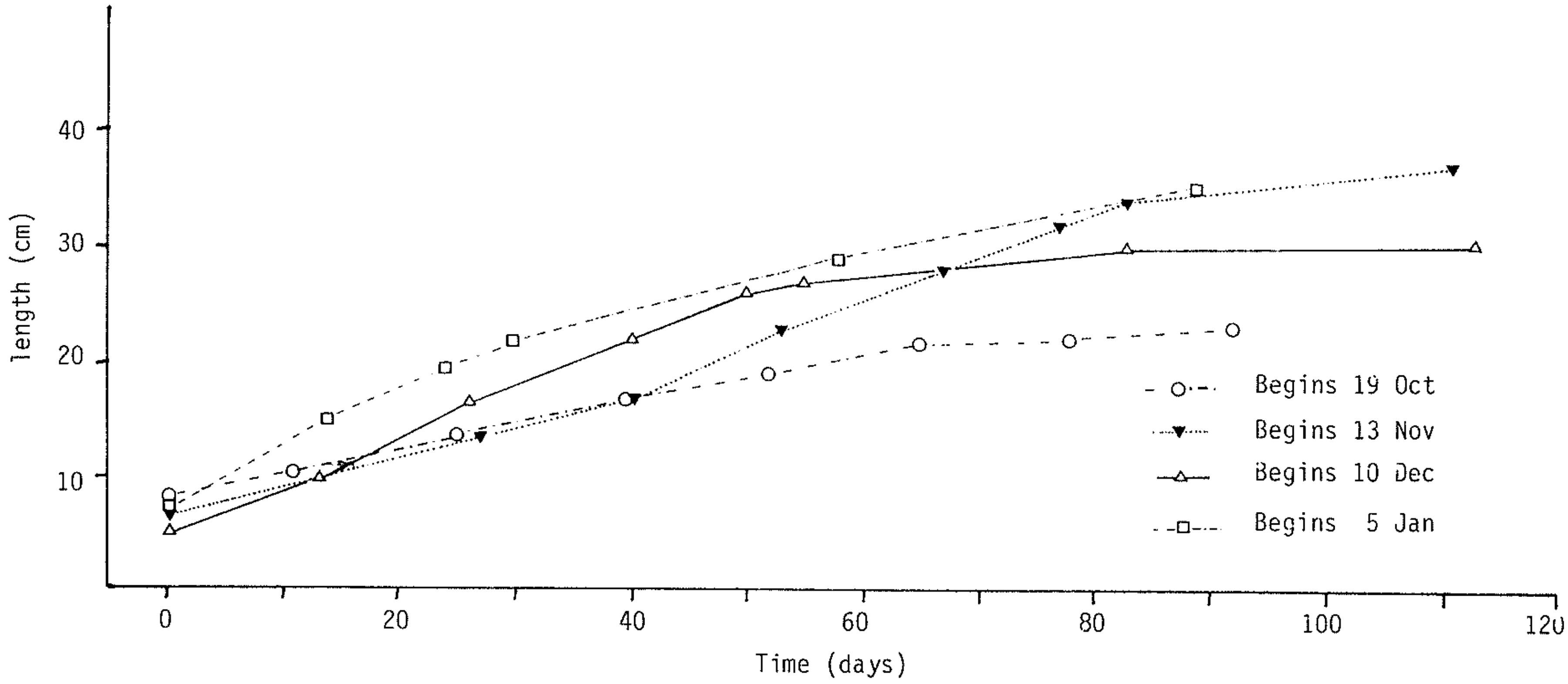


Figure 5. The elongation of sequentially initiated leaves of Tussac grass in Cumberland Bay, South Georgia

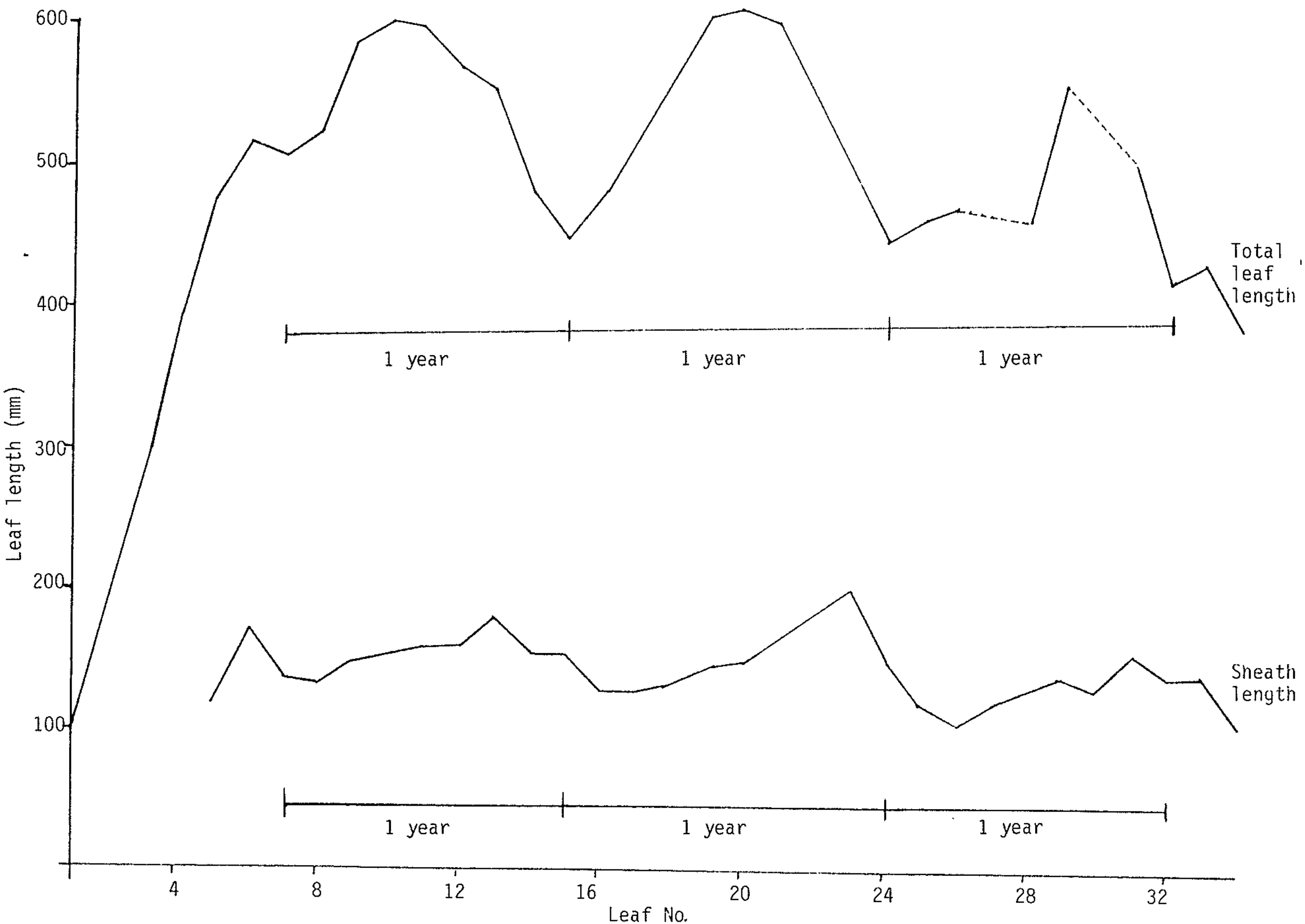


Figure 6. The leaf length (total leaf and sheath) spectrum from a single Tussac grass shoot showing the summer peaks and winter troughs in leaf length.

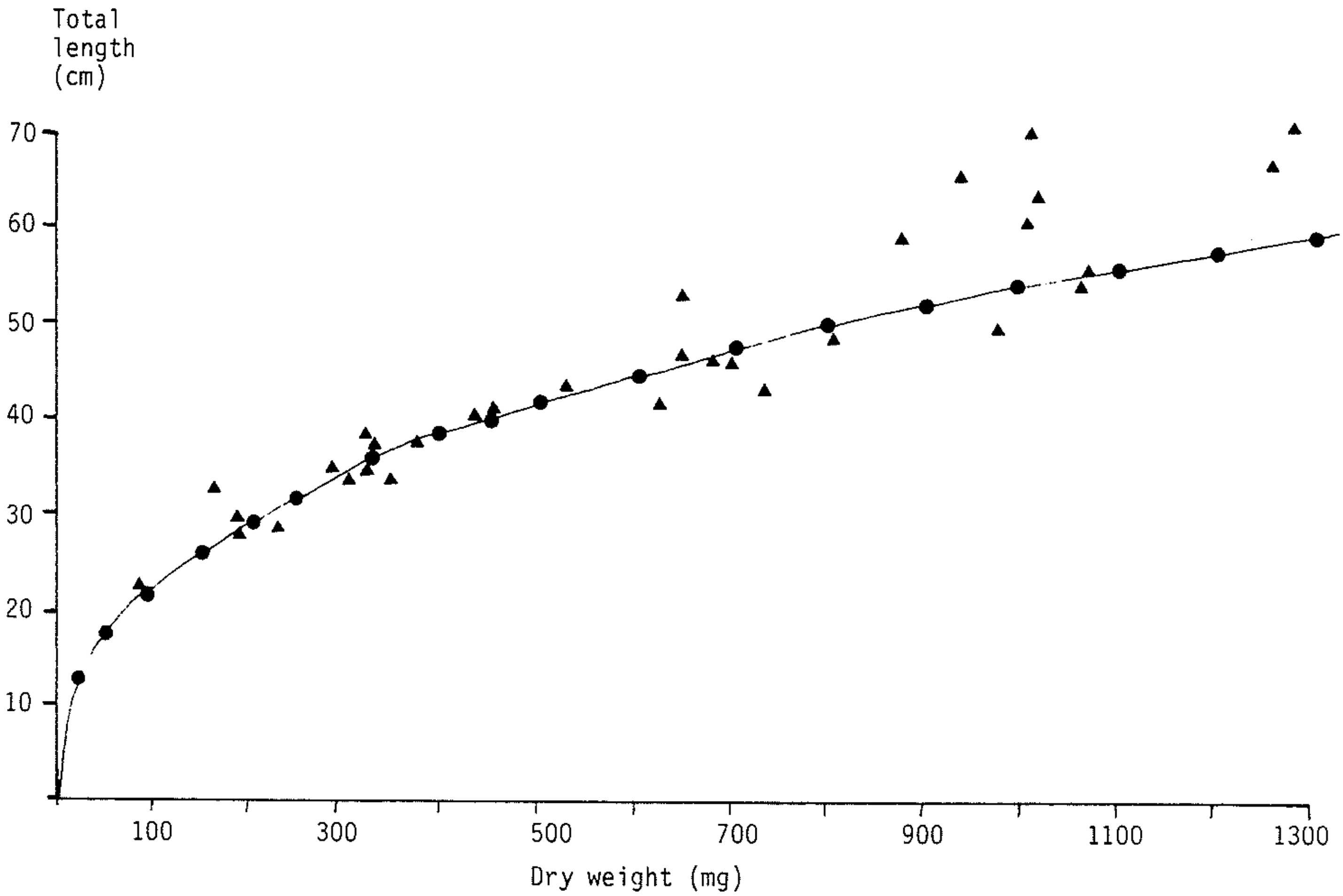


Figure 7. The relationship between leaf length and dry weight for fully expanded leaves of Tussac grass growing at Kind Edward Point, South Georgia.

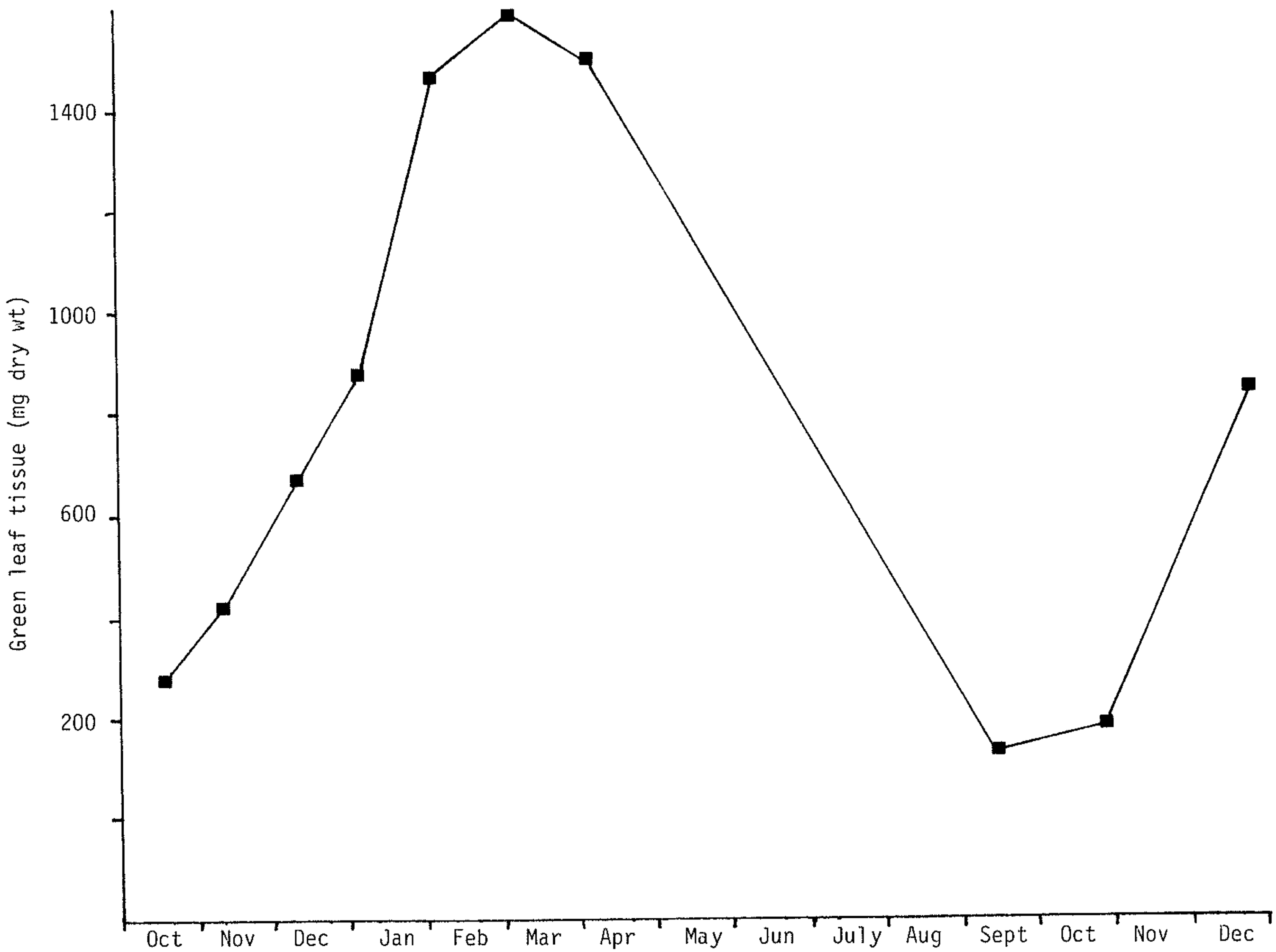


Figure 8. The annual pattern of green leaf tissue per shoot calculated from field leaf length measurements using the relationship established in Fig. 7.

many other species which allows Tussac to establish effectively in coastal sites, rather than any competitive growth ability.

2.4.6 Cytology

Bennet *et al* (1982) determined the chromosome count for South Georgian Tussac during an investigation of DNA content. The population was found to be tetraploid with 2n = 28. Determination of 4C nuclear DNA level gave 10.9 pg, a fairly low value. Bennet *et al* (1982) have suggested that DNA levels probably decrease with decreasing duration or increasing severity of the growing season to allow a species a better chance of reproducing.

2.4.7 Decomposition and fungal flora

The only data on the fungal flora for Tussac leaves has been produced by Hurst, Pugh and Walton, 1983, 1984 and 1985; Hurst and Pugh (1983). *Leptosphaeria* spp., *Mucor hiemalis*, *Penicillium* spp. and *Chrysosporium pannorum* were all identified in a successional pattern but always with a high proportion of unidentifiable sterile mycelia. *Chaetophoma* sp., *Botrytis cinerea*, *Cladosporium* spp., *Alternaria* sp., *Peyronellea* sp., *Acremonium terricola*, *Fusarium lateritium*, *Doratomyces nanus* and *Mortierella* sp. were also found on particular age classes of leaves (Hurst *et al*., 1983). The pattern of succession was related to availability of soluble carbohydrates (Hurst *et al*., 1985), competition with yeasts in spring (Hurst *et al*., 1984) and the water content of the leaf substrate which in turn is related to leaf age.

Studies on the breakdown of dead leaves showed an association between *Mucor hiemalis* and *Chrysosporium pannorum* (Hurst and Pugh, 1983). *Mucor* exploits breakdown products released when *Chrysosporium* enzymes attack the cellulose in the leaves.

2.5 Discussion and summary

South Georgia is an ideal locality for studying both the general ecology of Tussac grass and the effects of grazing. With ungrazed sites ranging from infertile to heavily manured, and grazed sites ranging from light grazing to total destruction of the native vegetation, it is possible to investigate most of the important features controlling production.

The available data suggest that production of established plants is markedly dependent on nutrient input from birds and seals, that standing crop can be very high compared with most grasslands but that it only reaches these levels in limited sites, and that the leaf carbohydrates are highly concentrated at certain times of the year and are extremely palatable to grazers. Grazing changes the shape of the plant, allowing more light in between tussocks and removing the skirt of dead leaves which in turn encourages the growth of competing species.

Tussac grass is a model plant to support reindeer as long as grazing pressure is not too high. Herd size is largely determined by winter feed and Tussac, which protrudes through the snow, is clearly visible and easy to excavate. In spring the Tussac stands can provide valuable protection for newly born calves against bad weather. Under heavy grazing the plant reacts badly. Grazers attack the accumulations of fructans in the leaf bases and meristems which seriously weakens the plant. Recovery of some overgrazed stands is possible if they are fenced but there is no evidence that single species tussac stands will necessarily be formed. Competition from the introduced grass *Poa annua* is a serious problem in the most badly damaged areas.

The plant is well adapted to the subantarctic climatic regime. With leaves up to 1 m long it is essential to have considerable internal strengthening to ensure leaf structure is not destroyed by wind. The anatomical studies show a strong 'girder-like' construction to achieve this. Physiologically the plant can photosynthesise below 0° C and is able to mobilise and translocate carbohydrates very effectively at sub-zero temperatures. Light saturation for photosynthesis is high so that in cloudy regimes the species will certainly not be light limited.

Leaf production per year is less than in the Falkland Islands, probably because of a more restricted growing season. Elongation rates can be high for young leaves, and the structure of the canopy ensures that the microclimate around and within the plant can be very favourable during the summer. Leaves are, by the standards of other grasses, very long-lived providing both a protective skirt for the plant and immediate photosynthetic capability at the end of winter.

The species is attacked by a number of fungi on South Georgia but none of them are seriously pathogenic. Leaf tip dieback normally begins before elongation has been completed. The pattern of fungal succession during decomposition is unremarkable except that the diversity of species appears to be considerably less than would be found in temperate sites. Decomposition of leaf material is slow and appears to be mainly controlled initially by carbohydrate content and then by leaf water content. Individual leaves can take several years to decompose.

The synthesis of all the available data from South Georgia will provide a clear picture of the ecological characteristics of this species. There remain a number of fields in which more data are needed. The methods of mobilisation of carbohydrates at sub-zero temperatures, the detailed structure of the canopy, the more rigorous assessment of root biomass and distribution, and the changes in translocation patterns and carbohydrate pool sizes under grazing all await further study.

3. FALKLAND ISLANDS

Establishment of Tussac grass for agricultural use

3.1 History of attempts at establishment

Early attempts to establish Tussac grass have been reviewed by Walton (1985). The first recorded attempts at establishing Tussac grass in the Falkland Islands and in Scotland using imported material were from seed (Moody, 1943; Scobie, 1949; Linney, 1899 in Walton, 1985). Moody recommended sowing seed in patches where, following thinning, mature Tussacs would develop. He estimated a three year establishment period. Linney (1899 in Walton, 1985) recommended picking out seedlings and transplanting to the final position. There is no evidence that any widespread planting has ever been done using seed or seedlings in this fashion, though where Tussac has been previously abundant, successful natural regeneration from seed can occur on fenced land adjacent to a mature Tussac stand (e.g. as has occurred on Sealion Island). Following successful large scale plantings using vegetative tiller clumps split from mature plants on West Point and Carcass Islands by Arthur Felton and Jason Hansen respectively, all further references to Tussac planting (e.g. Davies, 1939; Davies *et al.*, 1971) assume this technique to be the only one applicable.

Davies (1939) and Davies *et al.* (1971) recommend that fertilizer be applied at planting to aid establishment and Davies *et al.* (1971) stressed the need to control weeds and weed grasses in young plantations. There is ample evidence of plantations failing to establish because of excessive competition from invading species.

Although Tussac planting has been carried out for almost a century there has been no scientific research carried out on aspects of establishment such as seed germination, seedling vigour following germination, size of tiller clump at planting, time of planting, the necessity for fertilizer, site selection, spacing and competition. At present techniques for establishing plantations of Tussac grass are time consuming, resource expensive and success is unpredictable. Clear guidelines are needed to persuade farmers that there is a reasonable chance of a return from any investment made in planting Tussac.

3.2 Factors affecting establishment from tillers

In order to investigate some aspects of Tussac grass establishment from tiller groups, experiments were established at a range of sites during 1985/86. Aspects of seed germination and seedling establishment were investigated under controlled conditions in Northern Ireland and are reported later (Sections 4.1 and 4.2).

3.2.1 Size of tiller group

On the two farms where Tussac is still relatively widely used and planted - Sealion Island and Carcass Island - groups of approximately 6-10 and 12-15 tillers respectively are used by the farmers. Relatively large tiller clumps were probably used originally as an insurance against plant death and to promote more rapid establishment. However, using such a large tiller clump is relatively wasteful of planting material. This is not so important on Sealion or Carcass Islands where there is easy access to a large number of mature Tussacs. Where Tussac grass is being established in a completely new location or where the amount of existing Tussac grass is limited, the difficulty of transportation and the need for conservation of stocks mean that use of smaller tiller clumps must be given more consideration. At Port Howard the effect on establishment of pre-cutting tillers (to reduce bulk and respiration losses), tiller height (to use smaller tillers) and much reduced tiller clumps containing one and three tillers respectively was investigated.

Single tillers (130 cms long) uncut, 3-tillers uncut, 3-tillers cut 'short' (to 35 cm) and 3-tillers cut 'long' (to 55 cm) were planted in November (eight replicate plots per treatment) and received a common fertilizer application (50 kg N ha^{-1}) at planting. The size of the planting units adopted are shown in Table 3. The effect of tiller number and size on establishment and subsequent growth is shown in Table 4.

Overall, plant survival was unaffected by size of planting unit. Tussacs grown from 3-tiller units (cut long) had more tillers and were significantly taller and larger two seasons after planting than from any other tiller group. One-tiller plants were overall significantly smaller than from any of the 3-tiller groups.

It can be concluded from this experiment that the 3-tiller unit is the minimum tiller size which should be used at planting and cutting tillers shorter is deleterious to early growth.

3.2.2 <u>Fertiliser treatment</u>

Imported fertiliser is expensive in the Falkland Islands. In assessing the costs of establishing Tussac it is important to determine whether or not fertiliser application is essential at planting and, if so, what the minimum application might be.

As Tussac grass is found in coastal areas it has generally been assumed that the plant has a requirement for high fertility. Mature Tussac will respond to fertiliser either by increased tiller production (Carter, 1988) or possibly by increased vigour to overcome pest or rust infection (McAdam, 1985). The Grasslands Officer in 1967, while encouraging farmers to plant Tussac grass, recommended that a compound fertiliser be applied at planting (Young, 1967), reiterating earlier recommendations by Scobie (1849) and Davies (1939). None of these recommendations were based on experimental evidence. Within various facets of the present study, a series of experiments were established at different sites to investigate aspects of the effects of fertiliser on establishment of Tussac grass.

In an experiment to investigate the effect of interaction of nitrogen fertiliser, compound (phosphate and potash) fertiliser and chopped seaweed at Port Howard (Table 5) it can be seen that neither fertilisers (nitrogen, phosphate and potash) or seaweed had any lasting effect on establishment and growth of tillers over the two year period following application. Although more plants receiving 80 kg N ha^{-1} survived than those receiving zero or 160 kg N (Table 5a) these plants had smaller tillers than from the other two treatments. Two further experiments were carried out to investigate the effect of six levels of nitrogen at planting (at Port Howard) (Tables 6 and 7) (Plate IV). Where a greater range of fertiliser application was investigated (Tables 6 and 7) on two sites (one coastal and one inland) applied N had no effect on survival of plants, tiller number, plant circumference

Plate IV The inland site at Port Howard with Tussacs planted in rotavated whitegrass camp. The plants in this photograph were planted one year previously as 3-tiller clumps.

and biomass i.e. those factors which could be considered to constitute 'establishment'. The effect of fertiliser nitrogen (applied as an inorganic or an organic source) on establishment and early growth was investigated on Sealion Island in 1986 (Table 8). Fertiliser was applied only at planting and plants were measured through until 1988. The effect of liquid seaweed extract and nitrogen fertiliser was investigated on Keppel Island (Table 9 and Plate V) and seaweed extract and fertiliser were re-applied in the second year as well as the first. A response was detected following this second application. However, during the first year after planting, the initial fertiliser application had no effect on any of the measured parameters. It can be generally concluded that in the two other experiments where organic and inorganic sources of N were applied, establishment was unaffected by either source.

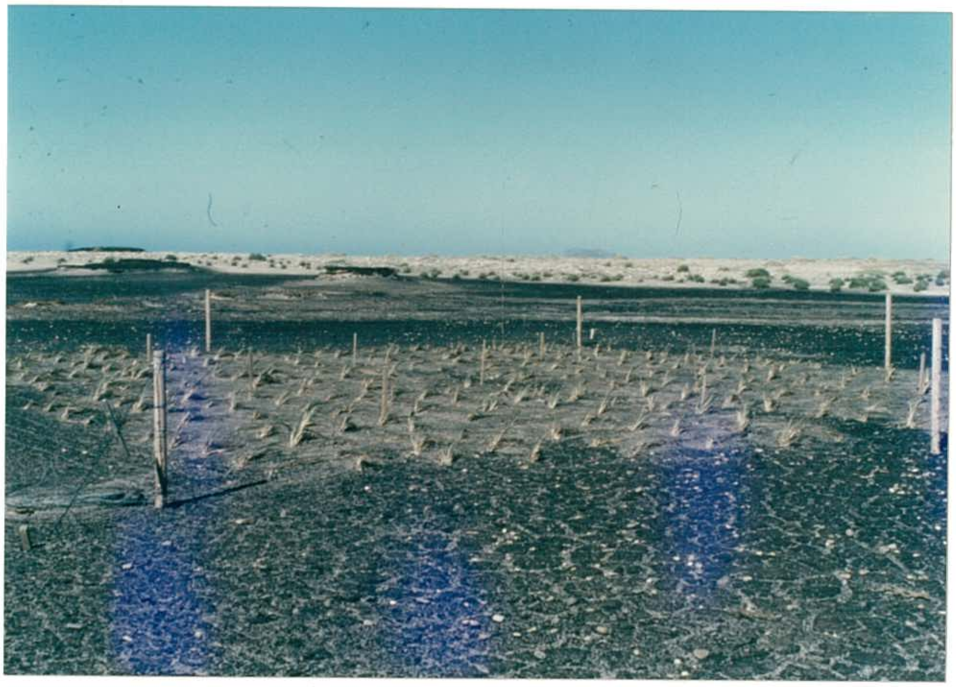
It must be concluded from the range of trials carried out on widely different sites that fertiliser, in whatever form and applied up to what must be considered a substantial level of application, has no effect on Tussac grass establishment.

3.2.3 <u>Weed control and planting density</u>

Tussac tiller clumps have been traditionally planted 1-2 m apart on a square grid. On Sealion Island, T. and D. Clifton have planted 'guard' rows of tiller clumps from mature plants at 0.67 m spacings in approximately 20 m square blocks (Plate VI). Within these blocks tiller clumps from young Tussac grass plants are planted at 2 m spacings. In well developed, mature, natural stands the spacing is probably more than this. Strange (Strange *et al*., 1988) reports plants with an estimated pedestal diameter of 2m on Beauchêne Island. This is probably exceptional but in most mature stands plant density will be such as to create a closed canopy. The spacing at planting is therefore relatively unimportant, its only effect being to influence the time taken to reach canopy closure. In situations where Tussac is being planted into previously cultivated grassland, competition with other plants, particularly grasses, is likely to be a problem during establishment. A closer spacing at planting may help to overcome this competition although this will need to be balanced against increases in both the quantity of planting material required and the effort needed if spacing is reduced. Extensive planting at Port Howard (1.6 m spacing) in the late 1970's was deemed to have failed because of competition from other grasses, mainly Yorkshire fog.

An experiment was laid down in 1986 to investigate the effect of spacing, with no subsequent weed control. Planting was in early summer 0.25 - 1.5 m apart in plots on an area which, prior to rotary cultivation, was dominated by Yorkshire fog.

Even by the end of the first season, the Yorkshire fog had regained dominance and the Tussac plants were completely overgrown. Within two years the whole site was covered with a dense crop of Yorkshire fog interspersed with surviving Tussac grass plants and assessments were neither feasible nor possible. Contrary to accounts from elsewhere, the Tussac was not killed by the rampant growth of the Yorkshire fog. The stand was cut for a successful crop of Tussac grass/Yorkshire fog hay in 1988. Recovery of the Tussac grass was poor and by 1989 few plants were still living. The trial illustrated the need to control competition from other grasses in previously cultivated sites. Dense planting alone does not improve the situation and is too wasteful of



a. One year after planting - note the poor condition of the plants.

b. Three years after planting - note the remarkable recovery and healthy plants on this extremely infertile site.

Plate V Trial on burnt, eroded peat, Keppel Island.

Plate VI Two types of tiller clumps used for planting on Sealion Island - close-planted rows of clumps split from large, mature plants to act as windbreaks and wider planting of clumps split from young (1 or 2 year old) Tussacs.

planting material. In some of the work carried out in N Ireland, closer spacings were used, and a close-knit 'sward' created from seedlings (see 4.3.2).

It is felt that the derivation of a theoretically 'correct' spacing for planting Tussac does not warrant further high-priority research. Current advice would be that the spacing adopted should largely be for practical reasons i.e. limited by the quantity of propagating material available, inter-row cultivation or spraying treatments etc. In situations where competition is likely to be a problem, positive control of the competing species will have to be taken. As areas of Tussac to be planted are likely to be relatively small it would be best to avoid planting into sites of previously sown grassland. On Sealion Island no competition is found when planting into 'Tussac' peat.

3.3 Site comparisons

To obtain some measure of the variability in growth of Tussac grass during the establishment phase, a comparison of data from the various experimental sites used in the trials in the Falkland Islands was carried out. The same size of planting unit (3-tiller) was used on all sites enabling at least zero fertiliser comparisons to be made and on the inland and coastal sites at Port Howard, fertiliser treatments were replicated.

3.3.1 Inland and coastal

The data from the Tussac fertiliser experiments detailed in section 3.2.2 were re-analysed for between-site differences. Although more fertiliser treatments were used on the coastal site than the inland site, the planting stock all had a common origin (Narrows Island) and similar size classes and planting dates were used for both sites. The 0, 120, 240 and 360 kg N ha^{-1} equivalent rates of fertiliser application were common to both sites. A comparison of growth at both sites for a range of measured parameters in January 1987, April 1987 and January 1989 is presented in Table 10. As the effect of fertiliser was generally not significant on either site, results are presented as means over all fertiliser treatments.

Up until April 1987, plant survival was better at the inland site than at the coastal site though by January 1989 survival had decreased on both sites, the decrease being greater on the inland site. This was largely due to the early presence of insect pests and drier conditions at the coastal site than at the inland site. Almost all plants killed at the coastal site were infected with a stem-boring weevil (Carter, 1988). Infection was slower to build up on the inland site, but by 1989 the level of infestation was high. Plants were significantly taller but had fewer tillers and hence lower circumference on the inland site than the coastal site. The larger number of smaller tillers on the coastal site did not compensate for the greater tiller size on the inland site and plants were smaller, at harvest, on the coastal site. Whether lower growing plants with a larger number of tillers are more desirable than plants with fewer larger tillers has yet to be determined though some of the controlled environment research on seedling vigour carried out later in Northern Ireland provides some analysis of this issue and will be discussed later (4.2.3). As the inland site (Plate IV) was previously a wet, whitegrass-dominant site and had minimal ground preparation whilst the coastal site was previously cultivated and fertilised, it is clear that this comparison further confirms the findings of the fertiliser trials i.e. site fertility as well as fertiliser application is unimportant for establishment. Other non-fertility related factors such as soil moisture and pest susceptibility may play a more important role.

3.3.2 Port Howard, Keppel Island and Sealion Island

Although time of planting, type and level of fertiliser application and source of planting material were different on all sites, size of planting unit used (3-tillers) and measurements taken were similar from the experiments at Port Howard (2 sites), Sealion Island and Keppel Island. As a zero fertiliser (control) treatment was common to all sites it is worth comparing between site differences for this treatment for plant height, basal circumference and tiller number (January 1987). Comparisons are available for 1987, 1988 and 1989 for the two island sites and are also presented (Table 11).

Best establishment and early growth was recorded from plants growing in Tussac peat on the site for the fertiliser trial on Sealion Island, and worst early growth (by 1987) on the eroded, long previously-burnt (in 1856?) site on Keppel Island (Plate V). Differences between 1987, 1988 and 1989 on these sites were substantial and these have already been commented on in the appropriate section. Although measurements were not taken at Port Howard in 1988, plants appeared similar to or worse than they were in 1987 so the same spurt of growth as recorded on the other two sites did not occur.

In 1989, 3 years after planting, it is clear that on the previously cultivated field (control) and the inland whitegrass site, both at Port Howard, Tussac grass has not established well and plants are struggling to survive. In contrast, on the two island sites, all plants are now approximately 1 m in basal circumference and 1.5 m tall.

Both island sites were largely unaffected by pests and this may contribute to the marked growth increase on these sites which was not recorded at Port Howard. These sites were also autumn planted whereas those at Port Howard were planted in the spring and this may contribute to the observed differences. To confirm the importance of this observation, a group of plants not used in the Port Howard experiments were planted in April on a wet, coastal, but previously cultivated site. These plants have grown substantially better than on any of the experimental sites at Port Howard and in January 1989 had a mean basal diameter of 970 mm and height of 1240 mm, i.e. comparable to the two island sites.

It can be concluded that there is considerable variation in rate of establishment over a broad range of sites in the Falkland Islands. This variation is largely attributable to site fertility and moisture, though external factors such as insect pest attack and competition from invading plant species may play an important role.

3.4 Disorders of Tussac grass

3.4.1 Rust disease

In certain years the leaves of Tussac grass become infected with a rust fungus (*Puccinia striiformis*) which can weaken plants considerably by reducing photosynthetic leaf area (McAdam, 1985; Walton, 1985) (Plate VIIa). The damage caused is invariably more severe on seedlings and establishing plants than mature plants though, in itself, the

a. A Tussac plant with the 'oily' brown appearance caused by a high level of rust infection.

b. Typical symptoms of insect pest damage. The plant on the left had a high infestation of stem boring weevils compared to the plant on the right.

Plate VII Disorders of Tussac grass

fungus is likely to be lethal only to young seedlings. If rust infection is accompanied by serious insect attack however, death may occur. It has been estimated that during a season when rust attack is particularly severe, the grazing potential of Tussac can be reduced by 50% (T. Clifton, personal communication) and stock reductions since the appearance of rust on Carcass Island and Sealion Island support this figure.

Rust disease almost certainly arrived in the Falkland Islands as wind-borne spores from the South American mainland in the late 1960's (Gennard and McAdam, 1985).

Little is known about the biology of this rust species on Tussac grass. Since this is a disease which affects major cereal crops, it is of considerable economic importance and fungicides have been developed which can effectively control the disease. Studies of the same fungus on wheat have shown that a mild winter, cool moist spring and high nitrogen application favour growth of the fungus whereas hot, dry spells and high phosphate and potash levels mitigate against it.

The organic, systemic fungicide TILT (Ciba Geigy Ltd) sprayed early in the summer or when the first signs of infection are visible has given moderate control on rust-infected Tussac grass grown in Northern Ireland (McAdam, 1985).

Even if conventional rust control by fungicide spray may be impractical for larger stands and, for economic and ecological reasons, is probably inadvisable in the Falkland Islands, it is important that measures to control rust have been adequately researched. If rust poses a serious threat to young establishing plantations information on prophyllactic measures involving the use of fungicides should be available, as such measures may be acceptable on a one-off basis to ensure future survival of the plantation. An experiment was carried out on Sealion Island to investigate the control of rust disease on Tussac grass using a range of proprietary cereal fungicides. In a fully randomised and replicated trial the following six spray treatments were investigated.

1. TILT applied on 1 December
2. TILT applied on 1 December and 1 January
3. TILT applied on 1 December, 1 January, 1 February
4. BAYFIDON applied on 1 December
5. CORBEL applied on 1 December
6. WATER spray (control)

In each case plants were sprayed for approximately 30 seconds using a knapsack sprayer. Each time tussocks were sprayed, random samples were taken (on 1 December, 1 January, 1 February and 1 March) deep frozen and analysed later in UK for degree of rust infection. The results are presented in Table 12.

Treatment with CORBEL on 1 December was ineffective compared with other fungicides in controlling subsequent rust infection. Of the other two fungicides applied as a single dose in December BAYFIDON gave the best control. Although both TILT and BAYFIDON gave satisfactory control up until 1 February, the BAYFIDON treatment persisted longer and gave adequate control through the summer whereas TILT control seemed to break down and there was a late flush of infection recorded. Where TILT had been applied later, this problem was overcome and satisfactory control of rust was obtained by two or three applications of TILT over the season. As would be expected, control of rust following three TILT applications was significantly better than for any other treatment tested. It appears that the effective period of action of TILT may be just too short for one whole season and unless the fungicide spraying was left until January, adequate control cannot be expected. There is no evidence that a cumulative dosage effect was not operating and a January-only TILT application would have tested this theory.

In conclusion, rust can be a serious problem on Tussac grass but, if the situation is such that fungicidal control of the disease is desired, then satisfactory control can be achieved using conventional cereal herbicides. If the rust outbreak is early in the season, there is evidence that one application of BAYFIDON will give control for the rest of the season. If TILT is used, unless it is sprayed on after mid-summer, a second application must be used for adequate control. It is recommended that the fungicide BAYFIDON be tried more extensively in preference to TILT as a single application fungicide. As was stressed earlier, the application of fungicide may not be economically or ecologically acceptable in a range of situations.

3.4.2 Pests (A.O. Carter)

During the course of investigations into the agricultural potential of Tussac grass, it has become clear that the larva of a beetle, (*Coleoptera: Salpingidae), Poophylax falklandica* (Champion), is probably the most important pest of the crop.

Current knowledge on and agricultural significance of pests of Tussac grass will be reviewed in this section and a report of an assessment of the effect of pests presented. Gunn (1974) cites Yellow Rust (*Puccinia striiformis*) and three insect species as the principal pests of the grass. Of these insects, one is considered the 'major pest': Gunn suggests that *P. falklandica* "is most probably responsible for the total destruction of areas of Tussac, as visited on Beef Island, New Island and the larger areas seen aerially on Staats Island and the nearby areas".

The larvae of *P. falklandica* are well protected within the leaf bases and never visible on the exterior of the plant. They have been found in a surprisingly large proportion of Tussac plants in the Falkland Islands. By the time symptoms of larval infestation are visible, internal damage is generally at a very serious level. Larvae appear to be active throughout the year, and tend to be found mainly on established plants. Insect damage probably only kills plants stressed by another factor (such as by an infestation of rust).

An infested plant appears a dull green colour at first, and later seems unusally yellow, with an abnormal number of tillers showing early senescence of the mature leaves (Plate VIIb). A large number of leaves may have holes in them caused by larvae boring through the young leaves prior to their emergence. Eventually dead leaves, severed close to their base, will become evident. Ultimately, the tiller dies when the meristem (with its high concentration of sugars) are reached by a larvae.

The yellow/bronze coloured, black-eyed beetles are c. 6-8 mm in length. Observations on the life cycle of the species suggest that adults emerge in large numbers in late September/early October to mate and lay eggs, though the first live adults recorded in the year have been found at tiller base level in early August. They seem to be attracted to the flower heads of Tussac grass, feeding on pollen. This might be illustrated by the following observation, made in January 1988. Two adjacent plants were seen, one of which was cut during the winter of 1987, and fertilised early in the following spring, the other was left uncut but was fertilised. The situation in summer was that the cut plant, on which regrowth was strong and flower heads short and protected by leafy tillers, was apparently uninfested by stem-borers, whilst the other plant was clearly weakened. It is possible that this disparity may have arisen because its flowers, held clear of the leaves on the longer stems, could have attracted insects more easily. Adults have not been found alive at other times of the year, though dead beetles have been discovered frequently among the dead material around the base of live tillers.

Eggs of an insect species, possibly *P. falklandica*, have been found in large batches amongst the dead leaf sheaths of a plant. The sheaths have not required any peeling back from the next leaf, and the ova are relatively exposed at plant surface level, though protected to an extent by the cover of live tillers. These were found in early November on second year plants established from transplanted tillers. Eggs have also been found loosely protected behind the curling edges of recently dead leaf sheaths. No eggs have been located behind live leaf sheaths, as found in the case of some other stem-boring insects.

Larvae of various sizes are found throughout the year, and only in live or very recently dead leaf sheaths. It is here that the plant stores its carbohydrates. Larvae range in size from 2-10 mm, and are a cream-coloured 'fish-tailed' grub, fairly flat in cross-section. They feed principally within tunnels within the older leaf sheaths, though occasionally have been found in the unemerged leaves. Tunnelling between sheaths is uncommon, though not unknown, and appears to be restricted to cases where large numbers of larvae feed on the same tiller. A large proportion of tillers seem to have some level of infestation, though in a vigorously growing plant, the activities of these sheath-miners in the older outer leaves seems to be insignificant. When infestations are high, or the plant has small carbohydrate reserves, larvae are more likely to be able to get to the greater concentration of nutrients at the meristem. It is this feeding at or around the growing point of the plant that constitutes the most serious aspect of stem-borer activity.

Preliminary investigations (Table 13)

1. In November 1987 a batch of 63 tillers were removed from a number of unfertilised plants. These were dissected in the ARC laboratory at Fox Bay Village, and the presence of any larvae was noted. The larvae found were all of the species *Poophylax falklandica*, identified as such by the British Museum, Natural History.

Daughter tillers were taken to be very young vegetative tillers, associated with green or recently dead leaves on the parent. Vegetative tillers were older and fully established. Healthy tillers had no sign of insect activity, whilst unhealthy covers a variety of symptoms, from very chlorotic, to dying or recently dead. The columns headed 'Damaged' contain data on the number of tillers or the percentage of the total number of tillers showing some signs of damage when dissected. The nature of the damage ranged from sheath mining to stem-boring. Larvae were found in all parts of the leaf bases, usually in ones and twos, though rarely feeding close together. In the case of less vigorous tillers, as many as five or six larvae of varying sizes were found on one tiller. A high proportion of vegetative tillers were infested and, of the unhealthy tillers, 70% are daughter tillers, often dying through the demise of the parent tiller. This latter point illustrates how stem-borers can be an indirect cause of death.

Another survey, at the same plantation, found 16 out of 20 tillers were infested to some degree. This sample covered a cross-section of fertilised and unfertilised, healthy and unhealthy plants.

2. The leaf cycle analysis of Tussac grass carried out during 1986/7 produced further information on the nature and effect of *P. falklandica* damage. Of the thirty tillers marked at the start of the study, eight died in the first 16 months through insect damage. These tillers represented 7 of the 15 plants included in the study. Damage varied from heavy sheath mining to growing point predation. Symptoms included young leaves being severed close to their bases, numerous holes in newly emerging leaves and early senescence of older leaves. Daughter tillers of affected tillers were particularly susceptible to damage, and a number of these were also killed. As part of the leaf cycle analysis, a number of tillers were dissected, and their unbroken leaves (live, dead and unemerged) measured. Figure 9 shows two of these leaf length curves. Tiller A demonstrates a normal curve, showing the winter dip in leaf length, and the increase in tiller size over time is shown by the most recent season's longest leaf (left hand peak) being taller than the previous season. Tiller B had a larva feeding inside leaf 1 (which has yet to emerge) - which suppressed the current season's growth.

The effect of stem-borer infestation is chronic, and a large proportion of tillers on individual plants in a plantation can be affected. If tillers are subjected to stress, eg, nutrient deficiency, grazing or rust, the problem can become acute, as the plant utilises more of its own reserves, thereby competing with the pest. Plants may only be killed by rust when the attack is accompanied by a pest infestation, the insect being the agent causing the death of the plant. As a corollary, removal of the pest may indirectly greatly reduce the various disorders suffered by the plant. For example, it seems probable that **Rust + Insects = Death**, whereas **Rust - Insects = A Problem** (which might be overcome through changes in management policy or the use of fertiliser).

The effect of stem-borer infestation on productivity is illustrated by Figure 9. Damage scoring and further destructive sampling (including larval counts) would also help to describe the problem. A closer investigation of the life cycle of the insect might provide guidance in the formulation of a control programme. Concurrent sampling and monitoring should be carried out on sites with different management and nutrient regimes in order to compare stem-borer environments. Any experiments designed to look at aspects of Tussac establishment and utilisation should also closely monitor insect pest status. There may be a set of management guidelines within which the pest cannot thrive, or a particular site, establishment technique or fertiliser regime which may result in a significant reduction in the pest populations.

3.5 Growth and development

Management of mature stands of Tussac grass (either planted or natural) has been poorly researched. However, it is historically established

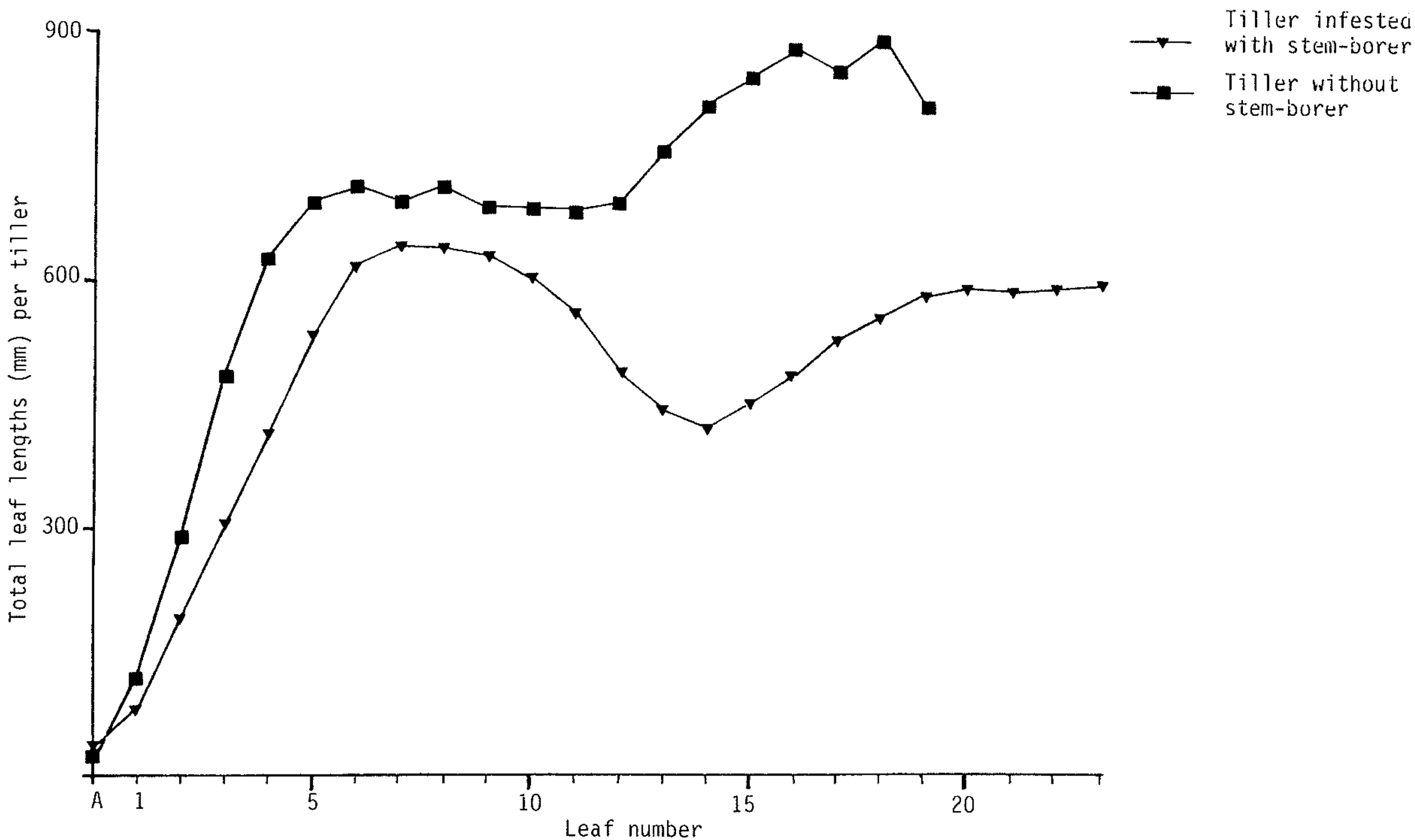


Figure 9. An assessment of the effect of stem-borer infestation on the growth of Tussac grass leaves.

that Tussac grass should only be grazed during the winter and its demise has been attributable in many instances to uncontrolled, year round grazing. On Sealion Island, individual Tussac plantations are grazed in late and early winter on a rotational basis to allow maximum recovery time. It is not clear when Tussac should be first grazed after planting, 3-5 years being commonly practised. No farms regularly apply fertiliser to Tussac grass stands, though obviously the interactions of grazing and fertiliser in relation to plant recovery following grazing and future winter standing crop are important issues. Most of the management guidelines have been derived on an *ad hoc* basis and a basic understanding of the principles of management of Tussac grass will only be possible when the annual vegetative growth cycle of the plant is understood. In this section, two experiments are reported which attempt to redress this situation and to produce information on which to base management decisions.

3.5.1 Response to fertilisers (A.O. Carter)

An experiment was conducted to investigate the effects of fertiliser on ungrazed Tussac grass growing in a nutrient poor soil.

Plants (3 replicates of 18 per plot) received either zero fertiliser, nitrochalk at an equivalent rate of 120 kg N ha^{-1} and a compound fertiliser at an equivalent rate of 120 kg N, 23 kg P and 72 kg K ha^{-1}. The plant population was estimated at about 17500 plants ha^{-1}.

Where a pedestal supported more than one discrete clump of tillers, each was treated as a 'plant' for the purposes of this investigation, as it has been shown that translocation of nutrients between tillers only takes place across very short distances - ie, Tussac grass is only weakly rhizomatous (A.J. Emmonds, personal communication). All samples were cut to within 50 mm of the tussock surface, using hand shears or a sharp knife.

Fertiliser was applied in October (1986) to untreated plants and plants harvested in mid-July 1987. Herbage yield and quality was assessed from this sample date. Yield was assessed by comparison with untreated control plants.

Results

The effect of fertiliser treatment on proportion of green matter and DM production is shown in Table 14.

Fertiliser increased the amount and proportion of green matter in Tussac grass plants.

Organic matter digestibility of the herbage was unaffected by fertiliser application (Table 15).

Table 16 shows the standing crop and digestible standing crop estimates for Tussac grass in midwinter (kg DM ha^{-1}). Three sets of estimates are recorded and these were derived as follows:

"Live Dry Weight": The mean dry weight of the green matter separated from each plant, multiplied by 17500 (and the digestibility estimate for the treatment).

"% Live/Total DWt": The mean total dry weight of plants from each treatment, multiplied by 17500, and divided by the mean percentage of the dry matter that was green. (The digestibility was then taken into consideration).

"Mean Tiller Weights": The mean number of live tillers/plant multiplied by the mean weight of those tillers, multiplied by 17,500 (and the digestibility).

The results indicate that fertiliser applied to mature Tussac grass plants will double the standing crop, by increasing mean tiller weight and live tiller number.

This response was significantly greater on plants fertilised using a compound fertiliser than on those using straight nitrogen. Tiller weight was not significantly affected by nitrogen. There was no significant difference in the total dry weight of the plants, though the proportion of live matter was significantly greater when fertiliser was applied.

Applying fertiliser to an established, though "unhealthy", mature Tussac grass plant increased the proportion of live DM by increasing the number of live tillers. This could be attributed to greater numbers of daughter tillers being produced, or to more rapid senescence of those tillers that were produced on unfertilised plants.

Compound fertiliser produced a larger individual tiller unit than either straight N fertiliser or no fertiliser application; this may be attributable to the production of more and/or bigger and more persistent leaves when P and K are applied. The apparent advantage of compound fertiliser must be weighed against the fact that twice the bulk of fertiliser was added to each plant in order to achieve comparable N applications.

The digestibility figures were obtained using the *in vitro* digestibility technique in the ARC Stanley laboratory and correspond well to the values obtained at the Department of Agriculture for Northern Ireland's laboratory in Belfast using the MAD fibre technique.

The standing crop available from an unfertilised stand in midwinter was approximately 400-500 kg DM ha^{-1}. This was increased by a factor of 2-3 by the application of fertiliser. These figures compare to an estimate of *c*. 1300 kg DM ha^{-1} at the same time of year derived from another Tussac grass trial which was carried out in an adjacent area of the same plantation. The higher value was attained by multiplying numbers of live tillers per plant by the estimated fresh weight of measured tillers. Neither figure is any more than an estimate of the standing crop. Without more data on plant sizes harvested from a range of plantations, it is difficult to make precise statements about the available standing crop. It is more likely that the overwinter standing herbage is at the upper end of the range 400-1300 kg DM ha^{-1} as more reliable estimates were made from the second trial.

3.5.2 Leaf production (A.O. Carter)

Introduction

A leaf cycle analysis (LCA) of Tussac grass was carried out on the same site as the fertiliser response trial (3.5.1). The study encompassed a number of components, including a series of samples for nutritional analysis, and was aimed at producing a set of data from which several agronomic factors could be determined or estimated.

The plantation consists of a mixture of self-seeded and planted Tussacs. The latter were established from transplanted seedlings. Although it has no resident wildlife, is not grazed, and receives little artificial manure, the plantation continues to thrive, albeit in a relatively nutrient deficient condition.

The analysis was carried out between September 1986 and December 1987 to provide baseline data on the growth of an ungrazed, unfertilised, mature stand of Tussac grass in the Falkland Islands.

Methods

An unfertilised section of the stand was chosen, and thirty tillers (two each on fifteen plants) were marked rings. These tillers were re-measured on a regular basis throughout the year (fortnightly, and monthly during the winter months).

To estimate the standing crop by non-destructive means, the leaf length:dry weight ratio was calculated from 250 leaves off 50 tillers collected in December 1986.

The relationship was then used to derive the standing crop estimates in this study. Tiller and plant density were calculated from 40 plants and from 5 five m^2 quadrats within the area.

In March 1987 twenty tillers were taken from plants adjacent to those being regularly measured. These were chosen from the centres of a number of reasonably sheltered tussocks, and as much dead material was retained with each tiller as possible. Following dissection the total lengths of all the leaves (emerged and unemerged) were then measured and plotted as leaf number/length profiles.

To carry out the LCA, the leaf lengths of 28 tillers (plus daughter tillers) were measured over a 12 month period. The length data were converted to weights using the formula calculated earlier. At monthly intervals samples were analysed (Food & Agric Chem Division, DANI, Belfast) for crude protein and MAD fibre.

Results

The relationship between leaf dry weight and length was calculated as

Log.Dry weight = -5.50 + (1.93 x Log.leaf length)

Mean tiller number per plant was 66 and mean plant density was estimated at 17500 ha^{-1}.

Figure 10 shows the total lengths of all leaves from the smallest unemerged leaf to the oldest undamaged leaf, which was produced during the spring of 1985. There were, on average, four unemerged leaves, which included two small white leaves only a few millimetres in length. Research in South Georgia by the British Antarctic Survey suggested that there are another two leaves to be taken into account that were not revealed by this study, as a microscopic dissection was not undertaken. The decrease in leaf lengths represents the winter period

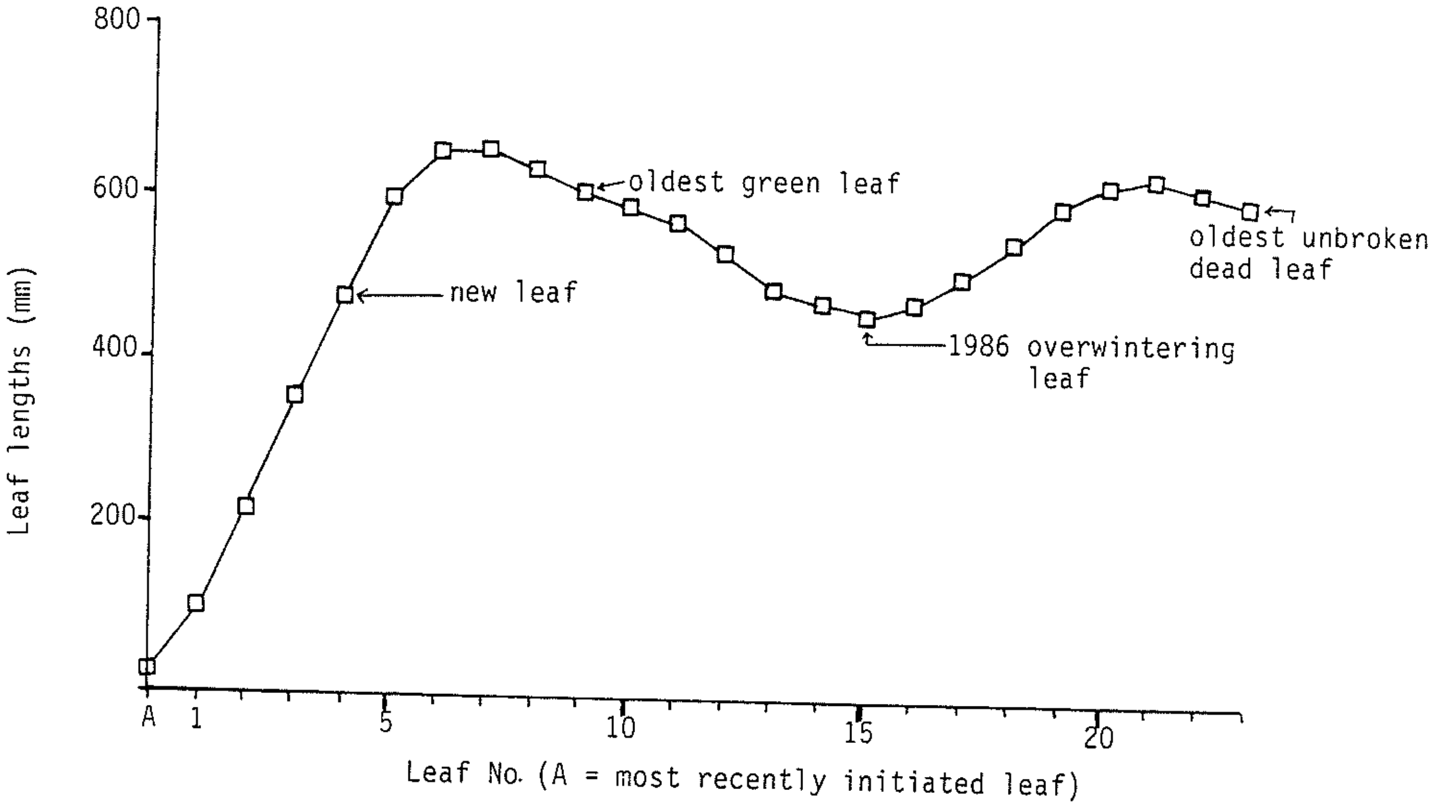


Figure 10. The total length of all leaves on a Tussac grass tiller over two years.

and, assuming no more leaves are to be initiated this season, it can be estimated that 12-14 leaves are produced annually.

A sample of daughter tillers produced during the summer of 1986 are plotted in Figure 11. Tiller B is apparently younger than tiller C, having produced only two leaves before the smaller winter leaf emerged.

The seasonal change in total and digestible standing crop is shown in Figure 12. The OMD of the green matter remained constant (0.65-0.70) over the whole season.

Crude protein levels may be lower in summer than the 9-10% recorded for the winter months (Figure 13), though these figures are derived from single samples taken from the same area every month.

The estimated green dry matter during the year September 1986-September 1987, of a healthy tiller which produced daughter tillers is shown in Figure 14. Each point on the graph represents the estimated dry weight of the whole of the green fraction of the live tiller on a particular measuring occasion. The curve does not include the estimated dry weights of the daughter tillers produced. Three daughters were produced by this tiller - two emerging in early January and a third in March. The diversion of photosynthate into vegetative reproduction is demonstrated by the two 'troughs' on the dry matter curve. Note also the winter 'dip' and the rapid growth of the tiller in the second spring (1987). This curve of estimated dry matter corresponds well to that shown in Figure 10.

The winter 'dip' in total leaf length illustrated in Figure 10 is attributable to the production of shorter leaves during this period, and also to there being fewer leaves present on the tiller. On average, healthy tillers had five to seven green leaves at any one time (Table 17).

Of the thirty tillers that were marked at the start of the measurement period only sixteen survived as healthy tillers into the next season. Eight tillers had died by September 1987, and a dissection of these established that the death of five of them could be attributed directly to insect damage (See Section 3.4.2).

Daughter tiller production occurred between the end of November and the latter half of March (Figure 15). The emergence and expansion of daughter tillers led to the maintenance of the peak standing crop attained in January, through until April. In Figure 17 data shown in Figure 16 is added to the estimated dry weights of the daughter tillers produced by those tillers. These graphs also illustrate the importance of vegetative reproduction in the stand: when the daughter tillers are included the September 1987 standing crop is greater than that of September 1986, whereas individual tiller performance shows a decline in green biomass. This is a similar situation to the overall picture shown in Figure 12 and could reflect the effect of a particularly cold winter (temperatures dropped to an unusually cold -12° C at Fox Bay during mid-July 1987) on the numbers of leaves and daughter tillers present at the beginning of the second spring. It may however, be a reflection of the low soil fertility.

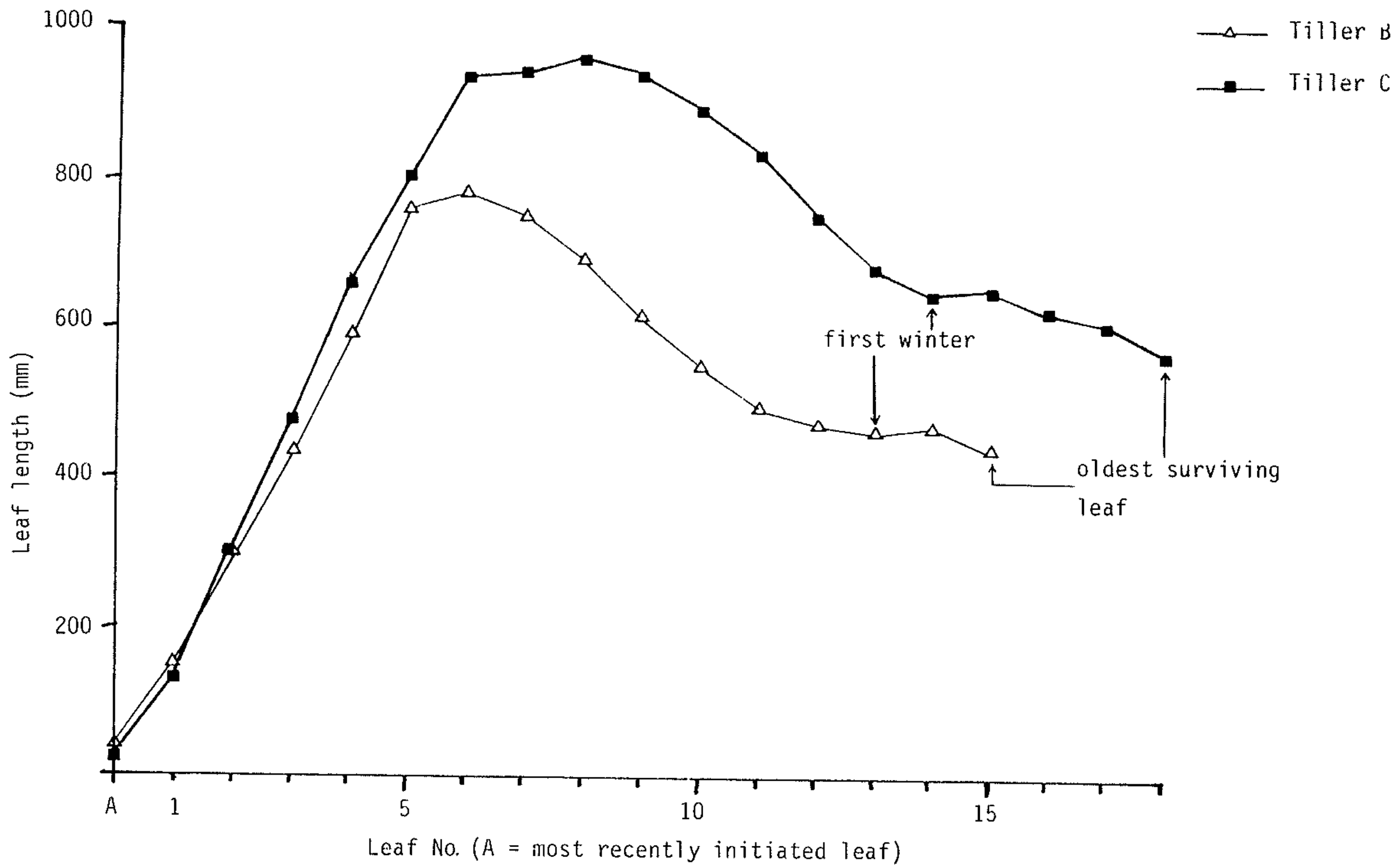


Figure 11. Mean total leaf length of two daughter tillers produced on one Tussac grass plant during the summer of 1986.

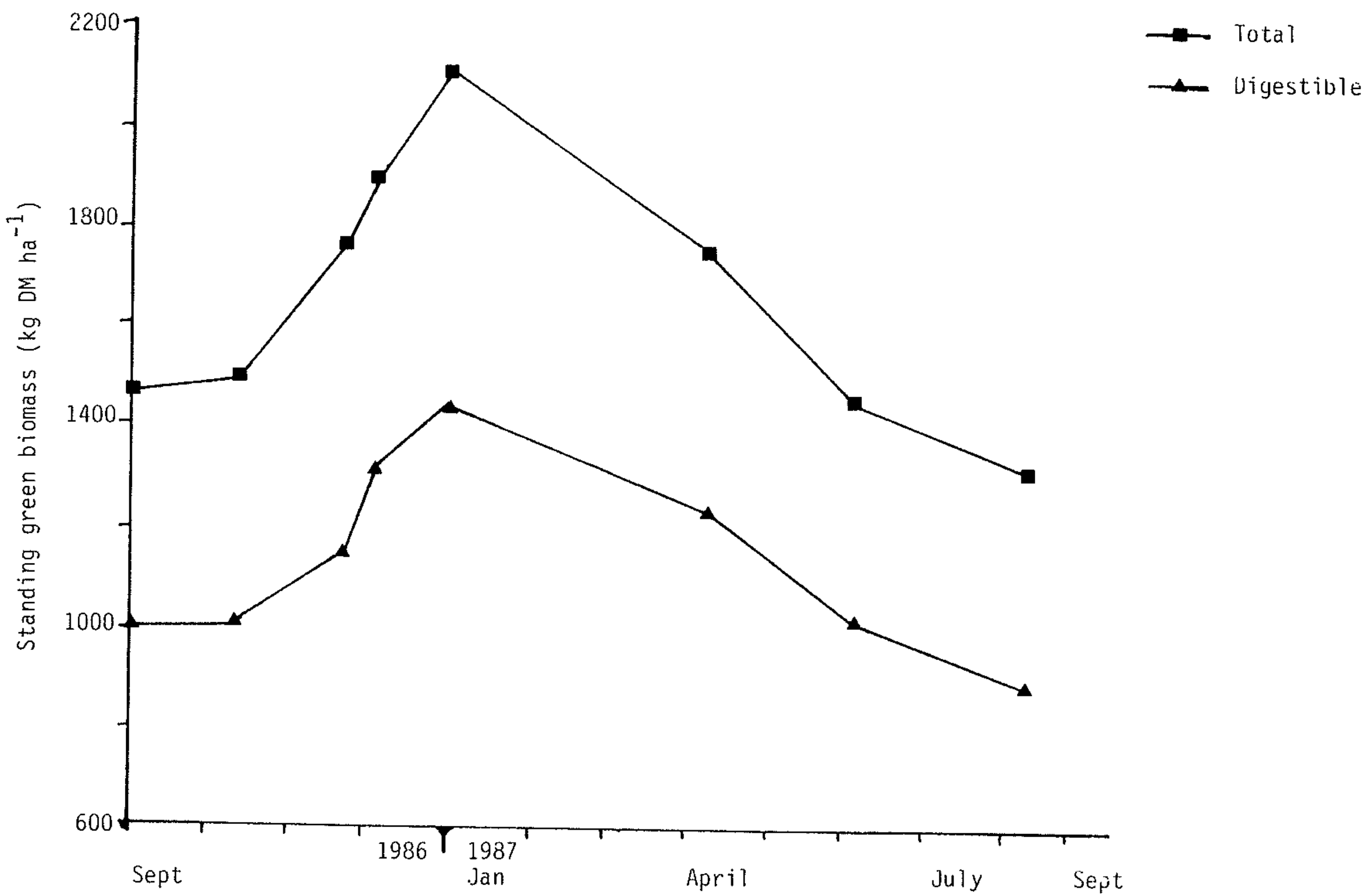


Figure 12. The seasonal change in total and digestible standing (green) biomass in a mature Tussac stand.

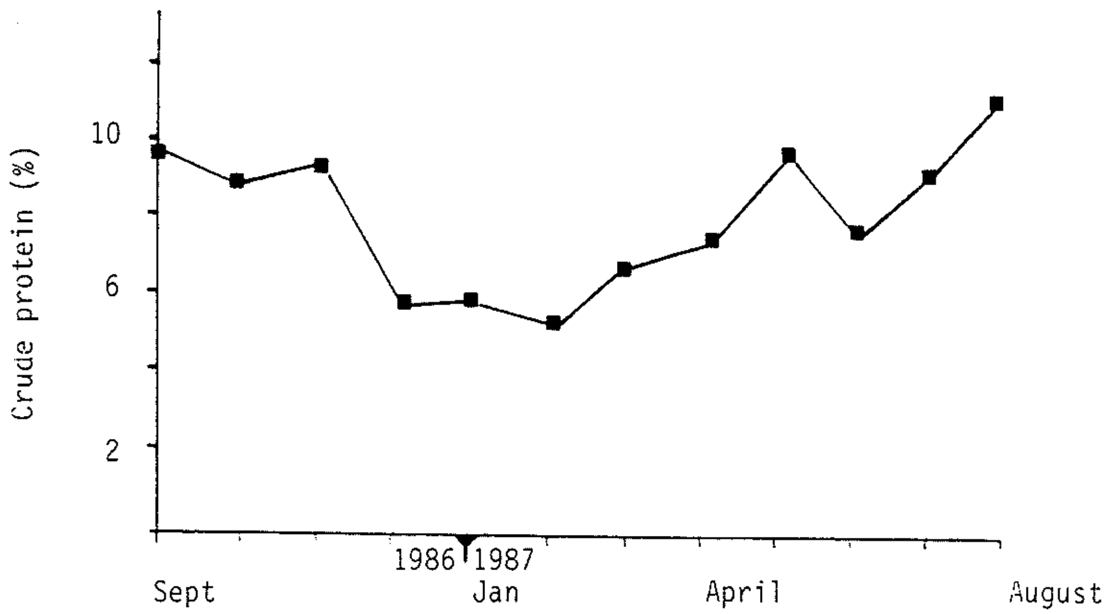


Figure 13. The seasonal change in crude protein levels in the live fraction of tussac grass leaves.

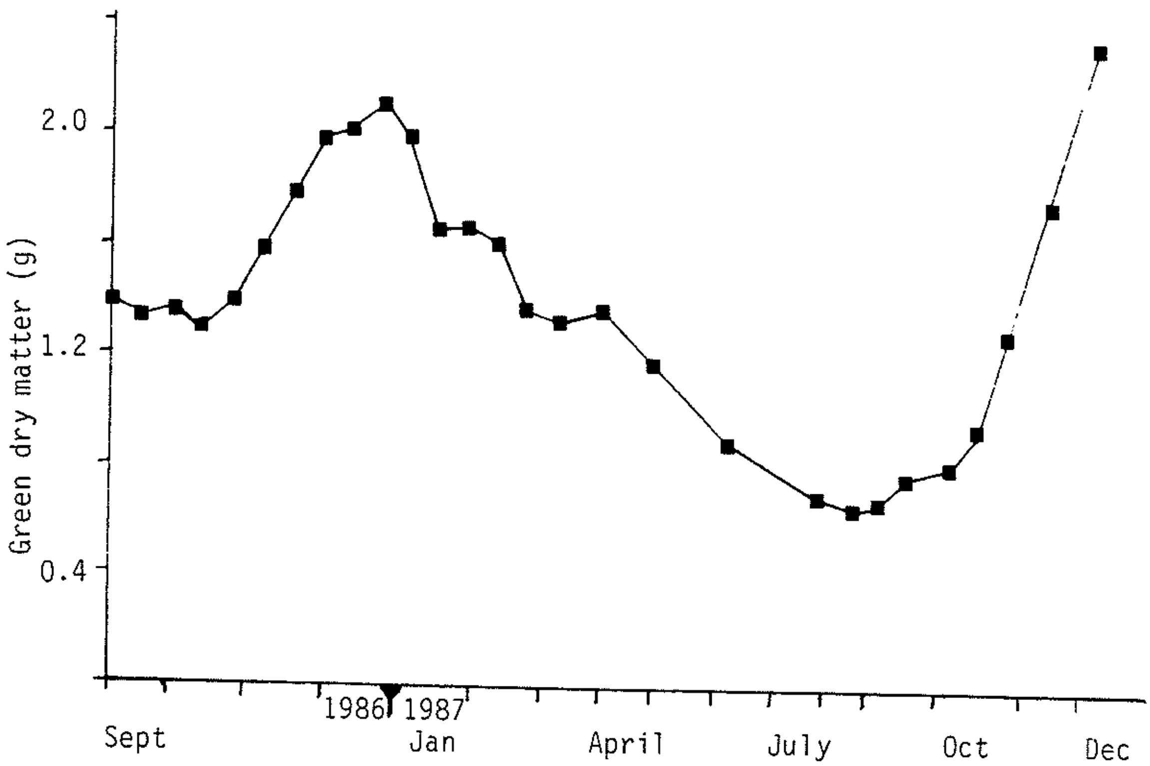


Figure 14. The seasonal change in green dry matter of a Tussac grass tiller producing two daughter tillers (in summer).

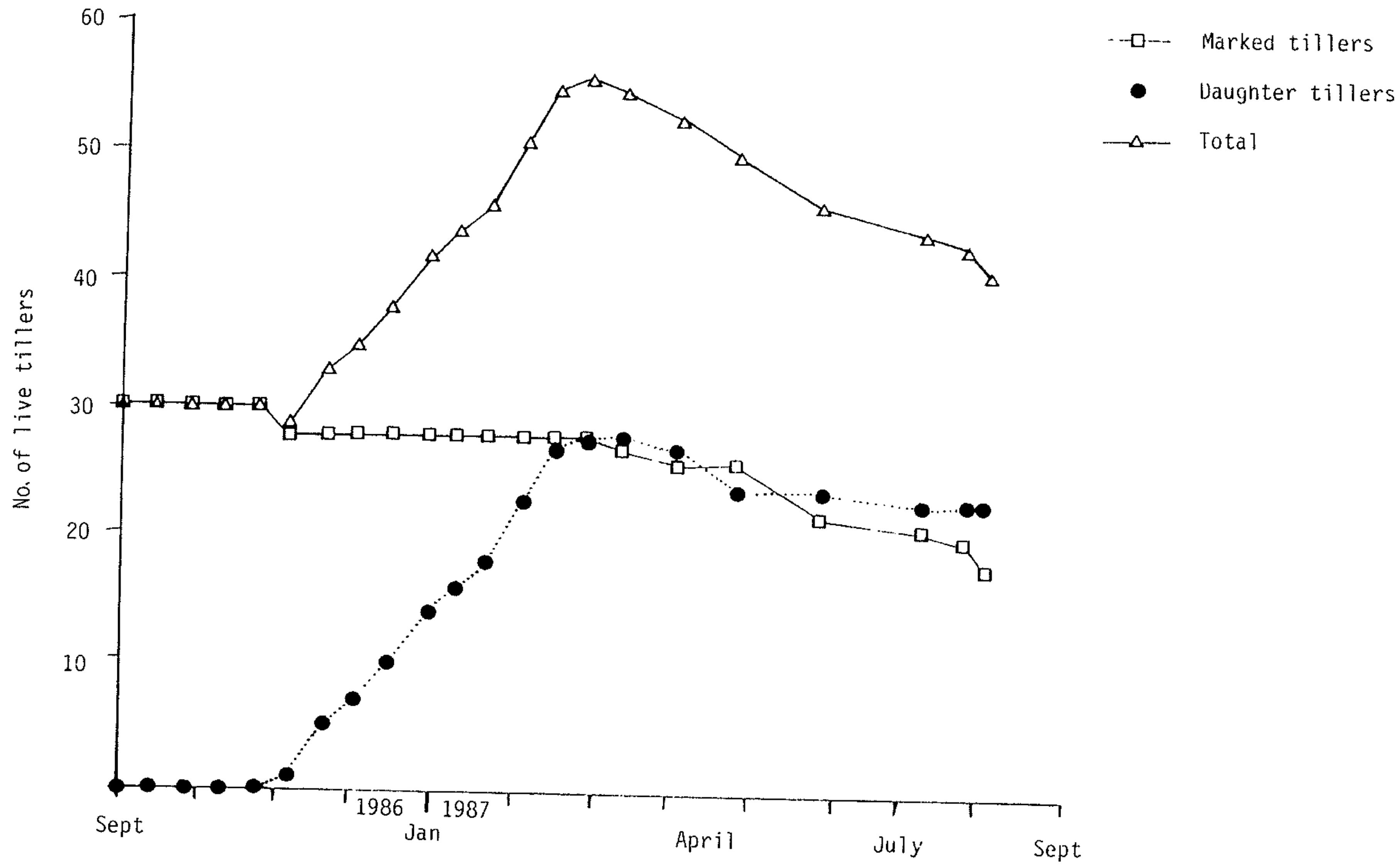


Figure 15. Daughter tiller production and tiller death in a population of 30 Tussac grass tillers marked in September and followed through for one year.

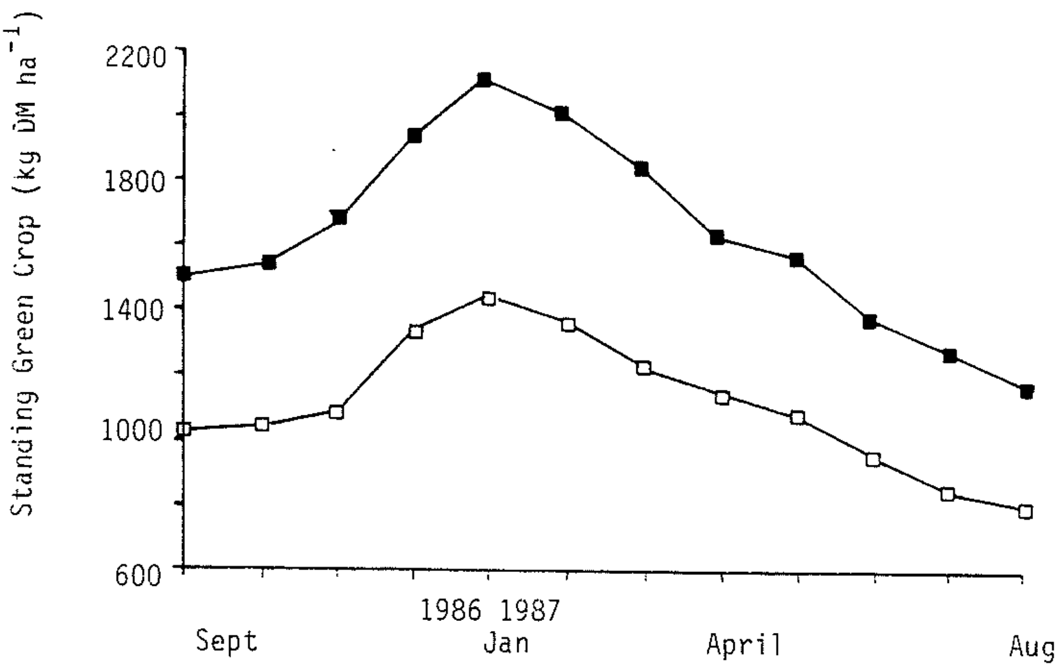


Figure 16. The seasonal change in the estimated total and digestible biomass (kg DM ha^{-1}) of Tussac grass calculated from individual tiller data.

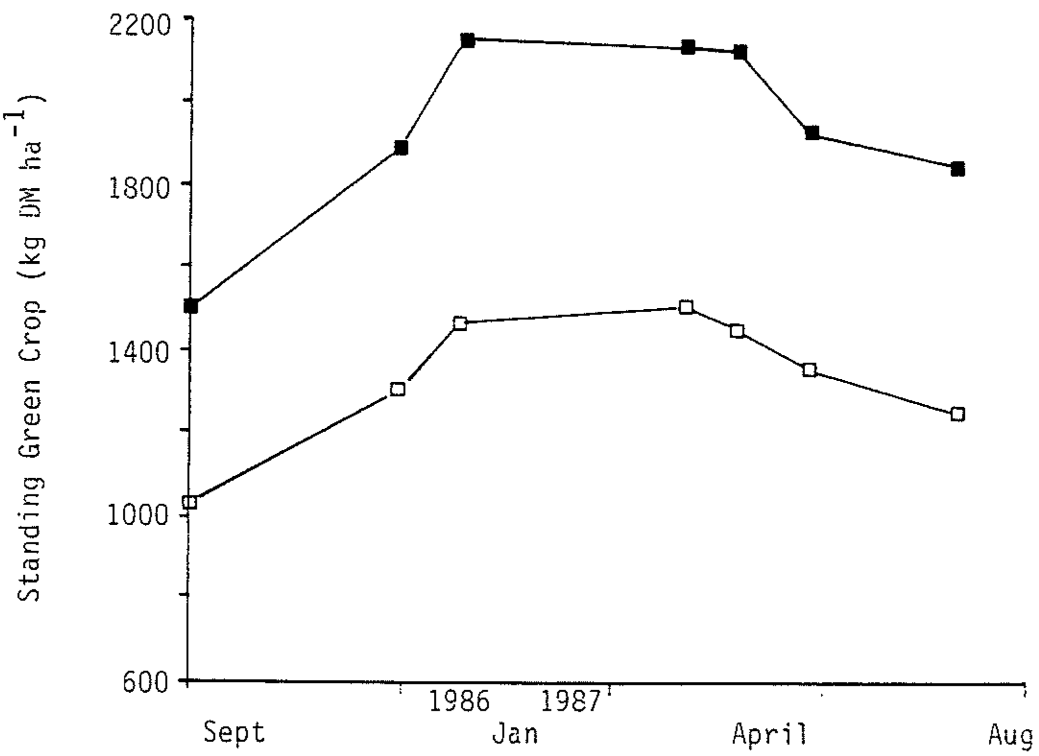


Figure 17. The effect of including daughter tiller production data (Figure 15) on the estimated seasonal change in the total and digestible biomass (Figure 16) of Tussac grass.

Leaf cohorts

The data from the LCA of the sixteen 'healthy' tillers was sorted in order to recognise leaf cohorts. A 'cohort' is a group of leaves from different tillers which were initiated at about the same time. In order to establish the cohorts, the maximum leaf length of the leaves emerging until 2/9/1987 were plotted for each tiller, eg Figure 18. 'Leaf 1' was the oldest live leaf at the start of the study, 'Leaf 6' was the leaf produced during winter and was allocated the letter X for the purposes of cohort sorting. Thus 'cohort 1' was the collective term for the first leaves to emerge after the winter of 1986 - in this case 'leaf 7' on the field record sheets. The curve is similar to those produced in the dissection exercise described above and enables the data for all sixteen tillers to be arranged around the overwintering leaf of 1986, which it is assumed was initiated at a similar time in every case. When the mean total leaf lengths of sixteen tillers were arranged in cohorts, the estimated number of leaves produced during the year was fourteen (Figure 19).

The active age of a leaf (defined as the period in days from emergence to death) varied from 175 days in winter to 100 days in spring and summer (Figure 20). This was partly due to the variation in maximum leaf extension rates (Figure 21). Winter leaves grew more slowly (to a shorter maximum length) than spring and summer leaves, at *c*.3 mm day^{-1}, winter expansion in total leaf length is significantly slower than the 5 mm attained during summer.

Conclusions

It was found that from a leaf cycle analysis of Tussac Grass carried out during 1986/87, each plant of Tussac grass produces (under poor nutritional conditions) about 14 leaves per year, and has a standing green crop of over one tonne DM hectare^{-1} in mid-winter. Significantly Tussac maintains an organic matter digestibility of c.0.65 throughout the year.

3.6 Discussion and Summary

The recommendations for further work emerging from the experimental programme reported are presented in Chapter 5 and referred to accordingly in this section.

The main issues involved in site selection are site fertility, likely weed competition and availability of planting material. Traditionally Tussac has been planted on coastal sites and growth on the two coastal sites used in the trial areas was better than on the inland site. Plants grew better on the deep peaty soil of an old, long grazed-out Tussac plantation at Sealion Island than on the Keppel Island site where the plants were in eroded peat overlying clay. It was seen from the Port Howard sites that old reseeded paddocks and areas near settlements are generally best avoided as competition from introduced grasses (particularly Yorkshire Fog) can be a problem.

There is no reason why Tussac grass should not be established inland. Plants established well on the rotavated infertile Whitegrass site at Port Howard but after 3 years some attention needed to be given to site fertility and pest control (see Chapter 5).

Tussac tiller clumps are bulky and heavy and nearness to planting stock is an important consideration.

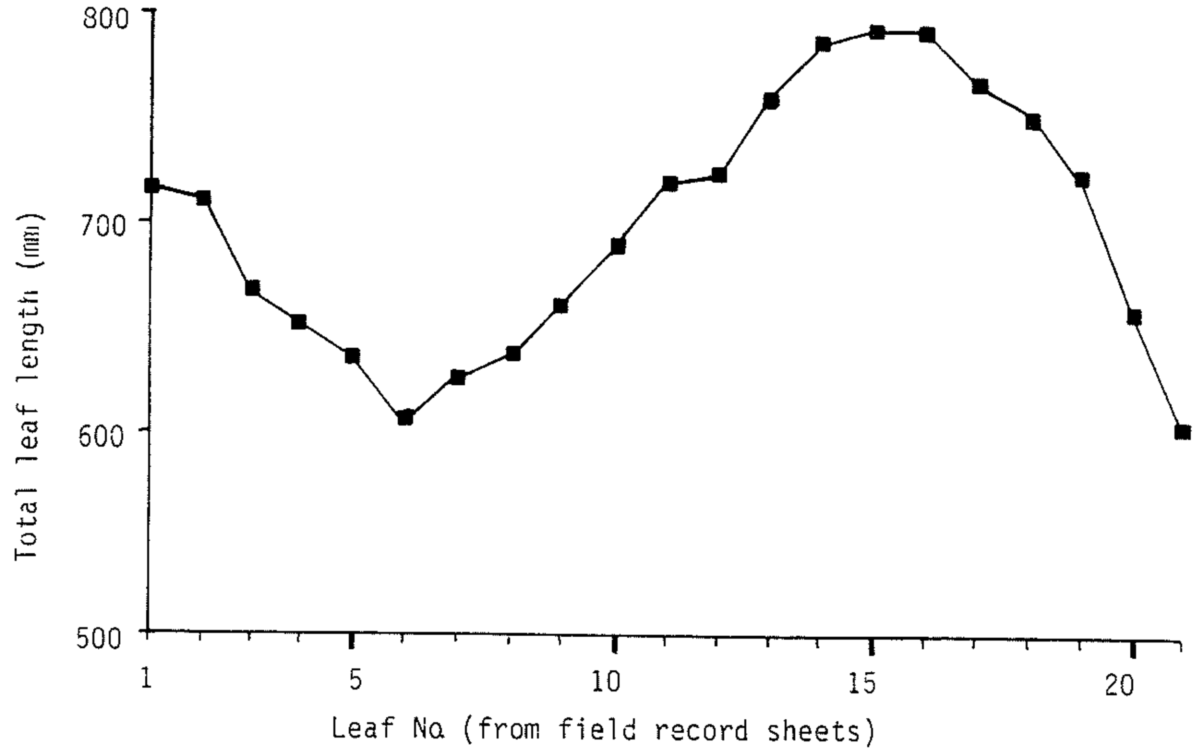


Figure 18. The maximum length of leaves emerging over one season per tiller (cohort sorting). Leaf 1 represents the oldest live leaf at the start of the recording period.

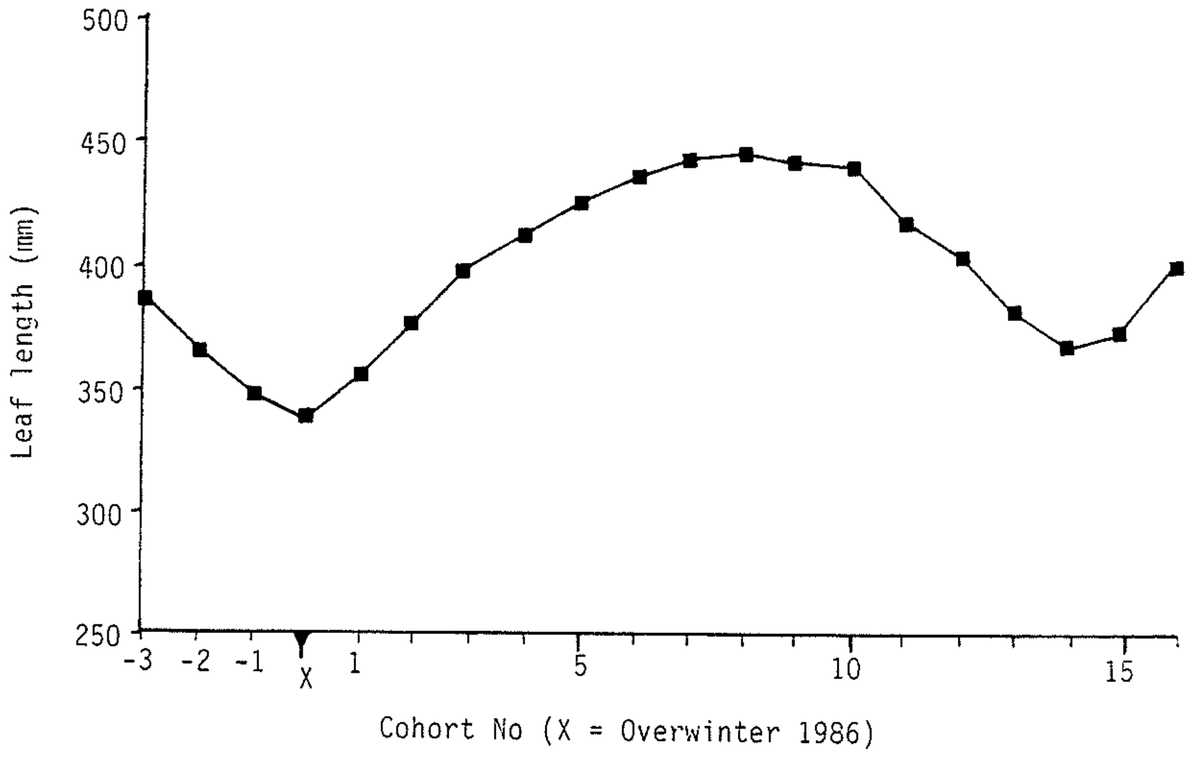


Figure 19. The mean total length of leaves (from 16 tillers) per cohort formed since overwinter 1986.

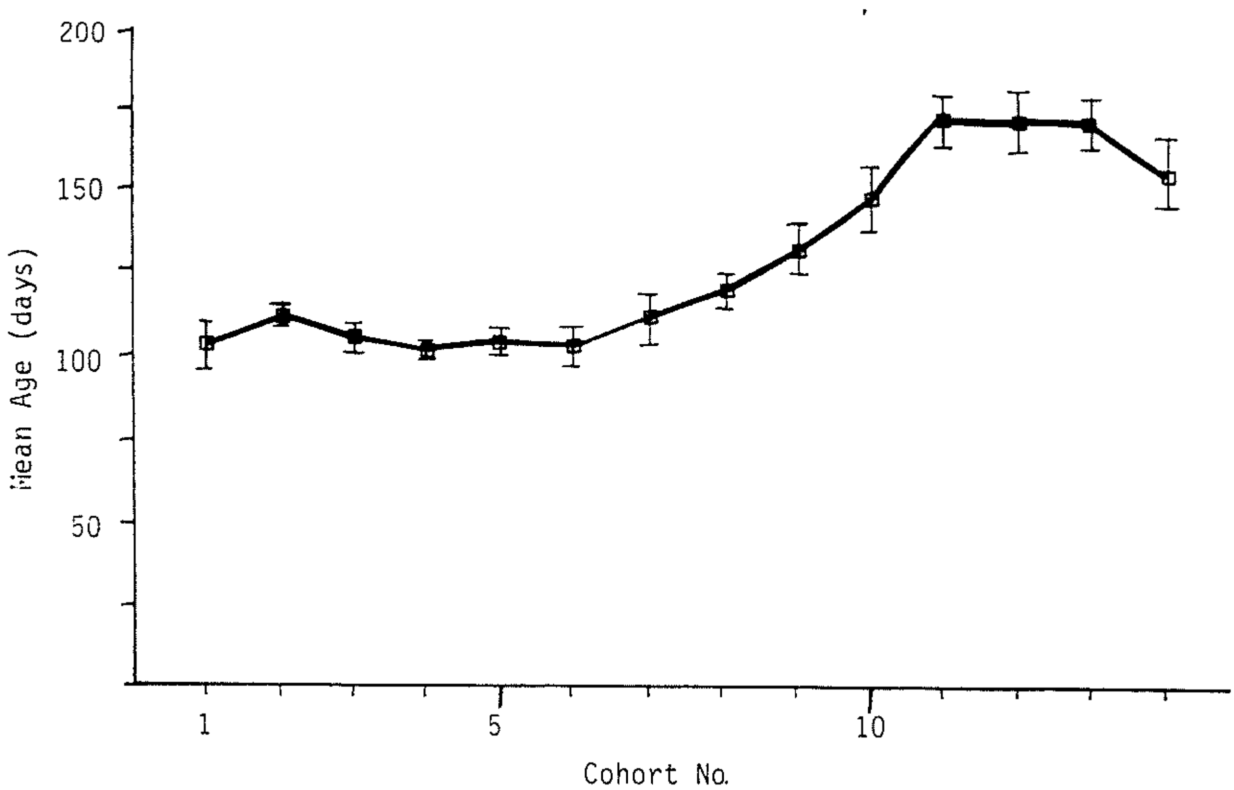


Figure 20. Leaf age expressed as mean period (day ± s.e.) from emergence to death per cohort.

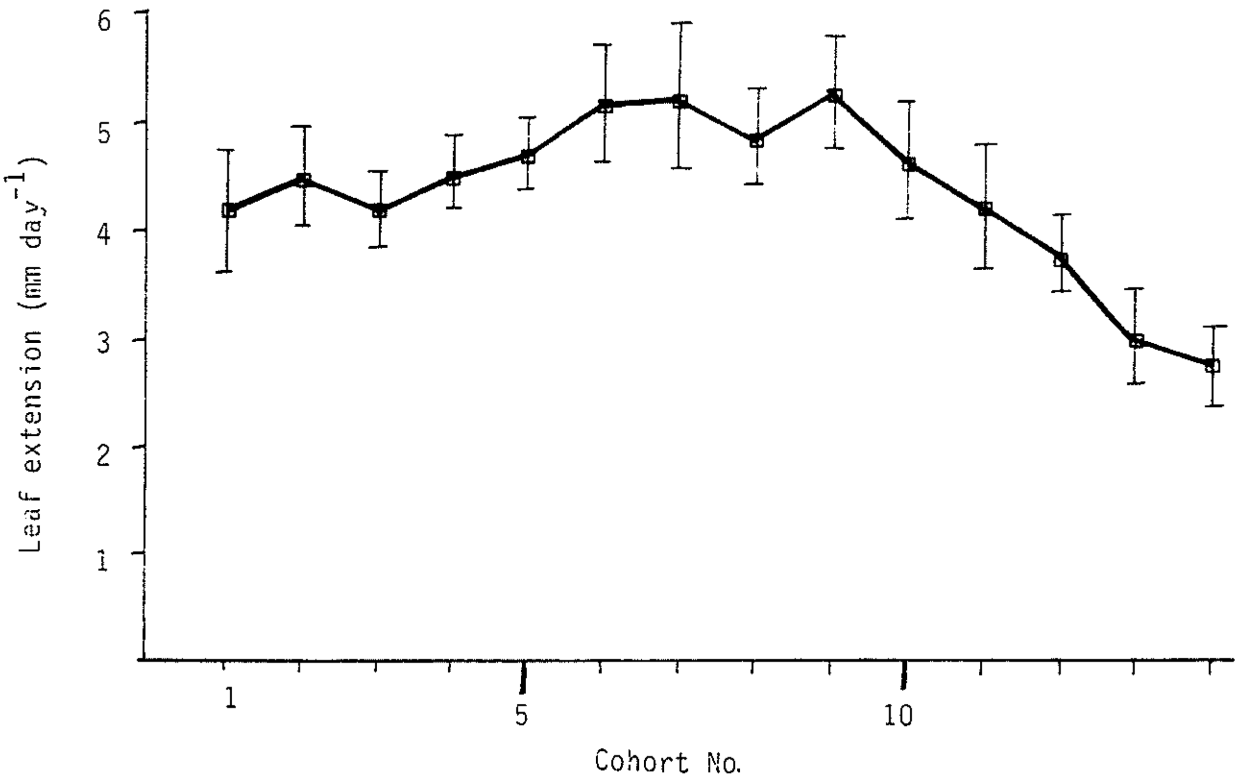


Figure 21. The variation in maximum leaf extension rates (mm day^{-1}) per cohort.

Although not formally investigated in this series of trials it is clear that planting between May and September gives best results. There are indications that early winter planting may be best from the point of view of avoiding bird damage and plant rooting ability (see Chapter 5). Planting will have to fit in with other farm work and winter is likely to be most convenient.

From the work carried out in N Ireland it is clear that Tussac seed has poor germination but there is considerable variation. Seed collected before mid summer from a few locations had higher germination than from other sources and hormone treatment enhanced seed germination. Further work needs to be done on the use of Tussac seed in the Falkland Islands (see Chapter 5). From the trials at Port Howard and from other research, 'sets' with minimum tiller number of 3-5 should be used. Such clumps should be chosen from young, healthy plants.

The Port Howard spacing experiment was largely inconclusive due to invasion by vigorous Yorkshire fog plants. Spacing is largely determined by the desirability of achieving rapid ground cover and the constraints of available planting material and labour.

The experiments were all conclusive in demonstrating that no advantage is to be gained - on any type of site - from using nitrogen or phosphate fertiliser at planting. There are indications that on the less fertile sites, fertiliser application will eventually be required and can be of considerable benefit to unthrifty, mature plants. In the trial carried out at Fox Bay, fertiliser N caused an increase in tiller number and 'green' herbage in mature plants.

The level of rust infestation on Tussac grass varies considerably within and between seasons. If fungicidal treatment is thought to be essential for the survival of, say, an establishing plantation then one application of the fungicide BAYFIDON before mid summer gives the best control. However, spraying is unlikely to be a practical or ecologically desirable option and it is felt that there is little point in carrying out further work on rust control until a greater understanding of the life cycle and biology of the causal organisms is known (see Chapter 5).

Insect pest attack presents a serious problem to establishing Tussac grass. Larvae of the species *Poophylax falklandica* was found to infect almost 60% of the tillers on plants at Fox Bay and a further 10% were estimated to have some damage. The inhibition of leaf growth by insect pests has been demonstrated. Conventional chemical control is unlikely to be feasible for the same reasons given for rust control and until a systematic study of the life cycle, population dynamics and predator prey relationships of the various insect pests has been carried out, little progress can be made (see Chapter 5).

The analysis of the samples taken at Fox Bay clearly demonstrated the high nutritional value of Tussac grass. Unlike other species of grass found growing in the Falkland Islands (and elsewhere) (e.g. Whitegrass *Cortaderia pilosa*; McAdam, 1986) the digestibility of Tussac grass does not decline over the winter period, remaining consistently high all year round. This must considerably enhance the value of Tussac grass as a grazing resource. The variation in the pattern of tillering occurring in late winter and early spring, whereby peak standing biomass is reached in the second part of the summer, is particularly important in relation to the grazing management of Tussac grass. If Tussac grass plants are producing about 14 leaves per year, the effect of removal of any of these leaves (and their subsequent likelihood of being replaced) will be an important determinant of the best time to graze a mature Tussac stand.

There is a wide range of factors affecting Tussac grass establishment in the Falkland Islands. Many of these have been investigated in only a preliminary manner in this study. The clearest lessons emerging concern the control of rust disease, the effect of fertilisers on establishment and the management implications of the seasonal pattern of tiller production. However the study also highlights a number of areas requiring further research (Chapter 5) if the establishment and growth of Tussac grass in the Falkland Islands is to be approached on a much greater scale than at present.

4. NORTHERN IRELAND

Experimental approaches

4.1 Seed germination

As an obvious alternative to establishing Tussac grass from rooted tillers, the grass could be grown from seed. Early accounts suggested using seed as a propagating material but by and large establishment from seed has attracted little attention. This may be due either to an inherently low viability for Tussac seed, the need to overcome weed competition at establishment or an adherence to traditional planting ideas.

Gunn (1976) found that a relatively high proportion of Tussac grass seed from South Georgia was viable; about 35% of unvernalised seed had germinated after forty days in the laboratory. Gunn suggested that there was a dormancy mechanism in the seeds. Smith (1985) reported that on South Georgia germination in the field occurred in great abundance but only a small proportion of seeds subsequently established. He proposed that on mossy sites fluctuations in temperature and moisture killed most of the seedlings before their root systems had penetrated to a depth where soils were permanently moist.

Tussac has an autumn-formed panicle, so that growth during the following spring can be concentrated into rapid stem elongation, flowering and subsequent seed set (Gunn, 1976). A panicle (seed head) may contain about 1500 viable seeds, with up to 100 panicles on a single tussock. Natural regeneration from seedlings is uncommon in the Falkland Islands. This is probably because seed germination seems to be poorer generally in the Falklands than in South Georgia and most of the situations where seeds are likely to fall suffer from desiccation, grazing or competition from introduced grasses.

In a situation where planting material is in short supply or it is desirable to introduce new genetic stock, the use of direct sown seed or of transplanted seedlings merits further consideration. Seed is best stored in cool conditions and temperature fluctuations avoided. Experiments on the viability of Tussac seed from a range of localities, the effect of time of collection, hormone application, temperature and sowing depth were carried out and the results presented below.

4.1.1 <u>Seed viability - site and season of collecting</u>

Seed Source

For one experiment seed was collected from South Georgia, Hill Cove, Port Howard (Whiterock), Port Howard (plots), Narrows Island, Fox Bay East (Coast Ridge), Fox Bay East (Doctors's Creek), Carcass Island, Monday Island, Kidney Island, Hooker's Point, Sealion Island, Beauchene Island and Northern Ireland seed (originally from Hill Cove) and used in laboratory germination tests. Seed was germinated in water in an incubator maintained at 20° C. The mean % germination after 40 days is shown in Table 18. It can be seen that there are considerable differences in the viability of seeds collected from different locations. Seed from the Fox Bay sites (Coast Ridge and Doctor's Creek), South Georgia and Carcass Island germinated better than that from the other sites tested. Although the three seed sources with the best germination (Coast Ridge, Carcass Island and South Georgia) all had relatively large seeds, there was no obvious correlation between seed size and germination percentage. Seed from the site with the heaviest seed, Sealion Island, did not germinate much better than the lightest seed, from Beauchene Island. There was no correlation between seed viability and the degree of shelter or fertility of the site where the parent plants were growing.

In another experiment, germination of seed previously collected in the Falkland Islands, South Georgia and first generation N. Ireland seed (of Falkland Islands origin) were stored under a range of conditions. Seed was germinated under the same controlled conditions as previously and germination recorded for up to 35 days.

It can be seen (Table 19) that all the older seed had poor germination only seed collected since 1983 performed well. From what comparisons are available, air drying of the seed is preferable to deep freezing for storage.

Time of harvesting

The maturity of seeds is thought to be one of the most important physiological factors influencing seed viability and seedling vigour. To test this hypothesis for Tussac grass, seed was collected from one site (north side of Coast Ridge, Fox Bay) at approximately fortnightly intervals from 30th October 1986 to 9th January 1987. Seeds were stored under uniform conditions and tested for % germination as detailed above to see if germination increased with duration of seed ripening before harvest. The results are presented in Table 20.

At first sight, the results do not confirm the general effect recorded for most other plants whereby seed germination is enhanced with maturity. The seed from the earliest harvest (30th October) which was still slightly green, had a germination percentage of approximately 30% while that of the most mature harvested (9th January) was approximately 15% though was a trend for the highest germination to be from seed collected later in the season. There did appear to be some relationship with seed size, the highest germinating seed (47%), harvested in mid-summer (10th December) had the highest seed weight (0.396 mg). The harvest dates showing the poorest germinating seed, harvested on 9th January and 27th November, also had the lowest seed weights (0.248 mg and 0.260 mg respectively).

Variation in seed weight, peaking in mid season and then declining again, does not appear to relate to period of ripening. Possibly the properly matured, heavier seed had already been shed from the panicles before the last harvesting date (9th January) near the end of the season. This would be an advantageous for good seedling establishment before winter and early seed dispersal has been noted for arctic and alpine plants (Billings and Mooney, 1968). The tendency of Tussac to pre-form flowers the previous season may have a confounding effect on the projection of stage of maturity into the subsequent season.

Conclusions

From these results it can be concluded that, as there is considerable variation between the viability of seeds from a range of sites and over a range of harvesting dates and ages, seed should be collected before mid summer from sites which regularly yield a relatively high proportion of viable seed and used within a few years of collection following dry storage.

4.1.2 Hormone treatment

Gunn (1976) suggested that a plant hormone, gibberellic acid (GA) could increase the rate of germination substantially on some seed lots. In view of the low germination of seed from some locations and collections, the effect of GA on germination was investigated. Three experiments were carried out to investigate the effect of 10^{-3} molar GA on seed germination of the following lots.

(i) Seed from three South Georgia sites measured for 15 days.

(ii) Seed from three South Georgia sites measured for 23 days (separate experiment).

(iii) Seed collected at different dates from Coast Ridge, Fox Bay.

The final germination percentage of South Georgian seed was increased by GA application (Table 21) and agree with those of Gunn (1976). One of the South Georgian lots had consistently low germination. In the other experiment however, using the Falkland Island seed, although GA enhanced the speed of germination it did not increase the final percentage of seeds germinated. As will be seen in Section 4.2, when the seedlings referred to above (Falkland Islands source) were monitored, hormone application to seed at sowing was found to have no subsequent effect on seedling vigour.

The seed from South Georgia was several years older than that used from the Falkland Islands and it may be that only the germination of older, more dormant seed is significantly enhanced by hormone application. In some situations, particularly where competition is anticipated following cultivation speed of germination may be an important consideration, otherwise, provided fresh seed is collected and used there is no conclusive evidence to recommend hormone treatment of seed pre-planting.

4.1.3 Sowing depth

Speed of emergence is an important factor in the establishment of grasses, particularly where competition or adverse climatic conditions might affect further survival. The ability of seeds to emerge from different depths has been used as a measure of seedling vigour (Rogler, 1954). Emergence and subsequent vigour has been related to seed size (Whalley *et al.*, 1960). An experiment was carried out to study the relationships between seed size and seedling vigour, measured by the ability of seedlings to emerge from different sowing depths. Seed from Northern Ireland (ex Hill Cove, Falkland Islands) and King Edward Point (South Georgia) was sorted by size into small, medium and large fractions. These were then planted at one of four depths (0, 1.5., 3.0 and 4.5 cm) peat-based in compost.

From both sites, emergence of seedlings was significantly greater from the smaller seeds than the larger seeds (Table 22). Over both sites and seed sizes, emergence was not significantly affected by planting depth.

The results from this experiment using Tussac grass seed are in marked contrast to those generally found for most plant species (Rogler, 1954; Whalley *et al.*, 1966). There is the possibility that seed class selection is masked by glume size (large seeds have large glumes) and actual endosperm differences are not that great. There is also the possibility that the glumes are involved in a dormancy mechanism. Gunn (1976) suggested that enhanced germination of Tussac seed following hormone application was evidence of a dormancy mechanism being broken.

He dissected seeds out of their glumes and concluded that the dormancy mechanism resided in the glumes. The results found in this experiment appear to further confirm Gunn's suggestion.

It can be concluded that if Tussac seed is ever to be sown on a reasonably large scale, provided seed is ripe, some sort of crude sorting, removal of large seed or use of an increased seed rate may be advisable. Mean seed size varies between sites (see earlier) and selection of seeds from sites with smaller seed might be beneficial. If some form of mechanical sowing were adopted, planting depth is unimportant and, by inference, seed bed preparation is not critical.

4.2 Seedling vigour

Seedling vigour can generally be considered as a measure of the competitive ability of individuals at the seedling stage. To be competitive, either with other plants or to withstand the rigors of the environment, seedlings must grow rapidly and robustly after germination. It is this speed and weight increase which constitute vigour. A study of the effect of a range of conditions on seedling vigour as well as on germination is important in relation to the creation of conditions which lead to establishment of strong, healthy, Tussac grass plants.

Hence a series of experiments were carried out to investigate the variability in vigour associated with seedlings from different sites and on the effect of fertiliser on this vigour. If plants are to be grown from seed under nursery conditions then planted out as rooted seedlings it is important to know if selection of seedlings at an early stage can influence subsequent performance of the mature plants. This relationship between seedling vigour and subsequent maturation of Tussac grass plants was investigated in a further experiment.

4.2.1 Site variability

The geographic location of the mother plant and site fertility has been shown to have a large influence on seedling vigour and maturity for cereals and tundra species. Shoot extension in the early, non-photosynthetic stage of growth was measured (Whalley *et al.*, 1966) to assess the vigour of seedlings from seed collected at a range of locations.

Once seeds used in the experiment reported in section 4.1.1 had germinated, the seedlings were placed on filter paper in darkened and uniform conditions. After 10 days, the length of the shoots of individual seedlings was measured (Table 18). The longest shoots were those from Carcass Island, South Georgia and Kidney Island seed. Carcass Island and South Georgian seed was relatively large and had high germination relative to seed from the other sites. Hence, although seedling vigour was greater from larger and more viable seeds, the relationship was not absolute, and was confounded by several marked anomalies. The correlation coefficients between shoot length, seed germination and seed size are presented below and indicate that the relationships are very weak.

Correlation coefficients between:-

Germination and vigour	0.38
Seed size and germination	0.28
Seed size and vigour	0.12

The exceptions to the general rule may have occurred as the seed was collected and stored under different conditions and collected at different times and hence might well be explained by the influence of external factors.

Seed from Northern Ireland (previously from Hill Cove, Falkland Islands), South Georgia, Carcass Island and Monday Island (control and with GA) were germinated, planted out under controlled environment conditions and their subsequent growth monitored for 3 months in another experiment. Tiller production, leaf production and individual leaf extensions were measured at regular intervals on plants and at the end of the experiment, plants were harvested to determine final dry weight.

From day 55, plants grown from untreated Monday Island seed had significantly fewer tillers than plants from other seed sources. This may have been due to poor initial germination of this seed which resulted in the plants being smaller initially. Otherwise, tiller appearance rate was unaffected by seed source (Table 23).

As was found for tillers, plants from seed collected on Monday Island had fewer leaves per primary tiller throughout the experiment.

Treatment with the plant hormone GA resulted in plants with initially higher numbers of leaves per primary tiller than from untreated seed.

However, after this period, subsequent leaf appearance rate on plants from GA treated seeds was lower than from untreated seeds (Table 23).

Leaf extension was enhanced by GA during the first 20 days of measured growth. This enhancement lasted for about 50 days duration on uppermost (extending) leaf of the primary tiller (Figure 22). The extension of other leaves on the primary tiller and on subsequent leaves which appeared on daughter tillers was unaffected by GA treatment of the seed.

Extensions rate of all leaves on the primary tiller and on the first and second leaves of the first daughter tiller were greatest on plants from Carcass Island seed than from any other seed source (Figure 23). Leaf extension was generally lower on plants grown from Monday Island seed than from any other source, though the effect was significant on only a few measurement occasions. Mean final dry weight of tillers of plants grown from Monday Island seed were significantly lower and those from Carcass Island seed significantly higher than from all other sources (Table 23). By the end of the 3 month period secondary (daughter) tillers were almost twice as large as the initial seedling primary tiller.

The superior vigour of Carcass Island seedling confirmed the result of the preliminary (10 day growth) experiment (Table 18) though there were anomalies with results from some of the other sources. In experiment 1, the South Georgia seedlings showed similar vigour to those from

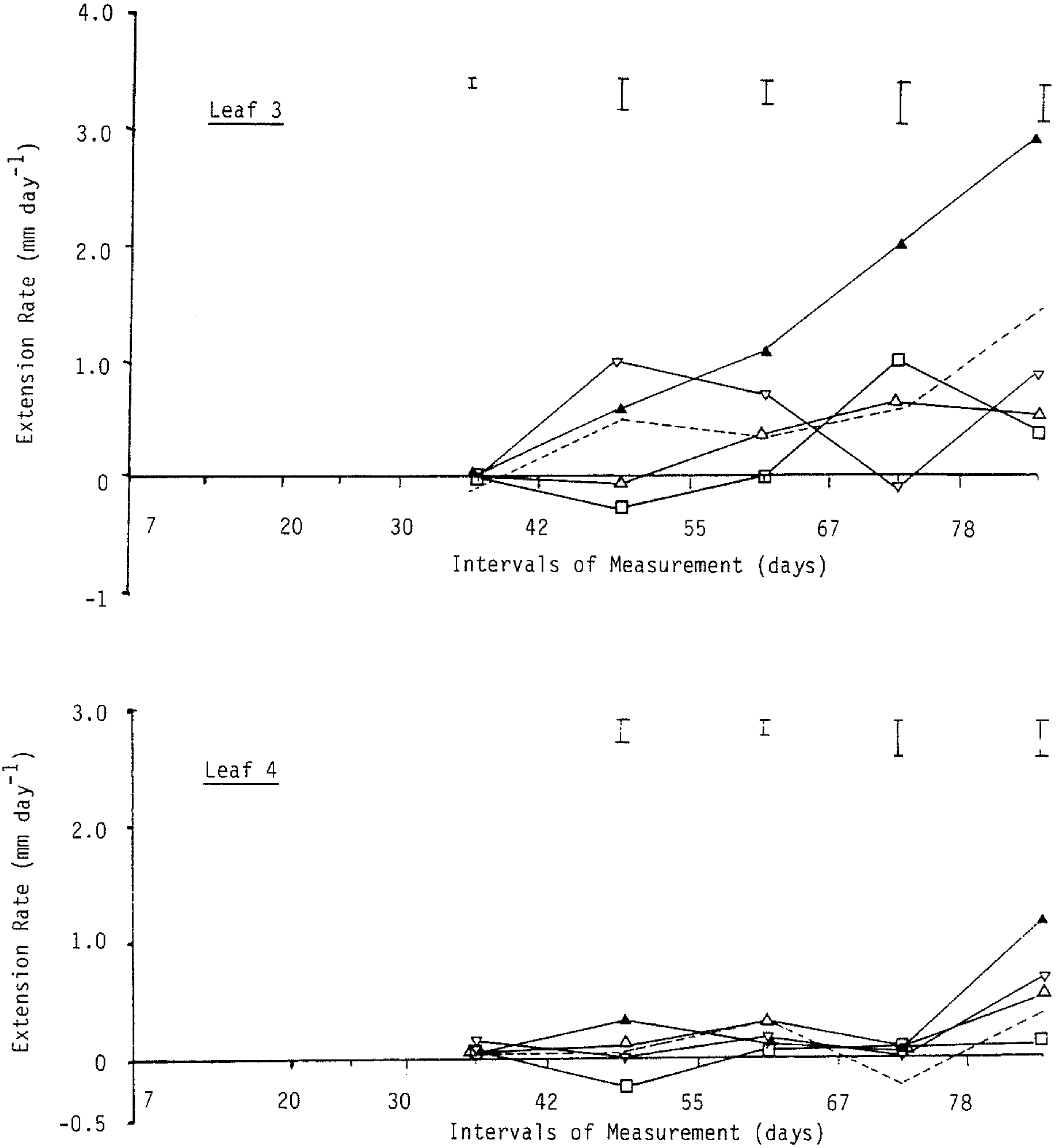


Figure 22. Extension rates (mm day^{-1}), over an 80 day period following germination, of leaves on the primary tiller of Tussac grass leaves on seedlings grown from seed collected in N. Ireland (---), S. Georgia (△), Carcass Island (▲) and Monday Island (with and without GA respectively) (▽ and □).

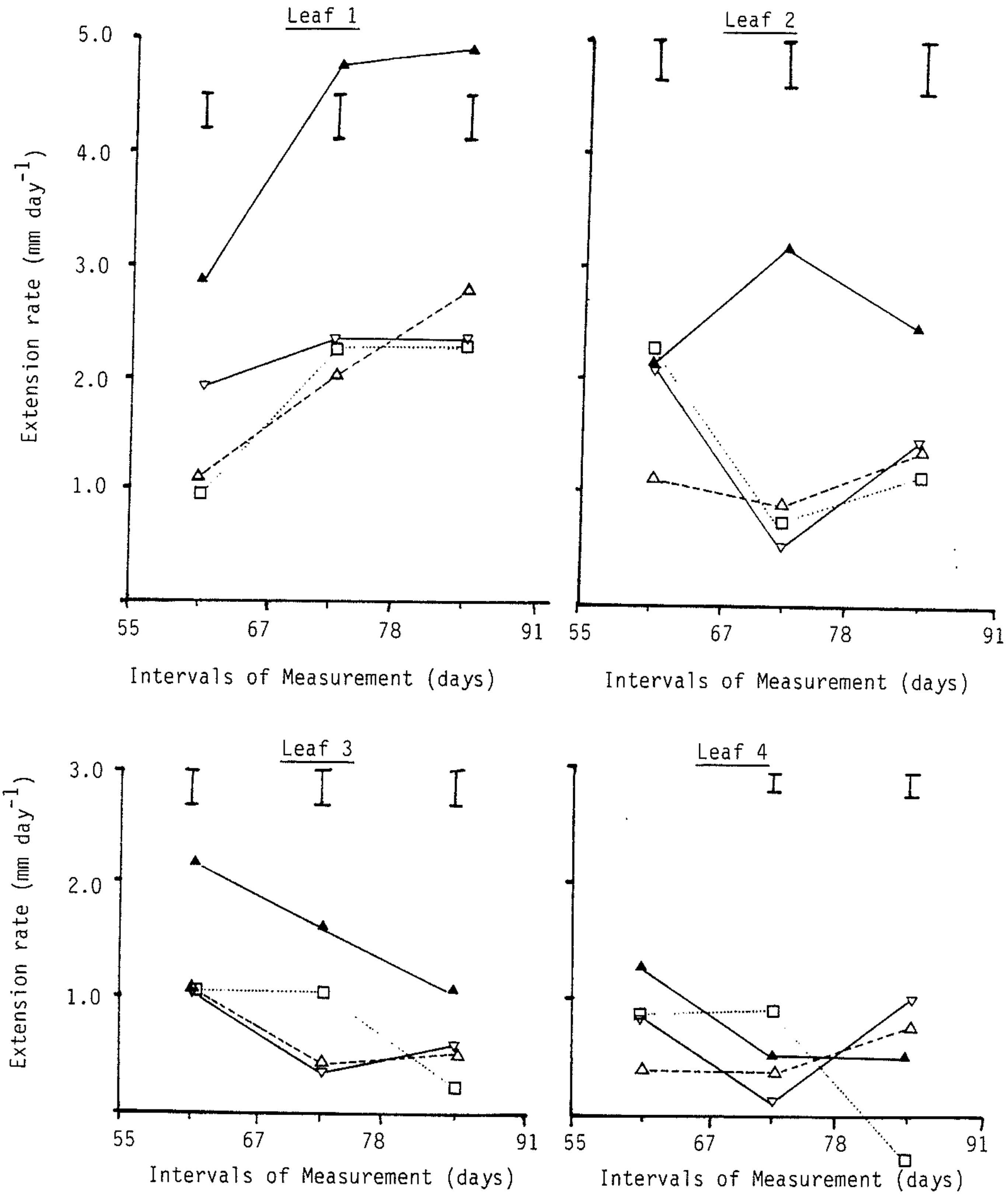


Figure 23. Extension rates (mm day^{-1}) of leaves 1-4 on the secondary (daughter) tillers of the seedlings described and illustrated in Figure 22.

Carcass Island whereas by the end of experiment 2, Carcass Island seedlings were significantly greater than those from South Georgia. Hence, early, rapid assessments of vigour must be treated with caution. The greater vigour of Carcass Island seed may be either a result of improved quality and quantity of seed reserves because of favourable conditions during seed ripening or a distinct genotypic variation in vigour between populations. The experiments indicated that there were likely ecotypic differences between Tussac grass from the Falkland Islands and from South Georgia. Such differences would seem not unlikely due to the separation between populations.

The different conditions experienced by seed from each source make interpreting the results difficult. A better comparison of seedling vigour could be made using a first generation of seedlings grown under constant conditions, harvesting seed from these and comparing vigour of the subsequent seedlings. It can be concluded that there are likely to be ecotypic differences between Tussac grass on the Falkland Islands and on South Georgia. Seedling vigour does not vary very widely between populations in one geographical area, though Carcass Island seed would be the best to use. A further selection of seed from specific vigorous plants on Carcass Island would be worthwhile. If conventional planting is undertaken using tiller clumps, it may even be desirable to use tillers from plants which showed early seedling vigour.

4.2.2 Seed maturity and hormone response

Some seedlings from seed collected at different stages of maturity, treated or untreated with GA and used in the seed germination experiment reported in 4.1.1 (b) were planted out and grown under controlled environment conditions for 25 days to assess the effect of seed maturity and growth hormone on vigour. Seedling heights were measured at 10 and 25 days after sowing out (Table 24).

Up to 25 days after sowing there was no interaction between harvest date and GA treatment on shoot height. Ten days and 25 days after planting seed from the late harvest (on 28th December 1986) had significantly taller shoots than those from other harvest dates which did not differ significantly from each other. Twenty five days after planting, germinated seedlings, those from the mid season harvest (on 10th December) were smaller than for any other harvest date. GA treatment had no significant effect on seedling vigour.

The results support the findings of the germination test reported earlier and confirm the view that seed should be collected before mid-summer, though no seedlings survived from the later summer planting for comparison.

4.2.3 Fertiliser response

It has been found that soil fertility on South Georgia often limited the growth of Tussac grass and that growth can be improved with nutrient enrichment (Gunn, 1976; Smith, 1985). Davies (1939) recommends the application of organic nitrogen fertiliser to encourage Tussac establishment in the Falkland Islands while Davies *et al.* (1971) recommend the application of a compound fertiliser at planting. However, the conclusive result from a wide range of experiments described earlier in this report (3.2.2) was that no advantage was to be had in applying fertiliser in any form when tiller clumps are planted. To investigate if the same response might hold true for plants established from seed or if early establishment of seedlings could be enhanced by fertiliser application, an experiment was carried out to study the effect of a range of levels of applied N and P on seedling growth of Tussac grass.

Pre-germinated seedlings from one seed source (N. Ireland) were planted into pots and subjected to a combination of 4 nitrogen (0, 50, 100, 200 kg N ha^{-1} equivalent) and 3 phosphate (0, 50, 100 kg P ha^{-1} equivalent) levels. Growth was assessed by measuring maximum seedling height 10, 30 and 60 days after planting.

Where 50 kg N ha^{-1} was applied growth was enhanced by P application. After 10 days and thereafter, seedling size was significantly greater at the 50 kg N ha^{-1} level than for all other nitrogen levels. There was a significant response to the highest level of P application throughout (Figure 24).

The findings of this experiment support the view that P and K may be important in Tussac growth (Smith, 1985). Although Davies (1939) proposed that Tussac is successful in chicken runs because of the added nitrogen, he had no scientific evidence to support this view. Chicken manure contains high quantities of P as well as N and chickens may control insect pests to an extent that visible growth responses may be detected. Tussac may not be able to utilise high levels of available N. The fact that Tussac is found growing in peaty soils where levels of available N are likely to be low would support this view. Hence, if Tussac is adapted to this nutrient environment, a more favourable response may be had using slow release organic fertilisers such as guano and kelp rather than conventional high-N inorganic fertiliser.

4.2.4 Morphological development

For some species, growth parameters or characteristics of seedling vigour can be used to select plants at an early stage which are likely to show desirable growth characteristics (eg. height, tiller number etc) at a later stage. To ascertain if this was true for Tussac grass seed from a single source (Hill Cove, Falkland Islands) was sown in water and as seedlings emerged 130 plants were planted individually in pots. The following measurements were recorded on each plant over the first month:-

No. of days to seedling emergence (EMER); no of days to appearance of leaf 2 (L2), leaf 3 (L3) and leaf 4 (L4); actual plant height at 7 days (HT7D), 14 days (HT14D), 21 days (HT21D), 28 days (HT28D); leaf number on first tiller after 21 days (LNO21) and 28 days (LNO28); tiller number per plant after 21 days (TNO21) and 28 days (TNO28); number of days to appearance of first daughter tiller (DT1).

A full data set was available for the 115 plants which survived to the end of 1 month and the statistics for each measured parameter are presented in Table 25. For plants surviving longer than 1 month the following parameters were also noted:-

Plant height at 1, 2, 3, 6, 9 and 12 months (H1, H2, H3, H6, H9, H12) and tiller number on the same occasions (T1, T2, T3, T6, T9, T12). All plants were harvested to remove material above 10 cm height after approximately 12 months and the biomass (DM) of each ascertained. The herbage was separated into green leaf lamina (GL%), leaf sheath (LS%) and total dead (TD%) components and the relative proportions of each calculated following drying and weighing. A full data set was only

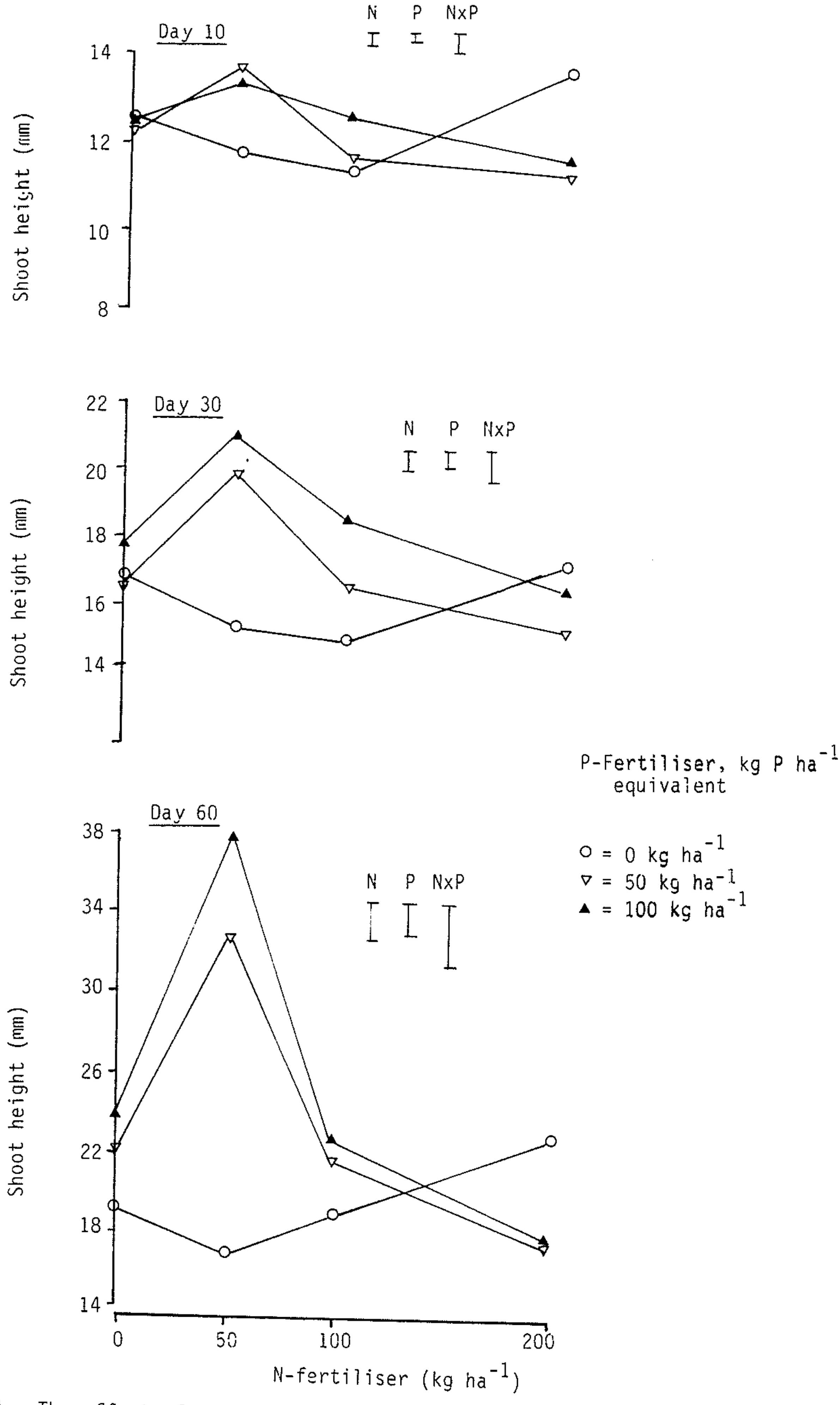


Figure 24. The effect of nitrogen and phosphorous fertiliser on shoot height of Tussac grass seedlings 10, 30 and 60 days after fertiliser application. The vertical bars represent standard errors of the means.

available for the 26 plants which survived for a full 12 months and the statistics for each measured parameter are presented in Table 26.

Correlation coefficients between each of the measured parameters were calculated to ascertain the nature of any of the relationships between the measured variables. Correlations between many of the combinations of variables are not applicable and the most important variable combinations are presented as a matrix for the 115 plants up to 1 month old (Table 27) and listed for the 26 plants surviving for 12 months (Table 28)

There was a considerable variation between plants for all parameters during the first month, however the mean values presented illustrate the progressive increase in plant height, leaf and tiller development with time. By the end of one month, seedlings were, on average, 24 cm tall, had 3 leaves and a mean tiller number of 1.3, although one plant had 4 tillers by that date.

Correlations between final (28 day) height and leaf and tiller number and leaf appearance were reasonably high ($r = 0.6$-0.8).

If early vigour is associated with rapid height attainment, plants which produced leaves faster and in greater numbers were a reasonable guide to vigour. If rapidity of tillering is seen as a desirable trait and measure of vigour, then correlations with leaf number per tiller were higher (0.89) than any other parameter. Overall the number of leaves per tiller and the rapidity of their appearance is the best measure of early vigour. Of those plants surviving for one year, height increase and tillering increased more rapidly over the last 3 months (months 9-12) than during any other three month period. It is of interest to note that this pattern of slow tillering followed by a period of extremely rapid tillering agrees with that found from the field experiments in the Falkland Islands (eg. on Keppel Island). Most herbage above 10 cm was green leaf with 30% dead. The main purpose of the experiment was to ascertain those characters in early stages of growth which result in more vigorous growth and larger plants. Although one year could be considered an arbitrary time interval, plants should be well established by this time. Hence it is of interest to study the correlations of growth with final plant size - biomass, height and tiller number and a measure of quality (% green leaf) (Table 28). Height was poorly correlated with any measure of final growth. Large plant size was best correlated with tiller number (r = 0.70). None of the growth measurements gave any indication of plant composition and none of the final growth measurements was related to rate of seedling emergence or speed of initial tiller production.

It can be concluded that overall, rate of tiller production is the best guide to seedling vigour and plant establishment in Tussac grass and in the initial stages, rate of leaf production is a reasonable measure of tillering potential and hence further seedling vigour.

4.3 Establishment of stands

The field programme in N. Ireland was carried out on a coastal lowland site at Ballywalter and lowland and upland inland sites at Newforge Lane (Queen's University field site) and Broughshane respectively (Table 29) (Plate VIII). Seedlings from a common stock (Hill Cove) were planted in May 1985 on all sites as spaced plants (at 0.75 m

Plate VIII Planting out Tussac grass seedlings on the upland field site at Broughshane in N. Ireland.

Plate IX Close 'sward' of Tussac grass established at the Newforge Lane site, N. Ireland.

spacings between plants and rows) and as 'swards' at 10 cm spacings (Plate IX).

4.3.1 Spaced plants

Seedlings grew rapidly in the field from time of planting as 3-tiller units in May and by August had 16 (±4.3) and 21 (±2.0) tillers, were 26.5 (±1.49) and 28.0 (±8.96) cm tall and had basal circumferences of 6.5 (±2.81) and 11.9 (±1.04) cm on the Newforge and Ballywalter sites respectively.

Problems with fungal (rust) and insect pest (frit fly) attack were experienced at both Newforge and Ballywalter. The Newforge site was worst affected and it was estimated that most of the 19.7% plant deaths recorded (Table 30) were due to frit fly attack. In an assessment of frit fly damage in July, 48%, 24%, 7%, 1% and 16% of tillers suffered 0-25, 25-50, 50-75 and 75-99% damage and death respectively through frit fly. Damage was assessed as the proportion of leaf area or infected tillers dead or yellowing. A discussion of pest control is presented in Section 4.3.4.

By July of year one, survival of spaced plants was high at the Ballywalter (coastal) and Broughshane (upland) sites (Table 30) and dead plants were replaced on all sites from spare stock grown on at each site.

The pattern of overwinter survival of spaced plants is shown in Table 30. Overwinter 3, 9 and 28% of plants died at the Broughshane, Ballywalter and Newforge sites respectively, with death occurring at a steady rate overwinter at Ballywalter and Newforge and particularly during January at Broughshane. January was particularly wet on this hill site and plants were in almost continually waterlogged, cold, peaty soil. Due to problems of weed control and insect infestation, spaced plant experiments on the Newforge site were discontinued at the end of year one.

By August of the following year, surviving plants at the Ballywalter and Broughshane sites had grown considerably and were, respectively, 81 and 62 cm tall, had 287 and 93 tillers and basal circumferences of 38 and 24 cm (Table 31). Initial survival at the Broughshane site was good because of the absence of rust and insect pest attack.

In conclusion, spaced plants of Tussac grass can be established successfully in the field in the British Isles and provided pests are adequately controlled, survival over the first winter can be high. During the second growing season plants developed rapidly, particularly on the lowland, coastal site where tiller number increased over year one from 3 to 16 tillers and over year two to 287 with concomitant increases in plant biomass (see 4.4.1).

4.3.2 Swards

In relation to most other grass species in the Falkland Islands, Tussac is both highly productive and nutritionally superior. Hence, if Tussac could ever be established from seed sown mechanically in a conventional manner then the creation of a 'high sward' maintained in a leafy state by cutting or grazing might be a valid concept. In view of the problems associated with plant competition and to investigate if Tussac grass could form a close-knit, short canopy when plants were established very close together, 'swards' were planted at several sites.

Plants were raised from seed and planted out as two or three-tiller seedlings at 10 cm spacing in May to form twenty four 1m^2 plots at the Newforge Lane site (Plate IX). The plants were not defoliated until October (i.e. 5 months after planting) by which time individual plants had a mean tiller number of 4.8 (±1.7) and the mean sward surface height was 481 mm (±6.7). Plants were hand-wed once over the summer period. Plots were cut to a height of 12 cm above ground level, DM yield was assessed and the cut herbage separated into 'green leaves', 'dead' and invading 'weed' species. The mean total standing crop (above 12 cm) was 2.60 (±0.089) t DM ha^{-1} equivalent of which 80.1% was 'green', 11.8% was 'dead' and 8.1% was 'weeds'.

At a plant density of 100 m^{-2}, a five month growing period (though the sward was established from rooted plants rather than sown seed) a yield of 2.1 t green DM ha^{-1} above 12 cm sward height must be considered relatively high (though see 4.4.1). However, the plants were still distinct units and had not tillered out sufficiently to fill in the between-plant space. Invasion, particularly by weed grasses such as Meadow grasses, would likely become a problem in subsequent seasons. The site was not able to be maintained for further seasons where it had been planned to investigate the effect of frequency of defoliation and nitrogen fertiliser on Tussac sward growth and persistence.

The trial did indicate that a Tussac sward can be established and is relatively productive. However 'swards' will only become a viable proposition if sowing and planting can be mechanised. Once established, issues such as the response to grazing and treading by sheep and cattle in relation to the maintenance of a tiller population sufficient to maintain adequate ground cover will require further investigation.

For the meantime it seems more prudent to concentrate the research effort on the establishment and maintenance of a stand of spaced plants but the concept of a Tussac sward merits further consideration.

4.3.3 Site variation

During Year 1

By November, ie. after one summer's growth, plants from the Newforge site had fewer tillers (basal circumference data presented) and were less tall than plants from the other two sites.

Plant tussocks decreased in height overwinter at an approximately similar rate on all sites, despite obvious climatic differences (Table 32). Approximately 4-5 leaves appeared on each tiller between November and April and mean leaf extension rates were 1.5 - 1.7 mm day^{-1} over the same period (Table 33). Between-site differences over this initial establishment period and up until one year after planting were not substantial. Any major variation was caused by site differences in form and severity of rust, weed and insect attack. Responses to applied nitrogen fertiliser were also similar for each site (Table 34).

Subsequent variation

As mentioned earlier, the Newforge site was abandoned at the end of year 1. Plants continued to be monitored at the upland and lowland sites (at Broughshane and Ballywalter, respectively).

4.3.4 Pest control

Tussac grass planted outdoors in the British Isles suffered more serious competition from invading weeds and was more susceptible to disease and pests than Tussac grass growing in the Falkland Islands.

Weeds

Even though plants were transplanted as seedlings into bare ground, within a short time invading weed species were posing serious problems. The invading species were largely site dependent but on all sites grass weeds (particularly *Poa annua, Agrostis capillaris* and *Elymus repens*) and forage legumes (particularly *Trifolium repens*) posed the most serious threat. On all three N. Ireland sites initial hand-hoeing was practised until this became too labour intensive. Subsequent control using paraquat (80 ccs. of active ingredient in 6 litres of water) with a nozzle guard to protect the young Tussac grass plants proved successful on the Ballywalter site. However white clover is resistant to paraquat and the inter-plant spaces gradually became clover dominant. Clover control can be achieved using glyphosate (250 ccs a.i. in 20 litres of water) but the problems of spray drift and translocation on overhanging Tussac leaves make this potentially a more hazardous operation. On the upland site (at Broughshane) invasion was much slower and in the first season no herbicide was applied. As a result plants were well established by the time weed competition, mainly from grasses and rushes, had become significant.

In an experiment at Harper Adams Agricultural College where Tussac seedlings were intersown with different legume species R. Coward (personal communication) found that while white clover generally overran Tussac plants and completely killed them, with red clover, Tussac survival was 78%. Yellow suckling clover (*Trifolium dubium*) and trefoil (*Lotus uliginosus*) were most compatible with Tussac grass. He also reported competition from weeds as the largest problem with growing Tussac grass and had to hand weed plots.

In N. Ireland, once the upland site was abandoned plants were overrun with *Agrostis capillaris* and *Holcus lanatus* in two seasons. On the lowland site at Ballywalter, hens (at a density of 1 per 40 square metres) gave excellent inter-tussock weed control.

Insects

Fritfly and aphid infestations were severe on the lowland site at N. Ireland and on plants grown at Harper Adams (R. Coward, personal communication). The insects burrowed into the tillers to the central shoots, resulting in eventual tiller death. Excellent control was achieved by spraying Malathion (Dursban 48E) at 1.4 l ha^{-1} in not less than 200 l water ha^{-1} on or around early May, mid June (optional), mid July and mid August. A high density of ladybirds were introduced to heavily aphid infected plants in a confined space but were unable to cope with a severe aphid infestation at Harper Adams (R. Coward, personal communication).

Diseases

Plants became infected with stripe rust (*Puccinia striformis*) at all sites. Infestation was first noticed on the lowland sites at Harper Adams and Ballywalter during the first season after planting and on the upland site (Broughshane) three seasons after planting. Successful control was achieved at all the N. Ireland sites using the cereal fungicide TILT (CIBA Geigy Ltd) applied at a rate of 0.5 litres ha^{-1}

a.i. equivalent (10 cc in 6 l water). On the lowland site at Ballywalter total control was only achieved if spraying commenced when the infection was first noticed (about mid June) and on at least 2 subsequent occasions. On the upland site a maximum of two sprayings per season were required for adequate control. Successful control was also achieved using the fungicide MISTRAL on the plants at Harper Adams (R. Coward, personal communication).

Conclusions

Tussac grass grown in the British Isles was much more susceptible to pest attack than Tussac grown in the Falkland Islands. In both localities however, rust infection and grass weed invasion were similar in nature, if not in degree of severity, and similar principles might apply. However fritfly is not found in the Falkland Islands and aphid numbers are low so the insect pest problems are likely to be exclusive to the British Isles (though see Section 3.4.2. on insect pest attacks in the Falkland Islands).

The problems of Tussac grass protection against pests and diseases in the British Isles this must be considered as a serious factor in the establishment of the grass and its use as an alternative forage crop in lowland areas though the problems are much less evident in upland areas where, taking into account its early growth habits (see 4.4.3), Tussac may have more potential as a forage crop in upland areas.

4.4 Biomass and production

Linear growth measurements, including leaf extension and plant overall dimensions, were carried out on plants growing at the Ballywalter and

Broughshane field sites during the second growing season. To enable these to be related to biomass distribution within the plant and to production intact, whole and cut Tussac plants were lifted from the field for detailed laboratory analysis. Plants were removed to coincide with the grazing periods i.e. in summer and winter (Aug. 86 and Dec. 86 respectively). Linear measurements on marked tillers and leaves commenced before grazing and were continued on a regular basis to monitor the recovery response to grazing. These detailed leaf measurements have yet to be fully analysed and presented. When complete and related to the biomass data, they will enable the investigation of:-

- Those factors which cause initiation of growth and tillering.
- The initiation, longevity, production and death rate of leaves on tillers.
- The timing of tillering in relation to leaf initiation, development and tiller size.
- Factors influencing the determination of tiller group size (of particular importance in relation to the plants' ability to withstand grazing).
- The position in the tiller, in time and in the tiller sequence of daughter and reproductive tiller occurrence.
- How much biomass is partitioned to reproductive tillering within the plant.
- The distribution of digestible material throughout the plant.
- The estimation of standing crop and biomass production.

In the following section details of:- the biomass and production of spaced plants at several harvest dates; a breakdown of the tillering structure within the plants at these harvest dates; the overwintering pattern of leaf extension and growth and the growth of Tussac at low temperatures in comparison with other species - are presented.

4.4.1 Whole plants

Mean Tussac grass biomass 15 and 19 months after planting at the Ballywalter (lowland) site was 0.55 and 0.82 kg DM $plant^{-1}$ respectively and at the Broughshane (upland) site was 0.17 and 0.13 kg DM ha^{-1} $plant^{-1}$ respectively (Table 31). It was found from the grazing experiment reported later (4.5.1) and from local Falkland Island experience that winter was the best time to graze Tussac grass. Hence, by the second winter (though in practice this is too early to graze in the Falkland Islands) when plants were grazed they were 80 cm tall and, at the spacing of 0.75 m x 0.75 m, total biomass per unit area was 14.2 t DM ha^{-1}. Of this 8.7 t DM (61%) was green leaf or sheath material (Table 31) with an OMD of approximately 0.75 (Table 35). By May of the following year i.e. two years after planting, mean total standing biomass per unit area was 20.8 t DM ha^{-1} with 74% (15.4 t DM) green leaf and sheath material.

At this time and on this site there were several exceptional plants with a biomass over 3.5 kg DM. If this plant size was consistent over the whole site, a standing crop biomass of 62 t DM ha^{-1} would be achieved, representing a potential for production in the order of 30 t DM ha^{-1} yr^{-1}. At this level of fertiliser application (60 kg N ha^{-1} yr^{-1}) this is almost four times the level of production likely on this site from any of the commonly sown European forage species. Even the mean biomass figure obtained from the site represents production in the order of 10 t DM ha^{-1} yr^{-1}, though considerable attention was paid to pest control. The high digestibility level of almost all the components of the Tussac grass plant make its level of production particularly noteworthy. These values are much higher than those reported from the field site in the Falkland Islands (3.5.1). However, much of the biomass is in leaf and stem bases, particularly in winter (Table 31b). At Ballywalter, 55% and 70% of the DM was in the basal stubble in August and December respectively. More of the dead matter was also present in the stubble, with 81% of the cut foliage green or sheath material. At the Broughshane (upland) site production was much lower than at Ballywalter and, unlike the drier, milder, lowland site, plants did not grow overwinter.

The data indicate that, provided pests are controlled, at a relatively close spacing, Tussac has potential for extraordinary levels of production of high digestibility material in an establishment phase.

4.4.2 Tillers

In Tussac grass there is considerable variation between plants in tiller size and number and within plants in tiller size and numbers of tillers in each tiller group. Tiller pulling and uprooting has been observed as the major type of damage to young plants when grazed (see section 4.5.3 and Plate X). Hence a study of the tillering pattern in developing plants is important in relation to the plant response to grazing, particularly to the initial grazing.

Following removal from the field detailed examination of marked tillers enables:-

i. Field leaf extension rates to be related to leaf biomass.

ii. The life history of tillers and rate of tillering to be related to initial size and time of initiation if the distribution of biomass within tillers and tiller units is known.

iii. The rate of leaf turnover and rate of leaf senescence to be related to season and to field measurements of leaf profiles of tillers in grazed and cut plants.

iv. Factors affecting flower initiation and seed production to be studied in more detail.

v. More accurate estimates of plant biomass and correlation with field measurements such as plant height and basal circumference.

vi. The distribution and proportion of tiller size and tiller groups to be ascertained so that the response to grazing can be predicted on a more scientific basis than previously.

Whole plants were removed intact from the Ballywalter (lowland, coastal) site 15, 19 and 24 months after planting (August 86, December 86 and May 87) respectively and from the Broughshane (upland) site 15, 19 and 21 months after planting (August 86, December 86 and February 87 respectively).

Tillers from these plants were frozen and stored pending further analyses to investigate points i-v above. As the initial priority in the programme was to relate tiller size and group size and distribution to the plant's ability to withstand grazing, an analysis of these tiller features was carried out (see vi above).

Within the plant tiller, units consist of any number of tillers from one to seven. A tiller unit is defined as the number of tillers occurring within the inside of two completely dead leaves on the tiller complex. Hence a tiller or tiller unit in a Tussac grass plant is independent of its parent tiller when there is a complete dead leaf in the tiller profile occurring between the two tillers.

Whole Tussac plants were subdivided into tiller groups and all the individual tillers within each group counted and weighed. Some tillers were further subdivided into 'green', 'dead' and 'sheath' material.

At the lowland, coastal (Ballywalter) site the overall production and turnover of tillers increased considerably between August and December (15 and 19 months after planting) with more live and dead tillers per plant. This was also reflected in a decrease in the live leaf component and an increase in the dead component of tillers between August and December (Table 36). Tiller death rate over the same period was much greater at the upland site (Table 31). Data on tiller size and distribution of tillers by numbers and weight across the profile of tiller groups from tillers collected on three dates at two sites are presented in Figures 25 and 26.

Almost half of the tillers died overwinter (Table 31) on the Ballywalter site with most of the deaths occurring in tillers in the larger tiller classes (i.e. with smaller tillers) (Figure 26). By May

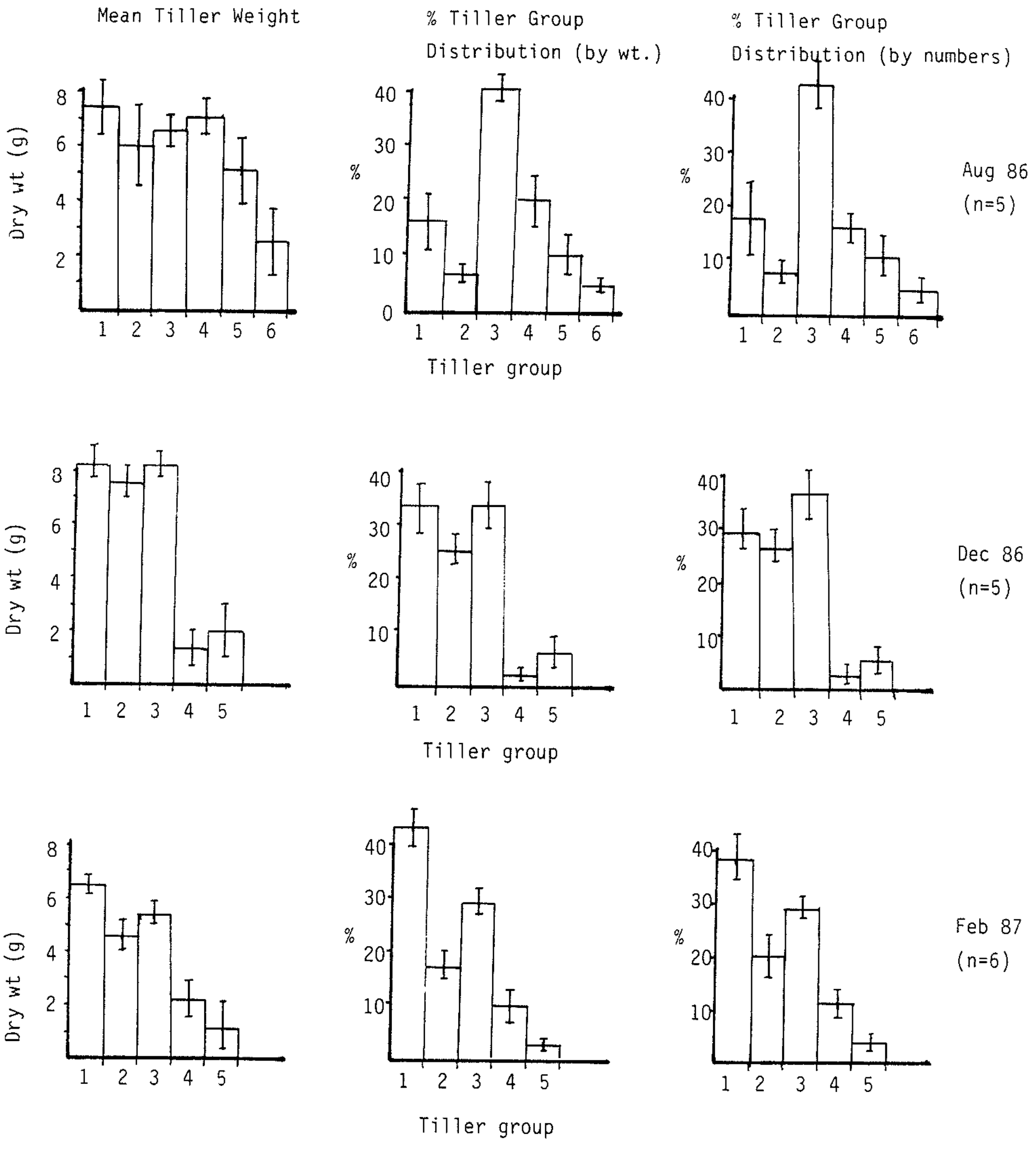


Figure 25. The mean size of individual tillers and the proportion and distribution of the total tiller component (by weight and number) of single plants on three harvest dates 15 (Aug 86), 19 (Dec 86) and 21 (Feb 87) months after planting on the Broughshane (upland) site. The vertical bars represent ± the standard errors of the means.

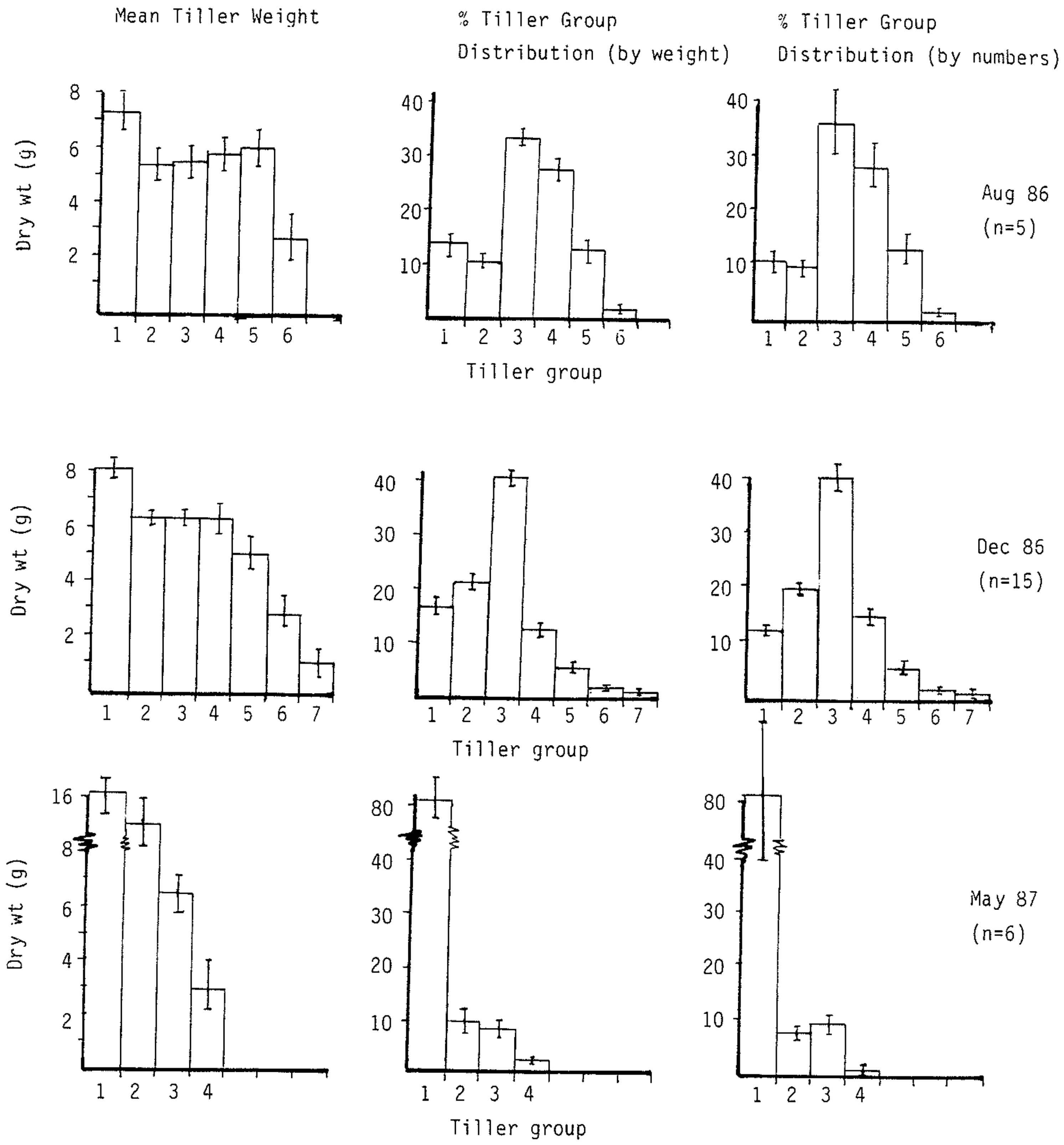


Figure 26. The mean size of individual tillers and the proportion and distribution of the total tiller component (by weight and number) of single plants on three harvest dates 15 (Aug 86), 19 (Dec 86) and 24 (May 87) months after planting at the Ballywalter (lowland) site. The vertical bars represent ± the standard errors of the means.

i.e. two full years after planting the tillers remaining were, on average, twice as large as those found in December.

Apart from at the last sample date at Ballywalter, mean tiller size was independent of the tiller group which that tiller belonged to for almost 94% of the tillers in each plant and on each site. For the two dates where they are directly comparable (Aug. 86 and Dec. 86) tillers were similar in size (6-8 g) from both sites. Tillers in the largest tiller groups (generally > 5 tillers) tended to be small (1-3 g).

The distribution of the proportion of tillers by weight and number was almost identical for both sites. There was a greater proportion of tillers in the smaller size groups (1, 2 and 3 tillers) in December than in August at both sites. Hence individual tiller size was greater in December than in August. This is of importance when the response of Tussacs to grazing at the two dates is evaluated (section 4.5.1) and overwinter survival considered.

4.4.3 Winter growth

Much of the value of Tussac grass as a winter forage lies in its ability to remain wintergreen and to grow over the winter period. To demonstrate and measure this property of Tussac, tillers were marked at each of the three field sites, leaf extension measured and rate of leaf appearance recorded. Plant height and basal diameter were also measured over the winter period. Over the period October - March, rate of leaf extension was approximately 1.6 mm per day with little site variation (Table 33). Almost one leaf more was produced on plants growing at the coastal site than at the other two (inland and upland) sites. This is a faster leaf appearance rate than commonly reported for Perennial ryegrass (*Lolium perenne*) over the same periods and indicates that, in N. Ireland at any rate, Tussac grass is actively growing over-winter.

4.4.4 Species comparisons

The reported ability of Tussac grass to start growth earlier in the season than other species is an important attribute of any forage grass. Experiments were carried out to measure the growth of Tussac grass (in comparison with other species) at a low temperature in a controlled environment and to compare the early spring growth of field grown Tussac grass with other species.

Low temperature growth

An experiment was carried out to investigate the growth at low temperature of a range of southern-cool temperate forage grasses grown in a controlled environment. Some of these grasses may have potential as novel forage sources on hill land in Northern Britain, though there are other problems, not necessarily related to growth, which may need to be overcome. In establishing Tussac grass in the Falkland Islands, Yorkshire fog and annual meadow grass can compete severely with Tussac. Material of two other Falkland Island grasses was included for comparison.

Plants (12 replicates) were grown in pots in a growth chamber maintained at 4° C and growth measured as leaf extension and leaf appearance over a series of time intervals. Leaf appearance and leaf extension at 4° C (Table 37) were significantly lower and faster respectively for young Tussac grass plants than for all other species. This experiment demonstrates that Tussac grass has potential for early growth and merits field trials.

Spring growth

A comparison of the growth of Tussac grass, Annual Meadow grass, Perennial ryegrass and white clover grown at an upland and lowland site was made between March and April. At each site one tiller (stolon) was selected from twenty random plants of each species within replicated plots at the beginning of each period. All leaves on each tiller were measured at approximately weekly intervals and leaf (stolon) extension and appearance rates calculated. The results for leaf extension, senescence and appearance of Tussac grass are presented in Figure 27.

Extension of Tussac grass leaves started earlier in the season and was greater than for the other grass species measured. Extension was greater at the lowland site than the upland site though rates of leaf appearance were greater on the upland site in early May than on the lowland site. Senescence rates increased to a peak in late April and subsequently declined - slightly later on the upland site than the lowland site (Figure 27). Hence, to achieve maximum growth potential in early spring Tussac requires a mild, relatively dry site.

4.5 Grazing and Defoliation

In the Falkland Islands it is widely recognised that overgrazing is the primary cause of death of Tussac grass plantations. Although this report is largely concerned with research into the establishment of Tussac, establishment can be considered to encompass both planting and early management. In this respect the plant's response to defoliation, particularly the first grazing after planting, is of critical importance. Information is required on the timing of initial grazing, severity of defoliation and the effect of the grazing process on individual Tussac grass plants. These issues are addressed in this section of the report.

Due to the limitations of size of the field site and the duration of the study, proper grazing management trials could not be carried out in N. Ireland. It is well documented in the Falkland Islands that Tussac should not be grazed until it is at least three years old. However within the constraints of the present study the comparison between summer and winter grazing had to be carried out on plants which were under two years old and on small plots where the duration of the grazing period was short. The experiment on defoliation reported in 4.5.2 was carried out under controlled environment conditions in the growth cabinet.

However it was felt that the general principles investigated in these trials would be widely applicable and would highlight issues for further work on grazing management of Tussac grass.

4.5.1 Timing of grazing

Small plots containing approximately 20 Tussac grass plants were grazed with sheep in summer (August) and winter (December). Before grazing, some plants were covered to protect them from stock, some were removed and some were cut (see Plate X). Sheep were removed from each plot when it was considered that they had grazed 1/2 to 1/3 of the green tissue from each plant. After the sheep had been removed from the plots, &k010Hleaves, tillers and other plant material which had been pulled out and rejected were carefully collected for analysis.

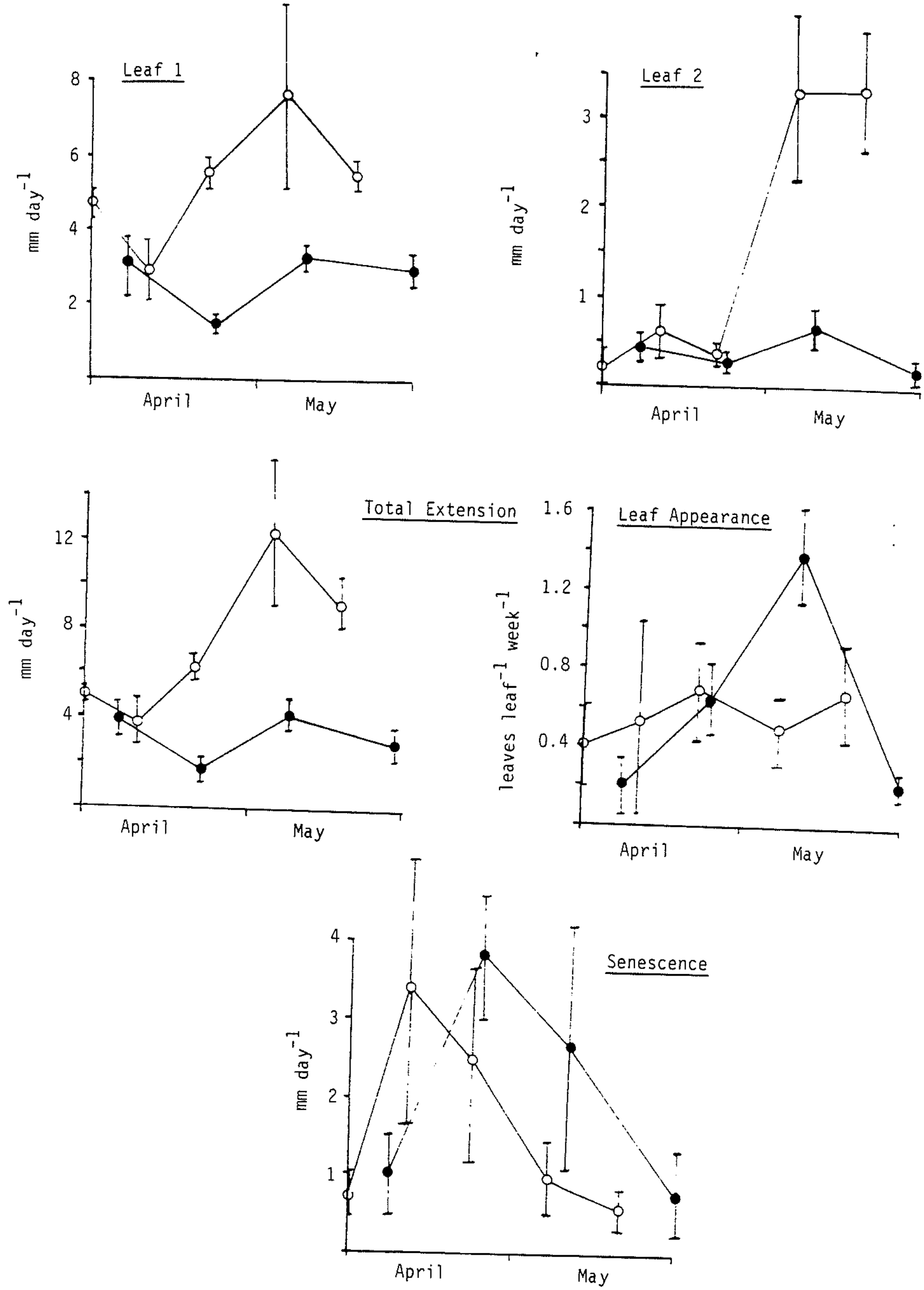


Figure 27. Rates of leaf extension (leaves 1, 2 and all leaves), leaf senescence and leaf appearance on mature Tussac grass plants growing at an upland (●) and a lowland (O) site in N. Ireland.

The mean dimensions, weight and constituent composition of the plants before and after grazing are presented in Table 38.

The overall plant dimensions of height and basal tussock diameter (circumference) were relatively unaltered by grazing. This is more a function of measurement methodology - plant height being measured as the maximum height of the longest tiller and this may not have been grazed on any occasion. During the summer and winter grazing respectively an estimated 38% and 46% of tillers and 55% and 43% of Tussac dry weight was removed. Hence the severity of grazing was relatively similar on both occasions. More severe tiller pulling and uprooting was observed on the summer grazed than the winter grazed plots (Table 38 and Plate X) (see 4.5.3) and twice as many rejected tillers were collected after summer than winter grazing.

This represents almost three times as much dry matter rejected from the summer grazed than the winter grazed plants. Tillers were, on average, smaller in summer (August) than winter (December) and there were more tillers in the smaller (numerically) tiller groups than in the larger groups (Figure 26). Hence it may be concluded that by December plants had larger, better differentiated, more discrete (and hence firmer rooted?) tillers which were better able to withstand the pulling action of the sheep grazing than the tiller group conformation in summer.

The other important issue in relation to Tussac response and recovery from grazing concerns the depletion of storage reserves within the plant. More dry matter was found in the leaf bases and lower stems in December than in August (Table 31), hence ameliorating the effect of winter grazing on storage reserve depletion, though in the current trial sheep did not graze hard into the tussock pedestal. From this trial it is clear that the response of Tussac to grazing involves two main issues, a mechanical response to the actual grazing process which is a function of the tiller size and conformation and the likely depletion of storage reserves which is a function of the seasonal pattern of growth. The interaction of these two issues requires further research on a larger scale in the Falkland Islands.

4.5.2 Severity of defoliation

From most accounts it is clear that the death of Tussac plants can largely be attributed to uncontrolled grazing. Whether this is a function of timing of grazing, severity of grazing or a combination of both is of fundamental importance to an understanding of the management of Tussac grass.

As a precursor to future grazing trials an experiment was conducted under controlled environment conditions to investigate the effect of severity of defoliation and nitrogen application on the growth of Tussac grass plants.

Plants were grown individually in pots in a growth cabinet with extended photoperiod and following initial establishment were cut to one of 3 heights (0, 2 and 8 cm) at approximately fortnightly intervals and received either 0, 150 or 300 kg ha^{-1} equivalent of nitrogen fertiliser. Leaf extension and production rates were measured throughout the experiment (Figure 28 and Table 39 respectively) and the amount of material harvested at each clip recorded (Table 39b).

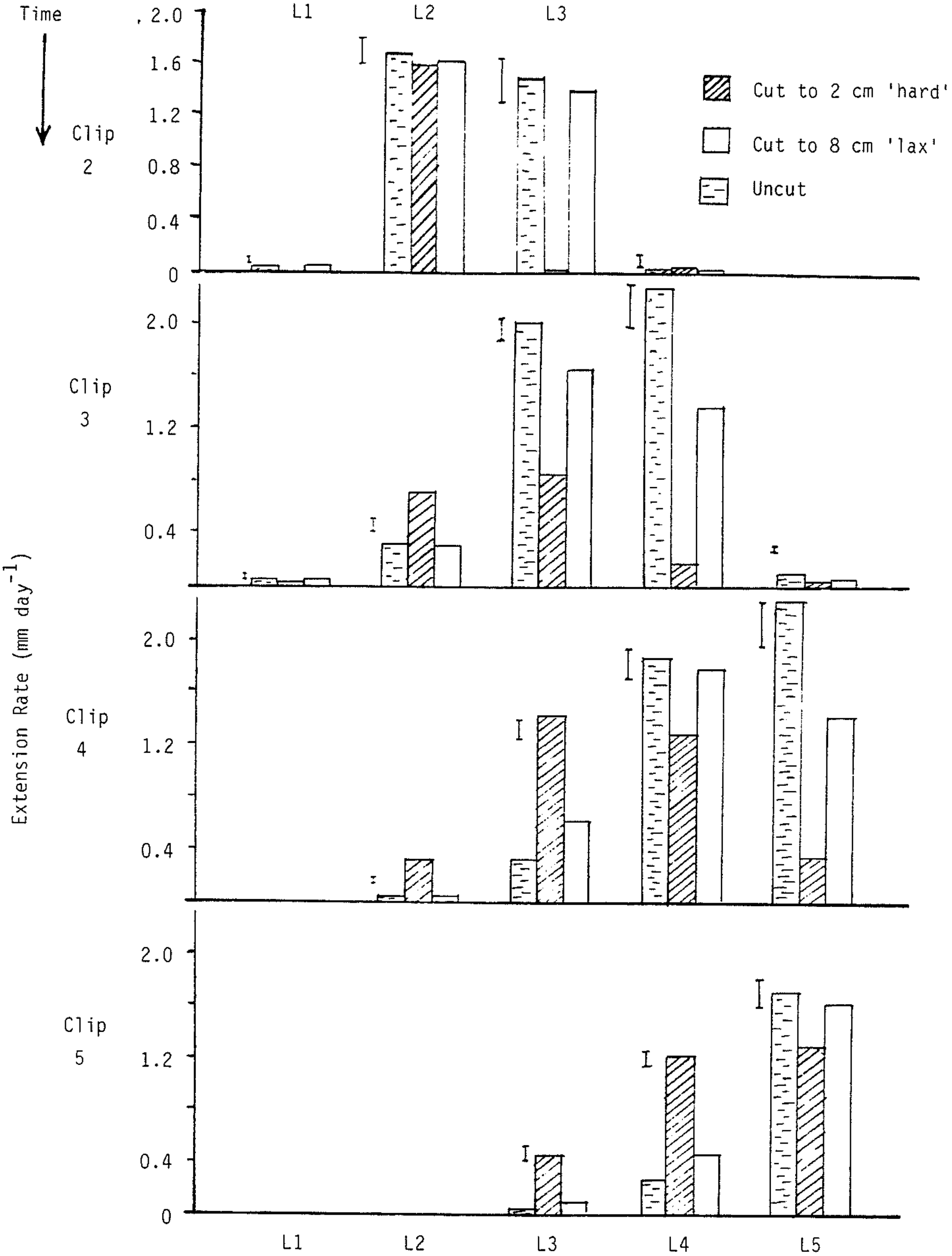


Figure 28. Rates of extension (mm day^{-1}) over five clips of individual leaves of tillers of Tussac grass either uncut (▤) or defoliated to 2 (▨) and 8 (□) cm.

None of the cutting treatments was affected by level of applied nitrogen for any of the factors measured and the results are presented as means for the cutting treatments only.

Leaf growth was slower following defoliation than when leaves were not cut (Figure 28). Growth of the youngest, most rapidly expanding leaves was significantly lower following severe defoliation (to 2 cm height) than lax defoliation (to 8 cm height). As leaves got progressively older, the effect was gradually reversed and eventually the older leaves were growing more rapidly where they had been more severely cut back than where they had been lightly cut. Rate of leaf production was significantly reduced by severe cutting and the total DM produced over successive clips (excluding clip 1) was greater when plants were lightly defoliated than when defoliation was severe.

It can be concluded that Tussac grass responds adversely to hard defoliation - leaf extension growth, new leaf production and dry weight increment are all greater under light defoliation than severe defoliation. As leaves age they grow faster where they had been previously severely cut than lightly cut. However these are the least nutritious and least attractive leaves to sheep so the applied significance of these results requires further verification.

4.5.3 Grazing behaviour

Plots containing approximately 20 Tussac grass plants were penned off and grazed over a short period with four mature Greyface (Scottish Blackface x Border Leicester) ewes per plot (Plate X). Each sheep was colour marked. Grazing was carried out on two occasions, summer (August) and winter (December) when plants were 15 and 20 months old respectively. On each occasion eight of the plots described above were grazed. During the grazing period (up to eight hours) observations were made on sheep behaviour at the end of each 5-minute period. Individual sheep were recorded as either biting, standing, lying, ruminating or walking. Individual Tussac grass plants were grid coded and, during grazing, a note was made of which plant the sheep were grazing or if they were grazing some of the between-tussock ground flora - usually Annual Meadow grass, white clover and groundsel (*Senecio vulgaris*). The data enabled the percentage of the time spent on each of the above activities, and rate of biting of individual Tussac grass plants to be calculated. Before grazing commenced measurements were made of the size of the Tussac grass plants in each plot and correlations were calculated between grazing rate and plant size parameters.

During the summer grazing it appears that plants were, overall, too small to be grazed as many tillers were uprooted and lay strewn about the plot with a concomitant effect on plant growth potential (Plate X). By the December grazing the problems of tiller uprooting were much less (see 4.5.1).

Plants were similar in size on both occasions (Table 38). On average about 50% of the time sheep were on the plots they were recorded as biting Tussac grass plants (Table 40).

There were considerable differences in behaviour between sheep. Often the duration and frequency with which an individual sheep grazed plants depended on how long they took to overcome their initial reluctance to graze the Tussac grass. Generally the inter-tussock vegetation was

a. Uprooted tillers - typical damage caused by sheep grazing. Note that some plants are protected for short periods (by upturned drums) to act as non-grazed controls.

b. Typical damage following hard grazing of immature plants. Note the high degree of tiller pulling and uprooting.

Plate X Sheep grazing trial on the lowland (Ballywalter) site.

completely grazed first before sheep turned their attention to Tussac grass. The long, relatively spiky leaves and fringe of dead matter apparently induced an alien tactile response in sheep used to eating more low growing, palatable herbage. Once the initial reluctance was overcome sheep grazed plants vigorously. The main variation between sheep was in the time taken to overcome this initial reluctance.

Generally correlations between grazing rate and plant size were low (Table 41). This was consistent for both grazing periods and, overall, plant height was the best size indicator of grazing preference ie. sheep tended to graze taller plants though the correlations were weak (0.32 and 0.30).

That plants were more susceptible to grazing damage in summer than winter may reflect the relative maturity of the plants in this experiment (15 months and 20 months respectively) and the different tiller size and grouping profiles (Figure 36) though there were no appreciable differences in plant size on the two grazing occasions. Sheep were observed to graze deeper into the Tussac canopy (ie. at the leaf bases) during the summer than the winter and this may have resulted in more tillers being pulled out, during that period than in the winter when only the laminae were grazed. This may be an attractant response to higher levels of carbohydrates in the developing leaves and leaf bases during the summer than winter. Gunn (1976) found that low molecular weight sugars were highest in the whole shoot during summer and total and high molecular weight carbohydrates were considerably higher in summer than in winter in the oldest (ie. outermost) leaves. In this trial these are the leaves sheep would have had time to sample during the relatively short grazing period and although total carbohydrate levels were higher in winter, these were due to high levels in the youngest, innermost leaves which sheep would not have had time to sample. Hence the differences in grazing between the two periods may be behavioural with biochemical induction. This, along with the difference in tiller size and group profiles (4.5.1) may partially explain why Tussac grass must be protected from grazing during the summer period in the Falkland Islands.

4.6 Discussion and summary

With current areas of Tussac grass (particularly on the mainland of East and West Falkland) so reduced and dispersed, the availability of planting material to establish stands of Tussac is a potential problem. The experiments on seed germination demonstrate the viability of this technique as a means of planting Tussac in the Falkland Islands.

There are indications that seed from some sites has higher viability than seed from other sites though this finding would be best confirmed over a number of seasons.

From the results it can be concluded that, as there is considerable variation between the viability of seeds from a number of sites and over a range of harvesting dates and ages, seed should be collected before mid summer from sites which regularly yield a relatively high proportion of viable seed. This seed should be used within a few years of collection following dry storage.

The benefits of hormone treatment of seed may well be negated by the poor, spindly growth form of the resultant seedlings and this issue requires further experimentation in the field (see Chapter 6).

Provided fresh seed can be collected and used relatively quickly, a high sowing rate of seeds to compensate for poor germination may be the best practical option. The selection of small seed or seed from certain sites can give enhanced germination and early growth, but unless the raising of large numbers of Tussac plants from seed was being undertaken as a specialist enterprise, such selection is hardly justified.

The experiments indicate that if Tussac grass plants are being raised on a large scale and under nursery conditions, issues such as soil fertility (particularly soil phosphorus) and salinity and attention to detail on early seedling vigour (particularly in relation to thinning of plants) and subsequent leaf and tiller production can result in substantial improvements in the final quality of plants produced. Mass produced, uniform seedlings lend themselves to some form of mechanical planting and, from initial investigations, vegetable and tree planting machines may be suitable for mechanising the planting of seedlings and tiller clumps respectively.

The other experiments carried out in N. Ireland demonstrate the potential of Tussac grass as an out-of-season high-quality forage resource and further trials on a small plot scale are warranted. The experiments also demonstrate that under the range of climatic conditions found in spring in the Falkland Islands, Tussac will grow faster than any of the commonly introduced species and probably faster than most native species.

If the planting process can be mechanised sufficiently, the establishment of 'high swards' of Tussac grass is a possible option.

The experiments demonstrated that swards could be effectively established but no information is available on management, particularly the response of Tussac swards to treading.

Although of a basic nature, the grazing trials did indicate that timing of initial grazing of Tussac stands is a critical management issue. The trial clearly indicated that unless plants have reached a certain size, damage, particularly through tiller uprooting, will be severe. Even allowing four extra months growth before grazing resulted in a substantial difference in plant stability and tiller strength. This may have been confounded by the different seasonality of the two grazing episodes though a study of individual tiller sizes and groupings indicated that structural changes within the tiller organisation may be important. The experiment does indicate that plants are better able to withstand winter grazing than summer, thus confirming the normal management practice in the Falkland Islands. The detailed analysis of grazed plants showed that the composition of plants in terms of size and number of tiller groups and in terms of carbohydrate content and digestibility may well be a reliable determinant of a young plants' likelihood of withstanding grazing. It appears that there is little likelihood of compensating for severe defoliation by addition of fertiliser.

An understanding of the seasonal movement and re-allocation of storage reserves throughout the plant is fundamental to an understanding of the plants' likely response to grazing and to a better appreciation of the basic principles of Tussac grass management.

Plate XI A lamb sheltering from strong wind behind a Tussac grass plant on the lowland (Ballywalter) site. The plant is recovering in early spring after overwinter grazing.

5. RECOMMENDATIONS FOR FURTHER WORK

This list follows the chronological order of the report and is not in any order of priority.

We recommend that:

1. **Ecological assessment of selected areas to provide more accurate data on extent, distribution and decline of Tussac grass be carried out.**
   Previous distribution surveys have utilised different methodology and in some cases have produced conflicting results. Distribution surveys are valuable in that they highlight the nature of the problem whereas ecological surveys are likely to be of value in predicting those factors contributing to the decline of Tussac grass.

2. **Experimental investigation of the interaction between type of planting material, site selection and soil cultivation be conducted.**
   Although individual experiments have used tillers and seeds at various sites, no experiments specifically compared these and factors such as the competitive ability and further growth of seedlings from hormone treated seed in the Falkland Islands.

3. **If relatively infertile inland sites are planted, fertiliser requirements between post-establishment and time of first grazing need to be assessed.**

On the infertile sites planted, although there was no initial response to fertiliser, it was clear that after about three years plants were suffering from nutrient check though this was confounded by weed competition and pest attack.

4. **The time of planting is investigated particularly in relation to rainfall patterns.**

There was considerable variation in growth on the trials depending on planting date. These may have been due to the specific season, rainfall or plant disease susceptibility. Hence, experiments may necessitate seasonal repetition and detailed information on plant health should be recorded.

5. **Establishment from seed in the Falklands is investigated.**

The raising of seedlings under 'nursery' conditions for planting out and a comparison between seedlings and conventional 'sets' as planting material is a clear research priority from the results reported here. Seed should be collected from a range of sources, particularly Coast Ridge (Fox Bay), Carcass Island, Sealion Island and Port Howard (Whiterock) and tested for viability over a number of seasons. The use of different composts, seed treatment and potting units should be used to produce uniform seedling units.

Consideration should then be given to mechanisation of the process of planting these seedling units. Trials should be carried out using modified vegetable planting machines (for seedlings and small sets) and tree planting machines for larger sets. If successful, the concept of planting 'swards' of Tussac grass and their response to management require investigation in the Falkland Islands.

6. **The basis for selection of sets for planting - eg. age and condition of parent plant, position within parent plant and amount of root material etc remaining on the sets should be investigated.**

   Although many of the trials used sets from mature Tussacs, their selection criteria were not tested. The production of uniform sets for mechanical planting should be included within these trials.

7. **The life cycle, population dynamics, predators and biology of Tussac rust disease and stem-boring insects must be established.**

   From the trials carried out in the study it is clear that this aspect of Tussac growth is of fundamental importance to the successful establishment of Tussac grass in the Falkland Islands.

   Within this study, the ecological relationships between the occurence of Tussock birds (*Cinchlodes cinchlodes*) and insect pests of Tussac grass may be important.

8. **The salt tolerance of Tussac grass is established.**

   Because of the numbers of variables affecting growth and the high salt concentrations in the atmosphere in the Falkland Islands, these studies should be carried out under controlled environment and hydroponic conditions.

9. **Selected, vigorous lines of Tussac grass should be grown for a possible selection of superior planting material.**

Over all the trials, there was enough evidence of variation between plants in their response to fertiliser and susceptibility to pest attack, to merit genetic selection under controlled conditions.

10. **Root growth and competition be studied (particularly with likely invasive species, eg. Yorkshire Fog) in the Falkland Islands**

Results of competition experiments were inconclusive and it is clear that to investigate above-ground interactions alone are insufficient in this case and to understand the mechanics of competition, root studies will have to be carried out.

11. **Large scale grazing experiments should be carried out in the Falkland Islands**

It is essential to determine the time of first grazing on new plantations, to derive a seasonal pattern of grazing and the relationship between these and severity of grazing and speed of recovery. Particular attention should be paid to the effect of late and early winter grazing and their interaction with severity of defoliation on individual plants and the tiller group profile of these plants. Following detailed morphological study of leaf initiation within tillers, the effect of removal of individual leaves or combination of leaves throughout the year should be determined.

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APPENDICES

1. Tables

2. Text of practical guide to establishment in the Falkland Islands.

Appendix 1 TABLES

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41 Correlation coefficients between plant size (measured as height, diameter and basal circumference) and frequency of biting individual Tussac plants grazed on two occasions.

NOTE: Where possible the standard errors of the means of the data are presented. These are accompanied by superscripts *, ** or *** where they are significantly different, representing levels of significance of $P = 0.05$, 0.01 and 0.001 respectively.

NAME	AREA (ha)	WOODS PHOTOGRAMMETRIC (1983) STUDY			STRANGE (1986)			PONCET *et al.* (1989)
		DENSE	SPARSE	TOTAL	DENSE	SPARSE	TOTAL	TOTAL
1. <u>WEDDELL ISLAND GROUP</u>								
PENN	155	42	18.5	60.5	71	0	71	56.5
BARCLAY	110	36	1.5	37.5	0	22	22	29
FOX	80	19	13	32	0	27	27	20
QUAKER	195	86	31	117	0	24	24	83
HILL	50	2.5	2.5	5	0	5	5	11.5
PITT	45	-	-	-	0	22	22	20.5
LOW	75	-	-	-	0	24	24	24
GULL	25	-	-	-	0	8.5	8.5	13.5
LETTERBOX	2	-	-	-	2	0	2	2
'STICK-IN-THE-MUD'	3	-	-	-	2	0	2	3
COFFIN	23	-	-	-	10	0	10	20.5
GOVERNOR	220	-	-	-	0	50	50	25
GREEN	25	-	-	-	-	-	-	19
STAATS	500	27	47	74	0	2	2	0
TEA	310	104.5	64.5	169	70	0	70	120
SKULL BAY	5	-	-	-	4	0	4	5
CHANNEL	53	-	-	-	0	18	18	29
2. <u>BEAVER ISLAND GROUP</u>								
SPLIT	72							29.5
CUCUMBER	3	-	-	-	2.5	0	2.5	3
ROOKERY	25	-	-	-	0	2.5	2.5	20.5
RAT	1	-	-	-	0.5	0	0.5	1
CHAIN	10	-	-	-	6	0	6	6

<u>Table 1</u> The area (ha) and estimates of Tussac grass cover (ha) for 22 islands in the Beaver and Weddell Island groups (where available), from surveys carried out by Woods, and Strange (in: Strange *et al.* 1988) and Poncet *et al.* (1989).

		Biomass m^{-2}	Biomass per tussock
Ungrazed	Fertile	860	1586
	Infertile	768	1134
Grazed	Light	617	791
	Hard	443	600

Biomass as dryweight in g. Four samples per mean

Table 2 Mean above ground biomass data for individual tussocks of Tussac grass at four sites on South Georgia.

	1-tiller	2-tiller	3-tiller
Leaf length (m)	1.30	1.27	1.28
Leaf biomass (g DM)	9.7	14.5	23.0
Stem base (g DM)	8.3	15.3	35.7
Dead (g DM)	2.5	10.8	20.1
Roots (g DM)	0.3	1.0	1.3
% of total shoot DM			
Leaf	47	36	42
Stembase	40	38	36
Dead	13	26	22
Shoot : root ratio	68.0	37.7	40.7

	Three-tiller group cut to: 35 cm (short)	55 cm (long)
% leaf biomass removed	78	36
Remaining biomass (g DM)		
Leaf	3.8	14.4
Stembase	20.1	19.5
Dead	11.9	10.7
Roots	2.2	1.7

Table 3 Size of planting material used in the experiment reported in section 3.2.1. Two-tiller group measurements are included though this size was not used in the experiment.

	1-tiller uncut	3-tiller uncut	3-tiller cut-short	3-tiller cut-long	Grand Mean	s.e.
Mean plant height (mm)						
Jan 1987	550	525	523	598	549	28.7
April 1987	560	511	473	601	536	21.5**
Circumference (mm)						
Jan 1987	134	183	191	243	188	12.5***
April 1987	126	233	199	265	206	17.7***
Tiller number per plant						
Jan 1987	3.0	3.9	3.5	5.9	4.1	0.61*
April 1987	5.5	6.6	6.6	16.2	8.7	1.85**
Tiller thickness (circumference ÷ tiller number)						
Jan 1987	46	53	69	43	7.5	53
April 1987	27	42	22	38	6.1	32
% surviving tillers						
April 1987	67	62	60	60	62	7.8

<u>Table 4</u> Effect of tiller unit number and thickness on characters of establishment and growth of Tussac grass plants planted in late 1985. (The level of statistical significance of the effect is indicated).

	(a) Plant height (mm)		(b) Basal circumference (mm)		(c) Live tillers plant^{-1}	
	Apr 86	Apr 87	Oct 86	Apr 87	Apr 86	Apr 87
NO	475	599	144	225	4.5	16.1
N80	540	585	160	234	5.6	16.8
N160	582	566	145	223	6.0	17.2
s.e.	9.6*	26.4	5.02	11.3	0.88	2.56
PKO	546	576	145	227	5.5	15.2
PK40	519	566	154	227	5.2	18.3
s.e.	15.9	23.2	5.8	11.9	0.41	2.39
Seaweed 0	534	599	150	229	5.7	16.0
Seaweed 80	530	568	149	225	5.0	17.5
s.e.	11.6	18.9	3.49	9.5	0.38	1.89
Grand Mean	532	584	150	227	5.3	16.8

	(d) Surviving plants (%)		(e) Total plant biomass (gDM)		(f) % Green matter (DM) in live plants		(g) Mean tiller size (circumference ÷ live tiller no)	
	Apr 86	Apr 87	Oct 86	Apr 87	Oct 86	Apr 87	Oct 86	Jan 87
NO	74	47	12.2	28.4	19.4	7.1	26.2	43.2
N80	75	55	13.0	43.4	27.7	7.9	21.8	37.1
N160	71	48	12.7	25.7	19.5	9.4	24.0	45.6
s.e.	3.8	1.7*	0.57	7.75	4.25	0.99	0.99*	2.81*
PKO	74	50	13.0	29.6	17.9	9.4	23.5	43.5
PK40	72	50	12.3	35.4	26.6	6.9	24.5	40.5
s.e.	3.6	1.2	1.06	5.02	3.82	0.89	0.99	4.11
Seaweed 0	67	47	11.7	30.5	24.4	8.8	24.3	42.6
Seaweed 80	79	53	13.5	34.5	20.0	7.5	23.7	41.3
s.e.	5.7	2.9	0.78	7.17	3.86	0.94	1.38	3.31
Grand Mean	73	50	12.6	32.5	22.2	8.1	24.0	42.0

<u>Table 5</u> The effect of nitrogen fertiliser applied at rates equivalent to 0, 80 and 160 kg N ha^{-1} (NO, N80 and N160 respectively), PK applied at 0 and 40 kg ha^{-1} (PKO and PK40 respectively) and mulched seaweed applied at 0 and 80 kg N ha^{-1} equivalent (Seaweed 0 and Seaweed 80 respectively) (assuming 1.5% N in DM) on Tussac plant height, basal circumference, live tiller number, proportion of original tillers planted surviving, total plant biomass, % green in surviving tillers and tiller size.

	Applied nitrogen (kg N ha^{-1})							
	0	60	120	180	240	360	Mean	s.e.
Plant height (mm)								
Jan 87	535	588	535	513	655	577	567	40.3
Apr 87	584	628	568	538	687	640	608	53.0
Jan 89	469		395		437	384	421	18.8
Basal Circumference (mm)								
Jan 87	184	203	199	185	240	212	204	18.3
Apr 87	209	200	214	180	251	237	215	33.0
Live tillers per plant								
Jan 87	5.6	8.2	5.5	6.2	11.9	7.9	7.5	1.4
Apr 87	12.2	14.2	10.2	9.4	21.2	21.7	14.8	6.25
Jan 89	7.7		4.6		8.3	6.1	6.7	1.47
% Surviving plants								
Jan 87	86	72	80	76	79	77	79	8.2
Apr 87	82	70	73	72	75	69	74	8.6
Jan 89	38		45		49	57	47	8.5
Tiller size (mean diam per tiller)								
Jan 87	39.7	26.4	40.8	32.9	21.5	27.0	31.4	5.47
Apr 87	20.1	16.1	22.9	21.0	16.3	12.8	18.2	4.54
Plant biomass (g DM)								
Apr 87	25.9	36.5	34.9	41.2	29.9	32.9	33.5	10.66

Table 6 The effect of level of application of nitrogen fertiliser on establishment and early growth of Tussac grass at a coastal site.

	Applied nitrogen (kg N ha^{-1})					
	0	120	240	360	Mean	s.e.
Plant height (mm)						
Jan 87	724	740	705	711	720	33.2
Apr 87	769	772	723	762	756	38.5
Jan 89	385	415	581	522	476	24.5**
Basal circumference (mm)						
Jan 87	185	166	181	180	178	7.9
Apr 87	255	256	243	256	253	9.8
Live tillers per plant						
Jan 87	3.6	2.6	2.7	3.4	3.1	0.35
Apr 87	8.5	10.8	9.9	12.7	10.5	1.01
Jan 89	3.3	3.1	3.3	4.2	3.5	0.34
% Surviving plants						
Oct 86	98	95	93	96	96	3.4
Jan 87	95	95	93	95	94	3.2
Apr 87	95	93	93	93	93	3.0
Jan 89	63	43	61	66	58	4.2*
Tiller size (mean diameter per tiller, mm)						
Jan 87	52.1	66.5	66.8	54.1	59.8	6.93
Apr 87	30.3	24.2	24.7	20.3	24.9	1.72*
Plant biomass (gDM)						
Apr 87	47.0	50.6	42.5	58.8	49.7	3.69

Table 7 The effect of level of application of nitrogen fertiliser on establishment and early growth of Tussac grass planted into rotavated whitegrass camp at an inland site.

	1986	1987	1988
Basal circumference (mm)			
Control	137	252	707
Nitrogen	111	232	676
Fishmeal	118	225	710
Mean	122	236	698
s.e.	21.1	37.3	35.9
Plant height (mm)			
Control	599	818	1028
Nitrogen	536	796	973
Fishmeal	617	815	1056
Mean	584	810	1089
s.e.	29.9	37.3	76.4
Tiller number			
Control	2.9	9.2	54.4
Nitrogen	3.0	10.4	58.9
Fishmeal	3.0	13.9	61.3
Mean	3.0	11.2	58.2
s.e.	0.21	2.21	4.08
Plant survival (%)			
Control		81	78
Nitrogen		90	80
Fishmeal		90	85
Mean		87	81
s.e.		6.4	4.8

Table 8 The effect of nitrogen fertiliser and fishmeal applied at 60 kg N ha^{-1} equivalent on Tussac grass planted as 3-tiller groups in March 1986 on Sealion Island.

	1986	1987	1988
Basal circumference			
Control	122	53	405
Nitrogen	96	51	446
Marinure (Low)	88	47	440
Marinure (High)	94	77	483
Mean	100	52	444
s.e.	13.7	15.1	25.6
Plant height (mm)			
Control	421	542	667
Nitrogen	453	580	740
Marinure (Low)	424	599	712
Marinure (High)	466	606	687
Mean	441	582	701
s.e.	21.2	27.0	58.4
Tiller number			
Control	3.0	1.4	17.2
Nitrogen	3.0	1.5	22.1
Marinure (Low)	3.0	1.4	24.3
Marinure (High)	3.0	1.4	24.7
Mean	3.0	1.4	22.0
s.e.	-	0.11	2.91

Table 9 The effect of seaweed extract (Marinure) applied at two levels (equivalent to 10 litres and 50 litres per hectare i.e. 1 & 5 kg N ha^{-1}) and nitrogen fertiliser (Nitrochalk, ICI Ltd.) applied at 60 kg N ha^{-1} equivalent at planting and one year later on Tussac grass planted on eroded Tussac peat in March 1986 on Keppel Island.

	Inland	Coastal	s.e.
Plant height (mm)			
Jan 87	720	576	18.1***
Apr 87	756	620	22.0***
Jan 89	476	421	10.2***
Basal circumference (mm)			
Jan 87	178	208	8.2*
Apr 87	253	228	13.7
Live tillers per plant			
Jan 87	3.1	7.7	0.59***
Apr 87	10.5	16.3	2.50
Jan 89	3.5	6.7	0.54***
% Surviving plants			
Jan 87	91	81	4.6*
Apr 87	93	75	3.3**
Jan 89	58	47	4.7
Tiller size (mean diameter per tiller, mm)			
Jan 87	59.8	32.2	3.24***
Apr 87	24.9	18.0	1.88*
Plant biomass (g DM)			
Apr 87	49.7	30.6	5.17*

<u>Table 10</u> A comparison between plant growth measurements for Tussac grass in January 1987, April 1987 and January 1989 and harvest data (April 1987) from an inland and a coastal site at Port Howard (meaned over 4 similar fertiliser treatments).

	Port Howard Inland	Port Howard Coastal	Keppel Island	Sealion Island	s.e.
Plant Height (mm)					
1987	724	535	557	793	43.7*
1988	NA	NA	667	1028	48.6*
1989	476	421	1306	1816	63.7
Basal circumference (mm)					
1987	185	184	53	240	15.9***
1988	NA	NA	405	707	44.9*
1989	253	228	1072	1048	96.5
Tiller number					
1987	3.6	5.6	1.5	9.2	1.28*
1988	NA	NA	17.2	54.4	2.32***
1989	3.5	6.7	71.9	78.8	10.97

Table 11 A comparison between Tussac grass plant height, basal circumference and tiller number (all at zero fertiliser) at 4 sites. NA indicates comparisons not available.

Treatment	Application Date	Assessments (mm^2 of rust mg^{-1} DM of leaf) 1 December	1 January	1 February	1 March
TILT	1 Dec	156	53	77	270
TILT	1 Dec, 1 Jan	119	50	75	57
TILT	1 Dec,1 Jan,1 Feb	72	47	36	21
BAYFIDON	1 Dec	83	63	58	63
CORBEL	1 Dec	97	145	252	166
Control	No treat	62	48	188	180
s.e.		31.0	19.6**	23.4***	23.1***

Table 12 The effect of six treatments on the extent of infection of Tussac grass leaves (calculated as the surface area of the leaf infected per mg dry matter of leaves) up to four months after initial treatment.

TILLER TYPE	% of total Damaged	With Larvae	No of tillers Total Inspected	Damaged	With Larvae
Flowering	86	57	14	12	8
Vegetative	72	69	37	26	25
Daughter	33	17	12	4	2
Healthy	66	60	53	35	32
Unhealthy	70	30	10	7	3
TOTAL	68	56	63	42	35

Table 13 Tussac pest survey, Fox Bay

Fertiliser treatment	% DM	Mean green dry weight (g)	Mean total dry weight (g)	% Live	No. Live tillers	Mean tiller weight (g DM)
Zero	38.0	28.7	235.8	10.5	52	0.44
120 kg N (+P+K) ha^{-1}	36.9	70.3	280.3	25.2	108	0.64
120 kg N ha^{-1}	38.7	56.9	285.2	20.6	106	0.51

Table 14 The effect of fertiliser treatment on composition and DM production of Tussac grass.

Fertiliser treatment	Organic Matter Digestibility
Zero	0.70
120 kg N (+P+K) ha^{-1}	0.67
120 kg N ha^{-1}	0.70

Table 15 The effect of fertiliser on herbage quality.

Fertiliser Treatment	Standing crop estimate from:- Live dry weight	% Live/total DWt	Mean tiller weights
Zero	502 (333)	432 (286)	404(268)
120 kg N (+P+K) ha^{-1}	1230 (780)	1238 (785)	1213(769)
120 kg N ha^{-1}	996 (669)	1031 (692)	929(624)

Table 16 Estimated standing crop of 'green' matter (kg DM ha^{1}) - with digestible standing crop in parentheses. The "live dry weight" estimate is derived from the mean dry weight of the green matter separated from each Tussac. The "% Live/Total DWt" is based on the mean total dry weight of the Tussacs from each treatment multiplied by the Tussac density and divided by the mean % of the dry matter that was green. 'Mean tiller weight' was derived by multiplying the mean tiller number per Tussac by the mean tiller dry weight.

1986	Leaf Number	1987	Leaf Number
September	5.9	January	6.9
October	6.1	February	6.9
November	5.6	March	6.4
December	6.5	April	5.9
		May	5.4
		June	5.3
		August	4.9
		September	5.3

Table 17 Mean number of green leaves per tiller throughout the season on Tussac grass growing at Coast Ridge, Fox Bay.

	Mean seed weight (mg)	Mean % germination (after 40 days)	Shoot length (after 10 days)
Coast Ridge (north coast)	0.41	54	14.2
Carcass Island	0.36	35	22.5
South Georgia	0.33	35	22.6
Doctor's Creek (Fox Bay)	0.29	32	18.8
Sealion Island	0.48	30	14.2
Kidney Island	0.23	29	20.8
Monday Island	0.23	28	19.9
Hookers Point	0.36	25	14.9
Beauchene Island	0.13	24	16.6
N. Ireland	0.30	21	13.6
Port Howard (White Rock)	0.23	19	8.0
Coast Ridge (South Coast)	0.40	12	12.7
Hill Cove	0.16	0	-
Narrows Island	0.33	0	-
Port Howard (plots)	0.22	0	-
Overall Mean	0.30	23	16.6
s.e.	0.08	2.7	2.57

Table 18 The size, germination and shoot extension of Tussac grass seed collected from 15 sites in the Falkland Islands, South Georgia and N. Ireland.

Location	Site characteristics	Harvest date	Storage conditions	Germination (%)
Hill Cove	infertile	1983	Deep frozen	66
Hill Cove	infertile	1979	Deep frozen	0
N. Ireland	fertile	3 July 1984	Deep frozen	78
N. Ireland	fertile	1 April 1984	Deep frozen	78
South Georgia (A)	fertile	22 Jan 1979	Air dried	2
South Georgia (B)	fertile	22 Jan 1979	Air dried	2
South Georgia	fertile	22 Jan 1979	Deep frozen	0
South Georgia	fertile	22 Dec 1979	Deep frozen	2
South Georgia	infertile	22 Dec 1979	Deep frozen	4

Table 19 The effect of site, collection date and storage method on germination of Tussac grass seed.

Collection date	Seed weight (mg)	% Germination
30/10/86	0.271	30
12/11/86	0.292	37
27/11/86	0.260	14
10/12/86	0.396	47
28/12/86	0.315	40
9/1/87	0.248	17
s.e.		4.9

Table 20 The effect of collection date (ripening of seed) on seed size and germination of Tussac grass seed collected from a group of plants growing at Coast Ridge, Fox Bay.

A South Georgia seed

	15 days (Expt 1)		15 days (Expt 2)		23 days (Expt 2)	
	Control	GA	Control	GA	Control	GA
South Georgia 1	11.5	48.5	4	19	5.5	72
South Georgia 2	0.5	20.5	3	16.5	3.5	58
South Georgia 3	6.5	7.5	0.5	0	0.5	0

B Fox Bay, Falkland Island seed

Collection date	15 days		32 days	
	Control	GA	Control	GA
30/10/86	16	17	30	32
12/11/86	20	31	37	48
27/11/86	11	5	14	15
10/12/86	42	50	47	56
28/12/86	24	23	40	34
9/1/87	6	13	17	16
s.e. (treatment)	1.3*		1.2	

Table 21 The effect of Giberellic acid treatment on seed germination recorded at 15 days for two seed lots from South Georgia and for 23 days of one of those lots and on seed harvested at six maturity stages.

Seed size	Planting depth (cm)				
	0	1.5	3.0	4.5	Mean
Large	33.4	23.8	31.0	28.4	29.2
Medium	35.1	32.6	34.0	28.8	32.6
Small	31.1	33.6	35.4	39.9	35.0
Mean	33.2	30.0	33.4	32.4	32.3

s.e. seed size = 1.12**; planting depth = 1.29

Table 22 The effect of seed size and planting depth on seedling emergence (%). The results are the mean for seeds from 2 sources.

		Seed Source					
	Days	Northern Ireland	South Georgia	Carcass Island	Monday Island (Control)	Monday Island (GA)	s.e.
Tiller no/ Plant	30	1.0	1.0	1.0	1.0	1.0	-
	60	1.5	1.3	1.4	1.1	1.4	0.08
	90	2.6	2.1	2.3	1.9	2.4	0.11
Leaves/ Tiller	30	1.5	1.5	1.6	1.5	1.6	0.10
	60	2.1	2.2	2.3	2.1	2.0	0.06
	90	2.3	2.5	2.3	2.1	2.3	0.07
Mean tiller Dry Weight (mg)	90	61.2	45.1	86.1	11.7	43.4	8.25

Table 23 The effect of seed source on tiller number, leaves per tiller and final mean tiller dry weight of seedlings of Tussac grass grown for 90 days under controlled environment conditions.

Date of Harvest	10 days			25 days		
	Control	GA	Mean	Control	GA	Mean
30/10/86	12.3	13.6	13.0	17.6	20.4	19.0
12/11/86	13.3	13.7	13.5	25.9	20.5	23.2
10/12/86	10.5	12.2	11.4	13.0	18.5	15.8
28/12/86	18.2	19.7	19.0	26.7	24.8	25.8
Mean	13.6	14/8	14.2	20.8	21.1	20.9
s.e.	Date = 0.69***			Date = 1.85**		
	Treatment = 0.49			Treatment = 1.31		
	Date x Treatment = 0.98			Date x Treatment = 2.61		

Table 24 Mean shoot heights (mm) at 10 and 25 days after planting for seedlings grown from seed of different harvest dates treated with water or GA

	Mean	Min.	Max.	s.e.	Coefficient of Variation
Days to Emergence	11.7	9	23	0.24	21.8
Days to L2	7.9	4	32	0.28	37.5
Days to L3	26.6	10	67	2.03	81.6
Days to L4	47.7	18	67	1.98	44.5
Height 7D	13.3	4	22	0.35	28.0
(cm) 14D	16.8	6	31	0.48	30.6
21D	21.6	6	48	0.77	38.2
28D	23.9	6	54	0.98	43.9
Leaf no. 21D	3.4	1	9	0.14	42.9
Leaf no. 28D	3.9	1	14	0.21	58.5
Tiller no. 21 D	1.2	1	1	0.04	36.9
Tiller no. 28 D	1.3	1	4	0.06	46.7
Days to 2 tillers	55	16	67	1.69	33.2

__Table 25__ Levels and statistics of variates measured on 115 Tussac grass plants surviving to 1 month from germination (see Table 27 for key to variates).

	Mean	Min.	Max.	s.e.	Coefficient of Variation
Days to Emergence	12.1	9	20	0.53	22.7
Days to 2 tillers	34.8	16	67	2.52	36.9
Ht 1 month (cms)	32.9	13	48	1.65	25.6
2 months	58.3	38	81	2.17	19.0
3 months	90.3	56	106	2.45	13.9
6 months	141.1	91	209	6.49	23.5
9 months	187.1	115	281	9.30	25.3
12 months	548.5	257	675	15.57	14.5
Tiller no.					
1 month	1.8	1	4	0.15	43.2
2 months	2.7	1	4	0.17	31.9
3 months	4.0	2	6	0.23	29.0
6 months	7.8	3	14	0.61	39.8
9 months	17.9	5	41	1.87	53.3
12 months	52.2	24	88	3.28	32.0
Biomass (g DM)	15.5	1.6	27	1.17	38.6
% Live Leaf	58.1	1.1	74	2.80	24.6
% Sheath	8.3	0	16	0.72	44.1
% Dead	31.0	19.5	57	1.64	26.9

__Table 26__ Levels and statistics of variates measured on 26 Tussac grass plants surviving for over 12 months.

HT21D	-							
HT28D	0.96	-						
Leaf No 21D	0.75	0.75	-					
Leaf No 28D	0.77	0.78	0.95	-				
Days to T2	-0.68	-0.73	-0.81	-0.82	-			
Days to L3	-0.57	-0.56	-0.62	-0.53	0.40	-		
Days to L4	-0.66	-0.72	-0.72	-0.72	0.79	0.52	-	
Tiller No 21D	0.56	0.61	0.83	0.83	-0.80	-0.28	-0.56	-
Tiller No 28D	0.67	0.68	0.84	0.89	-0.86	-0.31	-0.61	0.88
	HT21D	HT28D	Leaf No 21D	Leaf No 28D	Days to T2	L3	L4	T21

Key:- HT21D, HT28D = Plant height at 21 and 28 days.

Leaf No 21D, 28D = Number of leaves on plants at 21 days and 28 days after seedling emergence.

Days to T2, L3, L4 = No of days from emergence until the appearance of tiller no. 2 and leaves nos. 3 and 4.

Tiller No. 21D, 28D = The number of tillers on plants 21 and 28 days after emergence.

Table 27 Correlation matrix of variates measured on 115 Tussac grass plants up to 1 month. Absolute values are presented in Table 25.

	Biomass	Ht. 12 month	Tillers 12 month	% Leaf	% Dead
Days to Emerge	-0.07	-0.03	0.17	0.10	0.01
Days to 2 tillers	-0.08	-0.21	0.21	0.19	-0.09
Height at					
1 month	0.09	0.15	-0.10	-0.09	-0.02
2 months	0.19	0.31	0.02	-0.03	0.22
3 months	0.33	0.45	0.07	0.17	0.04
6 months	0.62	0.34	0.50	0.13	0.18
9 months	0.59	0.26	0.38	0.11	0.07
12 months	0.49	-	0.04	0.61	-0.11
Tiller No. at					
1 month	0.25	0.31	-0.05	-0.08	-0.01
2 months	0.24	0.25	0.07	-0.11	0.40
3 months	0.53	0.17	0.39	-0.21	0.58
6 months	0.48	-0.19	0.58	-0.37	0.38
9 months	0.50	-0.16	0.75	-0.33	0.58
12 months	0.70	0.04	-	-0.02	0.43
Biomass	-	0.49	0.70	0.25	0.13

Table 28 Correlation co-efficients between parameters of final Tussac size (biomass, height, tiller number and % composition) following harvest at 12 months and growth parameters measured during the growing period.

LOCATION	Position lat[N] long[W]	Altitude [m.a.s.l]	Rainfall [mm]	Soil Type	Site
BALLYWALTER (Co Down)	54°33′, 5°31′	1	800	Sandy loam	Coastal
NEWFORGE (Belfast)	54°33′, 5°56′	24	950	Medium clay/ loam	Inland/ Lowland 7km from coast
BROUGHSHANE (Co Antrim)	54°56′, 6°12′	260	1250	Peaty (30/40 cm)	Inland/ Upland 14km from coast

Table 29 Sites for field trials on Tussac grass, N. Ireland.

% Dead plants at:-

	Ballywalter	Newforge	Broughshane
May 1985 (Planted)			
July 1985	2.2	19.7	1.1
August 1985 (Dead plants replaced)			
September 1985	3.0	3.0	0.2
November 1985	5.5	16.1	0.5
December 1985	6.4	17.8	0.9
January 1986	7.6	21.9	0.9
February 1986	8.7	25.1	2.3
March 1986	9.2	26.4	2.8
April 1986	9.4	27.9	2.8
July 1986	9.5	SITE ABANDONED	13.5

Table 30 Survival of spaced plants over the first year of establishment at three field sites. Figures represent the % of the original plant population dead at each recording time.

(i) Ballywalter

	AUGUST 1986	DECEMBER 1986	MAY 1987
Height (cm)	81 (4.9)	82 (9.0)	77 (5.4)
Basal Circumference (cm)	38 (2.3)	49 (5.3)	53 (4.5)
Tiller number	287 (77.2)	363 (97.9)	147 (33.4)
Total plant dry wt (kg DM)	0.55 (0.136)	0.82 (0.231)	1.17 (0.5)
% Green leaves	56	34 (1.7)	47 (2.8)
% Leaf sheath	35	27 (1.5)	27 (1.4)
% Dead	9	39 (1.7)	26 (3.6)
Sample number	12	19	6

(ii) Broughshane

			FEB 1987
Height (cm)	62 (4.9)	53 (5.7)	40 (2.4)
Basal Circumference (cm)	24 (3.5)	25 (3.4)	24 (1.1)
Tiller number	93 (26.5)	41 (8.2)	38 (4.9)
Total plant dry wt (kg DM)	0.17 (0.068)	0.13 (0.021)	0.13 (0.0134)
Sample number	6	14	6

Table 31 (a) Mean size (height, basal circumference, tiller number and total dry weight) of whole plants removed from the Ballywalter and Broughshane sites 15 to 24 months after planting (August 86 and May 87 respectively. (The standard errors of the means are presented in parentheses.)

	AUGUST 1986	OCTOBER 1986
Height	78 (5.6)	77 (2.8)
Basal Circumference	37 (2.5)	46 (4.9)
% Green	63 (4.5)	
% Sheath	18 (3.4)	
% Dead	14 (6.4)	
Total plant dry wt (kg DM)	0.25 (0.041)	0.25 (0.042)
Sample number	15	19

Table 31 (b) Mean size of plants cut to 10 cm from the Ballywalter site 15 and 17 months after planting (August and October 86 respectively). (The standard errors of the means are presented in parentheses.)

(a) 6 months after planting (November)

	Mean plant basal circumference (cm) in November	Mean plant height (mm)
Ballywalter	13.8	303
Newforge	7.8	239
Broughshane	13.2	297
s.e.	4.12	6.3

(b) 6-12 months after planting

Plant height (mm) in:-	Ballywalter	Newforge	Broughshane	s.e.
Nov	303	239	297	6.3***
Dec	271	236	277	7.2*
Jan	229	226	249	3.9*
Feb	212	217	227	5.4
March	214	195	229	4.3
April	192	172	204	5.3*
Mean leaf growth (mm day^{-1})	1.52	1.67	1.68	0.050
Leaf Appearance (No.)	5.20	4.25	4.62	0.164*

Table 32 Mean Tussac plant size 6-12 months after planting at 3 sites.

Site	Leaf growth rate (mm day^{-1})	Leaf appearance (No. over winter period)
Broughshane	1.68	4.23
Newforge	1.67	4.25
Ballywalter	1.53	5.20
Grand mean	1.63	4.56
s.e.	0.06	0.26

<u>Table 33</u> Leaf growth rate and leaf appearance rate of Tussac grass over the period October-March from three sites.

	(a) leaf growth (mm day^{-1})					(b) leaf appearance				
Nitrogen	0	60	120	Mean	s.e.	0	60	120	Mean	s.e.
Broughshane	1.61	1.76		1.68	0.176	4.38	4.89		4.62	0.083
Newforge	1.64	1.71		1.67	0.055	4.22	4.27		4.25	0.053
Ballywalter	1.45	1.59	1.53	1.52	0.051	5.17	5.15	5.29	5.20	0.141

<u>Table 34</u> The effect of nitrogen fertiliser applied in August on leaf growth (mm day^{-1}) and leaf appearance of (leaves $leaf^{-1}$ $week^{-1}$) over the subsequent winter on 6 month old Tussac grass planted at three sites.

Whole tiller	0.74	Leaf 3	0.78
Dead leaves	0.61	Leaf 4	0.77
Dead leaf bases	0.61	Leaf 5	0.76
Unexpanded leaves	0.73	Leaf 6	0.72
Unexpanded leaf bases	0.86	Leaf 7	0.75
Leaf 1 (youngest)	0.77	Leaves 8 + 9	0.69
Leaf 2	0.78	Sheaths of leaves 1-4	0.79
		Sheaths of leaves 5-9	0.70

Table 35. The mean organic matter digestibility (OMD) of components of Tussac grass tillers calculated from determination of ashed MAD fibre. The results represent the mean fibre of 10 tillers sampled at random from Tussacs growing at Ballywalter in May 87 i.e. 24 months after planting out.

	August 86	December 86
No. of vegetative tillers	256 (70.1)	352 (82.9)
No. of reproductive tillers	1 (0.3)	3 (1.2)
No. of dead tillers	1 (0.3)	16 (14.3)
Maximum tiller length (cm)	53 (2.8)	67 (3.6)
% Green leaves	80 (16.3)	71 (7.6)
% Sheaths	20 (4.3)	14 (2.2)
% Dead	0.3 (0.08)	15 (2.5)

Table 36 The breakdown of tiller distribution and composition within Tussac grass plants 15 and 19 months after planting. Each figure represents the mean of approximately 25 plants.

Species	Mean leaf appearance rate (days)	Rate of leaf extension (mm week^{-1}) Leaf 1	Leaf 2
Agropyron magellanicum	16.08	-	-
Tussac grass (seedlings)	5.42	11.02	3.19
Tussac grass (mature plants)	3.70	9.27	3.19
Cinnamon grass	15.00	3.69	0.36
Annual meadow grass	6.75	2.57	0.57
Yorkshire Fog	6.00	7.05	2.25
Cocksfoot	6.85	4.42	2.01
Perennial ryegrass	7.08	6.91	1.88
s.e.	1.819	0.701	0.358

<u>Table 37</u> Growth (leaf appearance and leaf extension) of a range of grass species grown at 4° C.

GRAZING	SUMMER		WINTER	
	Before Grazing	After Grazing	Before Grazing	After Grazing
Plant height (cm)	81.2 (±4.91)	80.1 (±2.08)	81.7 (±9.11)	72.7 (±2.85)
Plant diameter (cm)	13.7 (±1.91)	12.7 (±2.83)	14.7 (±2.01)	10.9 (±1.04)
Basal circumference (cm)	42.5 (±1.91)	42.3 (±2.32)	49.5 (±5.31)	42.5 (±2.19)
Tiller number	287 (±77.2)	174 (±29.7)	363 (±97.9)	196 (±26.4)
Dry weight (kg DM)	.55 (±.136)	.25 (±.041)	.82 (±.23)	.47 (±0.091)
% Green leaf	36 (±6.4)		34 (±1.7)	
% Leaf sheath	30 (±4.0)		27 (±1.5)	
% Dead	32 (±10.8)		39 (±1.7)	

<u>Sheep rejects</u>

	Summer	Winter
Tiller numbers plant^{-1}	19.8 (±5.11)	10.3 (±4.62)
Dry weight (g)	60.9 (±9.9)	29.5 (±4.65)

<u>Table 38</u> Mean dimensions of Tussac grass plants before and after grazing and the nature of sheep reject material in plots grazed in summer and winter.

(a) Number of new leaves produced (per plant) March-May

		Defoliation height (cm)		
		0	2	8
Nitrogen	0	3.75	3.0	3.25
(kg N ha^{-1})	150	3.75	3.25	3.25
	300	3.75	3.25	3.50
Mean		3.75	3.17	3.67

s.e. - Height 0.179* Nitrogen 0.179 Height X Nitrogen 0.311

(b) Dry matter yield per clip (g $plant^{-1}$)

					s.e.
Clip	2	-	55.4	42.9	6.30
Clip	3	-	36.8	42.7	4.88
Clip	4	-	33.2	52.1	5.12*
Clip	5	-	33.1	68.1	6.83**
	Total		158.5	205.8	14.2*

Table 39 The effect of severity of defoliation on new leaf production and dry matter production over successive clips of pot-grown Tussac grass.

Season	Mean Time spent grazing (min)	% Time Spent:- Grazing Tussacs	Grazing weeds	Standing up	Lying down
Summer	227	50.5**	12.2*	27.6*	8.6
Winter	223	44.5*	4.6*	48.7	2.2

Table 40 The distribution of time spent by sheep confined in small plots containing Tussac grass plants. Where figures are marked * differences between individual sheep of time spent on that particular activity were significant.

(a) Summer	Plant height	Plant diam.	Plant basal circ.
Plant diameter	0.65	-	
Plant basal circ.	0.63	0.92	-
Biting Rate	0.32	0.26	0.14
(b) Winter			
Plant diameter	0.43	-	
Plant basal circ.	0.45	0.96	-
Biting rate	0.30	0.19	0.13

Table 41 Correlation coefficients between plant size (measured as height, diameter and basal circumference) and frequency of biting individual Tussac plants grazed on two occasions.

TUSSAC GRASS
A practical guide to its establishment and management in the Falkland Islands

Agricultural Research Centre, Stanley; Queen's University, Belfast; British Antarctic Survey, Cambridge

Tussac grass is potentially one of the most valuable native plants to sheep farmers and wildlife conservationists in the Falkland Islands. Its decline over the past 100 years has been due both to historic farming practices and economic considerations. Recent changes in farm ownership and farming attitudes have greatly increased interest in feasibility of re-establishing the species.

Over the past few years some research has been carried out on the establishment, growth and management of Tussac grass. Most of the work has been carried out in the Falklands by ARC (including some co-operative projects with Queen's University Belfast) though some specific aspects of growth and agronomy have been studied on South Georgia (by BAS) and in N. Ireland (by QUB).

Although there is still a lot to learn about Tussac grass and much more research needs to be carried out — ARC has an active, ongoing research programme on the grass — this is an opportune time to publish the practical guidelines which have come out of the research so far.

This booklet represents a summary of the current knowledge on certain aspects of Tussac grass establishment and management. More detailed information on the experiments and research trials is available from ARC.

It is hoped that it will encourage farmers to plant more Tussac, providing not only a valuable contribution to winter grazing but increased habitats for many native Falklands animals and birds.

VALUE OF TUSSAC GRASS

Tussac grass is important as a grazing resource to sheep farmers and as a wildlife habitat to conservationists. It grows and produces new leaves over the winter, starts growth earlier than other introduced and indigenous grasses and, most importantly, maintains a high level of digestibility all year round. In this respect it is unique among Falkland Island grasses.

Farmers and conservationists share a common interest in methods of establishment, early management and sustained long-term management.

WHERE TO PLANT

In deciding on sites to plant Tussac, the main issues involved are site fertility, likely weed competition and the availability of planting material.

Success is more likely when replanting old, grazed out Tussac plantations, either natural or planted. Tussac prefers a deep, peaty soil and if it has done well in the past on a certain site, it is most likely to succeed again provided fencing and management are attended to. All sites must be securely fenced from stock before beginning any planting.

Old, reseeded paddocks or paddocks and 'points' near settlements are best avoided as competition from introduced grasses and other weeds can lead to problems. Although traditionally grown near the coast, there are excellent Tussac stands growing inland and, provided soil fertility is improved, plantations can be established almost anywhere. In siting a plantation, eventual stock access should be borne in mind as careful control of grazing management is vital.

Tussac sets are bulky and heavy so if large quantities are needed, nearness to planting stock should be considered. Management will always be easier if the plantation is seen often or passed regularly.

Tussac can be planted in inland and coastal areas provided soil fertility is correct though former Tussac plantations would be the best place to start. The area chosen must be securely fenced. Reseeds and settlement areas should be avoided and accessibility of planting material considered.

WHEN TO PLANT

From limited experience, winter planting (May–September) is best. Further work is being carried out on this topic, particularly in relation to the issue of late vs early winter planting and the type of planting material used (seeds, seedlings, sets). Jackass penguins will pull out plants for nesting material, so in certain areas early winter planting will be best. *Nevertheless, most people will want to plant in winter because it fits in well with other sheep operations on the farm.*

HOW TO PLANT

From sets and self-sown seedlings

In the past all planting has been done using sets of varying sizes (6–20 shoots). Although this technique has many advantages in terms of speed of establishment and overcoming competition, it is slow and dependent on availability of mature and healthy Tussac plants. Research has shown that, as an absolute minimum, sets of 3-shoot (tiller) groups are adequate and the tops should not be trimmed off at planting. Soaking sets in water (with insecticide) for a few days prior to planting seems to encourage rooting and will ensure pest-free planting stock. There is evidence that 2 or 3 year old 'seedling' bogs grow more vigorously than others and these should be used in preference if available. On Sealion Island a combination of rows of sets from 'old' plants interspersed with sets from 'younger' plants for the main stands has been used and needs to be tested more widely.

From seed

Fencing off bare soil areas near existing plantations and allowing new Tussac to regenerate naturally has been successfully tried on some sites. Although Tussac will regenerate naturally from seed, little or no plantations have been established in this fashion in the past century. Seed of Tussac has poor germination and seedlings need protection against weeds, birds and pests for several years. With the addition of a small amount of a plant hormone, seed germination can be greatly improved. Seeds could be planted in beds in the garden or in cheap disposable or re-usable peat or plastic pots. One year old seedlings can then be planted out directly into the field and will grow rapidly. It is advisable to pick seed from the biggest, healthiest plants (irrespective of site fertility or exposure). Seed should be collected before mid-summer. It remains useful for a few years after collection, provided it is stored in a cool dry place.

What distance between plants?

Plant spacing is not of critical importance unless inter-row cultivation is being contemplated. The closer the planting, the more rapidly the ground will be covered by the canopy, but plants will be smaller and, more importantly, planting will be slower and more sets or seedlings will have to be used. This is more important than it may seem. For example, if plants are put in close together (say at 2 feet apart) 12,000 will be required to plant one acre. If they are planted 6 feet apart, only 1,000 will be required — approximately 4 man days work as opposed to 50 man days per acre — virtually a whole winter's work for 1 person to plant only 3 acres! On Sealion Island 'guard' rows of sets from mature Tussacs are planted at 2 foot spacings in approximately 20 yard square blocks. Within these blocks sets from seedling or young Tussacs are planted at 6 foot spacings. This sort of planting pattern is reasonable though perhaps on other less favourable sites a spacing of 4–5 feet would be an acceptable compromise.

Is fertiliser needed?

It has been found from a whole series of experiments carried out in the Falklands and N. Ireland there is no need to apply fertiliser to Tussac grass for at least 18 months after planting.

Use a minimum of 3 shoots per clump if planting conventionally. It is worth collecting seed from healthy vigorous Tussacs, sowing this in trays or cheap jiffy pots and planting out 1 year old seedlings.

Plants should be spaced 4–6 feet apart and close spaced 'shelter' rows of larqe sets every 10 rows or so are a good idea. No fertiliser is needed at planting.

WHAT EARLY MANAGEMENT?

When to start grazing?

No detailed research has been carried out on this important issue so far, but it is important that plants are strong and well established before initial grazing. As a rough guideline, plants should be about 3 feet tall and about 3 feet in circumference around the base of the tussock. Generally plants take about 3 years to reach this stage. Until the stand is 6 years old, grazing should be light and carefully controlled.

Does Tussac need fertiliser before first grazing?

It is unlikely that fertiliser will be required on infertile sites before first grazing and on 'Tussac' peat sites no fertiliser will be needed in later years. If the plantation is yellowing and not thriving an application of nitrogen (e.g. as urea or nitrochalk) in spring will help considerably.

Given reasonable growth, plants should be about 3 years old before first grazing and unless the site is poor, fertiliser need not be applied.

What seasonal grazing pattern?

For successful growth Tussac relies on building up its reserves and producing new shoots during the summer. During winter, leaves continue to grow but are using up these reserves. It is during this period that Tussac grazing causes least harm to the plant. Plants probably recover better after grazing during the first part of the winter (May–July) than from the later (August–September). Thus more care must be taken to avoid overgrazing if animals are grazing into late winter. Plants can survive having all the green leaves removed (right down to the crown of the tussock), but the sheep should be removed before they start to 'dig in' to get at the leaf bases (which are of vital importance for next season's growth) or start to pull out shoots. As a rough guideline, in a good, mature Tussac plantation, hoggs can be stocked at up to 10–12 per acre and dry sheep and ewes at 3–5 per acre for most of the winter (150–180 days). Obviously stock can be kept longer on Tussac at lower grazing pressure. More research is needed on this subject and on cattle grazing in plantations. If plants are cut for hay, an uncommon practice nowadays, the same basic rules as for grazing apply.

Does grazed Tussac need fertiliser every year?

Although establishing Tussac and Tussac on old plantation and Tussac peat sites does not need fertiliser, size and productivity of the plants can be greatly increased with fertiliser on 'starved' infertile sites. Although not yet conclusively researched it appears that the next fertiliser application should be after about 2 years growth on such sites. An application of about 15 g (a small handful) per plant of nitrogen fertiliser is sufficient to double productivity on some sites.

Tussac should be only grazed in winter and must not be overgrazed. Careful watch should be kept on late winter grazing. If plants are slow growing and weak 2 years after establishment, nitrogen fertiliser should be applied.

Control of rust and insect pests?

Rust does not kill Tussac grass but can reduce the grazing potential of a plantation by up to 50%. The problem is worse if a cool moist spring follows a mild winter. One application of the cereal fungicide Bayfidon (applied before December) will give good control of rust but the application of a fungicide may not be either economically or environmentally acceptable. Young plants are particularly susceptible and if a severe outbreak of rust threatens the survival of a new plantation a one-off spray with fungicide might just help the plantation succeed in establishing. Once plants form large tussocks, spraying becomes increasingly difficult to justify.

Insect pests pose a potentially greater threat than rust and in combination with rust may kill plants completely. Much less is known about the insect pests than rust disease and control by spraying cannot be recommended. Larvae of the main pest species (a small weevil) bore into centre of the shoots which subsequently turn dull green or yellow and die. Adult pests are best seen in mid–late September although larvae can be found all year. Strong healthy tillers can survive insect attack better than weaker ones or those infected with rust. Insect eating birds (eg hens, tussock birds) can help reduce the degree of infestation. The adults do not appear to be very mobile so when splitting up Tussacs to make sets for planting, check that plants are 'clean' and insect-free to start with. Pre-soaking tillers overnight in a drum containing a weak solution of insecticide will help to ensure that only 'uninfected' sets are planted. With basic care, and hygiene, it should be possible to keep young plantations insect pest-free for some time. Cats and rats should be discouraged as these will deplete tussock bird numbers and rats burrowing into the bases of tussocks have caused serious damage on many islands.

Rust weakens plants but is only fatal in combination with insect attack. Spraying *is environmentally inadvisable but as a one-off in establishing plantations the fungicide Bayfidon applied before December gives control. Little is known about insect pests but healthy plants are likely to recover. Check that all sets to be used for planting are uninfected and a pre-soak in an insecticide is advisable.*

ALTHOUGH MUCH REMAINS TO BE DISCOVERED ABOUT SUCCESSFUL TUSSAC GRASS ESTABLISHMENT AND MANAGEMENT, ENOUGH IS NOW KNOWN FOR PEOPLE TO 'HAVE A GO' AND CREATE SMALL TRIAL PLANTATIONS. GUIDELINES ARE PROVIDED IN THIS BOOKLET. REMEMBER THAT TUSSAC GRASS PLANTING IS GRANT-AIDED.

KEEP A RECORD OF THE PROCEDURES YOU USE SO THAT ARC CAN BUILD UP A DOSSIER OF THE REASONS FOR SUCCESS AND FAILURE. THIS WILL ENABLE MORE RELIABLE GUIDELINES TO BE PRODUCED IN THE FUTURE.

TWELVE TIPS FOR BETTER TUSSAC

- Securely fence off any area to be planted.
- Plant firstly on old Tussac peat them on reasonably fertile land with deep soil.
- Avoid old grass fields, reseeds and areas very close to settlements.
- Take sets from young, healthy bogs and pre-soak roots in water or a weak solution of insecticide.
- Plant 4–6 feet apart in winter.
- Plant without fertiliser.
- Try growing seedlings in small pots or trays under cover or in the garden, from seed collected before December off healthy plants.
- Provide shelter for the developing plantation by making every 10th row close-spaced large sets from mature Tussacs.
- Avoid grazing plants until they are about 3 years old and graze cautiously for a further 3 years.
- Graze in winter at about 4 ewes (or 12 hoggs) per acre and take great care to avoid over-grazing.
- Apply some nitrogen fertiliser to established plants if they appear unthrifty.
- Control rust through spraying only as a last resort to improve establishment.

KEEP A CLOSE WATCH ON YOUR PLANTATION AT ALL TIMES

QUEEN'S UNIVERSITY

Tussock Grass

- Tussock Grass Project -