THE EFFECTS OF SHEEP WINTERING ON SUBSEQUENT PRODUCTION FROM PASTURE

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by

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SUMMARY

1) Four winter grazing treatments (control - rested, grazed November and December, grazed January and February, and grazed November to February at 3½ ewes per acre) were applied to Lambing Field 1965-66 and Anchordales 1966-67. Production in the following grazing season was measured by recording the number of unit grazing days provided by each paddock. Control yielded the most in both years. Winter grazing altered the growth pattern so that early yields were poor but subsequent performance good.

Spring nitrogen was applied in 1966 at 1½ and 3 cwt./acre Nitrochalk. By mid-June the increase in unit grazing days due to the extra 1½ cwt./acre Nitrochalk was greater than the differences due to winter grazing. During the previous growing season Anchordales was managed under two nitrogen regimes, high and low. The beneficial effect of the high nitrogen was apparent all through the trial.

2) Paddocks were grazed in winter at 0, 4, 7 and 10 sheep per acre for 76 days. In March damage to pasture was proportional to stocking rate. Nitrogen was applied at 3 and 5 cwt./acre 21% Nitrochalk. The subsequent production was measured at three stages, early bite, silage and hay. Winter grazing seriously reduced yield at the early stage, but by the hay stage yield was not correlated with winter stocking rates. The level of nitrogenous fertiliser was

the factor controlling yield of hay.

3) A 5 by 5 Latin square was laid out in the winter of 1966-67. The treatments were control-rested, cut lightly, cut and poached lightly, cut heavily and cut and ~~grazed~~ poached heavily. The yield of early grass was highest on rested plots. Treading was supplementary to defoliation in reducing spring yield of grass. Heavily treated plots had particularly low yields. Regrowth was inversely proportional to yield of early grass.

HISTORICAL

Arthur Young (1771) described a means of producing winter food, or ROUEN, that was extensively used by Dorsetshire flock-masters. Rouen was aftermath grass, conserved in situ, for use in the early spring; it was reputed to be cheap and it provided a mixed diet, consisting of both autumn and spring tillers. This mixture was thought to provide a better balanced diet than either spring or autumn herbage on its own; in addition to this, the long autumn herbage sheltered the delicate spring tillers thereby encouraging earlier spring growth.

Sewell Read[143] described a method commonly practised in South Wales, in which grass was rested from May or June until the following spring, to produce a crop known as fog. The theory behind this practice was that the climate in Cardigan, Carmarthen and Pembrokeshire rendered haymaking an unreliable source of winter food as well as it being a laborious under-taking. Both the risk and the work were reduced by conserving the whole crop in situ till the following spring, when the low feeding value of the autumn herbage was augmented by the young spring tillers. Stock were reputed to thrive on the diet, though little is said of the annual production of such swards, or the stocking rates.

I. Sandison[148b] practised a traditional overwintering technique. After the hay crop, the sward was rested for from four to six weeks; during this period tillering was extensive and the sward provided an almost adequate diet for cattle during the winter. The summer performance of these animals was superior to that of inwintered animals.

During the Second World War, J. Stewart[158] suggested that Rouen might be a means of providing winter keep without the same labour demands as hay or silage. Davies[49] dealt with the historical aspects of the provision of winter keep, and concluded that winter grass, or foggage, was not necessarily poor in quality. During the period from 1920 to 1940 valuable work was done[50,154,156,165 & 173]; it established the importance of both time of resting for winter keep and the length of the rest period. Both palatability and burn were commented on and linked with the usefulness of grass in winter. The work done during this period laid the foundations for the Welsh wintering schemes[82-88]. These started with the problem of providing enough food in winter to keep sufficient stock to graze the pastures in summer. During the winter, sheep were allowed to graze a small area of Italian ryegrass and rape for two hours daily, the remainder of the day being spent on unimproved rough pasture. Not only were the animal results favourable but the Italian ryegrass sward provided winter keep on a scale previously unknown in that area, and good early growth. The main disadvantage of the system lay in the need to plough and resow the Italian ryegrass every year, often in difficult conditions. Hence timothy was tried, on account of its high palatability and wintergreenness; it was sown in rows, as experiments in Wales had shown that broadcast timothy tended to become weed infested, while rowcrop timothy made more vigorous growth and had a higher protein content. Timothy rows used for winter keep presented weed problems but the performance in terms of grazing days was good in winter, but poor in summer. The results from wintering on timothy were not invariably good, and production of winter keep was both expensive and difficult.

Undersowing of cereals with Italian ryegrass was tried, but this was fraught with problems and produced the inevitable dilemma in spring - the choice was between preserving the Italian ryegrass the following spring and foregoing a cereal crop, or ploughing up the Italian ryegrass just as it was becoming useful, and taking a cereal crop. Stubbs[159] tackled this dilemma and advocated the use of a non-gramineous crop for winter grazing. Instead of Italian ryegrass-Trefoil mixtures, Stubbs recommended Kale. Throughout this period most of the work done was aimed at producing a crop that was primarily of use in the winter; the general feeling was that if a crop did well in winter it earned a respite in summer and any production then was a welcomed and unexpected extra. In 1949 Stapledon[157] wrote: "I argue that if a particular acreage of land could be made to provide winter grazing for a goodly head of stock from, say, December 1st to March 15th, then we should not expect that acreage to earn money in any other way for the rest of the year."

With the introduction of new strains of grass, with higher yield potentials when grown during suitable periods, a change in emphasis was inevitable. Few farmers were willing to exchange the peak growth of May and June for the limited growth of October: winter keep from grass was still required, but it was not to be paid for by the loss of the summer's crop.

During the period 1946-1949 both Stapledon and Davies regularly produced articles on the subject of winter grass[155,156,157 & 49]. These articles contain a general awareness of the importance of using suitable strains of grass and the influence of management on production of grass for use during winter. These articles produced the theories and problems that subsequent research has attempted to examine.

THE PHYSIOLOGY OF HARDINESS

Winter hardiness is one of the characteristics of grasses that periodically assumes great importance. After the winter of 1962/63, a survey was carried out by the Grassland Research Institute at Hurley[79 & 79a]; they showed that grasses differed in their ability to tolerate severe conditions, and there were also variety differences. It was found that continental strains were marginally more tolerant than maritime strains. There were several indications that winter survival was linked to a number of factors, such as topography, weather conditions, previous management, age of sward, fertiliser status and strain of grass.

Winter injury results from one of three situations. Firstly, the effect of low temperature has been shown by Smith[150] and Ylimaki[174]; it varies according to the degree of insulation present and the daily temperature fluctuation. Ylimaki has shown that with an air temperature of $-30^{o}C$, the ground temperature under a 10 cm. layer of snow remained close to $0^{o}C$. At Hurley it has been suggested that snow for short periods has no detrimental effect on the herbage, but damage may become evident soon after the snow melts, both as a result of fungal attacks and alternating temperatures. Ryegrass is particularly susceptible to fungal attack by Fusarium species. Smith[150] commented on the effect of alternating temperatures on a crop without an insulating layer and suggested that such a condition was more damaging than a constant cold temperature. Winter injury can also be caused as a result of smothering; this occurs where drainage is poor or flooding common; the oxygen contained under the ice cap is progressively used up and the concentration of carbon dioxide rises. The third situation that gives rise to injury occurs when the soil is frozen, and consequently there is no movement of water. Transpiration continues in those plants that retain their leaves; although it decreases slightly in cold weather, its rate is more subject to variations in wind velocity. Under windy conditions with the top few inches of soil frozen, water loss through transpiration may exceed water uptake with the result that the plant becomes desiccated. It is possible that loss of leaf through burn may lower the winter water loss.

A. Kolosova[123] has divided some plants up into three categories, governed by their ability to withstand wintry and wet conditions:

1) Those that withstand severe winter conditions without loss:

   <u>Poa pratensis</u>.
   <u>Phleum pratense</u>.
   <u>Alopecurus pratensis</u>.
   <u>Festuca rubra</u>.
   <u>Bromus inermis</u>.

2) Those plants with very low cold resistance, but with the ability to survive prolonged desiccation or maceration by frosty or wet conditions:

   <u>Dactylis glomerata</u>.
   <u>Festuca pratensis</u>.

3) Those with extremely low winter tolerance:

Lolium perenne.

Two forms of winter injury are commonly found in grasses; the visual sign of one of these is browning or discoloration of the tips of the more mature leaves, whereas the symptom of the other is rotting in the basal regions of the grass. Cocksfoot and bent are both examples of grasses which burn easily, but there is little evidence that this is detrimental to their future production; it may even be an adaptation which enhances survival under severe conditions. Stapledon(154) compared the susceptibility of two strains of grass to burn under moderately sheltered conditions. One strain was from a very exposed habitat and this was the one that burnt more readily in his comparison. Beddows(21) found that extensive burn occurred very early in bent, accompanied by disintegration of the chlorophyll, but this did not limit the ability of the bent to survive the winter. Dastur(52) suggested that burn might be due to insufficient water reaching the assimilating cells of the leaf, hence burn might prevent excessive transpirational loss. The dead leafage could also provide an insulating layer protecting the young tillers, since burn tends to be a characteristic of longer, more mature, leaves. Rotting occurs extensively in the ryegrasses and Yorkshire fog. These are initially wintergreen, but given wet conditions they cushion badly, thereby reducing air circulation with the result that the basal regions remain wet and rotting is induced. The dense cushions of rotting herbage envelop and destroy the young tillers. Rotting, as was found in 1962/63, can seriously decrease the subsequent production of the sward.

Smith[150] and Tumanov[169] have described a process known as hardening which takes place as growth declines, days shorten, and temperatures decrease. It consists of various physiological processes that occur while the temperature is still above 0°C. These processes render the formation of ice in the cells of the plant more difficult. If weather conditions are conducive to growth in late autumn, hardening may be delayed and the plant can be subjected to an abrupt change in temperature, without the benefit of a preparatory stage. This abrupt change may be damaging to the plant. Furthermore a warm spell after the hardening process has started can reverse it. Numerous changes are reported as being connected with hardening; among them Dexter[54] includes increases in the soluble organic nitrogenous compounds, the cell membrane permeability and possibly both the dry matter and cell sap concentration, together with decreases in protoplasmic viscosity. He correlated winter tolerance with plant sucrose concentration, but found that this factor did not vary much among strains, and he was unable to distinguish between hardy and non-hardy varieties on these grounds. Akerman[2] found that the reducing sugar content (mainly monosaccharides) of winter hardy wheats was higher in winter than the content of less winter tolerant varieties. It has been suggested and corroborated by Kolosova[123] that winter hardy wheats are more efficient assimilators of carbon than the less hardy wheats in the period leading up to winter. Miles *et al.*[138] reported an inverse relationship between burn and concentration of soluble carbohydrates. On physical grounds, it can be argued that the higher the sugar concentration of the cell sap the greater is the depression of the freezing point and therefore the less the danger of damage resulting from low temperatures. It is well known that young vigorous leaves appear to be better equipped to tolerate low temperatures, possibly because the concentration of their cell sap is greater than that of older leaves. The sugars in the older leaves tend to be converted to cellulose, starch and lignin; these compounds do *not* lower the freezing point. Winter survival, as mentioned by Dexter, cannot be explained just in terms of cell sap concentration, especially since burn and winter kill are not inevitably linked.

Smith[150] has correlated winter survival with various morphological characteristics of plants, such as the proportion of small cells in the plant; small cells may be advantageous on account of their smaller vacuoles and more concentrated vacuolar contents. He also suggested that buried growing points might favour winter survival. Kolosova[123] stated that the ability to survive adverse conditions was connected with the depth of the tillering node. The tillering node of winter-hardy *Bromus inermis* was 18-20 mm. below the soil surface, whereas with *Dactylis glomerata* those nodes less than 8-10 mm. below the surface failed to survive the winter. Baker[7] did experiments on the death of *Lolium perenne* in winter. From them he suggested that if growth continued through the early part of the winter, plants could develop long basal internodes, especially if the cutting regime was lax. Cutting effects depend on both the frequency and the severity of the cuts; the Grassland Research Institute at Hurley(79a) showed that survival of a sward was best on those treatments that produced a large number of young tillers. A combination of management treatments was required to do this, namely high nitrogen in conjunction with frequent hard grazing or cutting. If the basal internodes are allowed to elongate there is a definite danger that cutting or grazing will remove the growing points. This explanation covers the lack of survival on Baker's(7) late cut plots, but survival was also poor on the controls. This may have been due to excessive growth in autumn reducing tillering. Martin Jones(115) corroborated this when discussing the factors influencing the timing of the last cut of ryegrasses. Weinman(171) mentioned work by Keim and Beadle(122) in which they suggested that winter survival was correlated with amount and penetration of root system. From this Weinman concluded that survival was partly controlled by the effect of the previous cutting regime on the root system. This reasoning was based on the somewhat dubious idea that because Keim and Beadle obtained a good correlation this was a cause and effect relationship. All that can be concluded from their work is that earlier fall-seeding can in some years result in better winter survival and spring performance.

Work at Hurley[79] found that the variable results exhibited by *Lolium perenne* after the 1962/63 winter could be ascribed to differences in variety, age of sward, grazing and fertiliser management. Age of sward was found to be proportional to the degree of killing, so that swards sown the preceding August and September survived the winter better than older swards. With *Lolium multiflorum* the results were similar but more consistent. Grazing and fertiliser systems which produced young tillers were the most successful in means of combating winter kill. A lot of work has been done on the effect of fertiliser dressings on winter survival, much of it on cereals in Eastern Europe. R. Beylot[22] improved the resistance of wheat to winter injury by a dressing of potash in the form of sylvinite. Wang *et al.*[170] found that lime with and without phosphate and potash increased the concentration of non-reducing sugars, but had no effect on the reducing sugars. Phosphate and lime with or without potash increased the starch content and both the total and water-soluble protein content. It was found that the resistance to winter-kill of lucerne was increased by the presence of large amounts of starch, non-reducing sugars and water-soluble protein. Tsuetoukine[168] used fertiliser dressings of phosphate and lime with and without potash; after the severe winter of 1946/47 those plots that had received potash emerged with less damage than the others. Avdonin and Kuzina[4] suggested that winterhardiness in winter cereals decreased with a fall in soil pH. This was associated with a rise in the availability of manganese and aluminium, and could be induced by the use of ammonium-containing fertilisers. Increasing availability of calcium and phosphate were correlated with increased winter resistance. Since any change in soil pH is accompanied by changes in the solubility of many essential minerals, these suggestions are too vague to be of much use. The MAFF leaflet[133] recommended autumn nitrogen for use with annual dressings of phosphate and potash as a means of producing worthwhile crops of grass for use in the winter. This was borne out at Hurley[79a] where it was found that high rates of nitrogen, when combined with low potash and phosphate, were likely to result in a high degree of winter kill. Dressings of phosphate and potash applied in the autumn make no economic difference to winter growth or survival providing they are applied as required during other parts of the year. Alder[1] found that there was no return from autumn fertilisers other than nitrogen; this increased both yield and winter-greenness. Beddows[21] stated that survival of a ryegrass sward was 15% better as a result of autumnal manuring. Dexter[54] found that nitrogen in the autumn could prevent the hardening process and that potash was beneficial, but both these effects were less important than disease problems. The effect of autumn nitrogen on herbage in winter varies; at Auchincruive[3] results were obtained showing that burn was highest on those plots which received most nitrogen, less on the intermediate plots and least on the controls. Gardner and Hunt[77] found that burn could be both increased and decreased by autumn nitrogen. If leaves became long as a result of the nitrogen this predisposed them to winter burn, whereas if the sward was closely and frequently cut, burn was reduced by autumn nitrogen. If the annual dressing of nitrogen was in excess of 300 lb. of nitrogen, swards of Lolium multiflorum suffered a high degree of kill irrespective of previous management.

Farmers and agronomists have a limited number of ways at their disposal of reducing winter kill; for a given sward, sensible management, both of fertilisers and harvesting, can increase the survival rate of grassland, and possibly spare the farmer the expense of resowing in the spring.

THE COMPOSITION OF WINTER GRASS

The composition of winter grass was shown to change with time by Thomas and Boyns[165] in 1936 and more recently by Roberts and Price[146] in 1966. The change is similar to the change in spring grass as it matures, fibre content increases and crude protein content decreases. These changes are complicated by the termination of growth and the onset of winter burn.

Davies and Fagan[50] examined the composition of grass in winter following different resting dates. Their results showed that for February sampling the yield of winter grass was greatest on those plots that had been rested from July, and least on those rested from November. The crude protein percentage was lowest on the former and highest on the latter; the crude fibre content was highest on the July rested grass and lowest on the November rested grass. The yield of dry matter from the July rested plots was the highest, but it contained substantially more burn than the November rested grass. From this experiment it can be concluded that the longer the rest period, the higher the yield of dry matter, but this high yield is both poorer in feeding value and considerably more burnt than the product of a shorter resting period.

Woodman and Oosthuizen[173] used rest periods of constant length but variable beginning. They compared the grass resulting from these rest periods with summer grass at an equivalent stage in its development. Most of their comparisons are scarcely relevant to this thesis but some of the corollaries are. From Woodman and Oosthuizen's results it appeared that the composition of winter grass was dependent on the date on which the rest period started rather than the length of the period. Although their rest periods were of constant duration, the yields varied from 1787 lb. per acre for the July to December rested grass to only 339 lb. of dry matter for the October to March rested grass. They commented on both the low crude protein content and the low digestibility of this grass relative to spring and summer grass. Not only was the digestibility poor but they experienced difficulty in getting stock to eat the grass, which appeared to be much less palatable than spring grass at the same stage in its development. This is supported by Ivins[111]; he stated that palatability varied according to time of year and it influenced the quantity of herbage eaten; digestibility also controls the quantity of herbage eaten, as it governs the rate of passage through the animal's gut, materials of low digestibility passing slower than others.

Winter burn adversely affects both palatability and digestibility. In addition it decreases the crude protein content and increases the fibre content of the herbage. Beddows[21] and Stapledon[154] suggested that burn was proportional to yield; this is true with certain reservations - Beddows showed that wide differences occurred in the susceptibility to burn both between herbage species and also among varieties of the same species. Hurley[79a] has also indicated that burn can be partly controlled by the type of management adopted in the preceding year.

In order to understand the behaviour of grass in autumn and winter, it is advisable to split the seasons into two periods. The first is one in which appreciable growth is made, albeit at a declining rate, and the second is a period in which growth has virtually stopped. Langer[126] found that Phleum pratense continued to grow in winter at a very slow rate. During this second period the slow rate of growth is obscured by processes of decay. These occur even in the summer and, according to L. Hunt[107], can account for 10 lb. of dry matter per day in a Lolium multiflorum sward. During the winter this loss of dry matter is accelerated by wet conditions and frost damage. The yield of herbage on a given date in winter is governed by the relationship between one period and the other. The longer the first period lasts the greater is the yield of dry matter and the lower is the feeding value of the herbage. The longer the second period lasts, the greater is the decline in yield and the increase in winter burn. The yield and composition of grass at a given date in winter depends on the length and combination of these two periods.

ROOTS AND THE ROLE OF THEIR RESERVES

Throughout the year the root mass changes its weight; this change does not coincide with the normal shoot cycle. Troughton[166] found that the weight of underground material was lowest in or around November, it then increased slowly with a minor decrease at the start of growth, and another at flowering, until August. These changes were complicated by the presence of dead roots.

The cycle of growth and decline is subject to variations resulting from the management imposed on the sward. There is a considerable amount of evidence suggesting that changes in the root system follow defoliation of the shoots, the change being rather slower in the roots than in the shoots. Root weight is partly dependent on the number of tillers; Troughton[167] suggested that a dense sward with small tillers may produce as much root as a more open sward with fewer but larger tillers. Root weight was found to be more dependent on the age of the sward rather than correlated with the size of roots. Cutting introduces two variables; one of these is the severity of cut and the other is the frequency. There is evidence from Hunt[103] and Weinman[171] that these are supplementary in effect so that the weight of the root system is dependent both on the closeness of the cut and its frequency. Weinman stated that the effect of over-cutting or over-grazing was no temporary affair as far as the root system was concerned, and that a root system reduced by cutting was rendered more susceptible to adverse conditions. Keim and Beadle[122] did experiments on the seeding date of Bromus inermis, Phleum pratense and Poa pratensis. These were planted at fortnightly intervals under conditions of adequate water supply. Root penetration for all species was proportional to the length of time between seeding and the onset of winter. The superior performance of the early planted plants was claimed to be a direct result of their larger root system and more thorough penetration of the soil.

Jones et al.[120] found that as cutting rates and fertiliser dressings increased, so the crude protein content of the herbage increased and the soluble carbohydrate content decreased. Baker[14] observed the disappearance of soluble carbohydrates following the addition of fertilisers - this was accounted for on the premise that the fertilisers permitted a higher level of plant synthesis, and the soluble carbohydrates were utilised as energy substrates. Sullivan and Sprague, in a series of articles[160,161 & 162], have shown marked changes in the soluble carbohydrates following defoliation. Davidson and Milthorpe[53] found that the rate of regrowth in the first two-day period following defoliation was strongly correlated with the content of soluble carbohydrates. May and Davidson[135] observed a decrease in the percentage of non-structural carbohydrates, following defoliation, and noted that this decrease proceeded at a diminishing rate for about eleven days, suggesting that the reserves were being used up during this period, probably as a source of respiratory substrate. Later

May[135a], when commenting on root changes after defoliation, suggested that percentages were an unreliable way of expressing root changes as there were changes in the actual weight of the root system following defoliation.

Storage of soluble carbohydrates varies in grasses; Phleum pratense has a bulbous base which contains a high proportion of the soluble carbohydrates, whereas ryegrasses rely more on their roots for storage. With Phleum pratense the amount of stubble left after defoliation determines not only the extent of the photosynthetic system but also the absolute amount of stored carbohydrates. With ryegrasses most of the carbohydrate reserves are in the roots, hence defoliation mainly affects the photosynthetic system. When the tops are removed from cocksfoot, there is a rapid fall in the stored carbohydrate, within three days of defoliation; most of this is used to supply energy and only a little produces actual shoot growth - this shoot growth is vital and should it be removed the plant's recovery is placed in jeopardy.

Much has been written about the role of reserve substances, many people have advertised the dangers inherent in autumn grazing, but experimental evidence is divided on this issue. The old popular school argued that the autumn was a period of consolidation, the plant built up its reserves and in the spring it cashed its reserves in the form of strong early growth. Jack[113] showed that other factors play a much more important role in determining the performance of a sward in spring - these include the variety of grass and the use of spring nitrogen. May and Davidson[135] stated that there was little evidence that stored carbohydrates, in the roots, played a critical role in regeneration. Baker[10] agreed and found that resting in September and October "to build up reserves" was not a critical factor in determining spring growth; earlier[8] he had suggested that recovery during dormant periods was a function of root reserves, since he found that early growth was best on those swards that had received lenient treatment during the preceding autumn. Sullivan and Sprague[162] found that new leaves were produced irrespective of light, in the period following defoliation. This indicated that shoot growth immediately following defoliation could be dependent on reserves, but Davidson <u>et al.</u>[53] found that after four days of growth photosynthesis was the dominant component of growth. Baker and others have observed marked variations in the content of soluble carbohydrates following cutting, so it would appear that root reserves are involved in recovery from defoliation, but in the past their importance has probably been exaggerated. Following defoliation there is a short period when regrowth is dependent on pretreatments, especially those connected with the level of carbohydrates. Once active leaf growth has started regrowth is independent of pretreatments (A. Davies, 55). Baker[9] found that cutting not only influenced the plant size but also the tiller number, so that swards cut in autumn tended to be denser the following spring. Baker[10] found that cutting reduced the root weight per plant but the root weight per unit area remained constant; furthermore, he obtained a poor correlation between early growth and content of water soluble carbohydrates but a good one between early growth and density of the sward and quantity of spring nitrogen. He concluded that a sward with a dense supply of vigorous tillers could survive the winter better, and exploit light more successfully in the spring, than swards consisting of larger, but fewer, tillers. Larger tillers are capable of earlier growth than smaller, more densely arranged ones, hence the performance of larger ones is better in the early part of the spring. Later the higher leaf area index of the dense sward encourages a higher rate of dry matter production and the advantage changes. If this is correct, it would appear that time of harvesting in spring is of great importance, as early harvesting will favour the open sward with large tillers, while later harvesting favours the denser sward. This may well account for some of the differences that have resulted from experiments on autumn management.

Jack(113) found that the more often a sward was defoliated, in a mild winter, the lower was its yield the following year. Further experiments on autumn management were carried out. With a low nitrogen regime it was immaterial whether one rested a sward from the first week in August, September or October, the yield the following spring was the same in each case. Under a high nitrogen regime the spring yields were greatest following the longest rest period. Unfortunately, Jack always trimmed his plots in December so he was unable to discover whether a quick defoliation in the dormant period had any effect on subsequent production. Jack's winter defoliation trial suggests that a quick defoliation, providing it is not repeated, has no effect on subsequent production.

In the past the importance of root reserves has probably been exaggerated. There are periods and conditions in which shoot recovery may be determined by the extent of the root system and the level of the reserves. The stubble also contains reserves; hence defoliation reduces both the photosynthetic surface and the reserves. Defoliation also has an important effect on tillering; thus by altering the density of the sward the root weight per unit area is maintained and the pattern of spring performance changed rather than yield being decreased. Spring production tends to be a function of factors other than the level of reserve carbohydrates built up during the autumn. These reserves are of little use if the sward has suffered extensive winter damage and is incapable of spring growth. This possibility is quite common in ryegrass swards that have been rested from early autumn. If management is concentrated on producing a sward containing dense and vigorous tillers, the reserves will probably be sufficient to provide good autumn growth.

GRASS CHARACTERISTICS RELEVANT TO WINTER GRAZING

The ideal grass for winter grazing should be capable of producing plenty of high quality herbage in the winter without any subsequent decline in summer production. Until such a grass is found, farmers will have to compromise. If the pasture is due to be ploughed up after the end of winter grazing, autumn and winter management are made much easier, since it no longer matters if the pasture suffers extensive poaching damage or is overgrazed.

The characteristics of grasses that should be considered are autumn growth, winter hardiness and winter feeding value. Foremost of these is the ability of the grass to make enough growth in autumn for grazing in winter to be worthwhile. Some grasses, such as the ryegrasses and tall fescue, can make appreciable growth at low temperatures, so that in mild winters they increase in yield. Some of the other grasses produce sufficient herbage in autumn for it to be worthwhile conserving their growth in situ and utilising it at another time. Other grasses make but poor growth in autumn and as such are not used extensively during the winter. During the winter the yield of the conserved grass tends to fall - growth is very slow at low temperatures, but decay continues regardless. This drop in dry matter yield results from the natural process described by L.A. Hunt[107] and a form peculiar to the winter, known as winter burn. Grasses vary in their susceptibility to these - timothy is both wintergreen and rot resistant, cocksfoot burns easily but does not rot, whereas the ryegrasses tend to be tolerably wintergreen but they cushion badly and thus encourage rotting(35 & 157). A burnt appearance can also be due to fungal infection; Stapledon and Davies(154) listed several grasses and their likely sources of infection, and added that it can be difficult to distinguish between fungal infection and burn. One of the side-effects of burn is that it reduces the palatability of the grass, especially if it is fungal burn as in the case of Mastigosporium on cocksfoot(11,18 & 133). Where burn is not the result of fungal infection the decrease in palatability is not so serious providing some green material remains. Palatability would appear to be connected with wintergreenness. Corbett(35) showed that the consumption of timothy and perennial ryegrass exceeded that of cocksfoot in winter, but this higher consumption did not result in better live-weight gains, since cocksfoot gave the best results. Probably this was due to the rapid rate at which the timothy and ryegrass travelled through the animal's gut, as demonstrated by the faeces being more fluid than on cocksfoot. Blaxter and Weinman(25), supported by Garner(78), found that the greater the digestibility of the diet, the quicker it passed through the animal's gut, and consequently more could be consumed, as intake is dictated by a maximum level of stomach distension. The increase in fibre and decrease in crude protein in cocksfoot as a result of burn was demonstrated by Fagan(73c); these changes probably affect the digestibility. Providing there is some green material among the burn, cattle and sheep will generally consume the herbage unless a more attractive diet is also on offer. However, palatability and greenness do not always go together as has been shown at Hurley[79b] - Yorkshire fog, in spite of its greenness, was refused by cattle.

COCKSFOOT

Cocksfoot is probably the most useful provider of winter keep found in Great Britain. It is a reliable bulk-producer in autumn[95 & 156], it lifts well[157], consequently it dries out fairly quickly thereby reducing losses through rot. However, it burns readily and is notorious in its lack of winter-greenness[157], with the result that it tends to be rather unpalatable[79b]. In spite of this it is capable of being used[156] and, as Corbett[35] has shown, it can out-class timothy and perennial ryegrass in stock-carrying capacity. Its dry matter loss in the winter is small[76] and it is a fairly persistent grass. During the long cold winter of 1962/63 there were few reported cases of winter kill in cocksfoot, but swards generally lacked vigour the following spring, whereas normally cocksfoot recovers well in the spring. Cocksfoot does tend to be rather prone to fungal infection from Mastigosporium[11,18,133 & 79] in mild winters; Stapledon also found that it was infected by Puccinia glumarum. Both these make it unpalatable.

Trials at Auchincruive[3] have shown that strains of cocksfoot vary in their susceptibility to winter burn. S 26 was relatively resistant; this was corroborated by Beddows[21].

There is a certain amount of controversy over the relative performance of S 37 and S 143. It would appear that they make similar autumn growth[141] and are equally lacking in wintergreenness[21]. S 345 makes good autumn growth[141]. Danish commercial varieties were rather poor but Copeman and Nicholson[33] suggest that Trifolium II, Daeno II and Pajberg II are rather better. Beddows found that the American varieties were the most susceptible to burn.

In spite of cocksfoot's susceptibility to burn, it can provide useful grazing in November and December. The herbage is plentiful and even though burnt it is still eaten and its feeding value is seldom inferior to that of medium quality hay. Not only is it a reliable bulk producer in the autumn but also it is capable of surviving winter grazing and producing a worthwhile crop in the spring and summer.

THE FESCUES

The Fine-leaved Fescues

Of these S 59 has the ability to make good winter growth[51 & 157]; as well as this, it remains both wintergreen and free from rot. Probably even more important is its tolerance to treading. Harkess[93] suggested that large yield reductions could follow poaching; on heavy land, used for winter grazing, S 59 might be worth including.

Meadow Fescue

Meadow fescue tends to lack the good characteristics of the grasses that are commonly associated with winter grazing, but it is not marred by any outstanding disadvantages. Sources vary in their opinions of it; it is not a good bulk-producer in autumn[95 & 104]. Those that champion its autumn growth[158] have probably compared it with timothy, which is notoriously poor in this respect. Baker[19 & 79] found that it wintered well; Stewart[158] found that it was rot-resistant and Beddows[21] found that it was rather susceptible to burn. Gardner[76] added that it was neither as persistent, nor as early as timothy.

The good representative varieties, according to the N.I.A.B. list for 1966[141] all show similar autumn growth, S 215, Combi Hay and Largo being slightly better than the others and more persistent too, with the exception of Mommersteegs Pasture.

Meadow fescue is usually found as a companion grass, when used for winter grazing. It is advisable to graze it only in the final year of the ley. It provides some keep after the period when ryegrass and cocksfoot are best used.

<u>Tall Fescue</u>

Tall fescue has the ability to make substantial growth in mild winters. Ritchie Cowan[41] found that it grew whenever the temperature exceeded 40°F, consequently it tends to be an early grass in the spring. It suffers the disadvantages of being difficult to establish, a poor producer in its first year and having significant seasonal changes in palatability -

during the winter it appears to be relatively more palatable than at other times. Special leys of it have been used with considerable success. Hughes[101] grew it in drills with lucerne and found that its good total annual production was slightly marred by poor summer performance. During the winter its erect habit reduces the risk of rotting, especially when it is grown in drills.

Tall fescue types used in the United Kingdom include the British S 170, the American Alta and the North African varieties. S 170 is an erect, wintergreen grass[94]. Both it and Alta came through the 1962/63 winter very well; there were virtually no reported incidents of winter kill[79], and it made good growth the following spring, but this was a little later than usual. Generally S 170 makes good autumnal growth[18 & 72] as well as being early in the spring[18]. During the winter it tends to be more palatable than cocksfoot[18] and it is slightly more digestible[133]. The North African varieties have featured in several trials. In the 1962/63 winter they were severely damaged, the low altitude Algerian being completely burnt, but the very high altitude Moroccan variety only suffered a small temporary set-back[79]. Compared with them, S 345 remained vigorous and survived the winter well. Experiments at Hurley[79c] have shown that during the winter the North African varieties produce few new tillers but the existing ones show considerable elongation. This growth is readily eaten and exceeds that of S 170. In general the summer production from these varieties was poor. Where autumn growth was conserved in situ, extensive damage was sustained by Algerian Syn. I and Moroccan Syn. II, whereas S 170 survived such management. It would appear that the North African varieties should be grazed as growth is produced[79d & 79e].

Tall fescue can be extremely useful in the winter, but it is very much a special purpose type of grass and it requires careful management. Summer production is both poor and difficult to use, while winter yields are not dependable. Because of these disadvantages its use is comparatively rare.

THE RYEGRASSES

Italian Ryegrass and Hybrid Italian

Italian and hybrid ryegrasses both possess the ability to make considerable autumn growth and also winter growth, in a mild winter[104 & 156]. Because of this they remain both palatable and wintergreen[79b]. But both are very susceptible to winter rot, they cushion badly[51 & 157] and dry out slowly after rain or snow. Baker[79] produced a report on the reaction of both forms of ryegrass to the 1962/63 winter; he noted that failure was common in the spring following a severe winter and it was aggravated by certain types of management, whereas in normal years survival was good and both were noted for their early spring production[113 & 115]. Jones[115] found that autumn grazing management played an important role in the subsequent survival of Italian ryegrass. If autumnal growth is not removed before the winter, the young tillers can be swamped and destroyed by the rotting herbage. If growth is controlled in the autumn, but defoliation also takes place before a very cold spell, the young tillers, having been deprived of their protective layer, can suffer extensive damage. This liability to rot in the ryegrasses is probably a function of their low crude fibre content[35]. Reduction in dry matter through the winter is correlated with reduction in subsequent performance. The latter reduction cannot be ascribed to burn, since this is limited to the older leaves and seldom appears to seriously affect spring production. Ryegrasses are also susceptible to infection from Fusarium species.

The Hurley report[79] found that the ryegrasses of continental origin were marginally more winter tolerant than the others.

Perennial Ryegrass

Perennial ryegrass is both wintergreen and also capable of useful autumn production[104]. In wet weather it is inclined to form dense cushions of wet herbage which are slow to dry out: these cushions encourage rotting, with the result that many young tillers are also destroyed. Its ability to survive the winter is a function of its age, the variety used, the grazing management and the fertiliser regime. Like other ryegrasses it is one of the less susceptible grasses to burn[21] and it remains palatable, but, as Corbett[35] showed, this may be of doubtful value.

Baker[19 & 79] found that the continental varieties were marginally more winter tolerant than the ones of maritime origin. He also suggested that early flowering strains were more susceptible to burn than later flowering ones - this may be as a result of their differing growth forms. The tetraploid variety, Reveille, survives the winter remarkably well. S 23 makes good autumn growth and provides useful keep towards the end of the year, but it lacks the earliness of S 24.

The ryegrasses provide a useful means of extending the grazing season for a short period at both ends. Autumn and early winter grazing are often necessary for the survival of the sward and to safeguard its future production. During the autumn the ryegrasses produce valuable and palatable keep, which if used does not necessarily jeopardise their subsequent production. If grazing is delayed till December or later the traditional opinion is that dry matter losses are high, especially if the grass was rather winter proud, and that grazing will seriously affect the future production of that sward.

TIMOTHY

Timothy was the grass used in the Cahn-hill experiment in an attempt to provide a perennial winter-grazing crop. Most of the people who have used timothy for winter-grazing have commented on its inability to produce adequate bulk in autumn[33,51,72,95,104 & 157]. Langer[126] found that leaf growth during the winter in timothy continued at a very slow rate. Timothy, although it lacks the bulk-producing quality of the ryegrasses and cocksfoot, has the advantage that it is both wintergreen and rot-resistant[21,51 & 157]. Hence the loss of dry matter in timothy during the winter is very small[76 & 146]. In a hard winter like 1962/63 timothy was the earliest grass in the following spring. It outwintered well and its earliness was unaffected by the winter[79]. It is very palatable in winter[35] but this is not always accompanied by good production, as its stock-carrying capacity, in Corbett's trial, was poor. Stapledon noted that it could be infected by Puccinia Phlei-pratensis[157].

Of the strains of timothy commonly used, S 51 is erect and multi-tillering, S 48 is very hardy, multi-tillering and wintergreen[51]. Stapledon[156] commented on the ability of S 48 to withstand winter-grazing and Beddows[21] commented on the high susceptibility of the Canadian commercial varieties to winter burn. The NIAB[141] have recommended the following as possessing better autumn growth than other strains of timothy:

S 51

Combi Hay Pasture

S 48

Garton's Own Leafy Pasture

Of these the first two possess better autumn growth and the second two are the more persistent.

Timothy, when used for winter-grazing, can be quite useful in the late winter; it is normally found in conjunction with other grasses.

MISCELLANEOUS

There are numerous comments about a wide variety of plants in connection with their use in winter.

The NIAB[142] have described rye as having the ability to make growth when the temperature is low. It must be sown early in the autumn for the best results. The following varieties are suitable for use in early spring:

Bernburg

Lovaszpatonai

Milns Grazing Rye

Rheidol

Work done on Lovaszpatonai at the Edinburgh School of Agriculture[71] found that rye was immune to damage even at temperatures as low as -12°C, whereas both Leda S Italian Ryegrass and S 345 Cocksfoot sustained a moderate amount of frost burn; moreover, most of the winter growth of the rye came through the winter unharmed. The rye then produced very early bite, but was subsequently outclassed by the grasses. Hurley[79] has also found that rye both overwinters well and produces valuable early grazing.

Crested Dogstail

Davies[51] recorded this as being wintergreen and Stapledon[156] considered that it made good winter growth. Neither of these two characteristics are good enough to warrant its inclusion in a seeds mixture, especially since standards of winter growth have risen considerably in the last twenty years.

Meadow Foxtail

Davies[51] commented on the merits of S 55 as a productive, rot-resistant, very wintergreen leafy grass, with good autumn growth - in spite of this eulogy its use has been severely limited by propagation difficulties. Stapledon[156] and Hughes[93] have both mentioned its wintergreenness and Beddows[21] found it was resistant to burn.

Meadow Grasses

Davies[51], Hughes[93] and Stapledon[157] have all observed the ability of rough and smooth-stalked meadow grasses to remain green in winter. Davies also commented on the winter growth of rough-stalked meadow grass. Nowadays meadow grasses are seldom included in seeds mixtures and even if they were their contribution to the net yield would be virtually negligible.

Yorkshire Fog

Hughes and Davies both found that Yorkshire fog cushioned badly and consequently was highly susceptible to rot. Hurley[79b] added that although it was able to remain green it was not eaten by cattle and it was definitely unpalatable. In spite of its name it is a most unsuitable grass for winter grazing.

None of this last group of plants are worth including in a sward which is to be used for winter grazing; some of them occur as common grassland weeds, but their contribution to winter keep does not warrant their inclusion or preservation.

MANAGEMENT IN WINTER

Some facets of this subject are dealt with later in separate sections; these include the ways in which winter grass can be used, why it is used, the effect of nitrogenous fertilisers and the timing of the rest period. Many details of winter management have not been subjected to experiment but nevertheless numerous comments have been made on various aspects of this subject.

Hughes[133] and Meadowcroft[137] recommended that well-drained land be used for winter grass production, that shelter be provided in the form of woods, hedgerows or artificial means and he stressed the importance of a dry lying area. Attention to these factors may improve both livestock and herbage performance, especially when combined with suitable grazing control. Although ruminants counteract cold with the heat produced in rumination, this is wasteful and increases the maintenance requirement[40 & 134]. Poaching and puddling can present problems if subsequent production is expected; Stapledon[155] recommended using temporary leys for winter grass just before they were due to be ploughed. Hughes and others have reduced the damage resulting from treading by growing grass in wide rows.

Many of the papers produced on winter grass stress the importance of some form of grazing control. This is claimed to reduce wastage and damage to the sward and also provide for better livestock utilisation[13,15,40,96,100 & 133]; this applies particularly in wet years. In Griffith's work[82-88] the high quality winter grass was rationed by time; Hughes[96 & 100] found that rationing by space resulted in fuller utilisation and less waste. Besides reducing wastage, grazing control has been used to restrict the number of defoliations in winter[40]; this has been accomplished by use of the electric fence, usually with a back-fence[13,40 & 140], or by means of paddocks[15 & 79]. Baker[13] suggested that strip-grazing was suitable for dairy cows but not for beef cattle which should be grazed on a paddock system. Many have suggested that winter grazing should be limited to one defoliation; both Frame[74] and Jack[113] have tested this experimentally. Both trials indicated that subsequent yields might be reduced by repeated defoliation in the winter, especially if the winter was mild[113]. The differences from repeated defoliation were not large and they were very much smaller than the nitrogen differences in Jack's trial. Both series of trials were defoliated a set number of times at fixed intervals, so that they did not simulate the effect of continuous occupation by stock. Observations at Hurley[79 & 79a] have suggested that swards which were frequently utilised on a rotational basis throughout the autumn until growth stopped, overwintered best. Winter survival was closely linked with species, age of sward, grazing management and fertiliser application. At high nitrogen rates swards with a lot of leaf in autumn were highly susceptible to winter kill; at very high nitrogen rates (over 300 lb. N per annum) winter kill occurred irrespective of autumn management. Baker[79a] included a trial in which nitrogen rate, frequency of defoliation and severity of defoliation were combined. A combination of high nitrogen and both frequent and severe cutting produced the most tillers in November, and it was these tillers that over-wintered best.

THE REST PERIOD PRIOR TO USE OF GRASS IN WINTER

In 1952 Hunt[103] related the yield of herbage following defoliation to the length of rest period. Given the conditions conducive to growth, yield of herbage was proportional to the length of the rest period. During winter, growth continues at such a reduced rate (Langer, 126) that a decrease in yield is frequently found, due to the high rate of dry matter loss resulting from decay. The autumn rest period covers a phase in which growth generally takes place and one in which growth is generally negligible, and decay may be the dominant factor. The performance of herbage in the rest period, prior to its use in winter, is closely connected with the weather conditions. Warm wet autumns favour growth; the later the mild weather extends, the longer is the period in which growth can take place. Very cold wet weather increases the rate of dry matter loss in the late winter. Various factors govern the efficacy of the rest period, namely, the date on which it starts, its length and the date of its termination.

In 1938 Davies and Fagan[50] described an experiment in which grass was put up for winter keep at five different dates, ranging from July to November. The yield at the end of February was greatest on the July saved grass and the yields progressively declined as the rest period shortened. Both Stapledon[156] and Cowling[44] obtained similar results. A corollary of Woodman and Oosthuizen's work[173] was that length of rest period was less important than the date it started. Gardner[77] pointed out that, by resting early in autumn, the period of short supply was shifted rather than being catered for. Smith[151] was prepared to accept this and he refrained from grazing his cattle at all during September and October. Baker[7] found that the date of resting perennial ryegrass profoundly affected its ability to survive the winter; October rested ryegrass overwintered more successfully than August rested ryegrass. Furthermore, the botanical composition of a mixed ley can vary with the effect of different resting date[50]. Early rested ryegrass-cocksfoot swards tend to become cocksfoot dominant, while late rested ones tend to become ryegrass dominant. Early resting in the autumn results in large yields of rather low quality grass, the dry matter loss tends to be high, and autumn grazing is restricted. Very late resting, such as after the beginning of October, produces practically no growth but what there is tends to be very nutritious. Most workers have suggested that the optimum time for resting is in August. Generally in Scotland the early part of August is adopted, but further south resting is usually delayed another fortnight. Gardner and Hunt[77] obtained a yield of 915 lbs. of dry matter per acre in December after resting from early August, and only 229 lbs. from resting in early September. Baker et al.[15 & 18] recommended that autumn resting should start in mid-August, Hughes[98] suggested early August, while Corbett[36] found that August 20th was too late in Aberdeenshire, but he added that closing much earlier in an attempt to obtain a larger yield was impracticable.

Woodman and Oosthuizen[173] used a fixed length of rest period and varied the date on which it started. The July-December rested plots yielded 1787 lbs. dry matter per acre whereas the October-March rested ones only yielded 339 lbs. of dry matter per acre. The yield from the August-January and September-February plots were intermediate. Therefore the length of rest period is not so important as the time that it starts. The yield depends on the relative length of the growth phase compared to that of the decline phase, and the absolute length of the former. Gardner and Hunt[77] sustained losses of over 40% of their dry matter yield in December as a result of prolonging the rest period till the end of February. Such losses are variable both for species and years; Gardner[76] found that losses in timothy and cocksfoot were light compared to perennial ryegrass. Quality also fell as a result of this delay and utilisation would probably have been poorer through stock refusal to eat the herbage.

The length of rest period varies with the species, depending on the swards available. Generally ryegrass is grazed by mid-November, cocksfoot in December and early January, and timothy in the following period[21]. The length of the rest period, and especially the second phase, are usually determined by the ability of the sward to tolerate unfavourable conditions.

USE OF WINTER GRASS

Winter feeding of stock is a problem that Griffiths[86] defined as "one of maintaining enough stock in winter to keep pastures adequately grazed in summer". Growth follows a seasonal trend, hence the farmer finds that during certain periods he has excessive growth, while at others there is little or no keep on his pastures. There are several ways of dealing with the problem: the farmer can sell off surplus stock, just retaining his breeding stock, or else he can pay another person for the use of their land during the winter. Others prefer to buy in food rather than away-winter their stock - this food being fed either indoors or out-of-doors depending on the weather, type of stock and availability of buildings or shelter. Some farmers are self-sufficient and tide over the winter using their own resources. Special crops can be grown and used in situ: the common ones are rape, kale and turnips. Grass grown in summer and conserved as dried grass, silage, haylage or hay is commonly the back-bone of winter rations. In addition to harvested forms of grass, winter grass, grown in the autumn, can be used to provide valuable feeding during the winter.

Winter grass is used extensively for many reasons: in autumn, there are large store sales and prices are generally rather low. Some farmers consider that a better price at a later date is worth the trouble and expense of winter feeding. Away-wintering is expensive, it involves heavy transport costs and the risk of bringing in disease from another man's land. The cost as quoted by Frame[75] ranged from 35 shillings to 45 shillings for an away-wintered hogg or from 1/- to 1/6 per week per head. The West of Scotland Agricultural College report on hogg-fattening in winter[130] showed that profit margins were slender and frequently losses were incurred. Bought-in foodstuffs can also be expensive - hay varies in price according to supply and demand, quality, and transport costs. Market prices seldom fall below £11 per ton and in the early part of the year may rise to over £20 per ton. Hence there is a strong financial incentive encouraging farmers to achieve self-sufficiency in winter by exploitation of grass and arable crops. During the summer surplus grass can be conserved, usually in the form of silage or hay. Both processes require a lot of labour and machinery[116] - the cost of making a ton of hay is seldom below £8 (private communication with Edinburgh School of Agriculture Economics Department). Heavy losses both while harvesting and also in the store are common to both conserved crops[116]; in field-cured hay they may reach 40%. The end product is variable in quality and in the case of silage seldom uniform. Its quality is such that winter grass compares well with other forms of conserved grass[151,173 & 132], though it does tend to be less palatable. The losses sustained by winter grass are seldom greater than those of hay and silage, providing the former is used before January, and its use involves little labour and little equipment.

There are problems associated with the use of winter grass. Its yield is seldom over a ton of dry matter per acre; it varies a lot and declines as the winter progresses. If all through winter grazing is expected, large areas of pasture must be rested in autumn - Smith[151] adopted this plan, but only by resting all his pastures during the autumn was he able to provide the required 2-2¼ acres of grass per cow. He was prepared to forego all grazing in autumn; in fact his period of insufficient grazing was shifted from winter to early autumn. This worked with him because his calving programme was tied to heavy concentrate feeding during this period, as a prelude to calving and the onset of lactation. He balanced the risk of losing his grass in a severe winter with the high prices obtained by winter milk and the general suitability of his locality to winter grazing. Winter grazing systems tend to follow one of two patterns: firstly, there is grazing all through the winter or for long periods while the grass lasts and, secondly, there is grazing for a short period at the end or at the beginning of the growing season. The pattern adopted depends on the type of stock, its age, and the severity of the winter.

Smith[151], in Essex, grazed his dairy herd all through the winter, cashing in on the higher winter milk prices. Runcie[148] was content to extend the grazing season, strip-grazing in the autumn to produce maintenance plus two gallons of milk. Copeman and Nicholson[33] recommended that better use could be made of September and October grazing as a means of reducing the concentrate bill. Runcie[148] suggested that store dairy cattle could be left outside till the end of the year in the east of Scotland.

Copeman and Nicholson[33] recommended that young stores could be outwintered till December; Hughes et al.[102] successfully overwintered 18-21 month stores before fattening them on grass the following summer. Cattle at other stages have been successfully overwintered for limited periods on winter grass[148].

The outwintering of sheep is very common among hill and mountain type herds and others too. Winter grass is commonly used to provide keep for the ewes up till the New Year. Runcie[148] found that autumn saved grass could provide 'meat' for flushing ewes before tupping; it could also be used for feeding store lambs. Used in this way it provides an adequate alternative to fat lamb production (Hughes, 97).

DRILL-SOWN GRASS FOR WINTER GRAZING

Widely spaced drills have been extensively used in the production of grass for grazing in winter[18,29,39,44,73a,76,83,84,85,87,95,96,101,104,133 & 139]. The advantages accruing from this are as follows:

1) Less seed is required.
2) The susceptibility to fungal attack can be reduced, as in cocksfoot[11 & 133].
3) Treading damage is reduced especially on heavy soils as animals tend to walk between the rows[95,104,101 & 133].
4) The grass dries out quicker after rain or snow, due to the better air circulation; consequently rowcrop grass is less prone to rotting and it tends to be more palatable[11,76,104 & 133].
5) There is a slight reduction in burn compared with broadcast swards[76 & 104].

Widely spaced drills are slow to establish, present weed problems and require inter-row cultivation, or some other means of weed control. Their production is determined by the spacing of the drills. Some people have used interdrill widths of two feet or more[29 & 139]; this, as Milton showed, was excessive, and compared badly with broadcast swards. Comparisons between wide drills and broadcast swards have yielded variable results both in winter and in their subsequent production. At very wide spacings between the drills, the broadcast swards have usually yielded better results[29,39,44 & 139].

Gardner[76] obtained results which varied with the type of grass used; drill performance was good for cocksfoot, but both perennial ryegrass and meadow fescue yielded better on the broadcast plots. On average the broadcast plots gave the better winter production.

Lucerne has been used to thicken up the drills, thus reducing the inter-row space to about a foot. Summer production from this type of mixture is as good as that obtained from broadcast mixtures, but it is restricted to those areas where lucerne can be established and maintained[39]. Lucerne drilled alternately with cocksfoot or tall fescue replaces the need for inter-row cultivation[104]. Not only does lucerne benefit from the autumn rest, but it dies back in November and is not damaged by treading[133]; Culpin <u>et al</u>.[48] have found that in a wet winter lucerne can be killed out through excessive waterlogging, resulting in ingress of rough stalked meadow grass and a general deterioration in botanical composition.

It would appear that widely spaced drills have a limited use in certain districts. Conditions must be suitable for lucerne establishment, as without the legume there appears to be little benefit from very wide rows. The main exception to this is where grass is grown for seed and inter-row cultivation is practised. Apart from this relatively minor exception, widely spaced drills of alternate grass and legume may have a place on farms where heavy land limits winter grazing, and drought in summer is common.

THE EFFECT OF WINTER GRAZING ON THE PRODUCTION OF SEED FROM GRASSES

T.A. Evans[70] investigated the possibility of renovating an aged stand of S 143 cocksfoot, grown for seed, by grazing in winter. The stand was liberally supplied with balanced fertiliser together with additional nitrogen in August. By January it had produced over one ton of dry matter per acre; this was quickly grazed. The subsequent yield of seed was not significantly reduced as a result of grazing either in early January or mid-February; there was an apparent but insignificant reduction in seed weight per fertile tiller. Grazing tended to increase the number of fertile tillers per unit area. Very late grazing (to the middle of April on a range system), with bullocks, resulted in a low yield of seed and a low weight of seed per fertile tiller.

Later experiments by Evans and others have supported most of Evans' earlier assertions. Evans[67] found that the slight non-significant reduction in yield of cocksfoot S 37 seed, following winter grazing, was easily balanced by a dressing of nitrogen. Both cutting and grazing tended to reduce the seed-weight per fertile tiller and it was this that was compensated by an application of nitrogen. Evans[68] found that grazing S 48 timothy during the winter had no effect on the number of fertile tillers per yard of drill or the weight of seed per fertile tiller. Nitrogen tended to decrease the former and increase the latter. Providing that the grazing was before early spring, yields were not reduced. From Evans' experiments (these produced numerous trends but few significant results) it would appear that rapid grazing in the December to February period is not followed by reduced yields of seed. Experiments in conjunction with Green[80 & 81] suggested that any reduction in seed yield of cocksfoot, following winter grazing, was easily balanced by additional nitrogen, since seed yield does not vary much as a result of the two-fold effect of grazing. The reduction in seed weight per tiller is compensated by the increase in number of tillers. With meadow fescue the latter increase dominates the former decrease, resulting in an actual gain in seed yield as a result of winter grazing during the period October to April. All these experiments used short periods of occupation, often at high stocking rates, such as 96 sheep per acre[70]; where grazing was repeated, reductions in seed yield were incurred. Strain reactions have also been discovered; the reduction in seed yield of early strains following winter grazing was noticeably greater than the reduction in late strains. Roberts[144 & 145] carried out more trials and concluded that grazing in winter had no effect on seed yields, but grazing in spring almost halved yield of seed with S 50 timothy, whereas grazing in either period increased yield of S 101 perennial ryegrass. His trials on cocksfoot suggested that removal of burnt herbage as a result of grazing in winter encouraged a quicker recovery in spring. Grazing in spring reduced seed yield but this was remedied by 35 lb. of nitrogen per acre. Evans[69] found that autumn defoliation produced variable results with S 24 perennial ryegrass, but nitrogen effects were normally of greater import than grazing effects. Lambert[124 & 125] reduced the yield of timothy seed as a result of April-May grazing and found that none of his grazing treatments produced better results with cocksfoot than resting in winter.

Although many of the results from the experiments mentioned above lack significance and vary both among different grasses and in different years, certain general conclusions may be drawn. Grazing in winter seldom results in a reduced yield of seed, any reduction being normally balanced by a light dressing of nitrogen. Spring grazing, especially after April, normally reduces yield of seed. Growth of grass in autumn can provide over a ton of dry matter per acre during the winter, and this can be grazed without seriously endangering the subsequent seed yield, provided grazing is quick and restricted to the winter. This form of winter keep is cheap, easy to produce and useful.

THE EFFECT OF FERTILISER NITROGEN ON THE PRODUCTION OF WINTER GRASS AND ITS SUBSEQUENT PERFORMANCE

Many experiments have examined the effect of nitrogen on the sward. The New Zealand ones[153] are omitted here because of the different conditions prevailing there. Three facets are relevant to this thesis: the effect of autumn applied nitrogen on autumn growth, the carry-over effect operative the following spring, and the role of spring nitrogen.

Temperature and rainfall are the two uncontrollable factors governing the action of autumn nitrogen; the returns obtained from autumn applications of nitrogen have varied widely from one year to the next. Baker[9] obtained an autumn response to nitrogen of 11.8 lb. of dry matter per lb. of nitrogen in 1955. The following year the response was 22.7 lb. Autumn responses can be very low; Copeman and Nicholson[33] found that returns varied between 6.8 and 15.5 lb. for the years 1954-56. The reason for this variability is that weather conditions at the beginning and at the end of the growing season are even more variable and less reliable than at other times of year. Nitrogen is only efficacious when the environmental conditions are conducive to growth. Grass requires warm wet weather for good growth; given both adequate rainfall and temperature the response to nitrogen applied in the autumn is good, but in cold dry autumns growth even with additional nitrogen is very poor. The length of growing period after the nitrogen has been applied is of great importance. If it is applied late, the grass growth is limited by low temperatures and lack of sufficient light. Because of this it is usual to apply nitrogen when the sward is rested, prior to its use in winter. In 1958 Jack[113] obtained a rapid response to August applied nitrogen. Gardner and Hunt[77] compared the effect of applying nitrogen in August and September. The December yield of the former, in response to 3 cwt. of Nitrochalk, was 2116 lb. of dry matter compared with only 768 from the September fertilised plots. The better quality of the latter was of negligible importance compared with its poorer yield. Gardner and Hunt[77] recommended that in the West of Scotland nitrogen should be applied in August for the production of grass for winter grazing. Cowling[44] considered that nitrogen could compensate for delay in date of resting; although the winter yield is increased by September nitrogen, the response is small and hardly economic. In comparing the response from early September and mid-October applications[46], he found that the former was 11-12 while the latter was only 6-8 lb. of dry matter per lb. of nitrogen applied. The time of application varies with location, but in general it is thought that nitrogen should be applied immediately after putting up for winter grass. In Scotland and the North this will be early August, while in the south it is normally delayed another fortnight.

The recommended level of autumn applications of Nitrochalk is 3 cwt./acre. This has been accepted by numerous people without attention being paid to the fact that during the past fifteen years 1 cwt. of Nitrochalk has changed from containing 15.5% N to 21% N. Consequently the older sources recommend that 52 lb. of N is the upper practical limit; modern sources agree with the weight of fertiliser applied but actually are recommending an extra 18 lb. of N. There are still others who have neglected to include the composition of their fertilisers with the result that guesses based on the date of their work must be made. Gardner and Hunt[77] compared the December yield of a sward after receiving August nitrogen at 3 and 6 cwt. (15.5% N). The extra herbage on the 6 cwt. plots was only 208 lb. of dry matter greater than that on the 3 cwt. plots. The return on the extra 3 cwt. was only 4 lb. of dry matter per lb. of N. Baker[11] obtained a return of 15 lb. of dry matter per lb. N on a dressing of 52 lb. N applied in the second half of August. The return from 104 lb. N was only 10 lb. D.M./lb. N. The extra 260 lb. of D.M. (at 1967 prices) cost 30/4d., allowing for bulk order concessions and no spreading costs (figures obtained from S.A.I.). This return is uneconomic and demonstrates the conclusion of others that 50 lb. of N per acre is a safe limit, especially in view of the uncertainty of weather conditions. When long range weather forecasts get more accurate and can give a reliable indication of the weather for the following three months, nitrogen applications may rise considerably in warm wet autumns. Some people are recommending from 3 to 4 cwt. of 21% N Nitrochalk - the earlier work would indicate that total returns may be substantial but marginal returns are small and may be uneconomic.

Results at Auchincruive[3] have indicated that winter burn was highest on the most heavily fertilised plots - nitrogen has normally been considered to decrease winter burn, but if growth in autumn produces a very leafy sward, winter burn damage can be extensive. At Hurley[79] winter kill was severe on those swards that had received over 300 lb. of N in the previous year, regardless of management. Nitrogen applied in the autumn decreases the soluble carbohydrate content of the roots and stubble[9 & 112], yet in the following year the autumn fertilised plots made the better growth; this was possibly a result of tiller strength differences.

An early August application of 50 lb. of N per acre costs 29/6d. plus 4/6d. to spread. The return is generally in excess of 8 lb. D.M./lb. N, thus giving an extra 400 lb. of dry matter. The cost of producing an extra ton of dry matter on an 8:1 basis is £9.10/-; usually the response to N is better so cheaper winter grass is obtained.

The second consideration when applying autumn nitrogen is the residual value after the winter. This may be in one of two forms. First, there is nitrogen left over in the soil after the winter is over. During the winter this soil nitrogen will tend to decrease through leaching losses. Secondly, there is nitrogen that resulted in herbage changes in the autumn. The earlier the nitrogen is applied in the autumn the greater is the proportion of it incorporated in the grass and the less there is subject to leaching losses. Some of this will be removed in grazing, but most will be returned in the form of dung and urine, especially if the animals are store stock. Corbett[37] compared different autumn nitrogen rates both for their effect on winter grass production and their effect on spring growth. The following year, May yields and May to October production were increased by the previous autumn's nitrogen. The recovery of nitrogen was very good from both August and September dressings, especially the latter which made up for its poor winter yield by very good spring production and recovery. Corbett, in commenting on the low leaching losses (15% for September N), suggested that nitrogen was taken up by the plants in the late autumn and stored. Meteorological data obtained at Craibstone (through Meteorological Office) suggested that although there was a dry period from January to April, the October-November period was a very wet one. Baker[9] got variable results in his attempts at examining the effect of autumn nitrogen on spring yield. In 1955 and 1957 autumn nitrogen made only a very small difference; in 1956 it increased the yield by a significant but not large amount. This was in a cold dry spring and spring nitrogen was not very effective. Autumn applied nitrogen failed to increase yields the following spring on Baker's county sites[10]. This may bear out Corbett's hypothesis that nitrogen is stored by plants during the winter, or else it could be that autumn nitrogen produces stronger tillers and these are capable of earlier growth the following year than unfertilised ones. Baker's conclusion to this article is worthy of mention: "In these two experiments neither autumn nitrogen, nor autumn grazing management, had any appreciable or consistent effect on the yields of herbage in the following spring. Spring nitrogen was the most important factor in determining the yields of spring herbage, whilst the weather in early spring determined the earliness of growth." This conclusion was a very important one, and its importance can be demonstrated by the frequency with which the essential elements of it crop up in later work. While Baker was investigating the problems associated with early grass production at Hurley, Jack was carrying out a large number of trials at Edinburgh[113]. Jack found that, following autumn nitrogen, ryegrass and cocksfoot reacted differently the following spring. In spite of his usual winter defoliation, ryegrass sometimes produced a lower yield in spring following autumn nitrogen than the control, no nitrogen, plots. Cocksfoot responded well in the spring; the yield of the plus nitrogen Danish cocksfoot was 161% of the no nitrogen yield. In another trial with Danish Italian ryegrass Jack found that autumn nitrogen increased yield in spring at all three levels but none of the differences were significant. This result was somewhat puzzling in that the high rate of nitrogen was expected to reduce the yield as judged by earlier trials, but this did not occur. Maybe this was due to lack of winter kill, or else the December defoliation limited winter injury; Jones[115] found that time of defoliation, relative to weather conditions, was an important factor in determining the survival of Italian ryegrass. It should be stressed that poor spring production of the ryegrasses resulted from winter kill rather than a lethargic start, as Jack stresses the ability of Italian ryegrass in particular to make abundant growth in early spring. Another of Jack's trials on drills of various grasses compared the effect of autumn and spring nitrogen on early growth. He found that the effect of spring nitrogen was significantly greater than the effect of autumn nitrogen. Autumn nitrogen was almost significantly greater than no nitrogen, and nitrogen both in autumn and spring was almost significantly greater than nitrogen in spring only. This showed that the effect of nitrogen in autumn could be additive to the effect of spring nitrogen. There were species differences; established cocksfoot reacted similarly to autumn and spring nitrogen, but first year cocksfoot showed a marked reaction in favour of spring nitrogen, a response that was also demonstrated by the Italian ryegrass. One suggestion was that the reserves were very much larger or more efficient in cocksfoot, or it may have been that the effect of autumn nitrogen on the ryegrasses was nullified by winter kill. In another trial Jack repeated the same type of experiment on swards; he found very little autumn nitrogen carry-over effect and the response from both autumn and spring nitrogen was only slightly greater than the response from spring nitrogen only. Jack's conclusions were that autumn nitrogen was detrimental to the spring yield of Italian ryegrass but was beneficial to that of cocksfoot. Cowling(44) found that spring production from cocksfoot could be increased by autumn nitrogen; Baker[10] did not obtain a spring response to autumn nitrogen on cocksfoot. Generally it was found that autumn nitrogen was less effective than spring nitrogen in encouraging good spring growth. These findings remain substantially correct, but later work at Hurley has rather modified the conclusions on Italian ryegrass. It would appear that autumn nitrogen may affect tiller production in autumn, and exert an indirect, but important, influence on spring production. Winter survival[79a] was closely connected with judicious use of nitrogen and that management system that produced the most young vigorous tillers.

Blackman's classic work[24] in 1933 provided a rational explanation for the contradictory results obtained from the use of nitrogen in early spring. He split the nitrogen effect into two components. Firstly, there is the increase in the degree of earliness (a fixed yield was chosen to determine this - 7½ cwt. dry matter per acre): the degree of earliness was the difference in time between the date on which the treated plot reached this yield and the date the control reached it. The second component was the increase in yield resulting from an application of nitrogen in early spring. Blackman measured the degree of earliness over 5 years and obtained results ranging from 2 to 14 days. He concluded that as long as the 4" soil temperature remained below 40°F, no appreciable growth was made. When it was consistently above 50°F, the growth rate of the no nitrogen and the plus nitrogen plots was the same. The pertinent period was in the region 42-47°F; during this period the growth rate of the plus nitrogen exceeded that of the control; the longer this period lasted the greater was the advantage in favour of the plus nitrogen plots. Blackman's explanation of this was that below 42°F growth was limited by low temperature, above 47°F microbial activity provided sufficient nitrogen to satisfy the requirements of a rapidly growing sward. Between 42° and 47°F microbial activity was limited and nitrogen was in short supply. During the period 1930-35 1 cwt. of ammonium sulphate increased the yield of certain fields by 41%, 20%, 74%, 87%, 23% and 28% respectively; 3 cwt. increased the yields by 105%, 129%, 121%, 200%, 79% and 74%. Similar results were obtained with sodium nitrate. The mean increase from 1 lb. of nitrogen, at the 3 cwt. level, was 11 lb. of dry matter. Baker[9] obtained returns of 11.8, 8.9 and 27.9 lb. of dry matter in 1955-57 respectively, and significant differences from the application, in spring, of 0, 35 and 70 lb. N and 0 and 52 lb. N. The increases were large compared to the one small autumn nitrogen response. Both Baker and Jack[9,10 & 113] found that spring nitrogen was of overriding importance in determining the yield of dry matter in spring. Edwards and Morgan[65] found that winter grazing did not alter the ability of a pasture to respond to spring nitrogen. Winter exploitation of pasture can thus be redressed by extra spring nitrogen. Meadowcroft[136] found that the 2 cwt. of hay reduction following winter grazing in September and October could be offset by a 4 cwt. increase resulting from spring nitrogen (average of 6 years). Frame[74] grazed plots heavily in March, for four days, and then applied nitrogen at different rates. He sampled the area towards the end of April and obtained significant results. The dry matter yield increased with heavier nitrogen dressings and about 45 lb. of N was required to redress the effects of March grazing. By the beginning of June the treatment differences were insignificant and the slight reduction, following March grazing, was removed by the addition of 7 lb. N. This showed that the later the harvest date, following winter grazing, the cheaper it was to repair the damage. These results were only obtained from one year but they both demonstrate a principle, and agree with the observed effects of spring nitrogen. Wilcox[172] also found that small quantities of Nitrochalk in spring compensated for the reduction in dry matter that frequently follows grazing in winter.

Hunt[108 & 109] has added various comments on the use of early nitrogen. If the sward is cut early in spring both the growth rate and the response to nitrogen are reduced. The time of nitrogen application in the spring is very important, especially in early years. In one of his experiments there was no evidence that nitrogen put on at the end of February was too early, and there was substantial evidence that nitrogen put on at the end of March was too late.

Autumn nitrogen can produce plenty of winter grass if it is applied soon after the pasture is put up for resting. There is no reliable carry-over effect, but cocksfoot does appear to benefit from autumn nitrogen. Although no carry-over effect should be expected, autumn nitrogen may bring about changes in the tiller content of the sward that encourage better subsequent production. Applications of over 50 lb. of N per acre should be used with caution but they can occasionally be justified in economic terms. Spring yield is mainly determined by the level of spring nitrogen, its time of application, the weather and the botanical composition of the ley.

THE SPRING AND SUMMER PERFORMANCE OF WINTER-GRAZED GRASS

The spring and summer performance of winter-grazed grass has been measured by several people. The techniques used have varied. Jack[113] and Baker[10], after applying autumn treatments, defoliated the plots to a uniform level. Edwards and Morgan[65] measured spring growth on their plots and reduced the yields by the appropriate pre-spring yield. Others, such as Frame[74], have not corrected their spring yields in any way following autumn or winter treatments. The adoption of one technique, rather than another, has depended on where the emphasis lay. Frame was primarily interested in the effect of winter grazing, Jack and the others were more interested in the production of early grass. It could be argued that Jack's differences, following his autumn rest periods, were reduced by defoliation of the trial in December. Likewise, Baker[10] may have lessened the effect of his September and October treatments by defoliating in November. Both might suggest that Frame's differences in spring resulted from the residual growth on the control and not from the reduced vigour of the other plots. This suggestion may be a valid one, but Frame did have an undefoliated control and he did not base his results on the assumption that a quick defoliation in November or December had a negligible effect on the subsequent production of the sward.

It is essential to pay the strictest attention to time of harvesting and its method when using subsequent production as a means of estimating the effects of winter grazing. As will be shown later, considerable differences exist between the residual effects of winter grazing soon after the onset of the growing season, and the residual effects two months later. Frame cut his plots at three stages in their development, to correspond with early bite, silage and hay. Jack cut at two times, one a fortnight after the other, in order to measure the rate of growth. Gleeson[90] cut the regrowth and repeated this through the season. Vetharaniam[175] was unfortunate in one of his trials - apart from his first cut there were no significant differences nor even a consistent trend that could be ascribed to winter grazing. Whether this lack of difference would have occurred if cows had not invaded his plots is a matter for conjecture. However, one can conclude that, following defoliation, recovery is not adversely affected by any residual effect of winter grazing. Gleeson[90] found that, following defoliation, recovery on the winter grazed swards tended to be better than on the winter rested. The total production of the former (one short period of grazing at 72 sheep per acre) exceeded that of the control, but his severe winter grazing treatment (December to April at 72 sheep per acre) did irreparable damage to the future growth in the period up to the end of June. Although the production after this period was very good it failed to compensate for the loss of early growth. Hanley <u>et al.</u>[89] found that the optimum winter treatment varied with the way one measured production. The ungrazed control had the highest hay yield at the first cut;

the differences at the second cut were very small. Loss of use in autumn and winter reduced the yield from the control to such an extent that its total annual production was inferior to some of the winter grazing treatments. Frame[74] found that the reduction in subsequent yield following his winter grazing treatments was greatest at the time of his early cut and least at his hay cut. Consequently, time of harvesting, and management policy, following winter grazing, are of paramount importance in determining the magnitude of the residual effects. The conclusion that can be drawn from these experiments is that large reductions in early yield may follow winter grazing, but these decrease as time of harvesting or defoliation is postponed. After the first defoliation the residual effect of winter grazing is seldom an adverse one.

Above it has been suggested that winter use of grass is detrimental to the future production of a pasture; there are some who have found that this is not necessarily the case, and that subsequent production depends on the autumn and winter management adopted. There is some evidence that the date of resting in autumn influences the future production from the sward. With cocksfoot, Cowling[44] has shown that the longer the rest period is, the better the spring yield - the hay yield was greatest on the plots rested from June and it progressively declined as the date of resting was postponed; the hay yields were means of winter grazing treatments. Autumn resting of ryegrass has been shown by many[9,10 & 113] to encourage poor future production, and good early bite can follow frequent autumnal defoliation[79c]. Jack[113] failed to obtain large differences in his autumn resting trial (he varied the date of the autumn rest period on a mixed sward) but he found that with Italian ryegrass the shorter rest periods gave better yields the following spring. With cocksfoot the August rested plots yielded better early growth than the September or October rested plots. He explained this on the grounds that the longer rested plots of Italian ryegrass had fewer tillers, their recovery from the December defoliation was slow, and they incurred more winter kill than those on the short rest period plots: these had been cut monthly up to the time of resting. The better growth rates of the latter probably resulted from their complement of many short tillers being a more efficient photosynthetic system than few long tillers. Baker has suggested that although the latter are capable of better growth initially they are eventually surpassed by the former.

Some of the variations in growth rates following winter grazing may be traced to differences in the time of winter utilization. Cowling[44] found that defoliation in February had little effect on the yield of hay but defoliation in November reduced it. Using the same type of mixture, Hanley et al.[89] found that with cocksfoot and lucerne the reduction in hay crop was negligible if winter grazing was restricted to the period November to February, but grazing in October or March could seriously reduce hay yields (12% reduction). The summer yield from the February grazed plots was only 65 lb. of hay less than the control, whereas the March plots were another 700 lb. behind. Grazing in November gave the highest total annual production; the slight reduction in summer performance (22 lb. of hay - total for two hay cuts) was more than balanced by the useful winter keep. Good early bite has been obtained at Hurley[79c] from resting in the autumn and grazing in January and February, but a severe defoliation in the September to December period adversely affected the spring yield. Fagan and Evans[73b] found that fields put up for hay at the end of February incurred a loss of hay amounting to only 3% when compared to December put up fields. This slight reduction was only just greater than the yield produced between December and end of February. Similar results were obtained from fields put up at the end of April - the loss in hay being compensated for by the grazing in March and April. Meadowcroft[136] found that the small reduction in hay yield (average 2 cwt. over 5 years) was amply repaid by the extra live-weight gain resulting from autumn grazing and that this small reduction was completely masked by a spring dressing of 31 units of nitrogen. Baker found that October grazing could occasionally have a small effect on the following year's production, but this effect may have been reduced by Baker's experimental technique. Jack, in his "Winter Defoliation Trial", found that the residual effects were negligible compared to spring nitrogen effects. Besides this, it was not possible to distinguish between the effect due to different times of resting, and that due to increasing the number of defoliations. In another trial his results were complicated by an awkward cold spell. Frame[74] examined the spring yield following different times of winter use, and concluded that March grazing was followed by a more marked reduction in yield than the other treatments. Reductions in yield tended to be heavier on those plots that were defoliated more than once. By the silage stage month of winter defoliation had ceased to be of much importance. These experiments and others were done using short periods of occupation in small plots; these do not necessarily portray the same effects as continuous occupation. Gleeson[90] found that the reduction following a short grazing period in January had disappeared by June but it remained all through the year for his December-April grazing period. In view of this, small plot trials using short periods of occupation may not be reliable indicators of the agricultural systems they attempt to simulate, though this disadvantage is balanced by the easy replication and sampling.

From these numerous experiments certain rather tenuous conclusions may be drawn. Subsequent production following use of grass in winter is determined by numerous factors. The summer defoliation policy is an important determiner of the yield. Early defoliation results in substantial losses at that cut but may produce compensatory growth thereafter. Later defoliation (at the silage stage) has shown that the percentage reduction may be less, but this does not inevitably mean that the reduction in absolute terms is less - Frame's results indicate that the reduction in lb. of dry matter can be more serious at the silage stage than at the early stage. By the hay stage the reduction, following winter grazing, is generally of negligible importance. There is a species effect on subsequent production resulting from the different ways in which the ryegrasses and cocksfoot react to autumn resting. The latter is favoured by a long rest period, regardless of use in winter, while there is a considerable amount of evidence that ryegrasses are harmed by early resting. Time of winter use produced substantial differences in the summer yields. Generally the optimum performance resulted from November to February use. If plenty of winter grazing was required, November was the optimum time, but if the emphasis was on summer production then February was a more suitable time to use grass in winter. Much more evidence is required before the effects of autumn nitrogen can be explained and evaluated; the evidence suggests that on occasions it can contribute towards growth in the following year. Spring nitrogen was of paramount importance in determining the subsequent performance of pasture, its addition obscuring the results of winter grazing on numerous occasions. Frame showed that the reduction in winter grazing could be redressed by a comparatively small investment in spring nitrogen (45 lb. at the early stage and only 7 lb. at the hay stage).

BOTANICAL CHANGES FOLLOWING WINTER GRAZING

Following several experiments on winter grazing, changes have been noted in the botanical composition, and the form of the sward. Gleeson[90] did April tiller counts on a sward that had been subject to different winter grazing treatments. The control, ungrazed, had many more tillers than the plots that had been grazed for a short period in January, and the latter had more than the plots grazed from December to April. Vetharaniam[175] obtained no significant results from his appreciation of perennial ryegrass tiller numbers at the end of March, following winter stocking treatments, but there was an indication that the severest treatments did cause slight reductions. This was compensated for by an increase in the Poa tillers in response to winter grazing. The clover results showed no consistent trends. In another experiment the proportion of bare space in the sward rose with increasing winter stocking rate on S 321 ryegrass, but this was not so marked for S 26 cocksfoot and S 48 timothy, probably due to the high Poa infestation of these two species. There was a general fall in the tiller number as winter grazing treatments became more severe, but this difference disappeared at the second cut.

Hughes[98] found that resting in autumn, with additional nitrogen for winter grazing, led to a reduction in the white clover content of the sward and the rapid ingress of miscellaneous species. Corbett found that the contribution by clover following winter grazing was negligible, but, since there was practically no clover in the November samples, this is not altogether proof that winter grazing was responsible for the fall in clover contribution. Frame[74] found no consistent trends following winter grazing treatments, but his control replicates were almost totally devoid of clover too. These reported cases of poor clover contribution following winter use of grass may be due to the general use of elderly swards for winter grazing. Their clover contribution is likely to be minimal. The disappearance of clover may possibly be encouraged by the long autumn period of rest[73]. Vetharaniam[175] suggested that the proportion of clover could increase as a result of winter stocking, but owing to the dramatic changes in his plots this assertion should be viewed with scepticism. Wilcox[172] found that clover composition was connected with level of nitrogenous fertiliser after the winter defoliation.

Among the grasses, changes in botanical composition are common - it has already been stated that in mixtures the ratio of cocksfoot to ryegrass is very dependent on the length of the rest period. No consistent trends were found by Frame or in work done at Drayton[140a], but Vetharaniam showed that Poa ingress could be extensive, especially at the first cut, but it was only transitory in effect; the sown species soon dominated and the Poa effect was substantially reduced.

In the past too many changes in botanical composition have been ascribed to winter grazing, often in experiments in which all plots were grazed in the winter. Experiments using an ungrazed control have indicated that these changes cannot be unequivocally linked with winter grazing, and they may well be accounted for by the general use of elderly leys for winter grazing experiments, as these tend to be particularly low in clover.

ANIMALS IN SUMMER AND WINTER GRAZING EXPERIMENTS

There are several animal factors relevant to this thesis; when animals are used in grazing experiments they introduce certain complications. During the outwintering phase, plane of nutrition can be of paramount importance to the survival of sheep. Often the ill effects of a low plane in winter are not evident till the extra strain of lambing is imposed on the ewe. Pregnancy toxaemia, or twin lamb disease, is a metabolic disorder arising out of a combination of winter feeding and demands of pregnancy. This generally occurs at a time when the demand for dietary energy is at its greatest. It is common in ewes that begin the winter in an overfat condition; subsequently they find themselves on a declining plane of nutrition just as their nutrient requirement is rising. This is especially prevalent in systems where ewes are outwintered without adequate supplementary feeding. The gradual decline both in the quantity and the quality of their diet occurs just as the foeti are making demands. Liability to this disorder can be reduced by ensuring that ewes enter the winter in a fit condition not a fat one. Fat ewes lack the inclination to search for food when keep becomes scarce. Supplementary feeding, especially in the last few weeks of pregnancy, reduces the likelihood of this disorder. Foot rot, common on overstocked pastures, may increase susceptibility to twin lamb disease by discouraging the ewe from foraging[147]. Other metabolic disorders follow the transition from low plane winter feeding to a diet based on lush spring grass; these disorders are particularly common where this transition period coincides with lambing.

The use of animals as recording agents is fraught with difficulty. The experimenter will generally have to compromise between a system of small plots using one or two sheep for short periods of occupation, and use of large scale field trials that are difficult to assess accurately and expensive in replication. The dangers inherent in the former method include the possibility of obtaining results that bear no relevance to field systems. The results obtained from such trials often achieve a high level of significance, but they do depend on the lack of eccentricity in a very limited number of sheep and the premise that the pattern of behaviour of these sheep will remain the same. One heavy shower of rain shortly before enclosing two sheep for a day on an area of 19½ square yards might well make that particular period of occupation rather different from one following a week without rain. Frame's work[74] used short periods of occupation. Where large field trials, using long periods of grazing are adopted, there tends to be a minimum paddock size. Consequently either very few comparisons can be made or else there is little replication. In the latter case results may lack statistical significance due to the inherent variability of a large paddock and the difficulties associated with sampling. In two of the experiments included in this thesis an attempt was made to reduce the error due to variability in the plots by measuring the number of ewe grazing days and the performance of the lambs, rather than cutting small strips from undisturbed paddocks. In order to do this successfully it is necessary to understand certain animal reactions to grazing in spring and summer. Where lamb performance is used as the index of yield certain difficulties are introduced. Initially the growth rate of the lambs is mainly dependent on the ability of their mothers to produce ample milk. Large, Alder and Spedding[129] suggested that a high plane of nutrition during lactation was more important than a high plane before lambing. Later on, lambs rely more on their herbage intake. During the summer there are seasonal trends in the growth rate of lambs[128], such that the highest growth rates are generally found in the spring[72]. Eyles[73] found that the best live-weight gain per acre was obtained by the management system that best utilised the spring period. During this period the digestibility and crude protein content of the grass are high. Voluntary intake is controlled by reticulo-rumen distension level[28]. Digestible foods pass through the reticulo-rumen faster than fibrous materials, hence voluntary intake is correlated with digestibility[25]. If a grazing system can coordinate efficient stocking on highly nutritious grass, with the inherent ability of lambs to grow fast in spring, then the total live-weight gain will be substantial. But grazing early and hard may limit the future production of that pasture (Spedding, 152). It is important to distinguish between live-weight gain per acre and live-weight gain per lamb. Grazing at light stocking rates produces good individual performance but poor production per acre. Heavy stocking produces good yields per acre but slightly poorer individual gains. Sheep[127] do better on short grass since it tends to have a higher leaf to stem ratio. Although heavy stocking may slightly limit the intake of food this is compensated for by the higher stocking rate and the production of grass that is not so mature and low in digestibility. Large and Spedding recommend that comparisons of systems using different stocking rates should not disregard the differential levels of parasitism engendered by their treatments[127].

When grazing animals are used to evaluate herbage results great care is required in interpreting the figures obtained. In small plot trials the yield is easily established by cutting techniques, but in large paddocks cutting small areas is of doubtful value. Ewe grazing days are a convenient index of yield providing a few precautions are observed. Stocking rates should be adjusted so that grass on all paddocks is kept eaten down to a uniform level. This is difficult where weekly adjustments are made since it requires an assessment by the experimenter; at no time should a paddock be scraped bare or allowed to get away from the sheep. Stocking in spring is a very delicate affair, since grass growth is subject to quick changes. Over or under-stocking during this period may well determine the subsequent performance of the pasture (Spedding). Evaluation in terms of lamb liveweight gain is of even great complexity. It may be convenient where an attempt is being made to demonstrate the financial or economic implications of grazing systems, but it introduces yet other factors in addition to those mentioned above. Growth rate of lambs is dependent on seasonal trends and the availability of ample digestible food. A system which produces abundant spring grass may well surpass, in terms of lamb live-weight gain per acre, another system which has the higher total dry matter production. Unless great care is exercised, interpretation of yields measured in such terms may be inconclusive. Care must also be taken that experimental animals are uniform in physical characteristics, healthy and temperamentally similar.

THE EFFECT OF TREADING

Poaching is the visual effect residual on a pasture after treading has occurred. Soils vary in their ability to withstand treading without exhibiting signs of poaching. Edmond[62 & 66] and Gradwell[92,92a & 92b] found that as soils became wetter so their tolerance of treading decreased. The water content of a soil is associated with several factors. Soils are made up of mixtures of gravel, sand, silt, clay and humus. These mixtures vary in volume of pore space and the distribution of pore size. The pore volume of a collection of spheres of uniform diameter is a fixed value that does not alter with the diameter. The pore volume of a mixture is dependent on the relative proportions of the constituents of the mixture. Competing for the pore volume are gases and water. In the smaller pores the surface tension forces are so great that water is held against the force of gravity. In the larger pores water is present when the soil is saturated, but as drainage takes place water is removed - at field capacity the free-draining pores contain gases. In clay soils the proportion of small pores is high, consequently such soils tend to have high moisture contents. Their infiltration capacities are low so that water may accumulate on the soil surface, this being aggravated if the subsoil is impervious or on impervious rock. Soils which contain a lot of water at field capacity are susceptible to poaching. Gradwell[92b] found that as soils became wetter they passed through a plastic stage and eventually tended to behave like a liquid. Heavy soils reached the liquid stage more readily than sandy soils. Moisture content also affects the strength of a soil and hence its bearing capacity. Most of the visual effects of treading result from shearing through the uppermost layer of soil[91], hence poaching damage is closely linked to the mechanical strength of the soil: the wetter the soil the weaker the upper layers. Clay soils tend to have low bearing capacities and consequently to be more susceptible to poaching. Soils on slopes are initially less prone to the ill effects of treading since most of the excess rainfall may be removed by run-off. Treading damage on slopes can be magnified by the more damaging effect of hooves penetrating a surface at an angle and the sideways displacement of soil. Horses are particularly harmful, with dairy cattle almost as bad; dry cattle are less damaging, and sheep are even less so.

One of the measurements often made in attempts to assess poaching damage is bulk-density. This is solely a measurement of total pore volume and it gives no indication of variation in pore size. The actual change in bulk density can be minute following treading[175] but the side-effects can be substantial. Following an initial compaction, marked changes in bulk-density can occur, but further compactions may have little added effect. Poaching damage is most common where a pasture is repeatedly trodden. This would indicate that changes in bulk-density do not account for the visual and botanical changes resulting from poaching. Gradwell and Tanner and Mamaril[163] have investigated bulk-density changes following compaction. Tanner and Mamaril established that when a soil is compacted there is a decrease in porosity: the change in bulk-density was small compared with the decrease in aeration porosity. Air permeability and penetrability were very sensitive to small changes in bulk-density. Small changes in the latter disguised large changes in the distribution of pore size. This change in distribution had a threefold effect. Following compaction, aeration was poorer in the soil, the total water content increased, but the hydraulic conductivity fell[164]. Although the compacted soil contained more water, there was in some cases a reduction in the mass of available water following compaction. Gradwell[92] supported these findings and suggested that poached soils temporarily lost some of their drainage ability. He found no relationship between drainage and total pore volume - it was the change in distribution of pore size that was the relevant one. From these results it would appear that small changes in bulk-density following treading may mask other changes which are of direct importance to the growth of plants.

The soil provides a medium which plants exploit; efficient exploitation is generally achieved by extensive root growth and the production of root hairs. Water and minerals are absorbed from the soil. Gaseous diffusion and exchange take place in the soil due to the abundance of living organisms contained therein. Compacted soils can affect these processes in many ways. Root growth and hair formation can be limited in compacted soils. Veihmeyer and Hendrikson[176 & 177] have suggested that soils have threshold densities such that root penetration is limited as a soil becomes more compacted. Fountaine and Page[73d] found no roots of wheat in soils with less than 30% pore space, and no roots of mustard in soils of less than 38.7% pore space. Tanner and Mamaril[163] found that excessive soil compaction increased the mechanical impedance to root growth. Russell[148a] suggested that root hairs and unsuberised portions of the root system were easily injured in unfavourable conditions. These conditions included poor aeration and lack of available water; their effect on plants was to hinder root hair formation and encourage suberisation. Edmond[60] found that compaction may limit root activity by altering aeration and moisture content. Russell[148a] found that root development was limited when the percentage of oxygen in the soil gases was less than 9-12%; furthermore, growth ceased at concentrations less than 6%. Depression of root growth rate is accentuated by low temperatures. These are common on soils that take a long time to reach field capacity in spring. Gaseous diffusion is limited following puddling and compaction, hence carbon dioxide can build up to possibly toxic levels. Soil respiration is impeded at high concentration of carbon dioxide. Lamba[123a] found that root growth was encouraged by artificial aeration in alfalfa. Edmond found that heavy treading produced a shallow pan 1½" below the soil surface; this tended to act as a diffusion barrier, retaining carbon dioxide and isolating the soil from oxygen. Gradwell[92a] suggested that reduction in aeration was a serious consequence of treading in that it directly affected the growth of plants. Poor aeration could reduce root growth by depressing root respiration, and the uptake of nutrients. Others have commented on the susceptibility to drought exhibited by poached soils when subjected to a subsequent dry period. This may be caused by a rearrangement of root distribution following treading or compaction. Edmond[59] found that such soils presented an impenetrable surface and excluded water. Veihmeyer and Hendrikson found that after compaction the densest soils were the driest and water exploitation was severely curtailed. Compacted soils with their lower hydraulic conductivity[164] are slow drying out in spring[177 & 92b]. The evidence suggests that the content of available water is reduced to such an extent that such soils may exhibit drought symptoms earlier than untrodden soils[92a & 92b]. The quantity of available water depends on pore size. Treading reduces the content of available water in two ways. The pore distribution is changed so that there is a reduction in available water due to the decreased number of large pores, and the remaining water is held tighter by the increased number of small pores.

Above it has been shown that treading can affect soil properties and that these may govern processes which are vital to plant survival. Experiments have been done in which attempts have been made to link treading to plant changes. Edmond[61,62 & 64] has suggested that treading can do direct damage to the plant. In dry conditions plants are bruised, but in wet conditions damage is far more serious, leaves are buried or smeared with mud, soil is displaced and the roots are damaged by the shearing action of hooves. These are direct effects; indirect ones have also been reported. Edmond exposed pastures to two stocking rates at three moisture levels[61]. The yield on the unstocked control was greater than the yield on all the other treatments. Reduction in yield was more marked at the higher stocking rate; it was also proportional to moisture content. There was a reduction in yield on the dry plots; this was due to direct physical damage to tillers and leaves as a result of treading. Treading has two components, one a compacting effect and the other a puddling factor. In one experiment Edmond[60] found that there was no reduction in yield following planting of seedlings in compacted soils, but there was a definite change in growth habit. In another experiment, described in the same article, he imposed four treatments: control, artificial puddling, artificial compaction and a combination of puddling and compaction. The yield following compaction exceeded the yield on the control plot. Puddling had a detrimental effect on dry matter yield, probably due to the formation of an impenetrable crust 4 cm. below the surface of the soil. This crust may have interfered with gaseous diffusion. There was no puddling and compaction interaction. In addition to these experiments, Edmond[59 & 64] used a race technique. This was an attempt to compare actual treading damage at different stocking rates without the complicating influence of defoliation or excretion. The stocking rates were calculated from figures similar to those quoted by Hughes[99] and Sears[149]. The disadvantages of this system and the errors inherent in it were repeatedly stressed by Edmond in his articles, but his results provide a useful indicator of the degree of damage that can follow treading at high stocking rates. Using his figure of 120 sheep grazing days, the recovery growth was 10-20% less than that of the control untrodden, whereas the recovery growth following stocking at 600 sheep grazing days was only 40% of the control's. From these experiments certain conclusions can be drawn. Compaction can reduce yield of herbage if the compacting influence damages the leaves and tillers. Puddling has a decidedly adverse effect on the growth of grass. Treading is generally followed by a reduction in yield proportional to the rate of stocking[59,61 & 64]. Edmond found that this reduction in yield was due to the initially lower plant density of the trodden plots, and to the poor performance of damaged leaves and tillers[62,63 & 66]. This tends to be a purely transitory effect[92,92b & 127]. Campbell[27] found that the changes following treading disappeared within 6 to 10 months and that there was no cumulative effect.

A species reaction to treading has also been recorded[93], but Campbell[27] found that species changes were transitory and not so important as those resulting from the passage of time. Tanner and Mamaril[163] found that such changes were not always accounted for in terms of bulk-density. Generally perennial ryegrass did well on trodden pastures[63].

Treading has undoubtedly played a role in governing the subsequent production of pastures grazed in winter. It is important that this role should be understood and separated from the role of defoliation. Experiments on winter grazing have not specifically distinguished between these two effects; this is unfortunate since besides providing keep in winter, pastures may be used to provide an enclosed area where sheep can be kept in moderate health rather than being exposed to the harsher conditions of the hill. Supplementary feeding in winter is simplified if stock are confined to a limited area close to the source of food. In this case treading damage may surpass defoliation as the primary factor limiting future production. Before advocating one winter grazing system rather than another the interrelations of these two factors must be unravelled; this is something that past work has failed to do.

THE EFFECT OF WINTER GRAZING ON STOCK PERFORMANCE

Winter grazing can affect the future performance of animals that have remained out through the winter as well as the performance of those animals grazing the swards during the spring and summer.

Many people have commented on the loss in weight when stock change from a winter diet to a spring one; this is particularly true where it coincides with a change from feeding inside to grazing lush, rich spring grass(36). It has been shown that outwintered animals do not suffer the same set-back(40). Jones et al.(121) found that the summer performance of yearling Friesian steers, following wintering on winter grass, tended to be superior to those animals fed through the winter on kale or silage. The cattle were able to withstand the wintry conditions aided by the heat produced in rumination(40); if the spring advantage from wintering animals is to accrue, the outwintering must be continuous(140) - there was a distinct disadvantage where cattle were put into courts in the middle of the winter as they both suffered a set-back then and when put out in the spring. Hughes(102) found that, providing the pastures contained adequate keep in winter for maintenance and a small gain in weight, outwintered animals had the better summer performance, and there were no differences in carcase quality. Jones(114) concluded that a period of low plane feeding had no effect on the final carcase quality. Exploiting the lack of spring check after winter grazing is a corollary of the commonly held view that stock that do poorly in one period are capable of using food more efficiently later, providing that the ration was adequate during the period of low plane of nutrition. Jackson[57,58 & 117] found that outwintered ewes produced heavier lambs and better quality fleeces. During a mild winter the outwintered ewes consumed 30% less hay, but in hard winters this advantage disappeared. Baker et al.[13], on 18 sites, found that winter grazed cattle invariably did better than similar animals outwintered on the normal feeding regime of the farm. Grass provided a valuable portion of the feed and the general condition and health of winter grazed livestock was satisfactory.

The summer performance[57,58 & 140a] of stock on winter grazed pastures indicated that sometimes advantages were to be gained from winter saving of pasture; in particular, lambs fattened slightly quicker on the winter-saved pasture and a higher proportion were sold fat before weaning; it has also been suggested that total production of lamb in the summer was superior on winter-saved pasture, but the published figures do not support anything more than a minute gain. The advantages from enhanced summer performance following winter resting seem to be too small and unreliable to merit the extra expenditure and feeding required.

Animal results following winter grazing have lacked consistency. This could be used as a reason to support whatever form of winter management is most convenient. Extrapolation of the results mentioned above to other parts of the country is fraught with danger. The Drayton results were obtained on a lowland farm at low stocking rates. In less congenial environments and at higher stocking rates the results might well indicate that inwintering benefited the future production and health of the ewes, and that an adequate ration was not available outside.

SUMMARY OF EXPERIMENTAL WORK.

Results were obtained from four trials.

1965-66 Lambing Field.

In this trial an estimate was made of the effects of time of winter grazing treatments on the subsequent growth and yield of the sward in spring and summer.

The grazing treatments were:-

a) Grazed November and December.

b) Grazed January and February.

c) Grazed November to February.

d) Ungrazed - control.

The trial commenced in November after resting from September. The output from the various treatments was assessed by three methods:-

a) Grazing days - ewe and twin lambs.

b) Lamb live-weight gain.

c) Herbage growth under cages.

Nitrogenous fertiliser was not applied before starting this trial. In March 1966 20.5% Nitrochalk was applied at two rates - 1½ and 3 cwt/acre.

1966-67 Anchordales.

The treatments of the first trial were integrated with two sward types into a further experiment. The two sward types were:-

a) High N. input in 1966 - 4 cwt/acre 21% N.

Nitrochalk in March, 3 cwt/acre in May and 3 cwt/acre in July.

b) Low N. input in 1966 - 4 cwt/acre in March only.

Resting prior to winter grazing started in September 1966. There was no spring application of nitrogenous fertiliser. The criterion of productivity in 1967 was ewe grazing days only.

1966-67 Lambing Field.

In this trial the effects of rate of stocking in winter were measured in terms of output of herbage in the following spring and summer.

The whole field received a dressing of 3 cwt/acre 20.5% N. Nitrochalk in July 1966. It was then rested till late October. The whole area was mob-grazed for a month. Experimental treatments started in late December after resting for a month. In March 1967 two rates of nitrogenous fertiliser were applied - 3 and 5 cwt/acre 21% N. Nitrochalk.

Yields of herbage were estimated at "early bite", silage and hay stages of maturity. Details of sampling areas were as follows:-

Early grass stage - 1 swathe 15 yards by 1 yard.

Silage stage - 1 swathe 10 yards by 1 yard.

Hay stage - 2 swathes 10 yards by 1 yard.

Small Plot Trial 1967-Lambing Field.

This trial was laid down to give information resulting from various winter treatments based on cutting and poaching of the sward. Yields of herbage were obtained in spring and summer from Allen scythe cuts. The first cut was on 18th. May, the regrowth was cut on 23rd. June.

Botanical studies.

In these trials estimation of herbage yield, before, during and after winter stocking, was made by means of intensive sampling with quadrat and shears. The degree of winter burn was also determined in addition to dry matter loss through the winter. Estimates of the N. content in the herbage dry matter, together with in vitro digestibility measurements, assessed the feeding value of the herbage to the animal.

EXPERIMENTAL WORK

Past experiments have suggested that winter grazing may be detrimental to spring and summer production, but conclusions on this are not unanimous. Undoubtedly variations in experimental design, technique and the timing of the experiment have given rise to controversy. The main trials recorded in this thesis were aimed at simulating long periods of winter grazing combined with reasonable winter management. Throughout, emphasis has been directed towards investigation of pasture production subsequent to winter grazing. The work recorded here differs in emphasis from much of the past work, since this was concentrated either on winter grass or early grass production. This series of trials has attempted to identify factors governing subsequent performance and thus produce facts on which sound winter management can be based.

LAMBING FIELD TRIAL 1965-66

AIM:

To measure the subsequent production of a pasture following four winter management regimes.

MATERIALS:

This trial was laid out in Lambing Field, Boghall, Edinburgh. The site was situated between 700 and 750 feet above sea level on a 1 in 6 South East facing slope. The soil is a sandy loam. In 1963 the field was undersown with the following mixture:

Perennial ryegrass S 23 and S 24	12 lb./acre
Timothy S 51	8 lb./acre
Late flowering red clover - Altaswede	2 lb./acre
White clover - New Zealand	1½ lb./acre

The field was limed and slagged in 1964 and a dressing of 2 cwt./acre Muriate of potash was applied both in 1964 and 1965.

The 9.52 acre field was initially divided into 8 paddocks, each of 1.19 acres. These 8 paddocks provided 2 replicates of the 4 grazing treatments. Throughout the winter, grazing was practised with Greyface ewes.

METHOD:

Winter phase:

Precuts were taken at the end of October 1965 to establish the yield of the paddocks. Quadrats of 1 square yard were cut with hand-shears. The number required per paddock was ascertained by cutting 40 in 1 paddock and then calculating the coefficient of variation per unit. From this it was possible to calculate how many quadrats were required to give a value not exceeding 5%. These calculations indicated that 25 might be sufficient but 30 was the number adopted. The 30 quadrats were cut according to a predetermined pattern; this ensured that the whole paddock was sampled and obviated the risk of bias. The harvested samples were put into polythene bags and sorted in the laboratory. First, soil and miscellaneous detritus were removed, then the samples were dried individually in an oven, at 90°C overnight, and weighed the following morning, thus giving the dry matter yield per square yard. The overall botanical composition was determined from the separation of fresh samples on 25th October.

On 4th November the grazing treatments started, using a stocking rate of 4 Greyface ewes per paddock. The treatments were:

1) November and December grazed.
2) January and February grazed.
3) November to February grazed.
4) Control - ungrazed.

On 31st December grazing ended on treatment 1 and began on treatment 2. All stock were removed on 25th February. At the end of December the dry matter yield of the paddocks was determined, using the same technique as before. In the middle of January samples were analysed for content of green matter. The yields of the paddocks were again determined at the end of February.

During the winter phase supplementary feeding was given to the ewes:

1) November and December grazed - 30 lb. hay/ewe.
2) January and February grazed - 49 lb. hay/ewe.
3) November to February grazed - 98.2 lb. hay/ewe.

RESULTS:

During the winter changes in dry matter yield occurred; these were due both to defoliation by sheep and processes of decay (table 1.1.).

Table 1.1. The yields of dry matter (lb./acre) during winter phase - differences shown in brackets.

Winter grazing period	Precuts		January		March	Difference Precuts to March
Nov. and Dec.	806	(428)	378	(107)	271	(535)
Jan. and Feb.	934	(330)	604	(194)	410	(524)
Nov. to Feb.	1043	(757)	286	(148)	138	(905)
Control	945	(491)	454	(+338)	792	(153)
SeM.	±38	(±69)	±66	(±32)	±56	(±76)
Sig. level	N.S.	(N.S.)	N.S.	(**)	*	(*)
Mean reduction		(501)		(28)		(529)
Sig. level		(***)		(N.S.)		(**)
Mean reduction-grazed paddocks		(592)		(171)		(655)
Sig. level		(**)		(*)		(**)
Mean reduction-ungrazed paddocks		(410)		(+115)		(152)
Sig. level		(*)		(N.S.)		(N.S.)

Up to 31st December there were only two different treatments, grazed and ungrazed. When these were compared the following results were obtained (table 1.2.).

Table 1.2. Yield at January cut (DM lb./acre).

	January yield	Difference precuts to January
Grazed	332	592
Ungrazed	529	410
SeM.	±37	±38
Sig. level	*	**

During the first phase of winter grazing there was a mean reduction in the yield on all paddocks regardless of whether they had been grazed or rested. On examination the reduction on the grazed paddocks was greater than that on the ungrazed ones. From this it would appear that if grass is not grazed off in the early winter its yield will decrease by natural processes; time of grazing is important if good use of winter grass is required.

During the second phase of winter grazing there were large treatment differences; the control paddocks showed considerable growth, while the previously ungrazed paddocks of treatment 2 showed the greatest loss of dry matter. The other treatments were intermediate. There was no significant overall reduction, but this can be ascribed to the increase in yield on the control rather than lack of reduction on the grazed paddocks. In spite of resting in January and February, treatment 1 failed to make any recovery growth.

Throughout the winter there was a general mean reduction in yield; only on the controls was this mean reduction insignificant (this lack of statistical significance was probably due to insufficient replication). It was interesting to note that the greatest reduction occurred on the November to February grazed treatment and the smallest on the control, with the other two treatments intermediate and virtually the same (table 1.1.).

A burn separation was carried out on herbage collected in the middle of January (table 1.3.).

Table 1.3. Burn data for mid-January.

Winter grazing period	Total Yield DM lb./acre	% Burnt	Yield burnt grass DM lb./acre	Yield green matter DM lb./acre
Nov. and Dec.	378	71	263	115
Jan. and Feb.	295	69	179	116
Nov. to Feb.	286	74.5	215	71
Control	454	54.5	248	206
SeM.		±2.4	±33	±13
Sig. level		*	N.S.	*

The mass of burnt herbage was independent of grazing treatments, but yield of green matter was closely linked to them. Grazing tended to increase the percentage of herbage that was obviously lacking chlorophyll; this was due to the removal of young succulent shoots by sheep, hence it was the mass of green matter that was altered by grazing treatments. Lack of active chlorophyll on the grazed paddocks may be instrumental in lowering their subsequent production.

ANCHORDALES TRIAL 1966-67

This was essentially a repeat of the 1965-66 Lambing Field Trial. A different field, Anchordales, was used in 1966-67. This provided a fairly level site about 650 feet above sea level, near Lambing Field, and on a similar type of soil. In 1965 it was undersown in barley with the following mixture:

Italian ryegrass	5 lb./acre
Hybrid ryegrass	15 lb./acre
Perennial ryegrass S 23	5 lb./acre
Late flowering red clover - Altaswede	3 lb./acre
White clover - New Zealand	3 lb./acre
	31 lb./acre

The Italian and hybrid ryegrasses were drilled and the remainder of the mixture broadcast. In 1966 the area was divided into 4 paddocks (each 2.8 acres); two of these were managed on a high nitrogen regime and two on a low nitrogen regime. Because of this it was impractical to use exactly the same design as had been used the preceding year; instead of superimposing spring nitrogen treatments on winter grazing treatments, the latter were superimposed on the two nitrogen regimes. This produced 16 small paddocks (2 blocks of 2 nitrogen treatments split into 4 winter grazing treatments). Unfortunately this design virtually eliminated the chances of obtaining statistically significant nitrogen effects, since the 'F' value for (1. 1.) degrees of freedom is very high for P = 0.05. The winter grazing treatments were randomised within each of the four main paddocks. A dressing of 3 cwt./acre 21% Nitrochalk was applied after winter grazing had finished.

METHOD:

Winter phase:

Sampling times and methods were the same as in the previous year. Burn was analysed both in January (at the time of sampling) and in March. In March the burn was split up into two fractions, stubble and burn; the former represented stubble left over from the autumn, the latter was that fraction of winter grass that was brown and decaying.

The same treatments as before were imposed on 1st November at a stocking rate of two ewes per sub-paddock (0.7 acre); treatments were changed on 2nd January and all stock was removed on 27th February.

During the winter ample supplementary feeding was available in the form of a flaked mixture called 'D' flake. During phase 1 only $11\frac{1}{2}$ lb. of this was fed. During phase 2 123 lb. was fed per ewe irrespective of treatment. 1 lb. of it supplied 948 Kcals and 0.07 lb. DCP. Just prior to lambing a pelleted steaming-up ration was also fed.

RESULTS:

The yields of dry matter and the changes that occurred in each phase of the winter are shown in table 2.1.

Table 2.1. The yields of dry matter (lb./acre) during winter phase - differences shown in brackets.

Winter grazing period	Precuts		January		March	Difference precuts to March
Nov. and Dec.	683	(453)	230	(+160)	390	(293)
Jan. and Feb.	546	(+26)	572	(224)	348	(198)
Nov. to Feb.	838	(367)	471	(227)	244	(594)
Control	694	(74)	620	(16)	604	(90)
SeM.	±84	(±67)	±79	(±20)	±67	(±60)
Sig. level	N.S.	(**)	N.S.	(**)	*	(**)
Mean reduction		(217)		(77)		(294)
Sig. level		(**)		(N.S.)		(**)
Mean reduction - grazed paddocks		(410)		(226)		(364)
Sig. level		(***)		(***)		(***)
Mean reduction - ungrazed paddocks		(24)		(+72)		(90)
Sig. level		(N.S.)		(N.S.)		(N.S.)
High nitrogen	892	(285)	607	(73)	534	(358)
Low nitrogen	489	(149)	340	(81)	259	(230)
SeM.	±89	(±18)	±79	(±.7)	±72	(±17)
Sig. level	N.S.	(N.S.)	N.S.	(*)	N.S.	(N.S.)
Interaction grazing x N.	N.S.	(N.S.)	*	(*)	N.S.	(N.S.)

As in the 1965-66 trial there were only two winter grazing treatments up to 2nd January 1967, grazed and ungrazed (table 2.2.).

Table 2.2. Yield at January cut (DM lb./acre).

	January yield	Difference precuts to January
Grazed	350	-410
Ungrazed	596	- 24
SeM.	± 43	± 37
Sig. level	***	***
Interaction grazing x N.	*	*

During the first phase of winter grazing there was an apparent overall reduction in herbage yield of dry matter; this was evidently due to the large decrease on the grazed rather than the negligible decrease on the ungrazed paddocks.

During the second phase there was no overall reduction, but there was a marked one on the grazed paddocks. The grazing treatments produced large differences; the two grazed paddocks showed similar reductions in spite of the January and February one having initially a higher yield. A surprising increase in yield was exhibited by the November and December grazed treatment, especially since this was significantly greater ($P = 0.05$) than the small reduction on the control paddocks.

Overall there was a reduction in yield over the whole winter period; this was negligible on the control and greatest on the treatment grazed from November to February, with other treatments intermediate. In 1966-67 paddocks grazed in January and February showed a smaller reduction in comparison with those grazed November and December, than in the previous year. This was evidently due to wide variation in response during November and December in the two years. In the first year there was a large drop in yield even on the rested paddocks during November and December, but this did not occur the following year.

At all times in the winter the yield of dry matter was higher on those paddocks that had been liberally supplied with nitrogen in the previous growing season. Generally the reductions in yield through the winter were greater on these paddocks. Although these differences seldom achieved statistical significance they were sufficiently large and consistent to merit attention. In addition to these, there were nitrogen times grazing interactions (tables 2.3., 2.4. and 2.5.).

Table 2.3. January yield (DM lb./acre).

	High N.	Low N.	Mean
Grazed	409	292	351
Ungrazed	804	384	594
Mean	607	338	

Table 2.4. Precut minus January yield (DM lb./acre).

	High N.	Low N.	Mean
Grazed	490	330	410
Ungrazed	80	-32	24
Mean	285	149	

These figures indicated that reduction in yield through grazing was greater under high N. because there was more herbage available, whereas on rested paddocks dry matter yield was penalised, possibly because of greater susceptibility to burn. There was also an interaction in the January and February period (table 2.5.).

Table 2.5. March yield less January yield (DM lb./acre).

Winter grazing period	High N.	Low N.	Mean
Nov. and Dec.	+278	+ 42	+160
Jan. and Feb.	-285	-164	-224
Nov. to Feb.	-343	-110	-227
Control	+ 59	- 90	- 16
Mean	- 73	- 81	

This was a period of possible growth; the rested paddocks made a good recovery - this was better on high N. paddocks. Where grazing occurred, reductions were larger on high N., hence response to winter treatments in the second phase on high N. paddocks was more variable than the response on low N. paddocks.

Burn separations were done both in January (table 2.6.) and March (table 2.9.).

Table 2.6. Burn data for January cut.

	Yield DM lb./acre	% Burnt	Yield burnt grass DM lb./acre	Yield green matter DM lb./acre
Grazed	351	83.5	294	57
Ungrazed	596	67	380	216
SeM.		±2.8	±28	±27
Sig. level		**	**	**
High N.	607	71	408	199
Low N.	340	80	266	74
SeM.		±5.6	±28	±42
Sig. level		N.S.	N.S.	N.S.
Interaction grazing x N.		N.S.	N.S.	*

The January burn figures revealed that the grazed paddocks contained a higher proportion of burn than the ungrazed, but, because of the very much greater yield on the latter, yields of both burn and green matter were larger on them than on the grazed paddocks. There was an interaction involving mass of green matter and nitrogen (table 2.7.).

Table 2.7. Mass of green matter (DM lb./acre).

	High N.	Low N.	Mean
Grazed	80	34	57
Ungrazed	318	114	216
Mean	199	74	

This result showed that resting and nitrogen were supplementary in increasing the yield of green matter in winter. Although nitrogen figures were insignificant when taken in isolation, they did show that nitrogen, in this experiment, increased the greenness of the paddocks, even though the mass of burn was increased too. This was not unexpected since burn tends to be high on those paddocks with the higher yields. Both burn and green matter were analysed for crude protein and digestible organic matter after the separation (table 2.8.).

Table 2.8. Crude protein content and digestible organic matter of burnt and green material.

	% Crude protein	% Digestible organic matter
Burnt material	8.02	37.9
Green material	24.97	77.0

These figures demonstrated the wide differences between young grass and old decaying grass. The high content of poor quality grass in late winter may be instrumental in discouraging grazing during this period. A heavy yield of such grass in March may also limit production and development of spring tillers.

During the January burn analysis it became apparent that much of the dead material was stubble left over from the previous growing season; when samples were analysed in March the stubble was extracted and weighed separately (table 2.9.).

Table 2.9. Burn data for March cut.

Winter grazing period	DM Yield (lb./acre)	DM Yield less stubble (lb./acre)	% Stubble & burn	Yield burn (lb./acre)	Yield green (lb./acre)
Nov. and Dec.	390	270	74	160	110
Jan. and Feb.	348	223	82	146	77
Nov. to Feb.	244	113	88	85	28
Control	604	514	56	241	273
SeM.			±3.7	±41	±28
Sig. level			**	N.S.	**
High N.	534	422.5	72	242	180.5
Low N.	259	137	78	73.5	63.5
SeM.			±2.2	±43	±6.0
Sig. level			N.S.	N.S.	*
Interaction grazing x N.			N.S.	N.S.	N.S.

There were large treatment differences; rested treatments were noticeably greener than grazed treatments. Nitrogen increased both yield of burn and green. These results indicated that the very low total January yield of the November and December grazed treatment was probably anomalous. On the control paddocks the total yield of stubble and burn decreased during this period, but on the November and December grazed paddocks it increased. The gain in green matter was approximately the same on both treatments. Mass of green matter in January did not control the gain in green matter in the following two months.

GENERAL DISCUSSION AND CONCLUSIONS - WINTER RESULTS:

During November and December, both years of the trial showed that grazing reduced the dry matter yield of grass. In 1965 there was also a reduction on the rested paddocks; in 1966 this reduction was minute. The early winter of 1966 was milder than that of 1965; Anchordales was a younger sward than Lambing Field, and it contained a high content of decay-resistant stubble. These facts may have accounted for the variation in response to the November and December period. In both years the reduction on the grazed paddocks was greater than the reduction on the rested ones.

During January and February 1966 control paddocks increased in dry matter yield, whereas November and December grazed ones showed a deficit. In the following year the converse occurred. Burn data and the extremely low January yield of the latter treatment indicated that this particular result was probably anomalous, since November and December grazed paddocks appeared to have acquired a considerable amount of dead matter during this period. Furthermore, the increase in green matter during this period was similar for both rested treatments.

The overall results were similar in both years, but the January and February grazed treatment showed up rather better in the second year than in the first. Sheep consumption during January and February was poor, probably due to a combination of low level of grass palatability and high level of supplementary feeding.

The different nitrogen regimes of 1966 had resulted in two very different swards. There was more herbage initially on high N. paddocks, consequently ewe consumption tended to be greater on these than on the others. High nitrogen and resting were supplementary in producing high herbage yields. High nitrogen paddocks remained greener, but contained both more burn and more green than the low nitrogen treatment.

Burn percentage was high on grazed paddocks because the green succulent grass was removed by grazing. Grass contaminated by burn and stubble was of low feeding value, and if plentiful might hinder the subsequent production from a pasture. There was very little grass capable of efficient photosynthesis left following grazing, consequently recovery growth could be slow.

The health of outwintered ewes was good, and they produced good lambs. Great care was taken to ensure that they were adequately supplied with supplementary rations. During winter 1965-66 a comparison with an inwintered group showed that outwintering resulted in a substantial saving in hay, equivalent to 234 lb. hay per ewe for the November to February grazed treatment. This gain must be balanced against the small loss in autumn grazing and any detrimental carry-over effects of winter grazing.

LAMBING FIELD TRIAL 1965-66 (contd.)

MATERIALS:

During the winter 1965-66 Lambing Field was divided into 2 replicates of 4 grazing treatments. Each of these 8 paddocks was split in March; nitrogen was applied at two levels, viz. $1\frac{1}{2}$ and 3 cwt. 20.5% Nitrochalk, on 10th March.

METHOD:

Measurement of subsequent production:

Measurement of subsequent production was accomplished in terms of both herbage yield and animal production. The dry matter yield was measured on all sub-paddocks, in early April and just before stocking. Measurements were based on 20 quadrats per sub-paddock. Shortly before stocking two 9' x $3\frac{1}{2}$' cages were put out on each sub-paddock. During the subsequent period dry matter yield was measured from samples produced under cages. This procedure allowed two cuts, each of one square yard, of uninterrupted growth; the cuts were timed to represent silage and hay stages. Following each cut, an area was trimmed just below the cage; the cage was then moved so as to cover that portion of the protected ground that remained uncut, and the trimmed area. This procedure provided a measurement of recovery growth following both silage and hay stages. Dried samples were ground and analysed for digestibility and crude-protein. Sub-samples from the cages were separated into their component species.

Sub-paddocks were stocked when they appeared to have adequate grass. The stocking rate was determined by a subjective assessment of dry matter yield. One Greyface ewe with twin lambs formed the grazing unit; the stocking rate was altered weekly as required. Details were kept of the unit grazing days per sub-paddock, and the lamb live-weight gains. All stock were removed on 20th June.

RESULTS:

Subsequent production assessed in terms of herbage performance:

The yield of dry matter was assessed on certain dates; the regrowth from the silage and hay stages was also recorded (table 3.1.).

Table 3.1. Yield of dry matter (lb./acre) on given dates.

Winter grazing period	Early April	Silage 19 May	Hay 1 June	Regrowth 19/5-21/6	Regrowth 1/6-1/7
Nov. and Dec.	237	1915	1851	1814	2184
Jan. and Feb.	396	1894	1924	1739	2767
Nov. to Feb.	196	1736	1835	1829	2229
Control	639	2400	2209	1876	2201
SeM.	±19	±140	±162	±137	±115
Sig. level	***	N.S.	N.S.	N.S.	N.S.
High N.	367	2057	2111	1930	2298
Low N.	366	1901	1798	1699	2394
SeM.	±15	±47	±84	±151	±82
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.	N.S.
Control v. Others	***	*	N.S.	N.S.	N.S.

There were large statistical differences in early April; yield data at the end of February (table 3.2.) indicated that the differences were not due to differential growth rates during March, but depended on the residual effect of winter grazing.

Table 3.2. The yield of dry matter (lb./acre) at end of February and in early April.

Winter grazing period	End of February	Early April
Nov. and Dec.	271	237
Jan. and Feb.	410	396
Nov. to Feb.	139	196
Control	792	639

By the silage stage there were no overall statistically significant differences, but yield on the control paddocks was much larger than that on any of the other treatments. The April differences were still apparent but were obscured by heavier yields. Winter grazing had no apparent effect on growth rate (table 3.3.).

Table 3.3. Dry matter increase (lb./acre) from early April to 1 June.

Winter grazing period		Nitrogen effects	
Nov. and Dec.	1614	High N.	1744
Jan. and Feb.	1598	Low N.	1432
Nov. to Feb.	1639	SeM.	±96
Control	1570	Sig. level	N.S.
SeM.	±153		
Sig. level	N.S.		

No differences were apparent at the hay stage; control was not statistically greater than the mean of the yield on the other treatments. There was some indication that initially production on the control was good but towards the end of the experimental period its performance was similar to that of winter grazed treatments. There were no statistical differences in the regrowths, showing that the effect of winter grazing on subsequent yield was transitory and did not survive defoliation. There were no nitrogen effects, but this was probably due to technical limitations imposed by sampling only two square yards per sub-paddock per period. This also accounts for the apparent lack of growth between 19th. May and 1st. June.

Analysis of crude protein content showed that winter grazing had little effect on subsequent quality of grass (table 3.4.).

Table 3.4. % Crude protein contained in dry matter on given dates.

Winter grazing period	Early April	Silage	Hay	Silage regrowth	Hay regrowth
Nov. & Dec.	22.6	14.6	11.8	19.3	16.6
Jan. & Feb.	22.6	15.0	11.1	20.5	16.9
Nov. to Feb.	24.5	15.2	11.6	18.2	17.3
Control	20.6	14.5	10.4	19.5	17.1
SeM.	±0.9	±0.5	±0.6	±1.1	±1.7
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
High N.	22.5	15.3	11.7	19.1	18.2
Low N.	22.6	14.4	10.7	19.6	15.7
SeM.	±0.8	±0.4	±0.4	±0.8	±0.4
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
Control v. Others	N.S.	N.S.	N.S.	N.S.	N.S.

There was some indication that the crude protein percentage was lower on the control paddocks than on the others. This was probably due to the more mature condition of the grass on the control paddocks. In terms of crude protein per acre, control was better than the others (table 3.5.).

Table 3.5. Yield of crude protein (lb./acre) on given dates.

Winter grazing period	Early April	Silage	Hay	Silage regrowth	Hay regrowth
Nov. and Dec.	53	281	219	347	363
Jan. and Feb.	87	280	220	356	463
Nov. to Feb.	48	263	213	330	389
Control	132	351	241	375	377
SeM.	±5	±26	±28	±44	±31
Sig. level	**	N.S.	N.S.	N.S.	N.S.
High N.	81	332	241	379	401
Low N.	80	256	206	324	396
SeM.	±4.7	±14	±18	±27	±18
Sig. level	N.S.	*	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.	N.S.
Control v. Others	***	N.S.	N.S.	N.S.	N.S.

Crude protein yield per acre was determined by total yield of dry matter rather than by composition of dry matter.

Analysis was also done on the dry matter for digestible organic matter (table 3.6.).

Table 3.6. % Organic matter digestibility on given dates.

Winter grazing period	Early April	Silage	Hay	Silage regrowth	Hay regrowth
Nov. and Dec.	64.5	79.5	73.5	68.8	71.8
Jan. and Feb.	61.0	79.8	74.3	70.3	72.0
Nov. to Feb.	65.8	79.8	75.3	72.0	72.0
Control	61.5	79.0	71.5	70.8	72.5
SeM.	±1.3	±0.4	±0.7	±0.6	±1.0
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
High N.	64.6	79.4	73.1	70.3	72.6
Low N.	61.9	79.6	74.1	70.6	71.5
SeM.	±1.8	±0.5	±0.4	±0.5	±0.4
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.	N.S.
Control v. Others	N.S.	N.S.	N.S.	N.S.	N.S.

Digestibility increased from early April to mid-May; this was further evidence that early April grass contained a high proportion of winter residue. At time of stocking digestibility was low on control paddocks. Digestibility tended to be high on the November to February grazed treatment. Apart from these there were no consistent differences. Stocking started on the following dates:

Nov. and Dec. grazed paddocks	May 2nd.
Jan. and Feb. grazed paddocks	April 29th.
Nov. to Feb. grazed paddocks	May 3rd.
Control	April 25th.

The yield of digestible organic matter is shown in table 3.7.

Table 3.7. The yield of digestible organic matter (lb./acre) on given dates.

Winter grazing period	Early April	Silage	Hay	Silage regrowth	Hay regrowth
Nov. and Dec.	152	1484	1354	1245	1563
Jan. and Feb.	230	1469	1462	1223	1993
Nov. to Feb.	129	1382	1376	1317	1610
Control	393	1894	1578	1320	1587
SeM.	±13	±73	±104	±108	±106
Sig. level	**	*	N.S.	N.S.	N.S.
High N.	228	1624	1540	1391	1668
Low N.	224	1490	1345	1162	1708
SeM.	±15	±49	±76	±83	±60
Sig. level	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	*	N.S.	N.S.	N.S.
Control v. Others	***	*	N.S.	N.S.	N.S.

The early April differences were due to the initial advantage of no winter grazing on the control paddocks. The January and February figure was high; this was due to lack of defoliation during its grazing period. This lack of defoliation was caused by both the high level of supplementary feeding prior to lambing, and also the difficulties inherent in grazing grass covered by snow. Undoubtedly a combination of these two factors contributed to this result. At the silage stage the control paddocks out-yielded the others. There were no statistically significant differences at the later cuts. The response to high nitrogen was poor. The interaction is given in table 3.8.

Table 3.8. Yield of digestible organic matter at silage stage (lb./acre).

Winter grazing period	High N.	Low N.	Mean
Nov. and Dec.	1795	1173	1484
Jan. and Feb.	1299	1639	1469
Nov. to Feb.	1408	1356	1382
Control	1995	1793	1894
Mean	1624	1490	

This interaction was statistically significant because of the wide variation exhibited in the response to both November and December, and January and February grazing. One of the two low N. paddocks (Nov. and Dec. grazed) had a high weed content and a low yield of dry matter. Owing to this the yield of digestible dry matter for the low N. treatment was particularly low. The unexpected difference in the January and February grazed figures was not corroborated by the yield of digestible organic matter at the hay stage. The figures for this stage were 1275 on the high N. and 973 lb. digestible organic matter/acre on the low N. This indicated that little reliance could be placed on the significance of this interaction.

Hunt[108,109] suggested that early stocking of pastures could impair their future production; he also found that response to nitrogen was reduced by early utilisation of herbage.

Table 3.9. gives data on stocking.

Table 3.9. Herbage data for treatments just prior to stocking.

Winter grazing period	Yield DM lb./acre	% Crude protein	% Digestible organic matter
Nov. and Dec.	561	20.8	75.8
Jan. and Feb.	578	22.3	72.5
Nov. to Feb.	609	22.8	77.1
Control	574	20.7	70.7
SeM.	±64	±0.5	±2.2
Sig. level	N.S.	N.S.	N.S.
High N.	644	23.1	74.6
Low N.	517	20.1	74.9
SeM.	±14	±0.7	±1.0
Sig. level	**	*	N.S.
Interaction grazing x N.	*	N.S.	N.S.

There were no grazing treatment differences but the yield interaction was significant (table 3.10.).

Table 3.10. Interaction - yield (DM lb./acre) at time of stocking.

Winter grazing period	High N.	Low N.	Mean
Nov. and Dec.	691	431	561
Jan. and Feb.	633	526	578
Nov. to Feb.	658	560	609
Control	595	553	574
Mean	644	517	

This showed that the better responses to high nitrogen occurred on the later stocked treatments. This was particularly true of the yield of digestible organic matter. The control paddocks were stocked soon after weather conditions became suitable for rapid growth; growth on this treatment had been negligible up till then. With nine days of good conditions the November to February grazed paddocks yielded well just before stocking, and the quality of the grass on offer was particularly good. The high N. treatment responded to the more favourable conditions.

In addition to crude protein and digestibility analysis, a botanical split was carried out on air dried samples at each of the four summer harvesting dates.

Table 3.11. Overall botanical composition, October 1965.

% Perennial ryegrass	% Timothy	% Clover	% Weeds
91.3	7.4	0.5	0.8

Table 3.12. Botanical composition at silage stage - % of DM.

Winter grazing period	% PRG	% Timothy	% Clover	% Weeds
Nov. and Dec.	73.9	18.3	1.8	6.0
Jan. and Feb.	75.6	21.6	2.1	0.7
Nov. to Feb.	76.5	20.6	1.5	1.4
Control	76.6	21.5	0.8	1.1

These differences showed that there were no large changes in botanical composition following winter grazing. There was practically no clover in the field when the trial started (table 3.11.), so it was not possible to assess how clover reacted to winter grazing. It was remarkable how weed-free the winter grazed paddocks were at the silage stage. The high weed content for the November and December grazed paddocks represented a very high weed content on one main paddock before the trial started.

Botanical separations for the other cuts are shown in tables 3.13., 3.14. and 3.15.

Table 3.13. Botanical composition at the hay stage - % of DM.

Winter grazing period	% PRG	% Timothy	% Clover	% Weeds
Nov. and Dec.	66.8	17.6	1.2	14.4
Jan. and Feb.	77.7	20.1	0.8	1.4
Nov. to Feb.	77.1	19.8	1.3	1.8
Control	82.4	13.8	0.7	3.1

Control was low in timothy and high in perennial ryegrass at the hay stage; neither of these was statistically significant nor were they of great agricultural import.

Table 3.14. Botanical composition at silage regrowth - % of DM.

Winter grazing period	% PRG	% Timothy	% Clover	% Weeds
Nov. and Dec.	57.6	13.2	2.4	26.8
Jan. and Feb.	67.7	22.2	4.2	5.9
Nov. to Feb.	65.0	24.4	4.1	6.5
Control	74.8	15.2	1.1	7.9

The differences that might have been due to winter grazing were small compared to seasonal differences - this supports Campbell's findings[27].

Table 3.15. Botanical composition at hay regrowth - % of DM.

Winter grazing period	% PRG	% Timothy	% Clover	% Weeds
Nov. and Dec.	77.7	10.9	2.3	9.1
Jan. and Feb.	79.3	8.8	3.6	8.3
Nov. to Feb.	74.4	12.5	4.7	8.4
Control	81.2	9.3	2.9	6.6

The means of these four botanical splits are given in table 3.16.

Table 3.16. Botanical composition - mean of cuts - % of DM.

Winter grazing period	% PRG	% Timothy	% Clover	% Weeds
Nov. and Dec.	69.0	15.0	1.9	14.1
Jan. and Feb.	75.1	18.2	2.6	4.1
Nov. to Feb.	73.3	19.3	2.9	4.5
Control	78.7	15.2	1.4	4.7

None of the changes in botanical composition were important; there was some indication that control paddocks had a high content of perennial ryegrass and a low content of timothy. Winter resting on the control paddocks may have encouraged perennial ryegrass to compete more aggressively in the early part of the growing season. Differences due to winter grazing were substantially smaller than those inherent in the field before this trial was laid down, and those due to seasonal fluctuation.

SUMMARY OF HERBAGE RESULTS:

Herbage results for subsequent performance were not recorded on Anchordales. Results from 1965-66 showed that the error associated with measuring paddock yield, using only two cages per paddock, was too high to be worth repeating. The results for 1965-66 showed that the lower spring and summer production on paddocks grazed in winter was solely due to the removal of dry matter from those paddocks during the winter. At the silage stage control had the highest yield. There was no evidence that winter grazing affected the recovery growth of paddocks following defoliation. The extra 1½ cwt./acre of Nitrochalk had no statistically significant effect on the yield of dry matter at any of the five cuts; this was probably a reflection of the error associated with the harvesting system rather than evidence that Nitrochalk was ineffective.

There were no significant differences in the amount of crude protein contained in the dry matter but at the first three cuts control values were particularly low. In terms of production (lb./acre) the results were similar to total dry matter ones. There were no differences in percentage of digestible organic matter.

Changes in botanical composition were small, though there were certain seasonal trends. The paddocks were generally remarkably weed-free, but there was one notable exception. As was found in many other trials the initial clover content was too low to provide a reasonable indication of the reaction of clover to winter grazing.

LAMBING FIELD TRIAL 1965-66 (contd.)

RESULTS:

Subsequent production assessed in terms of animal performance:

The number of ewe and twin lamb grazing days were recorded at various intervals. This indicated both the total production of the paddocks and the rate of production. In the following results the phase, unit grazing days, refers to occupation by one ewe and two lambs for one day. Grazing was started as soon as a paddock appeared to have enough grass. Table 3.17. shows the results for the first month of grazing.

Table 3.17. Unit grazing days/acre to 10th and 24th May 1966.

Winter grazing period	10th May	24th May	Difference
Nov. and Dec.	38	108	70
Jan. and Feb.	40	128	88
Nov. to Feb.	28	104	76
Control	79	161	82
SeM.	±4.4	±16	±13
Sig. level	*	N.S.	N.S.
High N.	50	138	88
Low N.	42	112	70
SeM.	±1.8	±8	±7.2
Sig. level	*	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Control v. Others	**	N.S.	N.S.
Nov. to Feb. v. Others	*	N.S.	N.S.

By 10th May there was a clear advantage resulting from winter resting; the November to February grazed treatment provided the least grazing up to this date, a result that can be ascribed to the necessary delay in stocking that treatment. The increase in unit grazing days in the following fortnight was independent of winter grazing treatment. By the 24th May the winter treatment differences were no longer statistically significant. The high level of nitrogen consistently produced more unit grazing days; there was no nitrogen times winter grazing interaction, so winter grazing did not affect the sward's response to nitrogen.

Table 3.18. Unit grazing days/acre to 7th June 1966.

Winter grazing period	7th June	10th May to 7th June	24th May to 7th June
Nov. and Dec.	192	154	84
Jan. and Feb.	206	166	78
Nov. to Feb.	213	185	109
Control	229	150	68
SeM.	±9	±6	±8
Sig. level	N.S.	N.S.	N.S.
High N.	239	189	101
Low N.	181	139	69
SeM.	±7	±8	±1.7
Sig. level	**	**	***
Interaction grazing x N.	N.S.	N.S.	N.S.
Control v. Others	N.S.	N.S.	N.S.
Nov. to Feb. v. Others	N.S.	*	*

On 7th June 1966 there were no significant winter treatment differences. During the period preceding 7th June the November to February grazed treatment provided more unit grazing days than any of the other treatments. The effect of an extra 1½ cwt. Nitrochalk became evident during this period.

All sheep were removed from the trial on 20th June. The unit grazing days to this date are shown in table 3.19.

Table 3.19. Unit grazing days/acre to 20th June 1966.

Winter grazing period	20th June	10th May to 20th June	24th May to 20th June	7th to 20th June
Nov. and Dec.	264	226	156	72
Jan. and Feb.	283	243	155	77
Nov. to Feb.	291	263	187	78
Control	298	219	137	69
SeM.	±11	±11	±23	±16
Sig. level	N.S.	N.S.	N.S.	N.S.
High N.	322	272	184	83
Low N.	247	205	135	66
SeM.	±6.7	±4.3	±7	±2.4
Sig. level	**	**	**	**
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.
Control v. Others	N.S.	N.S.	N.S.	N.S.
Nov. to Feb. v. Others	N.S.	N.S.	N.S.	N.S.

There were no statistically significant differences due to winter grazing either in the total number of unit grazing days nor in stocking rate during this period, but there was some indication that the stocking rate was high on the November to February treatment and low on the control.

Animal production was also assessed in terms of lamb live-weight gain (lb./acre). These results are given in tables 3.20., 3.21. and 3.22.

Table 3.20. Lamb live-weight gain (lb./acre) to 10th and 24th May.

Winter grazing period	10th May	24th May	Differences 10th to 24th May
Nov. and Dec.	58	196	138
Jan. and Feb.	51	194	143
Nov. to Feb.	35	179	144
Control	126	255	129
SeM.	±9.5	±36	±28
Sig. level	*	N.S.	N.S.
High N.	81	238	157
Low N.	54	178	124
SeM.	±4.9	±12	±13
Sig. level	*	*	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Control v. Others	**	N.S.	N.S.
Nov. to Feb. v. Others	*	N.S.	N.S.

In the first fortnight control paddocks produced substantially better live-weight gain. This lead was still evident on 24th May but it was not statistically significant. The standard error of the mean was very high. The rate of lamb live-weight gain was independent of both winter grazing treatments and nitrogen rate. The results for the next fortnight are given in table 3.21.

Table 3.21. Lamb live-weight gain (lb./acre) to 7th June.

Winter grazing period	7th June	10th May to 7th June	24th May to 7th June
Nov. and Dec.	259	201	63
Jan. and Feb.	258	201	64
Nov. to Feb.	289	254	110
Control	308	182	53
SeM.	±22	±16	±17
Sig. level	N.S.	N.S.	N.S.
High N.	316	235	78
Low N.	241	187	63
SeM.	±12	±13	±2.2
Sig. level	**	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Control v. Others	N.S.	N.S.	N.S.
Nov. to Feb. v. Others	N.S.	N.S.	N.S.

The results for the 7th June were not statistically significant for winter grazing treatments: during the grazing season it was evident that the November to February paddocks were providing the best live-weight gain per acre. Over short periods this way of measuring pasture production was very prone to large errors; these were due to the limited number of grazing units per paddock. This was borne out by the results for the whole period (table 3.22.).

Table 3.22. Live-weight gain (lb./acre) to 20th June.

Winter grazing period	20th June	10th May to 20th June	24th May to 20th June	7th to 20th June
Nov. and Dec.	308	250	112	49
Jan. and Feb.	312	261	118	54
Nov. to Feb.	352	317	173	63
Control	374	248	119	66
SeM.	±9.3	±2.4	±28	±16
Sig. level	*	***	N.S.	N.S.
High N.	384	303	146	68
Low N.	289	235	111	48
SeM.	±10	±12	±1.2	±2.8
Sig. level	**	*	***	**
Interaction grazing x N.	N.S.	N.S.	**	*
Control v. Others	**	***	N.S.	N.S.
Nov. to Feb. v. Others	N.S.	***	N.S.	N.S.

By 20th June grazing had been carried on for long enough to remove many of the errors that had appeared in earlier results. Control still had the best live-weight gain but it was closely followed by the November to February grazed treatment; in each fortnight the high N. treatment had the better production.

The interactions in table 3.22. were partly caused by the limitations of the experiment <u>per se</u>. There was not sufficient evidence to interpret these interactions; they may have been due to seasonal changes in lamb growth occurring during a period when the stocking rate was either too high or too low. There did appear to be periods when sheep on a particular paddock did exceptionally well or exceptionally badly, but there was not enough factual evidence to substantiate an explanation based on variation in lamb growth rate.

Lambing Field results for 1965-66 enabled a comparison to be drawn between subsequent production measured in terms of unit grazing days and lamb live-weight gain. Generally the winter grazing effects were the same regardless of how the subsequent production was measured. Both methods showed that during the grazing season there was a tendency for the November to February grazed treatment to outyield the others. Levels of significance were not always the same at a given time for both methods, but overall they gave the same results.

Both methods of assessing subsequent production showed a response to high spring nitrogen at all times and in each period. The interactions that occurred in the last month of grazing were inexplicable due to the brevity of the period and the scarcity of experimental weighings. This, more than any other fact, demonstrated that lamb live-weight gain was an unreliable index of production in the growing season. It was awkward to compute, variable in result, and difficult to interpret. As a measure of pasture production, unit grazing days was more reliable. Providing this was used over a long period and the stocking rate regularly and accurately adjusted this was a useful alternative to sampling by cutting.

ANCHORDALES 1966-67 (contd.)

RESULTS:

Subsequent production assessed in terms of animal performance:

There was considerable difficulty providing adequate stock in the summer of 1967, in particular there were not enough ewes with twin lambs of a suitable type. Because of these difficulties, measurement of lamb live-weight gain per paddock was impracticable, consequently only unit grazing days were recorded. On one block, a unit consisted of one ewe with twin lambs and on the other block it was one ewe with a single lamb. The unit grazing days for the period up to 19th May are given in table 4.1.

Table 4.1. Unit grazing days/acre to 5th and 19th May.

Winter grazing period	5th May	19th May	Difference
Nov. and Dec.	61	126	65
Jan. and Feb.	43	117	74
Nov. to Feb.	23	105	82
Control	124	179	55
SeM.	±6.3	±6.8	±18
Sig. level	***	*	N.S.
High N.	75	147	72
Low N.	50	115	65
SeM.	±5.9	±4.5	±17
Sig. level	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Control v. Others	***	***	N.S.
Nov. to Feb. v. Others	***	**	N.S.

There were large differences as a result of winter grazing both at 5th and 19th May. These were due to early grazing on control paddocks and late grazing on November to February paddocks. Stocking was carried out on the following dates:

14th April	- Control paddocks stocked	- High N. at 4 units/paddock
		Low N. at 2 units/paddock
19th April	- Nov. and Dec.	- High N. at $2\frac{1}{2}$ units/paddock
		Low N. at 2 units/paddock
	2 Jan. and Feb. paddocks	- High N. at 3 units/paddock
		Low N. at 2 units/paddock
26th April	- Nov. to Feb.	- High N. at 2 units/paddock
		Low N. at 2 units/paddock
	2 Jan. and Feb. paddocks	- High and Low N. at 2 units/paddock

By the 5th May there was some indication that the winter grazed treatments were being grazed more heavily than the control. The unit grazing days for 1st June are recorded in table 4.2.

Table 4.2. Unit grazing days/acre to 1st June.

Winter grazing period	1st June	5th May to 1st June	19th May to 1st June
Nov. and Dec.	183	122	57
Jan. and Feb.	195	152	78
Nov. to Feb.	164	141	59
Control	224	100	45
SeM.	±12	±13	±8.8
Sig. level	**	N.S.	N.S.
High N.	211	136	64
Low N.	172	122	57
SeM.	±13	±11	±8.3
Sig. level	N.S.	N.S.	N.S.
Interaction grazing x N.	*	N.S.	N.S.
Control v. Others	***	N.S.	N.S.
Nov. to Feb. v. Others	**	N.S.	N.S.

The advantages accruing through winter resting were still apparent on 1st June but they were diminishing rapidly. The interaction is given in table 4.3.

Table 4.3. The effect of previous nitrogen regime and winter grazing on unit grazing days/acre on 1st June.

Winter grazing period	High N.	Low N.	Mean
Nov. and Dec.	179	187	183
Jan. and Feb.	215	174	195
Nov. to Feb.	190	139	164
Control	260	188	224
Mean	211	172	

This interaction was not supported by interactions either on 19th May or on 15th June. The responses to initial nitrogen varied among winter treatments from one date to the next. Response to the previous year's high nitrogen was usually best on winter rested paddocks.

The results up to the end of the grazing period are given in table 4.4.

Table 4.4. Unit grazing days/acre to 15th June.

Winter grazing period	15th June	5th May to 15th June	19th May to 15th June	1st to 15th June
Nov. and Dec.	263	202	137	80
Jan. and Feb.	261	218	144	66
Nov. to Feb.	246	223	141	82
Control	263	139	84	39
SeM.	±13	±16	±9.4	±12
Sig. level	N.S.	*	**	N.S.
High N.	283	208	136	72
Low N.	233	183	118	61
SeM.	±15	±0.2	±10	±6
Sig. level	N.S.	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.
Control v. Others	N.S.	**	**	**
Nov. to Feb. v. Others	N.S.	N.S.	N.S.	N.S.

There were no grazing effects evident on 15th June. During the period 5th May to 15th June, winter grazed paddocks made particularly good growth, and completely removed the initial gain due to winter resting. The slightly low value for the November to February stocked treatment was due to its late stocking.

Those paddocks that had received high nitrogen in the previous year consistently performed better than the low nitrogen ones. This difference was not borne out statistically because of the lay-out of this trial, but in spite of this the difference was real and not transitory.

GENERAL DISCUSSION - ANIMAL RESULTS:

There was good agreement between the results obtained on Lambing Field and those on Anchordales. The different experimental lay-out on the latter allowed a more precise statistical analysis of the winter grazing effects, but this was achieved to the detriment of the nitrogen effects. By the beginning of May control had provided the most grazing and November to February grazed the least. This difference carried on for another month on Anchordales, but by the middle of May it lacked statistical significance on Lambing Field; during this period November to February grazed paddocks did particularly well on Lambing Field. Apart from this there were no differences in growth rates. By the end of the experimental period, winter grazing effects had disappeared. Production of grazing days per fortnight varied as a result of winter grazing; production was good in the latter part of the grazing period for the November to February grazed treatment on Lambing Field, but this was not the case the following year. Control paddocks had poor production during this period in both years. Compensatory production in May and June rectified the initial deficit resulting from winter grazing, so that by the middle of June the advantages of winter ~~grazing~~ resting had disappeared.

No direct comparison can be made between the nitrogen results for the two years, except that the total gain on Anchordales due to high nitrogen was equivalent to an extra 1 cwt. of 20.5% Nitrochalk, applied on Lambing Field after the end of winter grazing. Lambing Field results showed a consistent statistically significant return from the higher rate of spring nitrogen. Anchordales results also indicated that a consistently higher return was achieved, but it was not statistically significant. By the beginning of June, in both years, nitrogen effects were as important as winter grazing effects and by the middle of June they were much more important. If winter grazed pastures are to be used the following season, then winter grazing management is subordinate to nitrogenous fertilising. There were no interactions of any particular relevance. Time of grazing in winter did not appear to alter the ability of the sward to react to either residual or spring nitrogen.

This method of assessing subsequent performance demonstrated several advantages. Measurement was simple and relied on grazing of the whole paddock rather than sampling a minute area. It did away with the difficulty of reconciling efficient sampling of herbage yield with reasonable utilisation. Results obtained from this method over a short period were highly variable due to both the indivisibility of grazing units and the subjective assessment of yield and appropriate stocking rate. This method should not be used where the grazing period is less than a month and stock should be changed weekly immediately after the new stocking rates have been decided.

LAMBING FIELD TRIAL 1966-67

The first year's results indicated that differences in subsequent production, due to winter grazing, tended to disappear in the following spring and summer. If this could be proved it would appear reasonable to delay utilisation of pastures, grazed in winter, for as long as possible in summer; this could be accomplished by closing the pastures for hay in early spring. Lambing Field was used in the winter of 1966-67 for the study of the following problems:

1) At what level did winter stocking of pastures become impracticable?
2) What effect did time of harvesting have on the relative performance of pastures stocked at different levels in winter?
3) What role did spring nitrogen play in comparison with past management?

MATERIALS:

The trial was laid out using the same paddocks as in the previous year. It was ten months since the last treatments had finished and their differences had tended to disappear with time, so this procedure appeared reasonable. During the early autumn the sward was rested; the whole area was mob-grazed from 20th October to 25th November. This was done in an attempt to simulate one possible type of management, the autumnal growth being grazed off shortly before winter sets in and then the stock are confined at a higher stocking rate on a limited area. This overall grazing treatment yielded 193 ewe grazing days per acre.

METHOD:

On 20th December the paddocks were stocked at the following rates:

1) Control: ungrazed.

2) Low stocking: 5 ewes per paddock (1.19 acres).

3) Medium stocking: 8 ewes per paddock.

4) Heavy stocking: 12 ewes per paddock.

During the winter these received supplementary feeding as follows:

Ration per ewe:

Treatments 2 and 3 - 116 lb. 'D' flake and 18 lb. pellet.

Treatment 4 - $121\frac{1}{2}$ lb. 'D' flake and 18 lb. pellet.

The stock were removed on 6th March 1967; the field was then fertilised with a dressing of 2 cwt./acre Muriate of Potash on 13th March. Nitrogen was applied at two levels: one half of each paddock received 3 cwt./acre 21% Nitrochalk and the other 5 cwt./acre. The whole area was cut for hay on 16th June.

Before stocking treatments started precuts were taken in the usual way to establish the yield. After the removal of stock in March the whole area was sampled again. At this time certain paddocks were noticeably more trampled than others. A 10 point quadrat was used to establish the percentage of bare ground in each paddock - 40 throws per main plot. During the growing season yield of dry matter was determined at intervals that represented early grass, silage and hay stages. Yield at these cuts was based on swathes cut with an Allen scythe. A botanical separation was carried out at the silage stage to determine if winter grazing had changed the botanical composition. At all three summer cuts samples were ground and analysed for crude protein content and digestibility.

RESULTS:

The immediate effect of winter grazing is shown in table 5.1.

Table 5.1. Winter yield data (DM lb./acre).

	Precuts	March yield	Difference
Control	576	421	155
Low stocked	466	82	384
Medium stocked	392	28	364
Heavy stocked	503	9	494
SeM.	±86	±87	±38
Sig. level	N.S.	N.S.	*
Control v. Others		*	**
Correlation Coefficient (with stocking rate)		-0.79	+0.87
Sig. level		*	**

In March the yield of dry matter was very low, winter reductions were proportional to stocking rate, but of the four treatments only the control was different from the rest. The reduction in dry matter in this period was different and positively correlated with stocking rate. It was evident from these results that, at the stocking rates adopted in this experiment, the dry matter consumption in winter was primarily dependent on the precut yield rather than on the stocking rate. The lower yields on the more heavily stocked paddocks were due to technical difficulties associated with the harvesting of material that had been trodden into the soil. The main differences resulting from winter grazing were those of ground cover (table 5.2.).

Table 5.2. The percentage of ground bare on 16th March.

Control	34
Low stocked	52
Medium stocked	57
Heavy stocked	67
SeM.	±3.5
Sig. level	**
Correlation coefficient (with stocking rate)	+0.97
Sig. level	***

During March the differences were easily discernible from a main road one mile from the plots; much of the remaining herbage was damaged or smeared with mud. From these results it appeared, at the time, that on the heavily stocked paddocks a degree of damage had been achieved which would not readily be accepted by farmers; furthermore there was ample opportunity for extensive weed ingress on the grazed paddocks. Under these circumstances it was concluded that if winter grazing was detrimental to the future production of pasture then the subsequent results of this trial would demonstrate that.

During the winter Lambing Field provided a useful amount of keep and also a place of occupation. The ewe grazing days provided during the autumn and winter were as follows (table 5.3.).

Table 5.3. Ewe grazing days/acre on Lambing Field during the autumn and winter.

	Autumn	Winter	Total
Control	193	nil	193
Low stocked	193	317	510
Medium stocked	193	507	700
Heavy stocked	193	760	953

The overall pretreatment of 193 ewe grazing days/acre was achieved without supplementary feeding. The dry matter yield from precuts showed that there was little keep left after this grazing period. During the period of differential grazing a high level of supplementary feeding was required; consequently, during this period, the grazed paddocks provided occupation and only a little keep. At the end of the period the ewes were in good condition and produced good lambs.

Subsequent performance:

The first cut was on 4th May; this cut was taken at the stage at which grazing might normally start.

Table 5.4. Yield at early grass stage and growth since March (DM lb./acre).

	March	Early grass	Difference
Control	421	803	382
Low stocked	82	522	440
Medium stocked	28	364	336
Heavy stocked	9	255	246
SeM.	±87	±57	±153
Sig. level	N.S.	*	N.S.
High N.	140	574	434
Low N.	130	398	268
SeM.		±42	±38
Sig. level		N.S.	*
Interaction grazing x N.		N.S.	N.S.
Correlation coefficient (with stocking rate)		-0.94	-0.45
Sig. level		***	N.S.

By 4th May control was statistically greater than the other treatments (P = 0.05) and the yields on the grazed paddocks were inversely correlated with the rate of winter stocking. The increased yield on the control was due to its March advantage rather than a better growth rate in this period; there was no correlation between growth rate in the March to May period and previous stocking rate. Nitrogen at the high rate encouraged faster growth in this period.

Table 5.5. covers the period up to the silage stage. This was cut on 25th May.

Table 5.5. Yield at the silage stage and growth rate prior to it (DM lb./acre).

	Silage yield	Growth March-Silage	Growth Early-Silage
Control	3198	2777	2395
Low stocked	2750	2668	2228
Medium stocked	2572	2544	2208
Heavy stocked	2303	2294	2048
SeM.	±213	±160	±100
Sig. level	N.S.	N.S.	N.S.
High N.	2952	2811	2378
Low N.	2459	2329	2062
SeM.	±138	±147	±126
Sig. level	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Correlation coefficient (with stocking rate)	-0.86	-0.71	-0.66
Sig. level	**	*	N.S.

Although there were no statistically significant differences between yields at the silage stage, there was an inverse correlation between stocking rate and yield that clearly indicated that yield at the silage stage was partly dependent on the previous winter management. In addition to the effect of winter grazing there was a large response to the extra 2 cwt./acre of Nitrochalk; although this response was not statistically significant it compared favourably with some of the responses obtained by Baker[10]. Growth in the period

March to 25th May showed an inverse correlation with winter stocking rate. This appeared to contradict the results obtained at the early stage, especially as there was no inverse correlation for the period between the first two cuts. This can be explained on the grounds that both periods showed a tendency towards lower yields as winter stocking rates increased and the correlation in the early to silage period was almost significant at the 5% level.

Table 5.6. covers the growth rates up to the end of the trial and the yield at the hay stage, cut on 16th June.

Table 5.6. Yield at hay stage and growth rate prior to it (DM lb./acre).

	Hay yield	March-Hay	Early-Hay	Silage-Hay
Control	5989	5568	5186	2791
Low stocked	6210	6128	5688	3460
Medium stocked	5602	5574	5238	3030
Heavy stocked	5581	5572	5326	3278
SeM.	±303	±338	±285	±291
Sig. level	N.S.	N.S.	N.S.	N.S.
High N.	6033	5893	5455	3082
Low N.	5657	5528	5260	3198
SeM.	±200	±280	±172	±242
Sig. level	N.S.	N.S.	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.	N.S.

By the hay stage there were no differences that could be ascribed to the previous winter's grazing. The yield of hay was a little over $2\frac{1}{2}$ ton/acre on the heavily stocked paddocks; this was a reasonable yield in view of the amount of winter grazing obtained under this treatment.

At the early grass and silage stages yields of dry matter were significantly responsive to winter treatments. However these differences were not great and it appeared that growth in spring was little affected by winter treatments.

The effect of the differential manurial return, due to winter grazing treatments, was not measured. The manurial return was proportional to winter grazing damage and may have partially balanced the detrimental effects of defoliation and treading. From the results, levelling of yields appeared to be delayed till the hay stage; this may demonstrate the time lag between the application of animal return and its availability.

The extra two cwt/acre of Nitrochalk, on the high nitrogen treatment, had no effect on rate of herbage growth except in the period March to May. This lack of differences after the beginning of May was due to climatic effects. May was exceptionally wet; a high proportion of the applied nitrogen leached out, consequently there was a reduction in the nitrogen differential, which was demonstrated by lack of differences in the post May growth rate.

Table 5.7. Percentage crude protein in dry matter.

	Early stage	Silage stage	Hay stage
Control	22.9	15.8	9.6
Low stocked	26.2	17.8	10.9
Medium stocked	25.7	16.2	11.3
Heavy stocked	27.9	18.7	10.8
SeM.	±1.05	±1.14	±0.35
Sig. level	*	N.S.	N.S.
High N.	27.6	18.1	11.0
Low N.	23.8	16.2	10.3
SeM.	±0.48	±0.56	±0.5
Sig. level	**	N.S.	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Correlation coefficient (with stocking rate)	+0.9	+0.56	+0.67
Sig. level	***	N.S.	*

At the early stage crude protein percentage was affected by the previous winter stocking regime. Control paddocks had a low crude protein content; this indicated that either the herbage was more mature or else it contained herbage left over from the winter. At this cut a high proportion of the grass was left over from March; this did not occur on the other treatments, since their March yields were so small. The crude protein content of the grazed treatments at the early stage indicated that the herbage contained a high proportion of young succulent material, normally associated with young tillers rather than the low quality grass generally prevalent at the end of February. The presence of the old grass may have impeded production and growth of young tillers on the control paddocks, whereas the bareness of the grazed paddocks undoubtedly aided widespread tillering. The crude protein percentage was important in that it indicated that there might be a difference in the type of grass at the early stage, but as a value it is less important than the production of crude protein/acre; this is shown in table 5.8.

Table 5.8. Yield of crude protein (lb./acre).

	Early stage	Silage stage	Hay stage
Control	189	516	576
Low stocked	138	495	676
Medium stocked	94	420	629
Heavy stocked	72	432	607
SeM.	±16	±98	±27
Sig. level	*	N.S.	N.S.
High N.	156	536	667
Low N.	91	392	577
SeM.	±17	±28	±45
Sig. level	N.S.	*	N.S.
Interaction grazing x N.	N.S.	N.S.	N.S.
Correlation coefficient (with stocking rate)	∓0.74	∓0.49	∓0.19
Sig. level	*	N.S.	N.S.

Differences in crude protein yield disappeared quickly because of the inverse correlation between yield and crude protein percentage. Nitrogen effects were statistically significant at the silage stage, and at both this and the hay cut differences due to the extra 2 cwt. of Nitrochalk were more important than differences due to winter stocking.

A botanical split was carried out on samples taken from the silage stage grass. The results are given in table 5.9.

Table 5.9. Botanical composition at the silage stage.

	% Perennial ryegrass	% Timothy	% Clover	% Weeds
Control	86.5	12.2	0.85	0.55
Low stocked	77.3	20.9	0.5	1.3
Medium stocked	76.3	21.5	0.0	2.2
Heavy stocked	77.6	20.1	0.5	1.8
Mean	79.4	18.7	0.45	1.45
High N.	79.4	18.9	0.5	1.2
Low N.	79.4	18.4	0.4	1.8

There was virtually no change in botanical composition due to winter grazing. The very low weed content was surprising in view of the high bare ground figures in March on some of the paddocks. There was no difference in clover figures because the clover content was very low on this field before the trial started; there was no evidence to support the view that timothy was prejudiced by winter grazing; the figures quoted above indicated that timothy did well on a winter grazing regime, possibly because the aggressiveness of ryegrass was impaired, and its early growth retarded.

DISCUSSION:

In the preface to this trial three problems were presented. No definite answer was provided for the first one, but the results did indicate some of the ways in which winter stocking affected pasture production. Stocking in the pretreatment period provided a useful amount of unsupplemented keep. Stocking in the winter period provided only a little keep, and required heavy supplementary feeding. The burden of supplying carted foodstuffs was considerably eased by the use of 'D' flake instead of hay; this was kept on the paddocks and fed when required. The ration fed was slightly less than that fed to housed ewes; the main benefit from winter stocking was the provision of an area on which stock could be kept near the steading without requiring buildings or special shelters. A comparative assessment of ewe and lamb performance was not carried out; there were no similar ewes housed that year, but the shepherd was pleased with both the health of the ewes, and the strength of their lambs. If appearance in March had been used as the index of winter stocking practicability, then most judges would have ruled that four ewes to the acre was the optimum stocking rate in this trial: pastures should not be judged on their appearance in March, but on their production later on. If early grass is required then it is impracticable to stock the pastures in winter. Graziers have to choose the period in which they take advantage of out-of-season grass; if they require winter grass, then they should plan to rest the pasture in spring. If early grass is not required then winter stocking is practical at rates in excess of 4 ewes per acre. The reduction in hay yield at the high stocking rate was not significantly greater than the reduction on the other treatments, including control. It would appear practical to concentrate stock, in late winter, on a small area of pasture, and thus provide a larger acreage of grass that is capable of good early growth. The advantages accruing from this practice include easier feeding and supervision. Concentration of stock during the winter permits the resting of other fields for lambing and early bite. Winter grazing was achieved in this trial without sacrificing ewe health and with the loss of only a few bales of hay.

Time of spring and summer harvesting had a close connection with the relative performance of pastures stocked at different rates in winter. The best yields in spring were obtained following winter resting, but the grass harvested at this time was relatively poor in quality and contained a substantial amount of old and possibly unpalatable grass. Growth to the silage stage was slightly affected by winter stocking as the heavily grazed treatment was slower than the control. The hay cut revealed that winter grazing was not inevitably detrimental, and that light grazing in late winter produced a useful crop of hay. Delay in time of summer utilisation favoured winter stocking.

The response to an extra 2 cwt./acre of Nitrochalk was adequate, but not statistically significant due to the high standard error of the means. Nitrogen increased the rate of growth in the early period, and the results demonstrated that extra nitrogen could compensate for the detrimental effects of winter grazing. Spring nitrogen was no less important than winter grazing in determining subsequent performance.

Winter stocking rate had a statistically significant effect on yield of early grass and silage, but the results clearly demonstrated that at low stocking rates subsequent production was virtually the same as that found on winter rested pastures. This was even more clearly demonstrated when the differences in yield of crude protein per acre were examined. These differences were so small, that, in this trial, the benefits gained by winter grazing far outweighed the slight reduction in yield the following spring.

SMALL PLOT TRIAL 1966-67

In addition to the two main trials laid out in the winter of 1966-67, a small plot trial was also prepared. Results obtained in the summer of 1966 had indicated that reductions in spring yield could follow periods of winter grazing. Grazing has three main effects on a pasture - defoliation, treading and the excretion of partially available plant nutrients. Of these three defoliation and treading might have been the cause of the reduction in subsequent production experienced following winter grazing in 1965-66.

AIM:

To distinguish between the effects of defoliation and treading in winter at two levels, measured in terms of subsequent production.

MATERIALS:

Part of the lower half of one of the control plots on the Lambing Field Trial was used. The pretreatment was identical to that of the rest of the field. At the beginning of January the area was divided into a five by five Latin square, with individual plots measuring 6 feet by 15 feet. There were five treatments:

1) Control - no defoliation or treading.
2) Light defoliation only.
3) Light defoliation and light treading.

4) Heavy defoliation only.

5) Heavy defoliation and treading.

Implementing these treatments was a serious problem. Cutting treatments on (2) and (3) had to be accomplished with minimal compaction. The conventional means were unsuitable. An Allen auto-scythe, even with universal foot, would not have provided differential grazing treatments nor could it operate satisfactorily on uneven ground containing little herbage. Unevenness and the compacting effect ruled out use of a cylinder mower. Neither shears nor the modified Tarpan hedge-cutter were practical since both would have been too slow, uneven, and there would have been variable compaction resulting from their operation. The choice of a cutting implement depended on one which could produce differential cutting treatments for minimum compaction. This was achieved by using a 19" Flymo Professional (see photo). This had numerous advantages: it worked on a hovercraft principle, thereby reducing compaction, and its height of cutting could be altered by addition of spacing plates between the drive shaft and rotor blade. Simulating treading also presented difficulties. This was not done by stock because of lay-out difficulties and also the errors inherent in short periods of occupation by one or two sheep. Consequently artificial means had to be used. The first implement consisted of a treading bar containing several bolts with their rounded heads pointing downwards. This turned out to be impracticable for two reasons. A pressure of 40 lb. wt. was required per bolt, hence each penetration of the implement covered a minute

19" Flymo Professional

19" Flymo Professional

area. Using Edmond's figures[59], to simulate 1000 sheep grazing days the implement would have had to be pushed into the ground thirteen thousand times on each of the six heavily poached treatments and half this number of times on the light treading treatments. Eventually the area was poached by several people scraping it with stobs and stirring it up generally with their heels. The effectiveness of this method was demonstrated by photographs and later by measurement. The timing of treatments was as follows:

January 18th - All plots except controls cut lightly - Flymo with 2 spacing plates.

February 2nd - Heavily cut plots cut again with blade set one spacing plate lower.

March 3rd - Heavily cut plots cut for the third time.

January 24th - All trodden plots trodden a similar amount.

February 7th - All heavily trodden plots trodden again.

March 13th - 2 cwt./acre Muriate of potash on all plots.

May 4th - 3 cwt./acre Nitrochalk on all plots.

RESULTS:

On 18th May the plots were cut for the first time; a swathe 1 yard by 5 yards was cut from the middle of each plot. The regrowth from this cut was measured on 23rd June.

Small Plot Trial - March

Table 6.1. Small Plot Trial - Yield of dry matter (lb./acre).

	Cut 1	Regrowth	Total
Control	703	2136	2839
Light defoliation only	641	2396	3037
Light defoliation and treading	593	2467	3060
Heavy defoliation only	507	2515	3022
Heavy defoliation and treading	376	2580	2956
SeM	$\pm$29	$\pm$151	$\pm$85
Sig. level	***	N.S.	N.S.
Control v. Others	***	N.S.	N.S.
Defoliation v. Defoliation and treading	**	N.S.	N.S.
Light v. heavy	***	*	N.S.

A high level of statistical significance was obtained at the first cut; the yields were very poor, probably because Nitrochalk was put on so late. Control plots had the highest yield. Heavily treated plots had lower yields than lightly treated ones. The reduction due to treading was supplementary to that due to defoliation.

Analysis of the regrowth showed that winter treatments had no effect on dry matter yield. Examination of the possible comparisons indicated that regrowth on the heavily defoliated plots was marginally superior to regrowth on the lightly defoliated plots.

The sum of 'Cut 1' and the regrowth showed that total yield was independent of winter treatment. No differences could be ascribed to intensity of winter treatment or the residual effect of poaching.

Table 6.2. Percentage crude protein in dry matter.

	Cut 1	Regrowth
Control	22.8	14.7
Light defoliation only	25.1	12.2
Light defoliation and treading	25.7	12.2
Heavy defoliation only	25.9	12.1
Heavy defoliation and treading	28.3	12.0

The crude protein content was inversely correlated with yield. Only the control plots contained winter herbage at 'Cut 1'. In terms of crude protein production per acre control plots were superior to the others (table 6.3.).

Table 6.3. Crude protein (lb./acre).

	Cut 1	Regrowth	Total
Control	160	314	474
Light defoliation only	161	292	453
Light defoliation and treading	152	301	453
Heavy defoliation only	132	304	436
Heavy defoliation and treading	106	310	416

All plots at 'Cut 1' were analysed botanically; the results are given in table 6.4.

Table 6.4. Botanical composition at Cut 1.

	% Perennial ryegrass	% Timothy	% Clover	% Weeds
Control	75.3	19.2	4.0	1.5
Light defoliation only	73.7	17.1	7.8	1.4
Light defoliation and treading	74.3	19.1	5.7	0.8
Heavy defoliation only	70.6	22.0	5.5	1.9
Heavy defoliation and treading	70.8	22.6	5.6	1.0

There were no differences in botanical composition that could be ascribed to winter treatment. Winter treatments did not appear to be detrimental to the subsequent growth of timothy or clover. The low weed content, following two years of winter use, indicated that weed ingress was not inevitably encouraged by winter defoliation or treading.

Discussion.

Measurement of dry matter yield in May indicated that yield was inversely prorortional to the damage sustained by the sward in winter. Both high intensity of winter treatment and poaching tended to reduce May yield.

The yield of dry matter on the area surrounding the trial was assessed as 463lb. dry matter per acre at the beginning of March. Up to the beginning of March this had received the same treatment as the control plots in the Small Plot Trial. At the same time the heavily treated plots were given their final defoliation, consequently there was no determinable yield on these plots. By 'Cut 1' the heavily defoliated plots produced 507lb. dry matter per acre, whereas the yield on the control plots was 703lb. dry matter per acre. The March to May dry matter increase on the heavily defoliated plots was 507lb. dry matter per acre, whereas on the control plots it was only 240lb. dry matter per acre. Although the May yield on the control plots was superior to the May yield of the winter treated plots, there was no evidence that the rate of growth in spring was better on the control than on the others.

Winter resting has been advocated as an essential precursor for early grass production. The results mentioned above indicate that this assertion requires qualification. In March the control plots contained herbage that had weathered a long period of wintry conditions. Experience on Anchordales Trial demonstrated that a high proportion of the grass was senescent and presumably incapable of active growth. Hunt (107) has measured the rate of decay of Italian ryegrass in a sward. The amount of decay varies with the state of maturity, yield of herbage and environmental conditions. Inevitably the rate of decay was high on the control plots and consequently the mass of dry matter lost through decay was also high. On the March defoliated plots there was no herbage capable of decay and in consequence any subsequent change in yield was attributable to fresh growth alone.

These results demonstrate that winter grazing is not inevitably followed by low production in the subsequent growing season. Defoliation in winter may be advantageous to the sward, since it removes senescent material that might limit growth of spring herbage. Any loss of yield in the early part of the season is compensated for by the advantages gained through winter grazing, and the similarity in total yield of winter rested and winter grazed swards. Finally in old swards there appears to be little change in the botanical composition resulting from defoliation or treading in winter.

DISCUSSION.

Defoliation, treading and manurial return are the three major factors introduced by the grazing animal. Defoliation, in winter, results in the removal of herbage that would otherwise become more indigestible, but it also selectively removes a high proportion of the herbage that is capable of photosynthesis. Although winter grazing can result in damage to the sward, it lessens the accumulation of senescent material in the sward as spring approaches. Treading damage occurred in all paddocks that were grazed in winter; Edmond(59-65) has shown that treading reduces dry matter yield, damages tillers and affects botanical composition. The damage to tillers was borne out by the results of Lambing Field Trial in 1966-67. Gleeson(91) has shown that treading damage is correlated with the moisture content of the soil, consequently damage tends to be more serious in winter. The Small Plot Trial showed that treading was supplementary to defoliation in reducing yield of early grass. No work has been done on the subsequent effect of manurial return following winter grazing.

Frame(74) showed that the future production of a pasture was affected by the time of grazing in winter. None of the treatments in this series of trials included grazing in October or March; the results from the main trials suggested nevertheless that, provided winter grazing was between November and February, production in the following season was little affected. The duration of stocking may be more important; Gleeson's trial(90) corroborated this and demonstrated that a large difference in duration of winter stocking altered the pattern of spring and summer production. Density of stocking was also important. Lambing Field Trial 1966-67 indicated that winter damage was proportional to stocking rate; high stocking rates gave a low yield of early grass, but very low stocking rates had little effect. Moreover the dry matter yield on winter rested pastures declined due to natural and climatic causes and grazing at this time was a means of removing herbage that might otherwise be wasted through burn and decay. In consequence by March the composition of rested swards can be fundamentally different to that of grazed swards.

The two main trials were assessed by means of unit grazing days, which provide a measure of production on a specific date and also outline the pattern of production over a period. Large differences, between treatments, were detected in early May. After a long period of uninterrupted growth these differences tended to disappear; thus sampling for dry matter yield assessment in May produced totally different results to sampling in late June, as Frame [74] found too. In assessment of subsequent production care must be taken to distinguish between measurement of uninterrupted growth and measurement of recovery growth. On Lambing Field 1965-66 and Anchordales there were long periods in which production on winter rested paddocks was inferior to production on winter grazed paddocks, though on no occasion was total production lower on the control paddocks.

All four winter trials indicated that winter defoliation resulted in low dry matter yield in early May. Winter grazing effect was inversely proportional to yield of early grass. Where severe damage occurred in winter, as on the heavily stocked treatment (Lambing Field in 1966-67), recovery was prejudiced. By mid-June winter grazing effects were subsidiary to those induced by differences in nitrogen fertiliser application rate. It does appear from the results on Lambing Field 1965-66 and Anchordales 1966-67 that the superior performance of the winter rested pasture was not due to a faster rate of growth in spring. On all four trials total production was not influenced by winter treatments. The main conclusion from this is that the pattern of spring and summer growth, but not the total yield, may be affected by the type of management adopted in winter.

On both Lambing Field Trial in 1966 and Anchordales in 1967 the pattern of spring and summer production was affected by winter treatment. In particular it was apparent that after the beginning of May animal rate of gain was better on the winter grazed paddocks. Spedding[152] on the other hand found that grazing hard and early prejudiced subsequent production. Hunt[107 & 108] agreed and found that it limited the response to spring nitrogen. Since, in Lambing Field in 1966 and in Anchordales in 1967, the dates on which paddocks were stocked and the rates of stocking were carefully adjusted to the amount of available herabage, and the growth rate of each paddock, it is unlikely that there could have been any interaction between initial grazing effect and subsequent growth.

There was no evidence that the added manurial return on the grazed paddocks was a critical factor governing their subsequent production. Manurial return was certainly not the dominant factor determining growth in spring as there was no correlation between spring growth and winter stocking rate on Lambing Field in 1967. Any benefits to be derived from increased manurial return, due to higher stocking rate, appeared to be secondary in effect to the depressant effects of winter defoliation and treading.

Brougham[26] suggested that growth was dependent on Leaf Area Index (LAI). As this increased so the rate of dry matter production (RDMP) rose too; at an optimum LAI the RDMP tended towards a constant value. Brougham's model does not fit the pattern recorded on the winter rested treatments, in these trials, but it does approximate to the situation found on the winter grazed treatments. LAI is closely correlated with yield of grass; after winter resting yield was high relative to winter grazed herbage. From Brougham's model a higher growth rate on the rested pasture would be expected - this did not occur, therefore it may be presumed that the Net Assimilation Rate was low. The high yield of moribund material found on the rested treatment on Anchordales in March, and confirmed visually on the other trials, would appear to have reduced the mean photosynthetic activity of the rested paddocks. On the grazed paddocks the yield of senescent herbage was low, consequently growth in spring was not hampered by gradual decay of moribund material.

By spring, winter resting would, no doubt, result in a sward of high yield but of low photosynthetic activity; on the other hand the winter grazed paddocks, notwithstanding a low yield in early spring, could have been capable of more efficient assimilation. Therefore on the grazed swards growth rate was poor initially, but it increased rapidly as the LAI rose; on the rested paddocks growth rate was partially limited by the presence and gradual decay of senescent material.

winter grazing is reputed to change the botanical composition of a sward. Neither in these trials, nor in those of Frame[74] were any important changes detected. Hughes[98 & 100] mentions that winter grazing may result in weed ingress and a reduction in both timothy and clover. Vetharaniam[175] found that Poa ingress was transitory. Eye scores[140a] failed to link weed ingress with previous winter treatment. It is possible that the changes recorded by other workers have been due to autumn management rather than the effects of winter grazing *per se*. Management is reputed to alter the relative proportion of cocksfoot to perennial ryegrass[50]. Botanical analysis showed that in these trials winter resting tended to favour ryegrass at the expense of timothy - possibly ryegrass was better able to assert itself following winter resting. The level of weed ingress was remarkably low, in spite of the high proportion of bare ground on the heavily grazed paddocks (Lambing Field Trial 1966-77). In all three trials, in which botanical composition was determined, the clover content was too low to show any real difference attributable to winter grazing.

The high rate of nitrogen, applied in the previous year, on Anchordales resulted in more winter keep and changed the appearance of the sward. Its superior performance up till June of the following year, was achieved in spite of the higher clover content of the low nitrogen sward. This good performance due to high nitrogen was achieved after a lapse of several months. Analysis of the herbage in March showed that the high nitrogen regime resulted in more photosynthetically active material and these paddocks looked generally more vigorous. Corbett[36] found that nitrogen could be stored in the plants over winter, this may possibly account for the carry-over effect experienced on Anchordales. Baker's trials[9 & 10] found that one of the effects of autumn nitrogen was that it induced stronger and more prolific tillering, and that it was these changes that affected the yield the following year, in his trials. It appears that winter grazed swards of high fertility may offer advantages over the less densely tillered swards found under lower fertility conditions.

These trials have indicated that neither time (between November and February), nor rate of winter stocking, have any significant effect on total output from pastures in the following year. Winter grazing, however, does reduce the herbage available to the animal in spring; therefore, pastures, grazed heavily in winter, are not suitable for early bite. It appears, nevertheless, that the use of additional nitrogen in spring can lessen the detrimental effects of winter grazing on yield in the early part of the year.

Nitrogen application in the spring was very important in determining the level of spring and summer production of herbage. By mid-June the effect of varying the nitrogen rate was more important than differences due to winter management. There was no evidence in these trials that winter resting or grazing affected the dry matter response of the swards to nitrogen applied in the following March. These results agree broadly with the finding of Frame[74], who found that spring nitrogen could be used to compensate for the detrimental effects of March grazing. In Lambing Field 1965-66, differences in herbage output, from two rates of nitrogen application in March, were small in early spring but became larger as the season progressed. It appears therefore that a generous use of nitrogen in spring may offset, in part the initial deleterious effects of winter grazing.

It can be concluded from these trials that winter grazing has much to recommend it considering the slight practical disadvantages inherent in such management.

CONCLUSIONS

1) The highest yield of early grass was obtained by resting pasture in winter. This grass was low in quality and contained mature herbage left over from the winter.

2) Treading and defoliation were supplementary in reducing early yield of grass. At high stocking rates treading was particularly damaging to spring production.

3) Winter grazing altered the pattern of spring and summer production. Spring growth on winter rested sward was limited by the high content of mature herbage. Spring growth on winter grazed swards was limited by lack of herbage capable of photosynthesis and the reduction in plant cover. The relative performance of winter rested and winter grazed pastures depended on the extent of the retarding influence of these factors.

4) By mid-June yield of dry matter was determined by factors other than winter management.

5) By mid-June spring applied nitrogen was the main experimental factor affecting the yield of herbage dry matter. Winter grazing did not affect the response to spring nitrogen.

6) The beneficial effect of a high nitrogen regime during the previous growing season was evident all through the Anchordales Trial. The high nitrogen treatment resulted in better early production than spring nitrogen.

7) Changes in botanical composition due to winter grazing were of minor importance. Grazing in winter did not encourage weed ingress.

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