THE EFFECTS OF DEFOLIATION SYSTEMS ON THE PRODUCTIVITY OF PERENNIAL RYEGRASS/WHITE CLOVER SWARDS

by

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INTRODUCTION

There is an evergrowing awareness of the vital role of grassland in providing animal feed and ultimately animal products. As a result, there has been a concurrent increase in grassland research. The need for suitable and accurate techniques to measure and compare grassland productivity under various conditions of management has thus never been more urgent than at the present time. The need has been made more acute because of the necessity to evaluate the flood of new herbage varieties released by home and overseas plant breeders. In the Organisation for Economic Co-operation and Development (O.E.C.D.) scheme for the varietal certification of herbage seed moving in international trade, 873 cultivars of 81 species from sixteen member countries were listed in 1965 (O.E.C.D., 1965).

In Scotland, a programme of herbage variety evaluation was devised in 1950 by the Grassland Committee of the Scottish Agricultural Improvement Council. Trials termed 'variety potentiality trials' were conducted in two stages:

(a) single plant work on structure and development, measured and expressed solely in botanical terms and carried out by the Scientific Services Station of the Department of Agriculture and Fisheries for Scotland, East Craigs, Edinburgh.

(b) co-ordinated sward trials under cutting schedules (usually monthly cutting) to determine herbage quantity, growth rhythm and quality, and carried out by the three Scottish agricultural colleges at Aberdeen, Edinburgh and Ayr. To date, 171 herbage varieties have been evaluated by the colleges in this way.

The techniques used in the evaluation programme outlined above have the merits of speed, ease and economy in relation to the large volume of information derived, but are open to the criticism that at no stage is the evaluation work referred to the grazing animal.

As <u>in situ</u> grazing is the most important method of grassland utilization, the introduction of the grazing animal at some stage in the measurement of productivity would seem logical. Yet historically this logic was not appreciated until the turn of the present century when Somerville and Middleton in their classical experiments at Cockle Park assessed grassland output in terms of animal products; prior to this, output had normally been measured by simple cutting techniques and expressed in terms of herbage yield. However, because of the requirements of land, labour, animals, equipment and finance associated with animal production trials, agronomic cutting techniques are still mainly used to evaluate grassland (McMeekan, 1960; O.E.E.C., 1960).

The shortcomings of present evaluation techniques are recognized in the United Kingdom and consequently there are no official lists of recommended varieties. Instead, the National Institute of Agricultural Botany issue Farmers' Leaflets, which detail herbage varieties most likely to be satisfactory for general use. For example, assessment of grass varieties is made on the basis of lateness of heading, early spring growth, autumn growth, persistency, winter hardiness, hay yield and aftermath yield. In contrast, there are recommended lists for crops such as oats, barley, wheat, potatoes and sugar beet, for which suitable techniques of evaluation exist.

The experiments reported in this thesis were initiated in 1960 at Auchincruive and designed to determine the productivity of perennial ryegrass* and perennial ryegrass/white clover swards under various cutting and grazing

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* Common and scientific names of grasses, legumes and other plants mentioned in the thesis are listed in Appendix 1.

systems. In the grazing systems, sheep were used simply to defoliate the swards and to supply the effects of trampling, selective grazing and excretion. The object was to establish yield relationships between the various cutting and grazing systems. If relationships could be shown to exist, the simpler cutting systems could be retained and the results under grazing predicted. Only a few studies of this nature have been conducted (Taylor et al., 1960; Bryant and Blaser, 1961). This approach would seem warranted since cutting per se cannot simulate grazing yet the volume of grassland evaluation work makes it impossible for the widespread adoption of grazing techniques in place of cutting techniques.

From the experiments described in this thesis, a paper entitled "The effects of cutting and grazing techniques on productivity of grass/clover swards" (Frame, 1965a; Appendix 11) was read for the author by Mr. F.E. Alder of the Grassland Research Institute, Hurley, Berkshire, at the 9th International Grassland Congress, São Paulo, Brazil in the session on experimental techniques in pasture research. A further paper entitled "The evaluation of herbage production under cutting and grazing regimes" (Frame, 1966; Appendix 12) was presented by the author at the 10th International Grassland Congress, Helsinki, Finland in the section on grassland production.

REVIEW OF LITERATURE

The origins of methods of measuring grassland productivity are comparatively recent as up until the nineteenth century, agronomists were chiefly concerned with studies on arable crops. Cutting techniques to measure productivity in herbage terms such as dry matter and supplemented with expressions of quality such as crude protein or digestibility are the simplest methods. Refinements to simulate one or several or all the grazing animal effects of treading, defoliation and return of nutrients can then be incorporated into these cutting techniques. A further development is the use of animals as defoliating 'machines' to supply real animal effects but still retaining cutting techniques as the means of measurement. Lastly, in orthodox grazing techniques, productivity is measured ultimately in terms of stock carrying capacity, e.g. cow grazing days, animal products e.g. milk, or the two together expressed as starch equivalent output. These last-named techniques are outwith the scope of this review which is concerned with the agronomic evaluation of grassland productivity, with particular reference to small-plot cutting and grazing techniques. The relevant literature is reviewed for convenience in three sections as follows:

(a) Measurement techniques;

(b) Defoliation methods (cutting and grazing); and

(c) Defoliation intensity (frequency and severity).

(a) Measurement techniques

Cutting with herbage removed

The first measurements of herbage yield were probably made in 1816 by Sinclair, who cut and measured yields of hay and aftermath from small plots of various grasses and legumes in the gardens of Woburn Abbey (Beddows, 1953). Fream (1888) measured pasture yield from a series of cuts on plots comprised of turves from various sward types. With the founding of the Welsh Plant Breeding Station at Aberystwyth in 1919, rapid advances were made in techniques, cutting and otherwise, of measuring pasture productivity. Initially in trials to assess the potential value of a wide range of herbage species, varieties and seeds mixtures under various managements, yields were obtained by cutting sample areas of varying sizes with sheep shears, garden shears or scythes, all hand-operated. Sampling was later mechanised by the use of power-driven machinery. Attempts were made to simulate grazing conditions by adopting various systems of more or less frequent cutting and of more or less severe cutting (Stapledon, 1922, 1924; Stapledon and Davies, 1930). These techniques have since been adopted in grassland research throughout the world (Woodman et al., 1926, 1927; Hudson, 1933; Klapp, 1937; Lynch, 1947; Kennedy, 1950; O.E.E.C., 1960 and many others).

Cutting trials on small plots to simulate field mowing for hay, silage or dried grass have been carried out by Stapledon (1924), Watson et al. (1937), Holmes (1948), Hughes and Evans (1951), O.E.E.C. (1960), Aldrich (1963) and many others. The aftermath is usually cut to simulate grazing. The use of a single hay crop as a measure of productivity has been discussed by Hudson (1933), Lynch (1947), Ahlgren (1947) and Rosch (1956), who point out that a single crop represents production over part of the year only, takes no account of critical periods of low production during the season and if taken year after year, causes deterioration in the sward composition.

Many workers have used cutting techniques to measure production under permanently fixed cages set down on grazed pastures. The herbage was cut periodically during the season, weighed and discarded (Schuster, 1929; Robinson et al., 1937; Brown, 1937; Jones et al., 1937; Brandt and Ewalt, 1939; Charpentier, 1940; Brown and Munsell, 1945). To simulate grazing conditions more closely the cages were moved to different positions biennially or triennially (Gardner et al., 1935), annually (Brown, 1937) or several times during the season (Schuster, 1929).

Mowing with return of clippings

For pasture at a short-growth stage, Lynch (1947) has described a technique in which herbage produced by plots is returned after mowing and weighing. Several shortcomings were apparent. Procumbent plants ousted erect plants and production fell off compared with grazed plots though not so quickly as when the clippings were discarded after mowing. Clippings did not decompose under dry conditions and were harvested again along with subsequent fresh growth. Elliot and Lynch (1958) considered that the technique was only suitable for humid areas or where there was a sufficiently high worm population to ensure rapid incorporation of the cut herbage into the soil. Sears (1951a) found the method unsuitable for high-producing swards because of the smothering effect of the clippings on regrowth and resultant sward deterioration. In spite of the defects listed above, the technique has been adopted by the Extension Division of the Department of Agriculture, New Zealand, after comparison with other techniques, for soil fertility investigations on farms outwith its experimental stations (Elliot and Lynch, 1958). McNeur (1953) advocated drying and grinding the clippings before returning to the plots in proportion to individual plot yields. Wolton (1963) used the technique satisfactorily in Britain on 4-6 in. herbage. In a dry year, because of slow decomposition and smothering effects, she found it necessary to dry and mill the clippings before return. Watson and

Lapins (1964) in a part of Australia with a Mediterranean climate also dried and ground herbage clippings before return. Once pre-treatment of the clippings before return is necessary, the special facilities required preclude the use of the technique outside research stations.

Cutting with return of fertilizer nutrient mixture

Based on the principle that the return of nutrients in animal excreta is related to their uptake in herbage, McNeur (1953) devised a mixture of inorganic and organic fertilizers for returning to plots after cutting in order to replace the main nutrients lost by removing the herbage. His calculations were based on analyses of pasture at Palmerston North, New Zealand, as reported by Sears et al. (1948). The application rate of the mixture was 250 g per lb of herbage dry matter. Gardner (1961) used McNeur's technique but adjusted the composition of the mixture to take account of pasture analyses in Scotland. Like McNeur, he noted scorch injury to plants in dry weather. At Aberystwyth, a mixture of inorganic fertilizers was used to simulate the main nutrients (nitrogen, phosphorus, potassium and calcium) of the calculated dung and urine a plot would receive had the herbage been consumed (Jones, 1958). Wolton (1963) considered that McNeur's mixture could be modified to simulate the relative availability of the nutrients in animal excreta, but after preliminary trials, she suggested that simulation of urine return only, with inorganic nitrogen and potassium, would be more satisfactory because of the low availability of the nutrients in dung. Because of its simplicity, the use of a fertilizer mixture has many advantages for trials both within and outwith experimental stations.

Holliday (1953) advocated a mixture of urea and dried dung for application to plots at rates proportional to plot herbage yields but later (Holliday and Wilman, 1962) applied coarsely ground air-dried dung from dairy cows and fertilizer nitrogen to simulate the dung and urine respectively that would be produced from the herbage. In cutting trials to assess the relative productivity of perennial ryegrass varieties in Northern Ireland, McPetridge et al., (1958) cut plots when a yield of approximately 10 cwt herbage dry matter per acre was present and after each cut, applied a dressing of farmyard manure in proportion to the yield. They attempted to replace approximately 60% of the nitrogen removed by the cut herbage. Under their humid conditions, the farmyard manure soon decomposed and did not interfere with the harvesting of subsequent cuts. Henderson et al. (1960) continued to use farmyard manure but applied it in spring and autumn only, in dressings proportional to the annual yield of herbage the previous year.

Alternate mowing and grazing

This technique, in which selective grazing, treading and excretal return are introduced, was devised by Hudson (1933) to overcome the defects of the 'cutting with herbage removed' method. The experimental area is split into two parts, one of which is mown and the other grazed. The mown clippings are weighed and scattered over the grazed part. After a rest period, the treatments are reversed and the weighed, mown clippings again scattered over the grazed section. This alternation of defoliation method is carried on throughout the season. Hudson preferred a deliberate as opposed to random plot layout even although it precluded valid statistical analyses. The sheep used to graze the plots are 'conditioned' on pasture similar to that under trial to avoid transference of fertility, but as the treatment plots within the area are not individually fenced, the resultant open-grazing of plots with different production potential can lead to transference of fertility between plots (Lynch, 1947; Sears, 1951a). Hudson (1933) was cognizant of this defect and suggested the use of individual plots, each with its own 'conditioning' area. This detracts from the simplicity of the technique because it necessitates an elaborate arrangement of fencing.

Hudson's technique has been applied widely in Sweden and Norway, including an adaptation of the method with annual alternation of mowing and grazing using dairy cows (Gobel, 1940; Sakshaug, 1940).

Proportional return of nutrients

To prevent the transference of fertility from plot to plot which occurs when sheep graze treatment plots in a common enclosure, Sears (1944, 1951a) devised the technique of returning stock droppings in proportion to the herbage produced. Before grazing, cuts are taken in the plots, a sample of the herbage drawn and the clippings returned. The herbage is then eaten down to the level of the mower cut in 2-3 days by sheep harnessed for dung and urine collection. This harness has been described by Sears and Goodall (1942). After grazing, neglected herbage growth is trimmed and the collected dung and urine returned to the plots in proportion to the dry matter yields. The technique has been criticized by Lynch (1947) as laborious, expensive and not suitable for regional trials outwith research stations. McNeur (1953) noted that animals often concentrated on the mown strips and overgrazed the new growth to such an extent that the strips were conspicuous even after weeks of regrowth. Since the plots are open-grazed, the yield potential of palatable herbage plants could also be adversely affected by overgrazing.

Applications of the technique were made by Sears and collaborators in a large-scale investigation of the effects of mowing and grazing, with and without the return of dung and urine, on pasture growth and soil fertility (Sears and Thurston, 1952; Sears, 1953a; Sears et al., 1953). In Britain, Watkin (1954) and Wolton (1955) made use of the technique whilst Wolton (1963) later used a modification in which the plot herbage was cut, fed indoors to sheep and the collected dung and urine returned to the plots. In another cutting trial, Chestnutt (1960) applied dung and urine after each cut proportional to the excreta which would have been left by grazing animals. He also had each plot trampled by a pony to simulate the treading effects of grazing animals; in this connection, Holliday (1953) has surmised that the treading effect is simulated to some extent by the amount of walking on the plots that takes place when personnel make observations, plant counts or cuts.

Grazing to mower height

In this technique, herbage samples from quadrats or strips are cut from plots and the plots stocked heavily enough so that the herbage is grazed down to the level of the cuts in 2-3 days or less. After a rest period the cycle is repeated (Stapledon and Milton, 1932; Sears, 1944, 1951a, 1953a; Sears et al., 1953; Iruokuna, 1960b; Bryant and Blaser, 1961). The chief drawback is to ensure that grazing is neither above nor below the level of the cuts so as to prevent over- or underestimates respectively of the succeeding growth. To encourage uniform regrowth, the neglected herbage is usually mown after grazing to the cutting height and distributed evenly. As growth during the grazing periods is not accounted for, the measured yields are underestimates. This is not a serious objection in trials where comparative rather than maximum productivities are wanted and also because the periods are short. If required, estimates of growth during grazing can be made by measurement or calculation.

Transference of fertility from plot to plot can occur by way of the stock droppings if the plots are open-grazed. To obviate this Sears developed his 'proportional return of nutrients' technique in conjunction with 'grazing to mower height' (Sears 1944, 1951a). Another method of preventing fertility transference is the use of individually fenced plots, provided the animals are conditioned on areas of pasture treated in a similar manner to the treatment plots before entry; this ensures that the return of excretal nutrients is related to their uptake in the herbage. This procedure was carried out by Watkin (1954, 1957), Wheeler (1958), Brockman and Wolton (1963) and Herriott and Wells (1963).

In a modification of the 'grazing to mower height' technique, Wagner et al. (1950) described a 'mower strip' technique in which strips of herbage are cut to 2 in. from ground level by mower immediately prior to each cattle grazing. The sum of these cuts over the season is taken as an estimate of herbage yield. The method does not require much specialized equipment and is easy and simple to operate. It does not account for growth during the grazing periods and is unsuitable for continuously grazed pasture. Wagner did not state whether or not grazing to the mower height had to be attempted or was essential. All in all, the technique would not seem to be very precise. Applications of the technique have since been reported by Brundage et al. (1956) and Taylor et al. (1960).

Plucking or cutting to grazing height

In this technique, several frames or cages are placed on the plots to protect areas of herbage during grazing. After grazing, samples of the herbage within the frames are plucked by hand or cut to the level of the grazed herbage outside the frames. Account is thus taken of growth during the grazing period. With hand-plucking the aim is to copy the irregular defoliation pattern of grazing animals until the appearance of the sward within the frames matches that of the grazed sward outside (American Joint Committee Report, 1943, 1952;

Lynch, 1947; Sears, 1951a) but Sears has stressed the need for a reliable team of workers and for constant checking of the results by other measurement means since sampling is laborious and fraught with risk of personal bias. A similar risk is present when cutting to the approximate level of the grazed herbage outside the frames, a technique used by Sears and Newbold (1942), Sears <u>et al</u>. (194[illegible]), Sears and Thurston (1952), Ahlgren <u>et al</u>. (1944a, b), Wagner <u>et al</u>. (1950), Hughes and Davis (1951), Hunt and Thomson (1955).

As in the 'grazing to mower height' technique, transference of fertility can be prevented by using the 'proportional return of nutrients' technique in conjunction with open-grazing of the plots, or by using individually fenced plots with their own conditioning areas. Brougham (1959, 1960) used this latter method. If the grazing period is prolonged, yield may be overestimated because growth inside the cages, uninterrupted by grazing, will be at a higher rate than growth outside, which is interrupted by grazing.

The types of wire mesh cages or frames used as exclosures to prevent stock grazing in this technique and in those described later have been reviewed by Brown (1954). They vary in form and construction and may be rectangular or elliptical in shape, metal or wooden, roofed or roofless, portable or fixed. Provided their function of excluding stock is not impaired, the more open the cages, the nearer is the environment within to that outside. Amelioration of the environment within the cages has been noted by Daubenmire (1940), Williams (1951) and Cowlishaw (1951). The latter obtained an 11% increase in yield of herbage from cage-protected swards in comparison with unprotected swards. To overcome this problem, electric cages, consisting of a metal frame with 2 or 3 strands of wire electrified by overhead cable, have been developed (Sears and Newbold, 1942; Prendergast and Brady, 1955).

As suggested by Jones (1957), amelioration of microclimate is also possible in small, permanently fenced plots though conceivably not to the extent found in roofed cages with a fairly close wire mesh such as Cowlishaw (1951) used. Williams (1951) noted that amelioration was less with a roofless, hurdle-type exclosure than with a roofed cage.

Direct harvest technique

In 1934, an American Joint Committee on pasture research (Vinall, 1934) recommended a clipping method for estimating pasture production later designated as the 'direct harvest' technique by Nevens (1945). Between these dates, Hodgson et al. (1934) and Nevens (1941, 1943) made use of the technique. In the method, measuring cuts are taken at the beginning of the season prior to grazing and cages placed on the cut areas. Approximately 2-3 weeks later, the herbage from these areas is harvested and the cages placed on other pre-trimmed areas. This procedure is repeated until the end of the season. The interval between cuts can be arbitrary or adjusted either according to the seasonality of growth or to the grazing method employed. A similar technique has been applied by Morrison and Ely (1946), Boyd (1949), Davies et al. (1950), Hughes (1951), and Schultz et al. (1959), whilst its use is further endorsed by the American Joint Committee Report (1952).

The use of a trimming cut has been criticized by Linehan et al. (1952) and Brown (1954), because of differences in the growth rate on trimmed and untrimmed pasture. Initially growth is slower on the trimmed than on the untrimmed area, but later this position is reversed because of defoliation by grazing on the untrimmed area outside the cages. Also, the trimming method does not allow for herbage left uneaten after each grazing. To work satisfactorily the grazing intensity should be such as to defoliate the pasture to approximately the cutting height. If the pasture is grazed below the cutting height, the method will underestimate production.

A method similar to the direct harvest technique, except that the herbage is not trimmed before the cages are placed, has been described by Schuster (1929) and Rhoad and Carr (1945). Applications have been made by Hughes (1951, 1952), Tesar et al. (1958a, b) and Davis and Bell (1958).

New Zealand standard technique

Lynch (1947) has described the 'standard' technique used by the Extension Division of the Department of Agriculture in New Zealand. Herbage growth produced from pasture, pre-trimmed by mower and protected by cages, is measured by cutting. The cuts are not made until 2-4 days after the completion of grazing to allow recovery of the grazed herbage above the cutting height. At the same time new areas are trimmed to receive the cages. Measurement of production is thus always from cutting height to cutting height.

A so-called 'rate of growth' technique, also used in New Zealand has been recorded by Lynch (1951) and Lynch and Mountier (1954). It is an adaptation of the 'standard' technique but regular intervals, usually 2 or 3 weeks are maintained between cuts so that changes in production over the season can be closely followed. Application of the technique has been made by Weeda (1965).

Lynch's techniques are similar to Nevens' 'direct harvest' technique except that the cuts are delayed for 2-4 days after grazing. Brown (1954) classifies Nevens' method as suitable for rapid-growing herbage and Lynch's for slow-growing herbage.

Difference techniques

Several difference techniques used at Illinois to measure pasture production have been described by Fuelleman and Burlison (1939, 1940) and Nevens

(1941, 1945). Measuring cuts are taken at the beginning of the season and cages placed on these cut areas and also on uncut areas. Approximately 3-4 weeks later, herbage cuts are taken from these cage-protected areas and from unprotected pasture areas outside the cages. The cages are then shifted to both cut and uncut areas on the grazed sward. In effect the cages are placed on trimmed and untrimmed pasture. This procedure is repeated during the season. The types of samples may be listed as:

A - herbage cut from pasture protected by cages, placed on untrimmed areas.

B - herbage cut from unprotected pasture on same date as A.

C - herbage cut from unprotected pasture on previous date to A.

D - herbage cut from pasture protected by cages placed on trimmed areas.

Fuelleman and Burlison used A-C to estimate yield and D-B to estimate consumption but Nevens designated three difference methods as measures of pasture production, namely (i) A-B, (ii) A-C, and (iii) A+C+ end of season growth. The A-B method actually measures the herbage consumed or utilized (Vinall, 1934; Hodgson _et al._, 1942; American Joint Committee Report, 1943; Lynch, 1947; Rawes and Welch, 1964) and as such was taken by Nevens to represent an estimate of pasture production. Linehan and Lowe (1946) and Linehan _et al._ (1947, 1952) have also used the A-B method in this sense. They found that during favourable growth conditions or when the grazing period was prolonged, the method over-estimated production since the cage-protected herbage grew faster than the herbage outside the cage which was subjected to defoliation. Accordingly they introduced a correction factor in the shape of a mathematical formula to allow for these differences in growth. Applications of their technique have since been reported by Waite _et al._ (1950), Bosch, (1956), and Freer (1959).

Other workers have used the A-C method to measure the herbage growth produced (Lynch, 1947; Boyd, 1949; Procter and Lewis, 1950; Davies et al., 1950; Castle, 1953; Schultz et al., 1959; Moore et al., 1946). Moore and his co-workers in Australia cut to ground level with power-driven sheep shears whereas the other workers cut at a slightly higher level and used cutting equipment such as knife, clippers, rotoscythe or autoscythe. If stock can graze below the height of cut at sampling production will be underestimated.

If the 'D' samples above are summed over the season together with the measuring cut at the beginning of the season, the result would be an estimate of production according to the 'direct harvest' technique. Similarly, if the 'A' samples are summed, the result would be a measure of yield according to the 'direct harvest' technique on untrimmed pasture.

In another type of difference technique the herbage available for grazing is measured by pre-grazing sample cuts and the residual herbage after grazing by post-grazing sample cuts. The plots are stocked at a sufficient density to ensure that the herbage is grazed down in 1-2 days. The amount of herbage removed, which may be regarded as a measure of consumption or utilized yield, is obtained from the difference in weight between the pre- and post-grazing cuts. Jones (1932) used this method in conjunction with tethered sheep to graze down unfenced plots and later (Jones, 1937) with individually fenced plots or movable folds. The use of movable folds is cheaper than an elaborate network of fencing and interferes less with the growth environment and management of the swards. The technique approaches normal grazing conditions fairly closely and since the grazing period is short, growth during this period, which is unmeasured, is kept to a minimum. If the grazing period is prolonged the utilized yield will be underestimated unless an estimate is made of this growth as was done by Freer (1960). Sampling is usually carried out by cutting strip or quadrat areas of herbage with hand shears, power-driven sheep shears, hedgetrimmers or similar types of equipment. Applications of this difference technique have been made by Waite et al. (1950), Linehan et al. (1952), Maclusky (1955), Lowe (1959), Line (1959), Davison (1959), Freer (1959), Muokuna (1960b), Bone and Tayler (1963) and Campbell (1964). The cutting height must be low enough to prevent stock grazing below the level of cutting and to prevent underestimation of the grazed residue, some of which could be trampled below the cutting height; consequently, the samples are cut close to or at ground level. Recovery of the cut areas may be impaired due to this drastic defoliation and because stock preferentially nibble the regrowths on these areas at later grazings. With the need to take sufficient samples to estimate pasture yield satisfactorily, such cut areas can, if not restricted, accumulate to form a significant proportion of the total area and affect the subsequent growth and development of the sward. In large-scale trials there may also be physical limitations to the taking of sufficient samples.

Special mention may be made of power-driven sheep shears, the use of which was pioneered in Australia (Morgan and Geruldsen, 1931; Richardson and Gallus, 1932). The shearhead is a versatile instrument and can cut procumbent or tall herbage. It is also suitable for steep or uneven surface conditions where larger equipment would be unsatisfactory. Because of the narrow cutting-width, usually 3 in., care is required to avoid edge effects and for this reason, many workers cut within quadrats (Alder and Richards, 1962) although others cut long narrow strips along a straight edge (Green et al., 1952; Bone and Tayler, 1963).

With ground-level cutting, some degree of soil contamination is inevitable. This can occur as a result of excessively low cutting or of allowing the cut herbage to touch the soil surface. With care such contamination can be kept to a minimum. It is more difficult to eliminate the soil contamination which can occur as a result of stock treading especially in wet conditions or on an open sward. Soil can also be splashed on to the herbage by rain or blown on to it by wind. Contamination limits the use of dry matter as an expression of quantity. Some degree of soil contamination is also possible even when the cutting height is ½ to ¾ in. above ground level (Woodman et al., 1926, 1927, 1928, 1929, 1931; Woodman and Norman, 1932; Watson et al., 1932; Davies et al., 1950). These workers measured the extent of the contamination and accordingly adjusted their dry matter yield figures and chemical composition data. Thompson and Raven (1955) noted that analyses of major and trace mineral elements were adversely affected by soil contamination and also found that considerable leaching of these elements occurred when herbage samples were washed. Thus it would seem that ashing, with the use of organic matter as the expression of quantity is logical as suggested by Green (1959) and employed by Alder and Richards (1962) and Bone and Tayler (1963). Ash contents of grasses and clovers at various stages of growth have been listed by Watson (1951) and Evans (1960).

Electronic techniques

The use of electronic instruments to measure herbage yield in situ shows promise. Initial developments in this field have been reported by Fletcher and Robinson (1956) and Campbell et al. (1962). The latter have described an electrical capacitance measuring unit in which the introduction of herbage to a measuring head causes a change in capacitance. This change is then measured at a radio frequency and used to indicate the mass of herbage within the measuring head. Modified versions of this instrument have since been developed and reported by Alcock (1964a), Hyde and Lawrence (1964), Johns et al. (1965) and Johns and Watkin (1965).

Once perfected, an electronic technique of estimating pasture yield would have obvious advantages in a wide range of pasture measurement studies. It would reduce the effects of sampling for yield on subsequent pasture growth and development and increase the accuracy of sampling at the same time since large numbers of estimates could be made. Grazing at particular levels of herbage yield and grazing down to particular levels would be possible. These and other advantages have been listed by Campbell et al. (1962). Further research into electronic techniques of measuring pasture yield is therefore fully warranted and desirable.

(b) Defoliation methods (cutting and grazing)

Cutting effects

In most grassland research throughout the world, some form of cutting technique is usually employed to measure herbage productivity. Cutting is easy, quick, simple and cheap and a wealth of information can be derived particularly when herbage yields are supplemented with feeding value data such as digestibility (Ivins et al., 1958; Green, 1959; Ivins, 1960). A large variety of cutting equipment, hand and mechanically driven, has been developed over the years, including shears, sickle, scythe, lawn mower, field mower, motor scythe, hedgetrimmer and power-driven sheep shears. A general review of suitable equipment has been given by Brown (1954) whilst the C.A.B. Bulletin 45 (1961) details the types in general use at the Grassland Research Institute for Britain. More recently a self-propelled herbage plot harvester capable of cutting, collecting and weighing the produce of 120 plots per hour with a driver and assistant (Chalmers and Kemp, 1964) and a portable battery-operated cutter (Hatches, 1963) have been described.

Because of the importance of grazing in the utilization of grassland, many of the cutting systems have been devised to simulate grazing, e.g. cutting carried out every time the herbage reaches a 'grazing' stage of 7-9 in. herbage. Fixed intervals of time such as 4- or 5-weekly are also commonly used. With cutting, all the herbage is cut uniformly and suddenly to a designated level, palatable and unpalatable plants are equally defoliated, erect plants may be defoliated more severely than prostrate and the amount of herbage removed may differ from that removed by grazing. In contrast, grazing animals exert a treading effect, defoliate selectively not only plants but parts of plants, defoliate at random heights over a period of time and return nutrients in the form of stock droppings. Changes in botanical composition, reduction in yield and vigour and general deterioration of the sward have been noted with repeated cutting (Richardson and Gallus, 1932; Hudson, 1933; Sears, 1953a; Sears et al., 1953). The limitations to the presumption that cutting can fully simulate grazing have been recognized and reviewed by many workers (Stapledon et al., 1924; Klapp, 1937; Jones, 1939; Lynch, 1947; Brown, 1954; Jones, 1958; American Joint Committee Report, 1962; Jameson, 1963). As previously discussed under the section on measurement techniques, much effort has been devoted to overcome these limitations by the development of techniques in which the various grazing effects are simulated whilst still retaining the simplicity of cutting.

Objections to cutting do not hold when simulating field mowing for herbage conservation and many workers have satisfactorily measured hay, silage and dried grass production in plot trials (Stapledon, 1922; Stapledon and Davies, 1930; Holmes, 1948; Hood, 1956; Hunt and Gardner, 1956; Chestnutt, 1960 and many others). Cutting would also seem the most satisfactory method of assessing production on land where a high water table precludes grazing experiments (Nicholson et al., 1953).

Grazing effects : treading

Few critical investigations have been made on the treading effects of grazing animals on pasture. Treading damage was believed to be significant mainly around gateways, farm tracks and water or feeding troughs, where the pasture and soil were intimately churned up and the effects plainly visible. Such 'poached', 'puddled' or 'pugged' areas were regarded as inevitable. Apart from studies of the vegetation on stock paths and tracks (Bates, 1930, 1935, 1937, 1951; Davies, 1938), little regard has been paid to the less extreme effects of normal everyday treading during grazing. With the trend in recent years of higher stocking densities on pasture to increase the efficiency of utilization, interest in the effects of treading has been kindled and critical studies initiated, particularly in New Zealand where Edmond (1958a) evolved a special technique to study the short-term effects of treading as a single factor free from the effects of defoliation and return of excreta. Treading can affect the yield and botanical composition of a pasture directly, but also indirectly by its effects upon the soil environment.

Information on the size and shape of sheep hooves and the pressure exerted by them is sparse but Sears (1956) has estimated that the area of a hoofprint is about 2 sq.in. and the pressure around 30 lb per sq.in. Estimates of the distance walked daily by downland sheep during grazing have varied between 0.4 to 1.7 miles (Hughes and Reid, 1951; Cresswell, 1957).

Direct effects: By bruising or destruction, treading can cause direct injury to the growing points, stems, leaves and roots of herbage plants in pasture (Bates, 1930, 1935, 1951; Klečka, 1937; Davies, 1938; Lieth, 1954; O'Connor, 1956; Edmond, 1958a, c, 1962, 1963, 1964). With increased stocking rate and consequently increased treading, damage to the plants is also increased. Damage was reduced in long herbage (O'Connor, 1956) but direct injury, particularly root damage, plant displacement and burial in the soil, was greater in wet than in dry conditions (Edmond, 1962, 1963). Suckling (1956) observed that close-knit, dense swards with many small tillers, which developed under continuous grazing, suffered less damage from treading than the more open swards with fewer, although larger tillers, which developed under rotational grazing. Bates (1930), Davies (1938) and Donald (1941) have suggested that the structure of plants determines their tolerance to pressure or injury by hooves and to smother in puddled areas. Since the growing points of most grasses are at or near the soil surface (Sharman, 1947; Branson, 1953), they may all be to some degree susceptible to treading damage. The ability of perennial ryegrass, normally a tufted grass, to assume a rhizomatous growth form under heavy treading, may reduce its liability to damage and increase its ability to disperse and regenerate (Mitchell, 1960). Edmond (1958a, 1963) noted that the stems of white clover were particularly susceptible to damage.

Changes in the botanical composition of pasture can be induced since plant species differ in their reaction to treading. Bates (1930, 1935, 1937, 1951), Sears (1953a, 1956), Lieth (1954) and Edmond (1963, 1964) found that perennial ryegrass was tolerant to heavy treading whereas white clover was susceptible (Thomas, 1949; Edmond, 1958a, 1964; Klečka, 1937), although less so in summer, when it was actively growing, than at other times of the year and less so in moist than in dry soil (Edmond, 1962, 1963). The changes in botanical composition were permanent. Under heavy treading the ranking of plant tolerance from most to least of 10 pasture species as found by Edmond (1964) was: perennial ryegrass, smooth-stalked meadow grass, rough-stalked meadow grass, short-rotation ryegrass, browntop, white clover, timothy, cocksfoot, red clover and Yorkshire fog. Under moderate treading, the order was substantially the same. Dock, dandelion, ragwort and annual meadow grass were tolerant of treading and colonised poached areas (Edmond, 1958a, 1962, 1963, 1964; Thomas, 1960). The plant tolerance listing above is in broad agreement with that of the German worker, Ellenberg (1952).

Treading damage to the herbage plants and the invasion of weed species have the net effect of reducing the productive capacity of the sward. Edmond (1958a, c, 1964) and Schaaf (1965) showed that as treading intensity increased, herbage yield decreased. The reduction was greater under moist than under dry conditions (Edmond, 1962, 1963). The decrease in yield resulted from direct injury to plants and a reduction in the density and growth vigour of the grass tillers and clover nodes. In the Netherlands, Schothorst (1963a, b) found that yield reduction was greater in soils rich in organic matter than in light sandy soils and in wet than in dry years.

Some degree of treading can be beneficial to pasture since certain weeds of economic importance are more susceptible to damage than desirable plants and can be destroyed by heavy treading (Levy, 1955). Sears (1956) noted that bracken fern in New Zealand could be controlled in this manner. In Scotland, trampling by stock to check such plants as bog myrtle and blueberry is an important part of several surface seeding techniques to improve rough grazings (Gardner et al., 1954; Copeman and Roberts, 1960). Braid (1947) also found that the growth of bracken could be checked by trampling which broke the fronds and also destroyed frond buds while still in the soil.

Indirect effects: By the immediate effect of direct injury to the soil and the more persistent effect of causing change in the physical and chemical condition of the soil, treading can influence sward vigour and herbage yield indirectly. Treading causes compaction of the top layer of soil (Bates, 1935; Klečka, 1937; Liet , 1954; O'Connor, 1956; Thomas, 1960) and this compaction effects such physical attributes of the soil as apparent density, aggregation, pore size distribution and friability. These attributes influence plant growth through their effects on soil moisture, air, temperature and mechanical impedance to root development and shoot emergence. Soil type, plant species, stage of development of the plants and climate will determine which of these growth factors becomes limiting. Low water infiltration into the soil and puddling of the soil surface due to compaction by treading was noted by Chandler (1940), Alderfer and Robinson (1947), Edmond (1958a, b) and Bradwell (1960) whilst impeded gaseous diffusion, particularly of oxygen, was found by Edmond (1958a, 1963) and Tanner and Mamaril (1959). The thermal properties of the soil such as conductivity, diffusivity or temperature are influenced in part by soil moisture and soil air relationships (Richards and Wadleigh, 1952).

Compaction can also impede root penetration and development (Edmond, 1958b; Lutz, 1952; Rosenberg, 1964). Thus, reduced sward vigour and herbage yield due to compaction and its effects on the soil environment have been noted by Peterson et al. (1956), Edmond (1958b, 1963), Tanner and Mamaril (1959) and Gradwell (1965, 1966). These effects are modified by climate since heaving of the soil by winter frosts helps to remedy the effects of excessive trampling in temperate countries. Under arid conditions, the effects may be intensified and lead to wind and water erosion (Crocker, 1952; Thomas, 1960). The effects are also influenced by soil type. Soils with low organic matter contents such as light sandy types will not poach readily because they have a limited water-retaining capacity; in contrast, peaty or clay soils will poach readily, particularly in wet weather (Tanner and Mamaril, 1959; Schothorst, 1963b; Wind and Schothorst, 1965).

It is difficult to evaluate the tolerance of individual plant species to soil compaction alone since the direct and indirect effects of treading are exerted simultaneously. Thus, tolerance to treading in a plant is probably a combination of ability to withstand or recover from direct injury such as bruising or crushing and ability to withstand or overcome the effects of compaction on the soil environment. The tolerance classification of plant species to the direct effects of treading already listed will also apply to the indirect effects.

In some cases, moderate treading may benefit the soil by its consolidating effects. In the south of England, sheep folding on light land prior to cropping was long known and practised, partly for the return of excreta but more so for mechanical consolidation by the pressure of hooves. The effect was crystallized in the phrase 'golden hoof' (Keen and Cashen, 1932). Pasture establishment also benefits from some degree of treading (Davies, 1938; Herriott, 1958).

Consolidation is more necessary on light than on heavy soils and on dry than on wet soils.

Grazing effects : selective grazing

There is universal agreement that sheep and cattle graze pasture selectively though it is still not clear whether they select herbage because of greater acceptability of the selected relative to the rejected herbage, or according to their nutritional requirements (Tribe, 1950; Ivins, 1955; Garner, 1963; Waite, 1963; Arnold, 1964). The reasons why stock graze selectively are outwith the scope of this review. The influence of selective grazing has always been inseparably linked to severity and frequency of defoliation and to treading. It is therefore difficult to ascribe clear-cut effects of selectivity *per se* on yield or botanical composition.

Herbage selected: Direct observation studies and quantitative herbage measurements have shown that leaf is selected rather than stem (Davies, 1925; Stapledon *et al.*, 1927; Stapledon and Milton, 1932; Arnold, 1960), succulent young herbage is preferred to drier, more mature herbage (Stapledon and Milton, 1932; Stapledon, 1934; Johnstone-Wallace and Kennedy, 1944; Milton, 1953) and green material is chosen in preference to 'winterburnt' material (Stapledon and Davies, 1926; Stapledon and Jones, 1927; Milton, 1933; Cowlishaw and Alder, 1960). Easily accessible herbage is usually preferred to less accessible when the forages are of equal attractiveness to the stock (Davies, 1925; Stapledon and Davies, 1926; Norman, 1957) and possibly for this reason erect-growing plants are grazed in preference to prostrate-growing plants (Stapledon and Milton, 1932; Martin Jones, 1933d). However, Johnstone-Wallace and Kennedy (1944) found that short immature herbage may be selected even when taller herbage is present. They also noted that accumulated dead herbage at the base of the sward discouraged close grazing. Harshness and hairiness in plants renders them less acceptable to grazing animals (Davies, 1925; Stapledon, 1927) while the presence of disliked species can strongly influence the utilization of liked species (Milton, 1933, 1953) and the presence of fungal disease may make herbage obnoxious to stock (Davies and Thomas, 192 ; Ivins, 1952; Cowlishaw and Alder, 1960). Herbage contaminated by dung or growing in the vicinity of dung patches is not attractive to stock (Sears and Newbold, 1942; Johnstone-Wallace and Kennedy, 1944; Procter and Hood, 1953; Norman and Green, 1958; Maclusky, 1960). This effect is cumulative and the area affected will increase rapidly in intensive grazing systems unless some form of alternate cutting and grazing management is practised (Ivins, 1954). In contrast it has been noted that urine does not diminish the acceptability of herbage (Nevens, 1941; Norman and Green, 1958; Voisin, 1959).

Studies on the herbage intakes of grazing animals using faecal techniques have shown differences in nutrient value between the herbage available and the herbage grazed, indicating that selective grazing had occurred. Over a grazing season, Hardison et al. (1954) found that clipped available herbage had a poorer nutrient content and was only 94% as digestible as the herbage grazed. Similar findings have been reported by Raymond et al. (1956) and Meyer et al. (1957). Other workers (Torell and Weir, 1956; Heady and Torell, 1959; Weir and Torell, 1959) used oesophageal fistula techniques developed by Torell (1954) and Cook et al. (1958) to collect samples of the actual forage consumed. Comparison of the botanical and chemical composition of this forage with that available for grazing showed that a considerable degree of selection had taken place.

Several lists of the relative palatability or acceptability ratings of individual herbage species have been published (Davies, 1925; Stapledon and Milton, 1932; Reid, 1951; Ivins, 1952; Cowlishaw and Alder, 1960). Among the commonly used species, white clover, timothy and meadow fescue were usually rated very highly, perennial ryegrass, italian ryegrass and cocksfoot less highly, and tall fescue and red fescue very lowly.

Differences between stock: It is generally recognized that sheep graze more selectively than cattle. They graze a wider range of plant species but almost exclusively choose leaf (Stapledon et al., 1924; Stapledon and Jones, 1927; Schuster, 1929; Beruldsen and Morgan, 1934, 1938; Watson, 1948, 1951; Thomas, 1949). Levy (1955) noted the value of selective grazing for weed control in New Zealand where sheep grazed and thereby controlled the spread of ragwort, dock and ox-eye daisy in cattle pastures. In British experiments on downland permanent pasture, Norman (1957) found fewer forbs present after sheep grazing than after cattle grazing.

Differences between grazing systems: Selective grazing is most pronounced under conditions of extensive grazing since extreme selectivity can be practised by the stock (Martin Jones, 1933d; Tribe, 1948; Jones, 1952; Spedding, 1965). Excessive grazing of palatable species can reduce their competitive ability and ultimately cause their disappearance from the sward. When this happens to the more productive species in the sward, yield will suffer. In intensive grazing systems or in small experimental plots where grazing pressure is usually high, the opportunity for selective grazing is restricted and both palatable and less palatable plants may be equally grazed (Davies, 1925; Donald, 1941; Kydd, 1957; Blaser et al., 1960; Alcock, 1964b). Martin Jones (1933a, b, c, d) has clearly shown how the botanical composition of mixed swards can be altered at will by variations in grazing practices. Treading and excreta effects operated in his experiments, but selective grazing at various frequencies and severities and at various seasons of the year played the major part in changing the composition.

Grazing effects : excreta

The manurial value of animal excreta has long been recognized in agriculture but mainly in systems of husbandry involving winter housing of stock, where the excreta is collected, stored and later distributed on to the land. In contrast, the manurial effects of dung and urine from grazing animals has received scant attention. In recent years, investigations by Sears and collaborators in New Zealand have emphasized the role played by animal excreta in the fertility cycle of grazed pastures. As a result, many sward trials have been initiated to study the influence of dung and urine, either together or separately, on herbage production and botanical composition. In many of the studies, sheep harnessed for the collection of dung and urine were used to graze small plots and the normal return of excreta under grazing conditions simulated (Sears and Goodall, 1942; Watkin, 1954; Herriott and Wells, 1963).

Effects on herbage yield: Under intensive sheep grazing, Sears and Newbold (1942) and Sears et al. (1948) found that the combined application of dung and urine on grass/clover swards resulted in considerable yield increase compared with swards where the excreta were withheld; dung or urine added separately gave intermediate results. Similar effects on yield were obtained by Sears (1944, 1953a), Sears et al. (1953) and Herriott and Wells (1963) on grass and grass/clover swards from the combined use of dung and urine, and by Nevens (1941) and Mundy (1961) from urine alone. Growth response in the local vicinity of individual urine patches has been reported by Thompson and Coup (1943), Doak (1952), Norman and Green (1958), During and McNaught (1961) and Dale (1961) while response around dung patches has been noted by Norman and Green (1958). On the other hand, a temporary reduction or complete absence of local growth in excreta patches has been observed either due to urine 'burn' (Thompson and Coup, 1940; Doak, 1951, 1954; Dale, 1961) or to dung 'smother'

(Bornemissza, 1960). These harmful effects of excreta are intensified in hot, dry weather but are smaller and less permanent with droppings from sheep than from cattle. In the experiments reviewed here, excreta from sheep were mainly used, either by allowing natural return under grazing or by collecting excreta and simulating natural return. In some cases, cattle urine was collected and natural return simulated. Saunders and Metson (1959) have shown that the general effects of sheep and cattle urine on pasture are similar and depend upon the quantities of nutrients applied.

In other studies (Sears and Thurston, 1952; Watson and Lapins, 1964) herbage yields from swards were similar whether or not excreta were returned. These effects were also obtained by Watkin (1954) and Wheeler (1958) in the absence of fertilizer nitrogen but where fertilizer was added, particularly at high levels of 200-300 lb/ac nitrogen, the return of urine alone or with dung increased yield. Dung alone had little effect except at the highest fertilizer level. These results have been explained on the basis of antagonism between the various sources of nitrogen. Excretal nitrogen, especially from urine, or fertilizer nitrogen caused depression of clover with subsequent loss of symbiotic nitrogen. Thus yield was unaffected since the gain from added nitrogen was counterbalanced by the loss resulting from the reduction of clover nitrogen. Only when this loss was more than overcome by the application of high levels of fertilizer nitrogen, was a yield response obtained from the return of excreta. As suggested by Metson and Hurst (1953), the input of animal nitrogen into the clover nitrogen cycle does not supplement the output of sward nitrogen but substitutes for the clover nitrogen.

Green and Cowling (1960) have suggested that once a grass/clover sward has become grass dominant, a significant yield response to animal excreta is likely since the animal-clover nitrogen interaction will be small. Support for this hypothesis may be inferred from the data presented by Mundy (1961) and Herriott and Wells (1963). Yield increases from the return of excreta on pure grass swards have been obtained by Sears (1953a) and Sears et al. (1953).

Effects on botanical composition: Many workers have recorded the influence of animal excreta on the botanical composition of swards. The main effect was on the grass:clover ratio, which was altered to grass dominance by the return of both dung and urine or urine alone and to clover dominance by the return of dung alone or by the withholding of all excreta (Martin Jones, 1933c; Dusserre, 1933; Sears and Newbold, 1942; Sears, 1944, 1953a; Sears et al., 1948, 1953; Watkin, 1954; Wheeler, 1958; Herriott et al., 1959; Mundy, 1961; Herriott and Wells, 1963). This effect has been attributed to the readily available nitrogen in the urine fraction of the excreta. By stimulating grass growth, this nitrogen causes the progressive suppression of clover through the direct and indirect effects of shading on the clover by the taller grass (Blackman and Templeman, 1938; Donald, 1963).

In laboratory studies of the local effects of urine, Doak (1954) found that seeds wetted by urine were killed and the emergence of seedlings from below urine-impregnated soil largely prevented. Clovers were affected more than grasses or weeds. He also reported the presence of a root-growth inhibitor to which clover roots were extremely sensitive. Wheeler (1958), who noted that urine restricted the incursion of weed species into swards, later found that urine reduced germination and establishment of annual meadow grass (Wheeler, 1959). On grass-dominant permanent pasture, little change in botanical composition was noted by Norman and Green (1958) from single applications of urine or dung. Dale (1961) reported that Chewing's fescue was more resistant to urine 'burn' than perennial ryegrass.

Nutrient value of excreta: Studies on the return of animal excreta to the sward have shown that a large proportion of the nutrients contained in the grasses and clovers are excreted after ingestion, the amount retained varying with the age, physiological state and class of stock (Salter and Schollenberger, 1938; Sears, 1950, 1951a, b; Petersen et al., 1956b). Fattening cattle and sheep may excrete over 90% of the ingested nitrogen and ash, and dairy cattle about 75% of the nitrogen and 90% of the ash. Thus under grazing conditions the most important means of transfer of clover nitrogen to grass is through the grazing animal (Sears, 1953a; Walker, 1956; Maclusky, 1956). Measurements of the quantities of nutrients excreted at pasture have been made by Sears and Newbold (1942) and Sears et al. (1948) under New Zealand conditions and by Herriott et al. (1959) and Herriott and Wells (1963) under Scottish conditions. The Scottish workers showed that over a grazing season, the per acre return from sheep was 130-140 lb nitrogen, 115-120 lb potassium, 15 lb phosphorus, 15 lb calcium and 8 lb magnesium.

Major differences exist between the two forms of excreta as regards nutrient content and availability for plant growth. Urine contains most of the nitrogen and potassium while most of the phosphorus is in the dung. With sheep grazing, it has been reported that the urine contained 70-75% of the nitrogen, 85-90% of the potassium and 80-85% of the magnesium while the dung contained 98-100% of the phosphorus and calcium (Sears and Newbold, 1942; Doak, 1951; Herriott et al., 1959; Herriott and Wells; 1963; Mundy, 1961). Since the amount of soluble and readily available nitrogen and phosphorus in the dung is low, its full utilization by herbage plants can only be realized after prolonged action by the soil micro-organisms whereas the urinary nitrogen and potassium is almost immediately available (Sears and Newbold, 1942; Jewitt and Barlow, 1949; Doak, 1951, 1952; Watkin, 1957; Barrow, 1961). The marked effects of urine on the herbage yields and botanical composition of swards are thus related to its high content of available nitrogen and potassium. Herriott and Wells (1963) stressed the value of potassium in soils inherently poor in potassium. In their experiment, they concluded that the 22% increase in herbage yield from the return of excreta was attributable to potassium deficiency in the control plots. Conversely, Metson and Hurst (1953), who examined soil fertility in relation to the experiment of Sears and Thurston (1952), concluded that the high potassium-supplying power of the soil was largely responsible for high herbage yields even when excreta were withheld, by encouraging vigorous clover growth.

Apart from the major nutrients, Gisiger (1950) ascribed some value to trace elements, particularly manganese and boron. Value has also been attributed to indole-acetic acid and creatinine in the urine as growth-promoting hormones (Salter and Schollenberger, 1938; Sauerlandt, 1948; Doak, 1954) or to the water content of the urine (Sauerlandt, 1948; Watkin, 1957). However, Mundy (1961) found that neither the indole-acetic acid or water content of urine had any effect on the herbage yield and botanical composition of a grass/clover sward, although it is conceivable that the water content could be of local irrigation value in very dry conditions. Dung has value as a source of organic matter for conversion by soil micro-organisms to humus, which plays an important role in the maintenance of soil fertility and soil environment favourable to plant growth. These aspects have been fully reviewed and discussed by Russell (1953).

Pattern of excretal return: Many workers have shown that at low, normal and even relatively high stocking rates with cattle or sheep, the dung and urine are voided unevenly over the sward. The return of nutrients is therefore concentrated in patches which form only a small proportion of the sward (Petersen *et al.*, 1956a, b; Saunders and Metson, 1959; Maclusky, 1960;

Bornemissza, 1960; Elliot, 1962; Herriott and Wells, 1963; Hilder, 1964). Saunders and Metson (1959), for example, estimated that only 25% of the total area of pasture received urine in one year at an assumed stocking rate of 1 cow per 1½ acres, while MacLusky (1959) calculated that with 200 cow grazing days/acre, 20% of the pasture was affected by urine and 20% by dung, assuming a dung pat to affect an area six times its own size. Doak (1951, 1952) estimated that within an area of approximately 100 sq.in. affected by a single sheep urination, the equivalent of 200 lb/ac nitrogen was applied, but due to rapid hydrolysis of the urea, which constitutes the major fraction of the urinary nitrogen, and the high pH engendered, at least 12% of the nitrogen was lost by volatilization of ammonia. Climate is important since rainfall can cause leaching of the urea, and of the nitrites and nitrates from ammonia nitrification (Jewitt and Barlow, 1949; Doak, 1952) while volatilization is increased under hot, dry conditions (Thompson and Coup, 1943). After taking account of these losses together with the low availability of the nitrogen in dung, Walker <u>et al</u>. (1954) calculated that 50-60% of the total ingested nitrogen is available for re-utilization by the sward after excretion. The excessive nitrogen supplied to the sward in the urine patches also encourages grasses at the expense of clovers, so that symbiotic nitrogen fixation is restricted.

During and McNaught (1961) noted that a single cow urination could supply approximately 600 lb/ac potassium on a 420 sq.in. urine patch. High local concentration of potassium encourages 'luxury' uptake by the pasture and loss by leaching (Saunders and Metson, 1959). On soils inherently low in potassium, areas that have not received urine may be deficient again within a few months of applying fertilizer potassium while areas between the urine patches may suffer from nitrogen deficiency due to shortage of potassium leading to poor clover growth (Metson and Saunders, 1962).

With intensively-grazed sheep, Herriott and Wells (1963) calculated nutrient returns per acre of 160 lb nitrogen and 210 lb potassium on urine patches of 100 sq.in.; on dung patches of 12 sq.in. the quantities were 2100 lb nitrogen and 960 lb phosphorus. On the assumption that return was uniform, they calculated that over the season, an acre of sward would receive complete urinary cover six times, whereas with the dung, the frequency of cover was only 0.02. The nitrogen and the potassium of the urine were therefore more uniformly distributed than the phosphorus and calcium in the dung. This pattern of urinary return is only possible on very intensively-grazed swards. These workers also stressed the need for adequate pre-conditioning of the animals on swards similar to the experimental plot swards before entry to the plots. Otherwise, particularly over the short grazing periods usually adopted in small-plot techniques, the animals would possibly not return excreta proportional in quantity or nutrient value to the herbage consumed on the plots. This procedure is of particular importance in relation to nitrogen and potassium, because of their marked effects on sward growth.

Herbage yield under cutting and grazing

In the past, few trials have been conducted on the yield relationships between various cutting and grazing systems. Direct comparisons have been made by Taylor *et al.* (1960) and Bryant and Blaser (1961) in the United States but indirectly, relationships can be inferred from other studies (Richardson and Gallus, 1932; Sears, 1953a; Sears *et al.*, 1953; Wolton, 1963).

Grass swards: On a cocksfoot sward receiving 150-200 lb/ac nitrogen per annum over a 3-year period, Bryant and Blaser (1961) found that under various defoliation frequencies and severities, the yield with cutting averaged respectively 33%, 41% and 31% greater than with grazing. The lower yields under grazing were attributed to treading effects, over-close grazing on parts of the plots and inefficient nutrient return because of the uneven distribution of urine. Dung was removed from the plots. In contrast, on other grass swards receiving no nitrogenous fertilizer, Sears (1953a) obtained an average increase in yield of 3% over a 5-year period from grazing relative to cutting while Sears et al. (1953) obtained a 6% increase. Wolton (1963) obtained a 5% increase from grazing over a 4-year period on an old ryegrass/cocksfoot/timothy ley receiving 30-80 lb/ac nitrogen per annum. Similar effects can be deduced from experiments on the use of fertilizer nitrogen under mowing and grazing conditions, (Brockman and Wolton, 1963; Armitage and Templeman, 1964).

Grass/clover swards (no fertilizer nitrogen): Taylor et al. (1960) working with a cocksfoot/white clover sward found no significant yield difference between cutting and grazing over a 2-year period and suggested that little was gained from evaluation by grazing that could not be gauged under cutting. The sward was grazed from 4-6 in. and 10-12 in. down to 2 in. in 1-, 7- and 14-day periods and the six grazing intensity treatments likewise simulated by mowing. In the 1-day period treatment, all the herbage was cut down to 2 in.; in the 7-day period, half the top growth was removed the first day and the remaining herbage cut to 2 in. on the seventh day; in the 14-day period, a third of the top growth was removed the first day, a third the seventh day and the remaining herbage cut to 2 in. the fourteenth day. This represented an attempt to simulate the gradual defoliation which occurs under grazing. Sears (1953a) obtained a 4% increase on average over five years and Sears et al. (1953) a 6% increase on grass/clover swards in which perennial ryegrass and white clover were the major constituents but Richardson and Gallus (1932) recorded a yield advantage from grazing of 34% on irrigated permanent pasture in Australia. Jones (1958) and Miles (1960) noted that perennial ryegrass and timothy swards yielded slightly more with grazing than with mowing whereas the reverse occurred with Italian ryegrass and cocksfoot.

Clover swards (no fertilizer nitrogen): On a subterranean clover sward in Australia, Watson and Lapins (1964) found no difference between yields from cutting and grazing.

Grass/clover swards (with fertilizer nitrogen): Wolton (1963) obtained a slight yield advantage of 4% over a 4-year period from grazing relative to cutting but this advantage mainly resulted from the final two years of the trial. Klapp (1959) reported a 34% yield increase from grazing. Both worked with a grass/clover permanent pasture. Scheijgrond and Vos (1960) experimenting with ryegrass, timothy and meadow fescue swards also obtained greater yield from grazing; on average, they registered a 13% increase from grazing but timothy swards showed only slight increases compared with ryegrass swards. Further evidence indicating higher yield under grazing can be adduced from experiments carried out by Brockman and Wolton (1963) and Armitage and Templeman (1964).

The experimental evidence reviewed above indicates the dearth of information available on herbage yield relationships between cutting and grazing. There is therefore need to establish yield relationships using different grass species with and without clover and with and without nitrogen fertilizer, since the limited evidence available suggests that the results are influenced by these factors.

(c) Defoliation intensity (frequency and severity)

Frequency effects

The effect of frequency of defoliation on herbage yield has been widely investigated in the past and detailed reviews made by Kennedy (1950), Wagner (1952), Brougham (1959) and Huokuna (1964). Various frequency scales have been used: set time intervals e.g. monthly; stages of growth e.g. 'silage' stage; heights of herbage, often assumed to represent particular stages of growth e.g. 8 in. tall herbage (grazing stage) and herbage quantities e.g. 10 cwt dry matter per acre.

In Britain, early work with many individual grasses and grass/clover mixtures showed that herbage yield increased as the interval between cuttings lengthened (Stapledon, 1924; Stapledon and Milton, 1930; Roberts and Hunt, 1936; Woodman et al., 1926, 1927, 1928, 1929, 1931; Woodman and Norman, 1932). Similar results were obtained later by Proudfoot (1957, 1958), Chestnutt (1960), Reid and MacLusky (1960), G.R.I. (1960, 1961), MacLusky and Morris (1964) and Holliday and Wilman (1962) with cutting frequencies varying between two to sixteen times per season and working mainly with perennial ryegrass/white clover swards. Other workers obtained greater yields from cutting at a silage stage, usually 10-14 in. herbage than at a grazing stage, usually 6-9 in. herbage (Walker et al., 1953; Reid, 1959; Appadurai and Holmes, 1964; Armitage and Templeman, 1964), although Walker and his co-workers also found that yields from two hay cuts were less than from three silage cuts. Reid (1962) noted that cutting at a grazing stage of 6-8 in. tall herbage and again after a 5-day interval to simulate strip grazing without a back fence considerably reduced yield in comparison with cutting at grazing stage only.

Brougham (1959) summarizing New Zealand studies on the frequency of defoliation also concluded that yield increased with increasing length of rest period between defoliations. Investigations in Australia (Richardson and Gallus, 1932), Finland (Huokuna, 1960a, 1964), Holland (Ibáñez, 1963), Germany (Klapp, 1959) and Canada (Gervais, 1960; Langille and Warren, 1961; Heinrichs and Clark, 1961; Ashford and Troelsen, 1965) on many grass swards including ryegrass and cocksfoot under a wide range of cutting frequencies led to the same conclusion.

In the United States many defoliation frequency studies have been reported in the literature. Details of the earlier work have been reviewed by Kennedy (1950) and Wagner (1952) and the beneficial effect on yield of increasing the interval between defoliations noted. Later work with many swards including ryegrass, cocksfoot, bromegrass, tall fescue and Kentucky bluegrass has confirmed the earlier results (Peterson and Hagan, 1953; Crowder et al., 1955; Burger et al., 1958; Taylor et al., 1960; Bryant and Blaser, 1961; Hunt and Wagner, 1963; Wolf and Smith, 1964; Griffith and Teel, 1965).

In relation to the number of cutting studies cited above, few studies have been conducted on the effects of grazing frequency on herbage yield. However, investigations by Jones and Jones (1930), Iorwerth Jones (1933), Jones (1939), Hughes and Davis (1951) and Williams (1952) have confirmed the results from cutting trials in Britain. Elsewhere Maclean (1958), Brougham (1959, 1960), Huokuna (1960b), Taylor et al. (1960), Bryant and Blaser (1961) and Weeda (1965) working mainly with perennial ryegrass, short-rotation ryegrass or cocksfoot swards also obtained greater yields with increasing length of recovery period between grazings.

In the past, reduced yield from frequent defoliation has been attributed mainly to exhaustion of food reserves in the plants brought about by the effort of repeated initiation of regrowth (Sullivan and Sprague, 1943; Weinmann, 1948, 1961). These reserves are mainly in the form of non-structural carbohydrates such as fructosans, sugars and starch stored in the stem and leaf bases, stolons, roots and rhizomes (May, 1960). This role of carbohydrate reserves is now in question and it has been claimed that most of the reserves are used for respiration rather than as substrate for the synthesis of new growing points (May and Davidson, 1958; May, 1960). Mitchell (1954) found no evidence of utilization of carbohydrate reserves to promote regrowth in partially defoliated ryegrass plants but Alcock (1964b) notes that these reserves may be of more importance in completely defoliated plants since initial regrowth must depend upon some source of available energy already present in the plant.

It is also considered that herbage production is ultimately dependent upon the leaf area per unit of land (Leaf Area Index) available to intercept light energy (Watson, 1947; Donald and Black, 1958). Optimum leaf area indices for almost complete light interception and resultant maximum growth rate have been postulated for various species including perennial ryegrass, timothy and white clover (Davidson and Donald, 1958; Brougham, 1958). Frequent defoliation, by reducing leaf area to below the optimum, can depress yield because of poor light interception and accompanying low rate of growth (Donald, 1956, 1963). Brougham (1959, 1960) found that high annual yields could be maintained under frequent grazing provided defoliation was lax enough to leave a cover of herbage after grazing. The optimal leaf area varies for different species and varieties through differences in the orientation and shape of the leaves, but also with the light intensity. Wilson and McGuire (1961) suggested that because of differences in latitude and the difference in the mean elevation of the sun, a higher leaf area would have to be maintained to give maximum light interception and highest growth rate in New Zealand than in Canada. Their results did not support Brougham's theory of a specified minimum leaf area for maximum regrowth rate. There is therefore still some doubt as to whether carbohydrate reserves or photosynthetic tissue left after defoliation is the most important causal factor in the initiation of regrowth.

With few exceptions, the studies reviewed above have shown increases in herbage yields with longer intervals between defoliations or synonymously more mature stages of growth, taller herbage or greater quantities of herbage. There is a scarcity of yield data from grazing at various frequencies compared with those available from cutting experiments.

Severity effects

The severity of defoliation is the height of defoliation from ground level as opposed to the height at defoliation. Closeness of defoliation to ground level, height of stubble or of residual herbage are other synonymous terms for severity used in the literature. The influence of severity of defoliation on herbage yield has been investigated mainly by cutting techniques.

In Britain, Reid (1959), working with an established perennial ryegrass/white clover sward cut at grazing stage (6-8 in. herbage) and silage stage (10 in. herbage) over a 3-year period, found that herbage dry matter yield was increased by 39-44% from close defoliation to within 1 in. of ground level compared with lax defoliation to within 2-2½ in. Similarly in another trial on a ryegrass/clover sward (Reid, 1962), close cutting resulted in an average yield increase of 34% over five years. Analogous results were obtained by Appadurai and Holmes (1964) when moisture supplies were adequate but there was no yield difference between cutting to 1 in. and to 2½-3 in. under drier conditions. In other experiments with different severities of cutting under various frequencies, increased yields from close defoliation compared with lax were obtained on ryegrass swards (Reid and MacLusky, 1960; Chestnutt, 1960; G.R.I., 1960, 1961; MacLusky and Morris, 1964), cocksfoot swards (Jones, 1959; G.R.I., 1960) and timothy swards (G.R.I., 1960; Reid, 1962).

Huokuna (1960a, 1964) in Finland using three severities, namely, 3, 6 and 10 cm. from ground level on cocksfoot-dominant swards, obtained increased yield with increasing closeness of cut. Similar effects on cocksfoot, timothy, red fescue and bromegrass swards were reported from Canada by Gervais (1960), Wilson and McGuire (1961) and Langille and Warren (1961). In the United States herbage yield superiority from close defoliation relative to lax over a range of severities from ½ in. to 4 in. was obtained from swards of erect-growing species such as cocksfoot and tall fescue (Sprague and Garber, 1950; Tesar and Ahlgren, 1950; Burger et al., 1958; Bryant and Blaser, 1961; Hunt and Wagner, 1963; Griffith and Teel, 1965) and from swards of prostrate species such as Kentucky bluegrass and bromegrass (Graber, 1933; Mortimer and Ahlgren, 1936; Hughes, 1937; Mott, 1944; Robinson and Sprague, 1947; Kennedy, 1950; Robinson, et al., 1952).

Reid (1959, 1962), Reid and MacLusky (1960), Appadurai and Holmes (1964) and MacLusky and Morris (1964) have all attributed the increased yield from close cutting to the inhibition of stem and flower production and the resultant stimulation of tiller and leaf production, an effect noted by Cooper and Saeed (1949) and Langer (1957). Wilson and McGuire (1961) suggested that the beneficial effects of close cutting may have resulted from the need of a high light intensity near the base of the plants for the initiation of regrowth or from the removal of old non-functional plant material that shaded the younger functional leaves. The importance of light intensity for the initiation of regrowth has been recorded by Mitchell and Coles (1955) and Alberda (1957) while Campbell (1963, 1964) and Hunt (1965) have drawn attention to the build-up of dead material that can occur in a sward. Campbell found that in summer even under intensive grazing (1.2 cows per acre), 40-50% of the pasture available for grazing was dead material and postulated that this debris must intercept a certain amount of incident light energy and so lower the photosynthetic efficiency of the sward.

Few critical trials have been conducted to investigate the effects on herbage of grazing down to specified heights from ground level presumably because of the difficulties involved in grazing evenly to fixed levels. Over a 2-year period, Brougham (1959) obtained higher yield from grazing 6-9 in. herbage down to 1 in. compared with grazing 3-4 in. herbage to 1 in., 7-8 in. herbage to 3 in. or 9-12 in. herbage to 3-4 in. He stressed the importance of adequate rest periods after close grazing and noted that under frequent grazing, a more lenient defoliation was necessary to maintain high yield. Bryant and Blaser (1961) working with pure cocksfoot swards grazed at 5 in. and 11 in. over a 3-year period, reported increased yield from grazing down to ¾ in. above ground level compared with 2½ in. Conflicting results were obtained by Meeda (1965) since over the first two years of his experiment, grazing to 1-2 in. gave greater herbage yield than grazing to 3-4 in. whereas the reverse occurred in the final three years.

A number of workers have obtained increased herbage yields from lax cutting relative to close. Over a 32-day period, Brougham (1956) working with a short-rotation ryegrass sward showed that yield from a single lax defoliation to 5 in. was greater than that from close defoliation to 1 in. Yield from defoliation to 3 in. was intermediate. Since the rate of regrowth of the close-cut swards was highest at the end of the experimental period, it is conceivable that the results might have been reversed had he allowed a longer recovery period. However, in a 1-year trial with a cocksfoot sward Drake et al. (1963) reported greater yield from 3 in. cutting than from 1½ in. He noted that the yield from the closely defoliated sward was particularly affected during the hot part of the summer when conditions were dry, an observation in agreement with that of Appadurai and Holmes (1964). Other workers, using rows of plants or single spaced plants in the field or single potted plants indoors and working mainly with ryegrass, timothy, cocksfoot or Kentucky bluegrass, have also reported a yield advantage in favour of lenient relative to close defoliation under a wide range of severities from ground level to 6 in. (Stapledon, 1924; Stapledon and Milton, 1930; Graber and Ream, 1931; Roberts and Hunt, 1936; Kuhn and Kemp, 1939; Harrison and Hodgson, 1939; Jacques and Edmond, 1952; Juska et al., 1955; Jäntti and Heinonen, 1957; Ibáñez, 1963).

Several reasons have been put forward to explain the conflicting reports from defoliation severity experiments. Differences in the frequency of cutting systems applied was suggested by Reid (1959, 1962) who claimed that the benefits of close cutting were only attained when adequate time for recovery was allowed between cuts. Brougham (1959) also noted the necessity for adequate rest periods after close grazing. Huokuna (1960a, 1964) observed that in many of the trials showing reduced yield with increasing closeness of cut, the recovery time was only 7-10 days. The amount of photosynthetic tissue removed may partly explain the contradictory results from single plant and sward experiments. Single plants were often held upright for defoliation by hand clipping so that under close cutting, most or all of the leaf would be removed; in comparison, mechanical cutting of dense swards would not remove all the leafage even at close defoliation. In addition, many of the single plant studies were only conducted over short-term periods of 2-3 months. Soil moisture conditions also have an effect as noted by Jäntti and Heinonen (1957), Drake et al., (1963) and Appadurai and Holmes (1964). Poor regrowth after close defoliation has been attributed to the inability of severely defoliated plants to utilize soil water (Jäntti and Kramer, 1956) while induced unavailability of soil nitrogen through drying out of soil under severe defoliation has been reported by Mitchell (1957). It has also been considered that herbage species and varieties differ in their reaction to varying severities of defoliation. The main generalization is that prostrate-growing species can withstand a greater degree of defoliation than erect-growing species because a lesser amount of photosynthetic tissue is removed (Kuhn and Kemp, 1939; Brougham, 1959; Alcock, 1964b). Since many of the results cited earlier indicated yield advantage from close cutting for erect as well as prostrate species (e.g. Burger et al., 1958; G.R.I., 1960; Hunt and Wagner, 1963) this generalization is dubious.

From the experimental evidence reviewed above, it may be concluded that close cutting of field swards results in greater herbage yields than lax cutting provided adequate recovery periods are allowed between defoliations. Over short-term periods and in cutting trials with single or potted plants, the opposite effect is more likely. Experimental evidence on the effects of severity of grazing on herbage yield is meagre and inconsistent. Experimentation to determine these effects is therefore required.

EXPERIMENT 1

Experimental methods and materials

Field

The experiment was carried out in Cathcart field, the sward of which was established in 1957. The soil was described in a report by the Macaulay Institute for Soil Science as a freely-drained brown sandy loam overlying a yellowish-brown loam sand (Thomson, 1960). In 1958 and 1959, the field was rotationally grazed and received 133 lb/ac N and 136 lb/ac N per annum respectively, mainly as Nitro-chalk (15.5% N).

Sward

The sward was dominantly perennial ryegrass with small proportions of cocksfoot, timothy and white clover. The original seed mixture, sown under barley in 1957, was:

	lb/ac
Aberystwyth S.23 perennial ryegrass (British certified)	4
Ayrshire perennial ryegrass	6
New Zealand permanent pasture perennial ryegrass	6
Italian ryegrass	4
Aberystwyth S.143 cocksfoot (British certified)	4
Scots timothy	4
Rough-stalked meadow grass	2
Montgomery late flowering red clover	2
Kent wild white clover	1
Total	33

Manuring

In early spring 94 lb/ac P_2O_5 as superphosphate and 134 lb/ac K_2O as muriate of potash were applied to the experimental area and adjacent ½-acre holding paddock. During the experiment, 104 lb/ac N as Nitro-Chalk (15.5% N) was applied in two dressings, viz., 52 lb/ac in March and 52 lb/ac in July.

Experimental treatments

The experimental treatments were:

Defoliation method:

Cutting (C)

Grazing (G)

Defoliation intensity:

Herbage defoliated from:	3 - 5 in. to 1 - 1½ in.	(4-1)
	7 - 9 in. to 1 - 1½ in.	(8-1)
	7 - 9 in. to 2 - 2½ in.	(8-2)
	11 - 13 in. to 2 - 2½ in.	(12-2)

An Allen motor scythe fitted with a 3 ft wide cutter bar was used to apply the cutting treatments C(4-1), C(8-1), C(8-2) and C(12-2), and sheep for the grazing treatments G(4-1), G(8-1), G(8-2) and G(12-2). The defoliation treatments were applied independently under both cutting and grazing when the herbage reached the required modal heights per four replicate sub-plots. The herbage height was measured at ten randomly selected positions per sub-plot by gathering a handful of herbage and judging the modal height against a ruler. To cut herbage down to 1-1½ in. the motor scythe was fitted with a 'Universal' cutting assembly adjusted to leave stubble of this height while a 'Standard' cutting assembly was used to cut herbage to 2-2½ in. The grazing treatments were controlled by varying the number of sheep enclosed and the time spent grazing in the individual sub-plots as follows:

G(4-1) - 2 sheep for 1½ days	G (8-2) - 2 sheep for 1½ days
G(8-1) - 3 sheep for 1½ days	G (12-2) - 3 sheep for 2 days

Grazing cages, 18ft 8in. x 9ft 4in. (i.e. 1/250 acre), made of aluminium alloy angle strips, covered with aluminium mesh wire along the sides and constructed at a cost of £30 each for the material were used to enclose the sheep.

The only permanent fencing required was around the perimeter of the experimental plot area and also around the adjacent holding paddock on which the sheep were conditioned on a sward of similar type to the plots prior to entry. This minimised the possibility of fertility transference to the plots. A pen for handling the sheep was erected in the holding paddock. The sheep were Greyface (Border Leicester x Scottish Blackface) ewe hoggs drawn from a flock of 12 purchased at Ayr market in April and sold in October when the experiment was completed.

Experimental design

A split-plot randomised block design was used with four replicates of the two defoliation methods as main-plots (18ft 8in. x 37ft 4in.) and the four defoliation intensities as sub-plots (18ft 8in. x 9ft 4in.). Replicates were treated concurrently. Access to the sub-plots was provided by 5 ft paths between blocks I and II and between blocks III and IV (Figure 1).

Sampling machinery

At each cutting and grazing, pre- and post-treatment samples of the herbage were taken to ground level by using power-driven Wolseley sheep shears ('Ringer' shearing head, Series II, wide pattern) with a special 3 in. grass-cutting comb. Initially, power was supplied by a portable J.A.P. two-stroke 50 c.c. engine (Plate 1) and later from a Brockhouse B.M.B. Hoe-mate light tractor with a 1¾ H.P. engine (Plate 2). A standard 6 ft Wolseley flexible driving shaft with slip clutch was used with both machines.

Yield sampling

Available herbage (pre-treatment samples): A pre-treatment herbage sample consisted of three herbage sub-samples taken from separate thirds of the sub-plots to provide an estimate of the mean yield of the sub-plot and to take

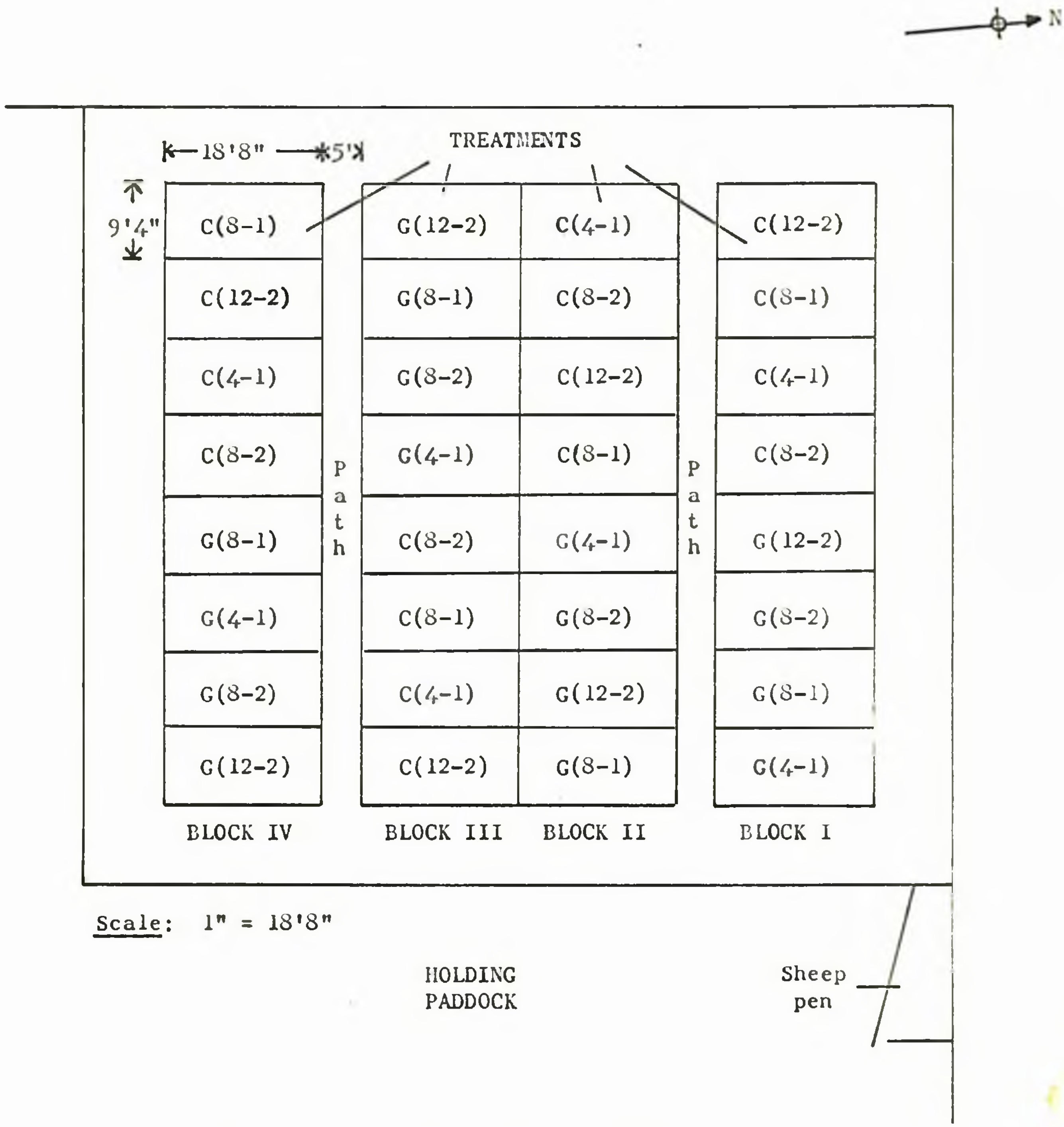


Figure 1 Experimental plot layout for Experiment 1

Plate 1

Portable J.A.P. engine fitted with Wolseley sheep shears.

Plate 2

Brockhouse B.M.B. Hoe-mate light tractor fitted with
Wolseley sheep shears.

account of within sub-plot variation in herbage yield. A third of a sub-plot (9ft 4in. x 6ft) provided 12 sampling strips each 6 in. wide. The whole sub-plot contained 36 such strips numbered 1-36. The location of sampling strips to be used at any one sampling was decided by selecting a number between 1 and 12 at random e.g. number 2, and sampling that strip together with strip numbers 14 and 26 in corresponding positions in the other thirds of the sub-plot. The positions of the strips were fixed by reference to a template made of an 18 ft length of aluminium alloy angle marked off at 6 in. intervals. This was laid along the central 18 ft of the 18ft 8in. length of the sub-plot. The cutting edge was marked by a 9ft 4in. length of the alloy angle set across the plot at right angles to the 18 ft length. Each herbage sub-sample consisted of a single sweep of the 3 in. wide shearhead of the sheep shears along the 9ft 4in. length of alloy angle. The three herbage sub-samples were bulked to provide a sub-plot sample, collected in a polythene bag and taken to the laboratories for yield and chemical composition determinations.

Residual herbage (post-treatment samples): The procedure was similar to that for available herbage above except that the three herbage sub-samples were shorn from sample strips adjacent and parallel to the pre-treatment herbage strips. Once these random positions had been chosen they were not used again until all the other strips had been sampled. Since there were twelve potential sample strips in each third of a sub-plot, it was possible to take paired pre- and post-treatment samples six times before returning to previously-selected positions.

Sampling for botanical analyses

At the start of the experiment in April, botanical samples consisting of ten snips of herbage shorn to ground level with the Wolseley sheep shears from random positions, were taken from each of the four block areas, collected in polythene bags and taken to the grassland laboratory for analyses. A similar procedure was carried out in October at the completion of the experiment but the samples were then taken from each sub-plot.

Determination of herbage yield

For yield determinations, pre- and post-treatment herbage samples from the sub-plots were weighed on an Avery balance to 0.1 g. Under both cutting and grazing, herbage yield was calculated as the difference between pre-treatment available herbage yield and post-treatment residual herbage yield. This yield represented the amount of herbage utilized, whether cut by motor scythe and removed, or grazed by sheep. The annual available herbage yield i.e. the sum of the individual available herbage yields over the season does not represent annual production since the carry-over of residual herbage yields is included repeatedly in the available herbage yield estimates. The herbage yield is thus derived from the expression:

Available herbage yield minus residual herbage yield

(i.e. Pre-treatment herbage yield minus post-treatment herbage yield)

Determination of herbage botanical composition

The botanical samples were separated by hand on a fresh matter basis into perennial ryegrass, cocksfoot, timothy, white clover and unsown species. Rough-stalked meadow grass, although sown, was classed under the unsown species. These separate constituents were weighed to 0.1 g on an Avery balance and the relative proportions calculated.

Determination of herbage chemical composition

Chemical analyses of the available and residual herbages were carried out in the analytical laboratory of the Chemistry Department as follows:

Dry matter (D.M.): Laboratory samples of 300 g each were taken from the field sub-plot herbage samples and dried at 98-100°C for 16-18 hours in a Birmingham and Blackburn Unitherm Drier. The dried samples were weighed to 0.1 g and ground through a 0.6 mm. screen in a laboratory mill and stored.

Organic matter (O.M.): Sub-samples, each 1 g from the re-dried, bulked laboratory samples of the four replicates from each treatment, were ashed overnight at 450°C.

Crude protein (C.P.): Sub-samples, each 1 g from the re-dried, bulked laboratory samples of the four replicates from each treatment, were analysed for total nitrogen content by a macro-Kjeldahl procedure.

Summary of terminology

Main-plot: 18ft 8in. x 37ft 4in. defoliation method treatments.

Sub-plot: 18ft 8in. x 9ft 4in. defoliation intensity treatments.

Third sampling area: 9ft 4in. x 6ft sampling area in a sub-plot.

Sample strip: 6 in. wide herbage strip in a sampling area from which 3 in. wide herbage sub-sample was shorn.

Herbage sub-sample: 3 in. wide strip of herbage shorn from within a 6 in. wide sample strip.

Sub-plot herbage sample: Bulked herbage sub-samples from a sub-plot. Used for yield and chemical composition determinations.

Pre-treatment sample: Sample of available herbage taken before defoliation treatment applied.

Available herbage yield (pre-treatment herbage yield): Synonymous terms for herbage yield on sub-plots before defoliation treatments applied.

Post-treatment sample: Sample of residual herbage taken after defoliation treatment applied.

Residual herbage yield (post-treatment herbage yield): Synonymous terms for herbage yields on sub-plots after defoliation treatments applied.

Utilized herbage yield: Herbage removed by motor scythe in a cutting treatment or by sheep in a grazing treatment. Calculated from expression:

Available herbage yield minus residual herbage yield

Botanical sample: Representative sample of fresh herbage, usually around 100 g, taken from experimental area to grassland laboratory for botanical analysis.

Laboratory sample: Representative sample of fresh herbage, usually 300 g, taken from sub-plot herbage sample in the analytical laboratory for dry matter analysis.

Laboratory sub-sample: Representative sub-sample, usually 0.5 - 1 g, taken from the dried, ground laboratory sample for chemical analysis in the analytical laboratory.

Meteorological data

A summary of the meteorological data during 1960 is given in Appendix 2. As a result of above-average soil and air temperatures from March to June, 1960 was a year of early spring growth. There was less rainfall than normal in the months of May, July, September and October.

Presentation of Results

Herbage yields are expressed throughout as organic matter (O.M.) since this corrects for soil contamination of the herbage associated with ground-level sampling techniques. Yields of crude protein (C.P.) are also given. All the yields are expressed in 100 lb/ac and rounded off to the first decimal place. The percentage organic matter (% O.M.) of the herbage is shown on a dry matter basis and the percentage crude protein (% C.P.) on an organic matter basis. Mean values are presented in the body of thesis as tables together with results of statistical examination by analyses of variance (Snedecor, 1956) where relevant. To aid interpretation some of the tabular data are also presented graphically. Tables of original data and detailed statistical analyses are lodged in the Grassland Husbandry Department, West of Scotland Agricultural College, Auchincruive, Ayr. Certain conventional statistical abbreviations are used as follows:

Mean = Mean value for specified characters.

F = Variance ratio for specified conditions.

*, **, ***, or $P<0.05$, $P<0.01$, $P<0.001$ = Significance at 5%, 1% and 0.1% cases respectively for the treatment differences.

NS = Non-significance at the 5% level.

C.V. = Coefficient of variation.

$S\bar{d}$ = Standard error of difference between means. This is given for the main treatment effects whether they are significant or not.

L.S.D. = Least significant difference value at the 5% level of probability. This is given only for significant treatments and interactions.

The usual plus/minus limits apply to the last three terms but to simplify the presentation the ± sign is omitted from the tables.

The results are presented under the following sub-headings:

Dates of defoliation

Annual herbage yields

Botanical composition of the herbage

Mean annual chemical composition of the herbage

Seasonal distribution of herbage yields

Accumulative herbage yields

Seasonal chemical composition of the herbage

EXPERIMENT 1

Results

Dates of defoliations

In the season from April to October the herbage usually reached the required defoliation height in the grazing treatments more often than in comparable cutting treatments (Table 1). The intervals between defoliations were therefore shorter under grazing.

Table 1 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6	7	8	9
C (4-1)	22/4	13/5	31/5	21/6	15/7	11/8	27/9		
G (4-1)	22/4	11/5	31/5	17/6	20/7	8/8	5/9	22/9	12/10
C (8-1)	6/5	2/6	20/7	9/9					
G (8-1)	6/5	2/6	23/6	22/7	27/8	3/10			
C (8-2)	6/5	27/5	21/6	20/7	1/9	12/10			
G (8-2)	9/5	27/5	20/6	11/7	29/7	1/9	30/9		
C (12-2)	16/5	21/6	22/7	9/9	12/10				
G (12-2)	14/5	21/6	27/7	2/9	10/10				

Annual herbage yields

Utilized yields of organic matter and crude protein were significantly increased by grazing compared with cutting (Table 2). This effect was greatest with the (12-2) and (8-2) intensity treatments. Organic matter yields differed significantly as a result of the intensity treatments; the highest yield was obtained with defoliation treatment (12-2) and the lowest with treatment (4-1). The (8-1) treatment outyielded the (8-2) treatment. Defoliation intensity had less effect on the crude protein yields, although yields from the (4-1) and (12-2) treatments were higher than those from the remaining treatments.

Table 2 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter C	Organic matter G	Organic matter Means	Crude protein C	Crude protein G	Crude protein Means
Intensity						
(4-1)	37.5	39.9	38.7	9.6	12.1	10.8
(8-1)	41.8	46.8	44.3	8.5	11.7	10.1
(8-2)	37.0	44.8	40.9	7.8	11.7	10.0
(12-2)	44.6	51.2	47.9	9.4	12.1	10.7
Means	40.2	45.7		8.8	12.0	

Significant effects:	Organic matter	Crude protein
Method	**	**
Intensity	***	NS
Method x intensity	NS	NS
C.V. (%)	7.7	7.7

Differences between:	Sd	L.S.D.	Sd	L.S.D.
Method means	0.5	1.6	0.1	0.3
Intensity means	1.7	3.6	0.4	-
Intensity means within a method	2.4	-	0.6	-
Method means within an intensity	2.1	-	0.5	-

Botanical composition of the herbage

Table 3 shows that the main botanical change occurred in the balance between perennial ryegrass and cocksfoot. There was an increase in the proportion of perennial ryegrass and a compensating decrease in cocksfoot in all the grazing treatments and in the (4-1) and (8-1) cutting treatments. In the (8-2) and (12-2) cutting treatments, the changes were reversed. The unsown species were mainly annual meadow grass, bent grass, chickweed and dandelion.

Table 3/

Table 3 Percentage botanical composition of the swards in April and October

Date	Treatment	Perennial ryegrass	Cocksfoot	Timothy	White clover	Unsown species
April 22	Nil	64.2	21.5	4.6	2.7	7.0
October 21	C (4-1)	71.6	17.5	3.0	1.8	6.1
	G (4-1)	76.5	13.5	3.0	2.2	4.8
	C (8-1)	66.8	20.7	2.3	1.8	8.4
	G (8-1)	71.3	12.6	4.6	3.2	8.3
	C (8-2)	59.7	25.4	4.2	1.3	9.4
	G (8-2)	71.2	12.6	3.8	2.7	9.7
	C (12-2)	52.0	30.1	4.1	2.7	11.1
	G (12-2)	70.8	17.4	3.8	2.0	6.0

Mean annual chemical composition of the herbage

Table 4 shows the annual chemical composition data for the available and residual herbage in each treatment. In both types of herbage, organic matter contents were affected by the severity but not by the method of defoliation and were lowest in the (4-1) and (8-1) treatments. Under all the treatments, organic matter contents were consistently higher in the available herbage than in the residual herbage but the percentages in both herbages reflect a considerable degree of soil contamination since uncontaminated herbage usually has an organic matter content of between 88-91%. The greater contamination in the residual herbage will be related to the passage of cutting machinery and treading effects of sheep when applying the treatments. Both of these factors can disturb the soil surface and press herbage into the ground or cause soil to adhere to the herbage, particularly under wet conditions.

Crude protein contents were affected by both the method and intensity of defoliation. Under grazing there was a mean increase of 4.4 percentage units in both the available and residual herbage. Crude protein contents were highest in the (4-1) intensity treatments and lowest in the (12-2) treatments.

Since the available herbage was mainly leafy regrowth, the crude protein contents were greater than in the residual herbage which was mainly stubble and dead leaf bases.

Table 4 Weighted mean annual percentage chemical composition of the available and residual herbage

Method		Organic matter C	Organic matter G	Organic matter Means	Crude protein C	Crude protein G	Crude protein Means
Herbage	Intensity						
Available	(4-1)	84.7	84.3	84.5	22.3	26.7	24.5
	(8-1)	84.7	85.0	84.8	18.7	23.6	21.1
	(8-2)	87.2	87.0	87.1	19.0	24.0	21.5
	(12-2)	87.5	87.8	87.7	18.5	21.9	20.2
	Means	86.0	86.0		19.6	24.0	
Residual	(4-1)	79.8	79.0	79.4	18.7	22.7	20.7
	(8-1)	75.0	81.0	78.0	15.0	21.4	18.2
	(8-2)	81.8	80.4	81.1	17.4	20.7	19.0
	(12-2)	79.0	82.8	80.9	15.8	19.6	17.7
	Means	78.9	80.3		16.7	21.1	

Seasonal distribution of herbage yields

Table 5 shows the seasonal distribution of utilized herbage yields for each treatment, while the yields of available and residual herbage from which the seasonal figures were derived by difference, are tabulated in Appendix 3. There was considerable variation in organic matter yields during the season under the various treatments, but particularly in treatments C(12-2), G(8-2) and G(12-2). By the third or fourth week of June, 50% of the annual yield had been produced in all the treatments. There was little consistent effect of either the method or intensity of defoliation, but defoliation frequency had a major effect in the early part of the season due to the height of herbage at defoliation. Yields at the first defoliation from the (4-1) intensity treatment made up 15-18% of the annual production compared with

32-38 from the (12-2) treatment. Yields from the (8-1) and (8-2) treatments were intermediate. In most treatments, the top yields were at the first defoliation of the season in April or May. The (4-1) treatments were exceptions with top yields in September under cutting and in June under grazing. The lowest yields occurred mainly in June with the low severity treatments, (4-1) and (8-1) and in July or October in the (8-2) and (12-2) treatments.

In general the high yields of crude protein occurred at the same time as the high yields of organic matter and similarly in the case of the low yields. Peak yields were mainly around 240-280 lb/ac and bottom yields 60-120 lb/ac.

Table 5 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Organic matter	Crude protein	Organic matter	Crude protein
	C(4-1)		G(4-1)	
1	6.8	1.6	6.0	1.4
2	7.0	1.9	4.8	1.5
3	2.9	1.0	3.7	1.3
4	3.3	0.8	6.7	2.0
5	3.3	0.7	4.7	1.3
6	4.7	1.2	3.2	1.2
7	9.6	2.4	5.0	1.5
8			2.3	0.9
9			3.4	1.0
	C(8-1)		G(8-1)	
1	14.3	2.8	11.9	2.3
2	7.8	1.6	10.0	2.6
3	10.0	2.0	5.6	1.2
4	9.8	2.0	8.2	2.0
5			4.4	1.3
6			8.7	2.4
	C(8-2)		G(8-2)	
1	8.7	1.6	11.7	2.1
2	7.4	1.7	6.4	1.6
3	3.9	1.1	4.0	1.3
4	8.6	1.6	1.8	0.6
5	5.7	1.1	5.6	1.8
6	2.8	0.7	8.4	2.5
7			7.0	2.2
	C(12-2)		G(12-2)	
1	17.0	2.8	16.4	2.5
2	8.5	2.1	8.1	2.3
3	6.7	1.6	7.5	2.0
4	8.5	1.9	10.7	2.7
5	3.9	1.0	8.6	2.6

Accumulative herbage yields

The development of accumulative yields over the season (Figure 2) shows that the superiority of the crude protein yields under grazing treatments relative to comparable cutting treatments began in June or July whereas the superiority of the organic matter yields began slightly later.

Seasonal chemical composition of the herbage

The percentage organic matter and crude protein data of the available and residual herbage for each treatment throughout the season are shown in Table 6 and Figure 3.

Available herbage: There was little effect of treatment on the seasonal variation of organic matter contents. Top levels were usually recorded at the start of the season and the lowest in late season.

Crude protein contents were affected most by the method of defoliation. Under cutting the top values ranged from 20-25% whereas comparable values under grazing were 27-29%. With most treatments the values were lowest in early season and highest towards the end of the season.

Residual herbage: Apart from generally lower values under severe defoliation compared with less severe defoliation to 2-2½ in., treatment had little effect on the organic matter contents. The lowest contents of around 66-78% were evidence of a high degree of soil contamination as a result of the application of cutting or grazing treatments with their effects of disturbing the soil surface.

In all the treatments, crude protein contents were usually lowest at the start of the season and highest at the end with a gradual rise in between, but throughout the season, the contents were several percentage units greater under grazing than under cutting. The largest seasonal variation was shown by treatments C(12-2) and G(8-1).

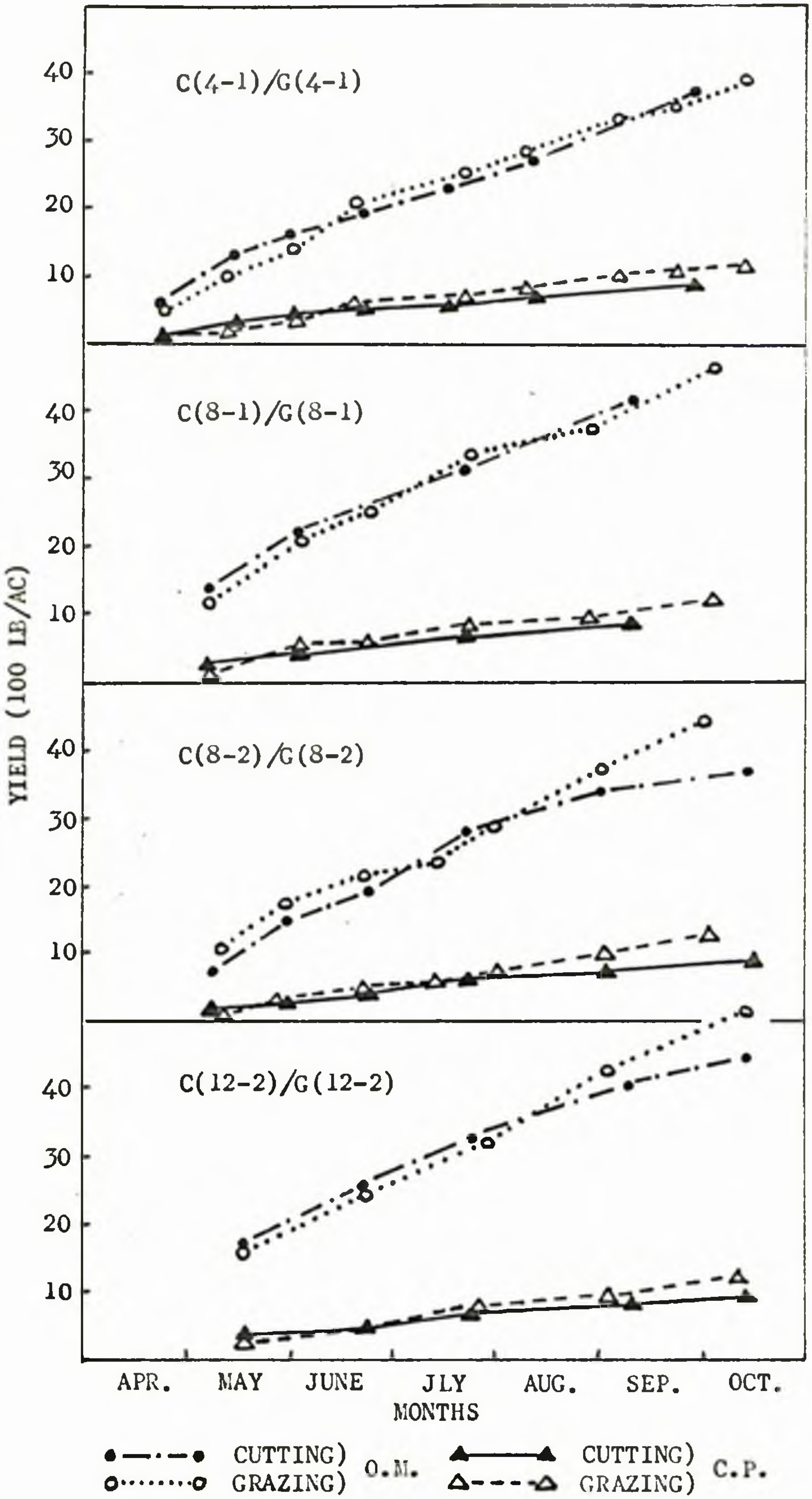


Figure 2 Accumulative utilized herbage yields for each treatment

Table 6 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage O.M.	Available herbage C.P.	Available herbage O.M.	Available herbage C.P.	Residual herbage O.M.	Residual herbage C.P.	Residual herbage O.M.	Residual herbage C.P.
	C(4-1)		G(4-1)		C(4-1)		G(4-1)	
1	87.9	22.9	90.6	21.9	84.7	21.4	84.7	20.8
2	82.1	25.2	85.3	27.2	65.9	20.3	78.1	21.5
3	83.4	23.4	84.5	27.5	79.5	19.2	75.8	23.6
4	85.0	20.7	87.7	27.4	85.2	18.8	84.7	21.5
5	77.8	18.1	82.5	25.0	77.5	17.0	79.9	21.2
6	89.9	21.0	84.5	27.6	83.4	16.7	83.5	22.0
7	86.6	23.8	87.4	27.1	81.4	19.3	86.2	23.2
8			76.5	28.9			63.9	24.8
9			76.2	28.2			79.2	25.3
	C(8-1)		G(8-1)		C(8-1)		G(8-1)	
1	90.9	19.0	91.5	18.6	85.6	14.7	82.7	17.0
2	77.8	17.4	82.2	23.8	68.9	14.1	84.9	19.8
3	85.7	18.6	86.4	24.2	76.9	15.2	80.3	19.6
4	83.7	19.8	84.0	23.0	75.7	16.6	77.6	20.7
5			86.2	26.3			82.5	24.1
6			79.9	27.0			78.2	26.6
	C(8-2)		G(8-2)		C(8-2)		G(8-2)	
1	91.2	17.2	89.3	18.0	87.9	15.7	86.3	17.5
2	90.4	19.8	90.3	22.3	87.3	17.2	85.5	19.2
3	89.9	20.6	87.0	26.1	82.5	17.7	79.8	22.6
4	89.0	16.7	84.5	24.3	78.2	15.2	77.0	21.9
5	85.2	19.0	87.3	25.3	81.1	18.2	79.2	20.1
6	74.1	21.7	85.4	26.6	74.4	19.9	75.1	21.8
7			83.0	28.7			84.2	22.7
	C(12-2)		G(12-2)		C(12-2)		G(12-2)	
1	91.2	15.1	91.2	15.4	80.5	12.4	86.5	15.3
2	87.4	19.5	85.3	23.3	82.9	16.5	77.0	19.2
3	84.7	18.4	89.3	23.0	70.0	15.0	86.8	20.3
4	87.5	19.3	88.4	23.4	81.5	15.2	82.8	21.3
5	83.5	23.5	82.2	28.1	83.1	21.1	79.8	22.2

Comparison of available and residual herbage: With few exceptions, organic matter and crude protein levels were higher in the available herbage but the seasonality of these levels was similar in both herbages.

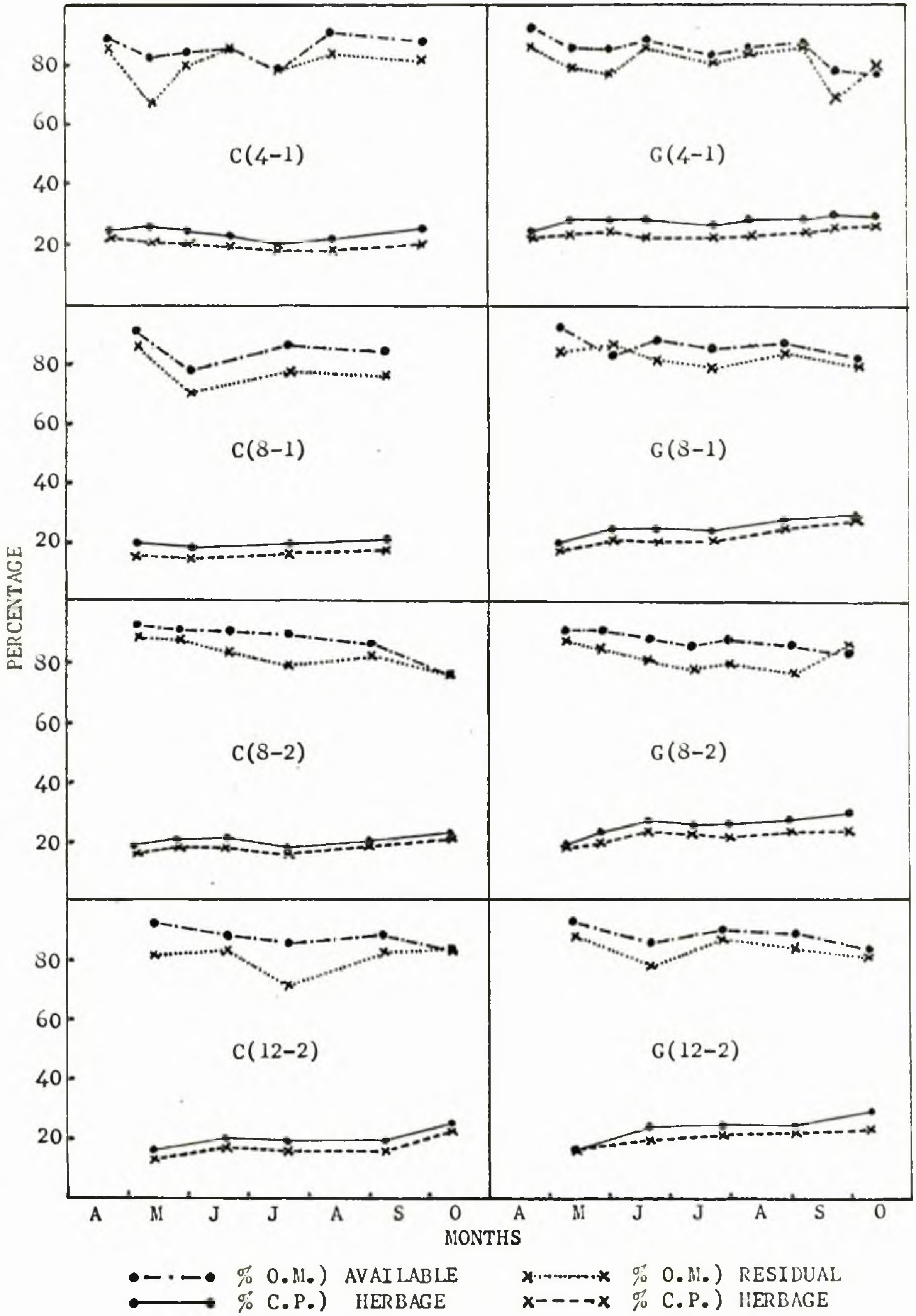


Figure 3 Seasonal percentage chemical composition of the available and residual herbage for each treatment

EXPERIMENT 2

Experimental methods and materials

Field

The experiment was carried out in North Holm field on a sward established in 1954. The soil was classed as a freely-drained brown sandy loam overlying a yellowish-brown loam sand (Thomson, 1960). The plots were laid out and permanently fenced in 1958. During 1959, a preliminary experiment, identical to that projected for 1960, was conducted to gain experience in the techniques of handling sheep, grazing small plots and testing a variety of specialized cutting equipment. Prior to 1958, the field had been rotationally grazed by dairy stock and latterly was receiving up to 133 lb/ac N mainly as Nitro-chalk (15.5% N) during the grazing season.

Sward

The plot swards were dominantly perennial ryegrass with some cocksfoot and traces of timothy and white clover. The original seed mixture, sown under oats in 1954, was:

	lb/ac
Aberystwyth S.101 perennial ryegrass (British certified)	4
New Zealand perennial ryegrass	8
Italian ryegrass	4
Aberystwyth S.143 cocksfoot (British certified)	3
Scotia cocksfoot	3
Aberystwyth S.51 timothy (British certified)	4
Montgomery late flowering red clover	3
Kentish white clover	1
Total	30

Manuring

In early spring, 94 lb/ac P_2O_5 as superphosphate and 134 lb/ac K_2O

as muriate of potash were applied to the experimental area and adjacent half-acre holding paddock. Nitro-chalk (15.5% N) at 34 lb N/ac was applied in March and after each defoliation during the season except the last. The annual totals were 208 lb/ac N for the plots defoliated at monthly intervals and 312 lb/ac N for the plots defoliated at variable intervals and for the holding paddock.

Experimental treatments

The experimental treatments were:

Cutting, monthly frequency (CM)

Grazing, monthly frequency (GM)

Cutting, variable frequency. 7-9 in. herbage (CV)

Grazing, variable frequency. 7-9 in. herbage (GV)

Grazing and cutting alternately, variable frequency.
7-9 in. herbage (GCV)

Grazing, variable frequency, post-grazing trimming cut.
7-9 in. herbage (GVT)

An Allen motor scythe with a 3 ft cutter bar was used to apply the cutting treatments CM and CV and sheep for the grazing treatments GM, GV and GVT. The GCV treatment was a combination of the GV and CV treatments applied alternately. The monthly defoliations were fixed at calendar-monthly intervals starting in late April. The variable frequency treatments were defoliated independently when the herbage reached a modal height per four replicate plots of 8 in. from ground level. The herbage height was measured at ten randomly-distributed positions per plot by taking a handful of herbage and judging the modal height against a ruler. In all the treatments, the herbage was cut down to 1-1½ in. by means of a 'Universal' cutting assembly fitted to the motor scythe. The grazing treatments were controlled by varying the number of sheep enclosed and the time spent grazing in the individual plots as follows:

GM - 3 sheep for 3 days

GV - 3 sheep for 2 days

GVT - 3 sheep for 2 days

As soon as grazing was completed in the GVT treatment, the motor scythe was used to trim the residual herbage evenly to 1-1½ in. All the plots in the experiment were individually fenced using stobs at 5 ft intervals with 3 ft high, 4 in. mesh, 16 gauge sheep netting and a top and bottom plain wire. Gates with a 12ft x 3ft 3in. framework of aluminium alloy angle strip and covered with sheep netting were used to close off the plots, all of which opened on to a central 8 ft path (Figure 4). A pen for handling the sheep was constructed in the adjacent holding paddock. The sheep were drawn from the flock of Greyfaces used in Experiment 1. As far as possible the sheep were conditioned in the holding paddock prior to entry to the plots in order to minimise fertility transference.

Experimental design

A randomized block design was used with four concurrently-treated replicates of the six treatments as 36ft x 12ft plots (i.e. 1/100.8 acre).

Sampling machinery

The sampling machinery was the same as that described for Experiment 1 (page 48).

Yield sampling

The sampling procedure for the available herbage (pre-treatment samples) and the residual herbage (post-treatment samples) was similar to that in Experiment 1 (page 48), but since the plots were larger in Experiment 2, there were twenty-four potential sample strips of 12ft x 6in. from which to take

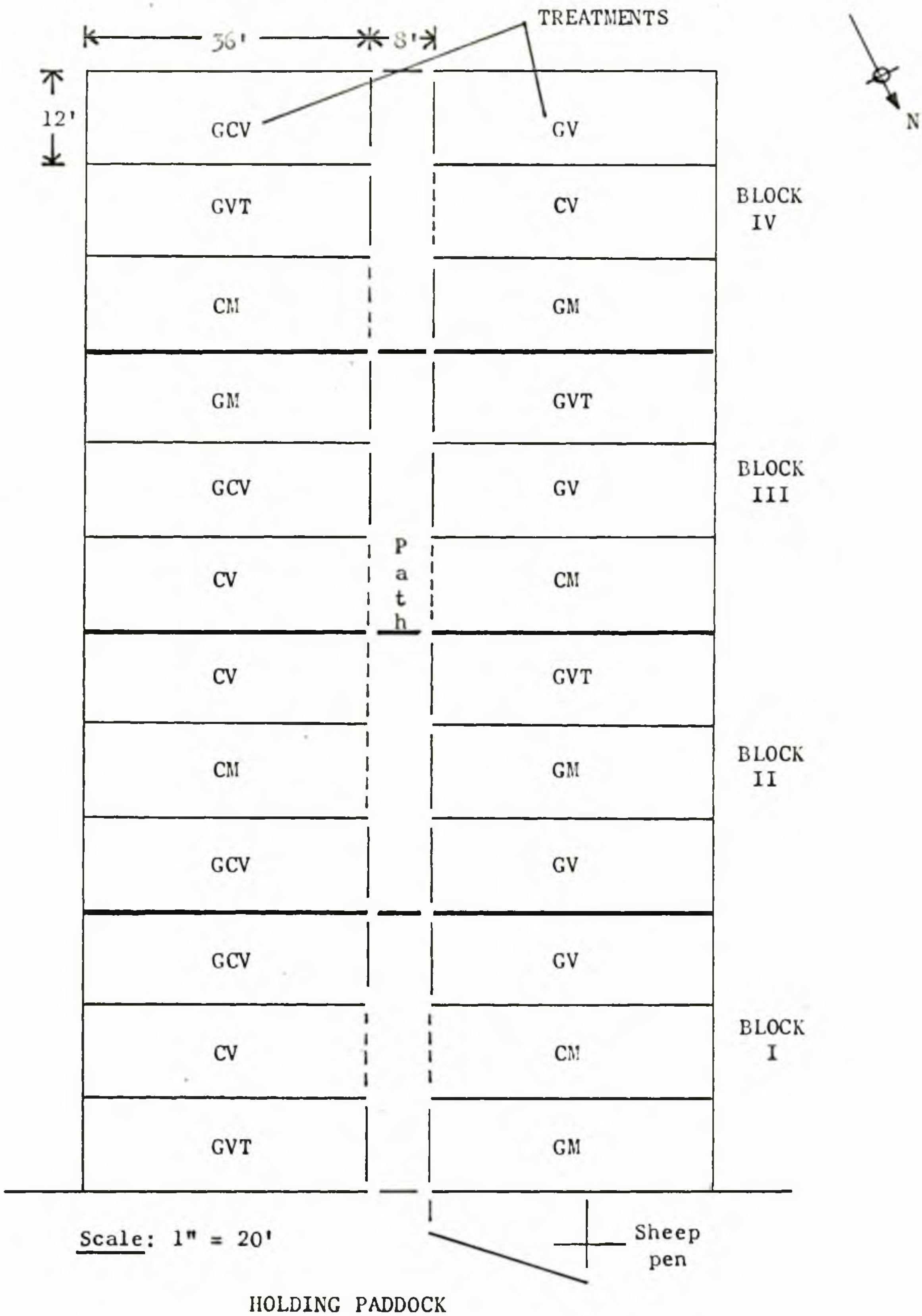


Figure 4 Experimental plot layout for Experiment 2

12ft x 3in. herbage sub-samples in each third of the plot area. It was therefore possible to take paired pre- and post-treatment samples twelve times before returning to previously-sampled positions.

Sampling for botanical analyses

The sampling procedure was again similar to that in Experiment 1 (page 51) but since the treatments had also been applied in 1959, each plot was sampled in April as well as in October.

Determination of herbage yield	As previously described for Experiment 1 (pages 52-54)
Determination of herbage botanical composition	
Determination of herbage chemical composition	
Summary of terminology	
Meteorological data	
Presentation of results	

EXPERIMENT 2

Results

Dates of defoliations

During a season from April to October, there were six defoliations under the monthly treatments and nine under the variable frequency treatments (Table 7).

Table 7 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6	7	8	9
CM } GM }	27/4	24/5	23/6	25/7	24/8	26/9			
CV	8/4	11/5	3/6	24/6	18/7	5/8	7/9	2[illegible]/9	18/10
GV	8/4	29/4	19/5	3/6	27/6	18/7	9/8	8/9	8/10
CGV	8/4	3/5	20/5	16/6	5/7	2[illegible]/7	22/8	9/9	6/10
GVT	8/4	3/5	23/5	16/6	7/7	1/8	30/8	2[illegible]/9	18/10

Annual herbage yields

There were significant differences among both the organic matter yields and the crude protein yields from the treatments (Table 8) although the yields under monthly defoliation are not directly comparable with those under variable frequency since the monthly treatments received less fertilizer nitrogen over the season. For the treatments in which cutting and grazing can be directly compared, namely, CM with GM and CV with GV, higher yields of utilized organic matter and crude protein were obtained under grazing. The organic matter yield from the CGV treatment was similar to that from the GV treatment but the crude protein yield was intermediate between those from the CV and GV treatments. The highest yield of organic matter was obtained from the GVT treatment in which the herbage was trimmed after grazing; the yield thus included the herbage cut by machine as well as grazed by sheep. The crude protein yield in this treatment was similar to the yield under the CV treatment.

Table 8 Annual utilized herbage yields (100 lb/ac)

Treatment	Organic matter	Crude protein
CM	55.1	10.5
GM	63.3	14.3
CV	55.3	12.6
GV	65.3	19.1
GCV	65.8	17.4
GVT	72.1	18.9
Statistical details:		
F	**	***
Sd	4.2	1.0
L.S.D.	9.0	2.1
C.V. (%)	9.4	9.7

Botanical composition of the herbage

The composition of the swards in April reflects the effects of the treatments applied in 1959 while the composition in October shows the development of these effects during 1960 (Table 9). Perennial ryegrass has increased at the expense of cocksfoot under grazing treatments, under frequent cutting and much more so under the grazing plus trimming (GVT) treatment. Most effects had taken place in 1959 and the further changes in 1960 were slight.

Table 9/

Table 9 Percentage botanical composition of the swards in April and October

	Treatment	Perennial ryegrass	Cocksfoot	Timothy	White clover	Unsown species
April 8	CM	65.5	29.6	1.0	0.4	3.5
	GM	73.2	21.2	1.1	0.9	3.6
	CV	71.5	24.1	1.3	-	3.1
	GV	72.8	23.2	0.6	0.1	3.3
	GCV	73.8	21.1	1.8	0.8	2.5
	GVT	85.7	10.4	0.9	0.2	2.8
October 20	CM	63.1	32.0	0.9	0.2	3.8
	GM	71.1	23.3	0.5	0.1	5.0
	CV	73.5	19.8	0.6	0.6	5.5
	GV	76.9	18.3	-	0.4	4.4
	GCV	75.3	19.8	0.3	0.3	4.3
	GVT	85.7	7.0	1.2	1.1	5.0

Mean annual chemical composition of the herbage

Herbage from grazed treatments (GM, GV) showed only slight differences in organic matter contents but markedly higher crude protein contents than herbage from cutting treatments (CM, CV) for both the available and residual herbage (Table 10).

Table 10 Weighted mean annual percentage chemical composition of the available and residual herbage

	Available herbage		Residual herbage	
Treatment	Organic matter	Crude protein	Organic matter	Crude protein
CM	88.6	17.3	80.1	14.9
GM	87.2	20.5	81.6	18.3
CV	85.3	20.1	81.1	17.6
GV	84.1	25.3	80.1	21.1
GCV	86.2	23.7	81.1	20.4
GVT	82.0	24.6	83.2	21.8

Monthly-defoliated treatments had slightly higher organic matter contents and lower crude protein contents than the variable frequency defoliation treatments for available herbage. Similar differences in crude protein levels were shown for residual herbage but the organic matter levels were similar for all treatments. Residual herbage had lower organic matter and crude protein contents than available herbage.

Seasonal distribution of herbage yields

The utilized yields, derived by difference between the available and residual herbage yields which are tabulated in Appendix 4, showed considerable variation over the season in all treatments (Table 11). Under monthly defoliation, the highest organic matter yields were obtained at the beginning of the season and the lowest in the July-August period with both cutting and grazing while the range of yields was also similar. In contrast, under variable frequency defoliation the yields under cutting showed a wider range than under grazing. In the CV treatment, yields were generally highest in early season and lowest later whereas in the GV treatment yields were also high in April and May but had further peaks in June and August. The general trend of organic matter yields in the GCV treatment was similar to that in the CV treatment whilst apart from the final low yield of 270 lb/ac in October, yields in the GVT treatment varied least of all with a range between 710-1070 lb. By the second or third week in June, 50% of the annual production had been produced in all the treatments.

The crude protein yield distribution over the season followed the organic matter distribution but within much narrower limits since the scale of the yields was much smaller. Thus the high yields of organic matter were usually accompanied by high yields of crude protein and similarly in the case of low yields. The greatest variation in yield was again in the CV treatment and least in the GVT treatment.

Table 11 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Organic matter	Crude protein	Organic matter	Crude protein
	CM		GM	
1	13.7	2.5	11.8	2.5
2	10.9	2.3	15.3	3.2
3	10.3	1.5	12.8	2.2
4	7.1	1.4	6.1	1.8
5	5.9	1.3	7.4	1.9
6	7.3	1.5	10.0	2.9
	CV		GV	
1	7.7	2.2	6.4	2.0
2	13.6	2.9	9.9	2.8
3	6.9	1.5	5.4	1.7
4	7.0	1.3	5.5	1.7
5	2.2	0.5	8.4	2.0
6	3.6	0.8	6.0	1.7
7	7.2	1.5	10.0	2.9
8	4.7	1.3	7.0	2.2
9	2.5	0.7	6.8	2.1
	GCV		GVT	
1	6.3	1.8	8.8	2.5
2	9.8	2.8	7.1	2.0
3	9.6	2.4	9.2	2.2
4	10.9	2.4	10.7	2.5
5	6.5	1.2	10.0	2.2
6	8.2	2.4	8.5	2.2
7	4.2	1.1	7.4	2.3
8	2.7	1.0	7.6	2.2
9	7.7	2.3	2.7	0.8

Accumulative herbage yields

Figure 5 shows the development of accumulative herbage yields over the season for the treatments. In treatment comparisons CM with GM and CV with GV, the organic matter and crude protein became higher under grazing than under cutting quite early in the season. The differences were wide by the end of the season.

Figure 5/

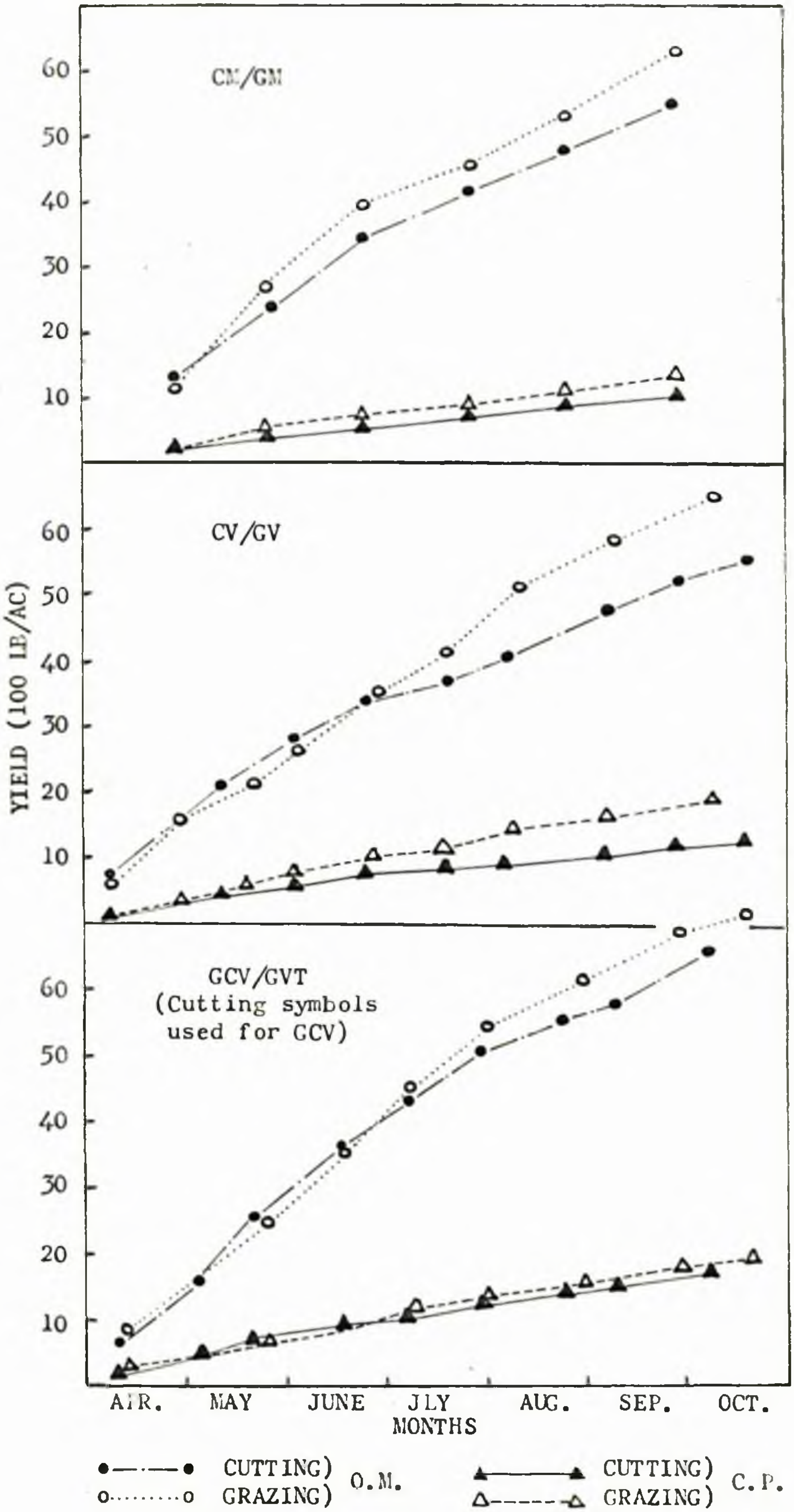


Figure 5 Accumulative utilized herbage yields for each treatment

Seasonal chemical composition of the herbage

Table 12 and Figure 6 show the organic matter and crude protein contents in the available and residual herbage for each treatment over the season.

Table 12 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage O.M.	Available herbage C.P.	Available herbage O.M.	Available herbage C.P.	Residual herbage O.M.	Residual herbage C.P.	Residual herbage O.M.	Residual herbage C.P.
	CM		GM		CM		GM	
1	89.7	18.2	88.1	20.0	85.0	16.9	89.2	17.7
2	90.7	19.0	90.7	19.0	88.1	15.4	90.0	16.2
3	88.1	15.8	88.2	16.8	75.9	12.9	74.2	16.6
4	86.6	17.0	86.7	21.0	76.0	14.1	80.5	17.4
5	89.6	17.5	83.2	22.5	80.5	14.0	83.8	20.5
6	86.5	19.5	85.3	25.8	81.6	17.9	80.1	22.6
	CV		GV		CV		GV	
1	84.8	27.8	83.9	29.9	80.6	26.1	79.0	26.8
2	87.4	20.4	86.1	27.4	84.5	18.1	84.6	25.2
3	83.5	18.8	86.2	24.9	75.0	16.1	81.2	22.2
4	86.5	16.4	86.0	24.0	79.8	14.7	87.1	19.4
5	85.2	15.7	81.2	20.1	82.0	15.8	79.3	17.2
6	88.0	18.4	81.6	24.1	86.5	16.1	75.6	19.8
7	88.4	19.9	86.1	24.5	84.5	19.6	79.4	18.6
8	83.2	22.5	84.4	28.6	79.0	19.0	75.6	24.6
9	76.7	24.8	80.2	28.9	81.0	24.0	75.1	24.1
	GCV		GVT		GCV		GVT	
1	86.2	27.7	84.3	27.6	84.2	25.7	76.4	25.7
2	87.1	26.4	85.4	26.5	85.1	21.0	82.2	22.4
3	88.5	22.1	76.5	23.5	85.8	18.5	88.0	22.7
4	88.0	21.5	87.6	22.0	81.2	19.1	86.3	19.9
5	81.4	17.2	76.1	20.8	77.2	16.1	86.3	18.7
6	86.0	24.3	85.6	23.7	81.7	19.2	83.6	21.1
7	88.8	22.0	84.8	27.4	84.8	19.1	81.7	22.9
8	82.3	27.6	81.8	27.6	75.6	24.7	78.2	23.4
9	86.8	27.9	72.4	27.5	78.1	24.7	73.7	23.1

Available herbage: In most treatments, organic matter contents were highest in early season and lowest in late season, though the fall was irregular. There was little consistent effect of treatment but top and bottom values under monthly defoliation were both slightly higher than under variable frequency defoliation. The range was widest in the CV and GVT treatments due to the low values at the final defoliations.

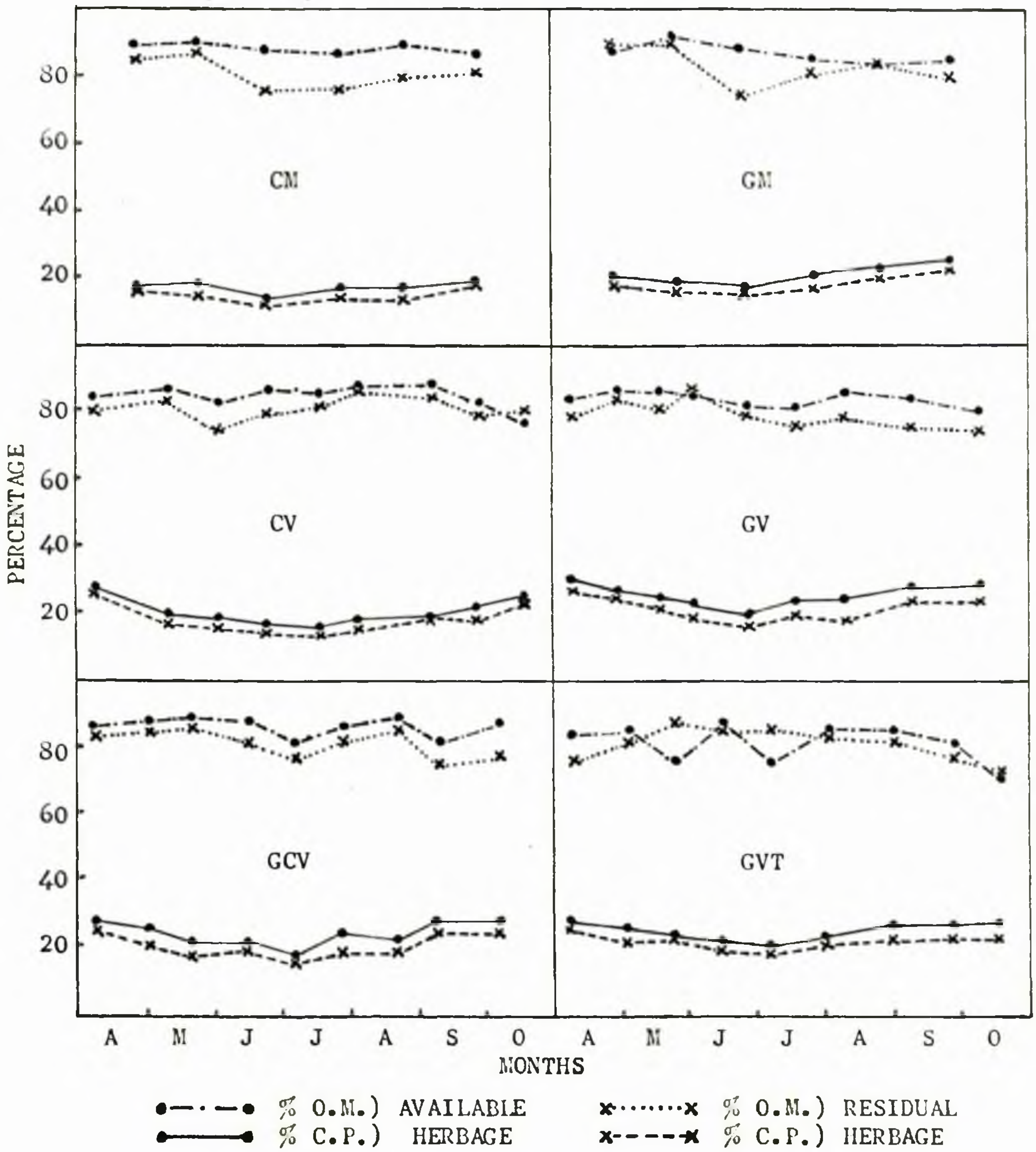


Figure 6 Seasonal percentage chemical composition of the available and residual herbage for each treatment

The levels of crude protein were generally higher under grazing than under cutting and under variable frequency defoliation than under monthly. In every treatment, the lowest values were always in the June-July period and the highest at the beginning and end of the season. As shown in Figure 6, the fall to midseason and the rise thereafter were fairly regular.

Residual herbage: Treatment had evidently little effect on the organic matter contents since the highest values were around 86-90% and the lowest values, 74-76%. The range was widest in the GM and GVT treatments. The low values shown by the treatments indicate considerable contamination of the herbage by soil. The top values were recorded mainly in May while the low values were most frequently recorded in late season under variable frequency defoliation and in June under monthly defoliation.

Crude protein contents were generally higher under grazing than under cutting and also under variable frequency defoliation relative to monthly defoliation. The range between top and bottom levels was 7-12 percentage units under variable but only 4-6 units under monthly defoliation. The peak values were usually obtained at the first defoliations in April while the lowest values were most frequently obtained in July. After July, the values rose again towards the end of the season.

Comparison of available and residual herbage: As shown in Table 12 and Figure 6, the levels of organic matter and crude protein were invariably higher in the available herbage, but the seasonal range of the organic matter contents was broadly similar and that of the crude protein contents closely similar in both types of herbage.

EXPERIMENTS 1 AND 2

Discussion

Enclosures

The movable aluminium alloy folds used to enclose the sheep in Experiment 1 were light, easy to handle and capable of being quickly moved from one treatment to another. The folds were expensive but their non-rust nature gave them a long life. They could also be dismantled and the material used for other purposes. In the absence of a network of permanent fencing, there was free access to the plots with sampling machinery. Manoeuvring the Allen motor scythe to apply the cutting treatments was facilitated. Because the cages were only placed on the plots for the 1½-2 day periods of grazing, modification of the sub-plot environment as noted by Cowlishaw (1951) and Williams (1951) was minimized.

All the plots in Experiment 2 were individually fenced with sheep netting wire, therefore modification of the microclimate would be the same in both cutting and grazing areas. The fencing made it difficult to cut the outside edges of the plots. The use of either grazing cages or small plots reduces the area normally required for grazing trials and allows replication and the use of statistical design.

Sampling

The constant sampling became too much for the J.A.P. two-stroke engine, although its smallness, lightness and portability made it a useful source of motive power for the Wolseley sheep shears. The B.M.B. Hoe-mate light tractor finally adapted to take its place proved very reliable and satisfactory. The Wolseley shearing equipment was also satisfactory, both mechanically and as a means of cutting herbage to ground level. Routine maintenance was an important factor in keeping all the sampling equipment serviceable. The shearhead was suitable for the various types of herbage sampled which ranged from 11-13 in. available herbage to 1-1½ in. residual stubble and no difficulty was encountered cutting the narrow 3 in. strip along a straight edge, although care had to be taken that the short residual herbage was not flicked away by the vibration from the cutters. It is easy to adhere strictly to ground level when cutting residual stubble since the ground can be clearly seen but when shearing tall herbage, ground level is determined more by the feel of the knuckles of the hand holding the shearhead than by sight. Bone and Tayler (1963) found that shearing to ground level was less accurate with tall herbage than with short whilst Alder and Richards (1962) consider that the shearhead is best used for sampling herbage not taller than 4-5 in.

Application of treatments

The mean available and residual herbage yields of organic matter per defoliation (Table 13) show that the various intensities of defoliation under cutting and grazing were satisfactorily applied in the two experiments considering the differences in the manner of defoliation between motor scythe and sheep. The motor scythe cut down the herbage cleanly and evenly at the various severities required whereas defoliation by the sheep was uneven since parts of the plots were grazed barer than the designated heights and other areas undergrazed, particularly those fouled by dung or treading. The areas around the perimeters of the plots were always closely grazed since these areas were rarely fouled. Grazing was less satisfactory in wet weather when some of the herbage was trampled down rather than grazed. Stapledon and Jones (1927) and Jones (1937) noted that sheep in folds spent less time grazing than usual in wet weather. The unevenness of grazing was reflected in the uneven appearance of the regrowths compared with the uniform regrowths after cutting.

Table 13 Mean available and residual herbage yields of organic matter per defoliation in experiments 1 and 2 (100 lb/ac)

Herbage	Defoliation intensity	Defoliation method Cutting	Grazing
Available:			
Experiment 1	(4-1)	10.2	8.4
	(8-1)	14.7	12.9
	(8-2)	14.1	12.6
	(12-2)	17.4	17.5
	Means	14.1	12.9
Experiment 2	Monthly (M)	15.7	20.7
	Variable (V)	12.5	13.9
	Means	14.1	17.3
Residual:			
Experiment 1	(4-1)	4.8	4.0
	(8-1)	4.3	5.1
	(8-2)	8.0	6.2
	(12-2)	8.5	7.3
	Means	6.4	5.7
Experiment 2	Monthly (M)	6.5	10.2
	Variable (V)	6.4	6.7
	Means	6.5	8.4

Dates of cutting and grazing did not coincide under a given defoliation intensity treatment. In Experiment 1 the interval between grazings was shorter than between cuttings so that there were more grazings during the season. In Experiment 2 there were equal numbers of cuttings and grazings although the intervals were usually shorter under grazing except towards the end of the season. Thus, in general the rate of growth was slightly faster after grazing. This effect will be partly due to the return of excretal nitrogen since Walker et al. (1954) calculated that 50-60% of the total ingested nitrogen is readily available, mainly as urine, for re-utilization by the sward. The effect may also be partly due to differences in the photosynthetic efficiencies of the residual herbages. Efficiency would be greater after grazing since the uneven defoliation would leave a greater ratio of photosynthetic tissue to stubble than would be left after uniform cutting. The importance of this ratio in the rate of initiation of regrowth has been noted by Brougham (1956, 1959).

Herbage yields

Effects of defoliation method: There was an increase of 14% in the organic matter yield from grazing compared with cutting in Experiment 1 (Table 2). A similar increase of 16% was recorded in Experiment 2 using the results from the two comparable pairs of treatments, CM/GM and CV/GV (Table 8). Yields from grazing treatments would be slightly underestimated since no account was taken of growth during the grazing periods. Individual grazing periods were short, but over the season totalled 9-13½ days in Experiment 1 depending upon treatment and 18 days in Experiment 2 for each treatment except the alternate cutting and grazing treatment GCV where it totalled 10 days. Compared with the CV treatment the yield under the GCV treatment was 17% greater whilst there was a 30% increase from the GVT treatment which included a trimming cut after grazing. Crude protein yields were also greater under grazing by 36% in Experiment 1 and 45% in Experiment 2. Relative to the CV treatment, crude protein yield was 38% higher under the GCV treatment and 50% higher under the GVT treatment. Sears (1953a), Sears et al. (1953) and Wolton (1963), working with perennial ryegrass-dominant swards, also obtained dry matter yield increases from grazing relative to cutting. In contrast, Bryant and Blaser (1961) obtained a 33% yield advantage from cutting on a cocksfoot sward but since the grazing periods were only 12 hours or less and the dung droppings were removed, the return of excreta was not in proportion to the amount of herbage grazed.

Yield responses from grazing relative to cutting have been attributed to recirculation of sward nutrients (Sears and Newbold, 1942; Sears et al., 194 ; Watkin, 1954). With intensive grazing on small plots, Herriott et al. (1959) and Herriott and Wells (1963) calculated that sheep returned 130-140 lb/ac nitrogen and 115-120 lb/ac potassium on a grass/clover sward. Because of low availability of nitrogen in the dung and losses of urinary nitrogen by hydrolysis of the urea fraction (Sears and Newbold, 1942; Doak, 1951, 1952; Watkin, 1957) it has been calculated that only 50-60% of the excretal nitrogen is available to the sward (Walker et al., 1954). Nitrogen has the greatest effect on yield unless the soil is potassium-deficient, and most of the readily available excretal nitrogen is in the urine (Sears and Newbold, 1942; Doak, 1951, 1952; Watkin, 1957; Mundy, 1961). Although excretal nitrogen can be ineffective under extensive grazing conditions because of uneven distribution, this would be unlikely in Experiments 1 and 2 because of the high stocking rates employed. Under fairly similar conditions, Herriott and Wells (1963) calculated that over a season, the sward would receive urinary cover six times. Also, since the experimental swards were both grass-dominant, there would be little of the antagonism between clover and urinary sources of nitrogen recorded by Sears and Thurston (1952), Watkin (1954), Wheeler (1958) and Watson and Lapins (1964). The yield response obtained supports the inference of Green and Cowling (1960) that recirculated nitrogen is effective on grass swards. Data presented by Mundy (1961) and Herriott and Wells (1963) also support this inference. The crude protein yields shown in Tables 2 and 8 show that more nitrogen was available under grazing than under cutting and as shown by Figures 2 and 5, the recirculated nitrogen was cumulatively effective in increasing yield, since the superiority of the organic matter yields emerged slightly later in the season than the superiority of the crude protein yields.

The yield advantage from grazing may conceivably have been lessened by the trampling effects of the sheep on the swards. Edmond (1958a, c, 1964) and Scheaf (1965) have shown reduced yield from treading as a result of direct injury by bruising and destruction of the growing points, stems, leaves and roots of the plants and a reduction in the density and growth vigour of the grass tillers. Reduced vigour and herbage yield due to soil compaction have also been noted (Edmond 1958b, 1963; Tanner and Mamaril, 1957; Gradwell, 1965). These treading effects are intensified in wet weather. The treading effects on the yield from the experimental swards may have been mitigated since perennial ryegrass which was the dominant constituent in the swards has been rated as very tolerant to treading by Ellenberg (1952) and Edmond (1964). The other main constituents of the swards, cocksfoot and timothy, have been rated as medium-tolerant.

Because of the high stocking rates, which were equivalent to 500-750 sheep per acre in Experiment 1 and 300 in Experiment 2, there was little inter- or intra-plant selective grazing in the experiments but there was inter-area selectivity since herbage fouled by dung or trampled was neglected whilst other areas were cropped bare. Urine did not appear to affect the acceptability of herbage. Any reduction in utilized yield due to non-utilization of the neglected areas would to some extent be counter-balanced by the utilization beyond the desired level of the areas grazed bare. The net effect of the selection which operated on the experimental swards is thus difficult to determine though Bryant and Blaser (1961) considered that over-grazing on parts of their plots was one of the main factors responsible for lower yields from grazing than from cutting.

Effects of defoliation intensity: In Experiment 1, organic matter yields were increased by infrequent compared with frequent defoliation. Thus, the yield was greatest when defoliating 11-13 in. herbage and lowest with 3-5 in. herbage (Table 2). Yields from 7-9 in. herbage were intermediate. These results are in agreement with those from workers in Britain and elsewhere both for cutting (Wagner, 1952; Reid, 1959; Chestnutt, 1960; Taylor et al., 1960; Bryant and Blaser, 1961; Muokuna, 1964) and for grazing (Williams, 1952;

Brougham, 1959, 1960; Taylor et al., 1960; Bryant and Blaser, 1961; Weeda, 1965). The crude protein yields were also affected by the frequency of defoliation. The yields under the (4-1) and (12-2) defoliation treatments were similar since the low organic matter yields of the former were accompanied by high crude protein contents and the high yields of the latter by low crude protein contents (Tables 5 and 6). The crude protein yields from treatments (8-1) and (8-2) were similar but were slightly lower than the yields from the other two treatments. In Experiment 2, the yields from treatments defoliated monthly are not directly comparable with those defoliated at variable frequencies since the monthly treatments received less fertilizer nitrogen. The effect of defoliation severity is shown in the comparison of (8-1) and (8-2) treatments in experiment 1 and the GV and GVT treatments in Experiment 2, in which close defoliation has given an 8-10% increase in organic matter yields but has had little effect on crude protein yields. Marked increases in dry matter yield from close defoliation relative to lax have been recorded in cutting trials by Reid (1959, 1962), Chestnutt (1960), Bryant and Blaser (1961), Huokuna (1964) and MacLusky and Morris (1964) and in grazing trials by Brougham (1959), Bryant and Blaser (1961) and Weeda (1965) although the latter obtained greater yields from lax grazing after the second year of his trial.

Differences in yield as a result of varying the severity of defoliation have been attributed to differential effects on stem and leaf formation in the plants (Reid, 1959, 1962; Reid and MacLusky, 1960). By removing developing inflorescences, close defoliation stimulates tiller and leaf production; in contrast, by permitting flower development, lax defoliation inhibits tiller and leaf production. Studies by Cooper and Saeed (1949) and Langer (1957) support these suggestions. Wilson and McGuire (1961) have also suggested that close defoliation improves the light intensity at the base of the sward which in turn stimulates tillering.

Botanical composition of the herbage

Changes in the botanical composition of the swards in the two experiments were slight (Tables 3 and 9). The ryegrass was favoured by all the grazing treatments and frequent or severe cutting whereas cocksfoot was favoured by infrequent cutting. A similar differential reaction from ryegrass and cocksfoot to cutting and grazing systems has previously been noted (Stapledon and Milton, 1932; Jones, 1939; Sears, 1953a; Wheeler, 1958; Weeda, 1965).

Chemical composition of the herbage

Since herbage similar to the available herbage in the experiments usually has organic matter contents in the region of 88-91% (Watson, 1951; Evans, 1960), considerable soil contamination has occurred under both cutting and grazing throughout the season, but particularly in late season (Tables 6 and 12). Contamination in the residual herbage followed a similar seasonal trend but the degree of contamination was greater since this herbage was affected by the passage of cutting machinery or the trampling of sheep during the application of the treatments. Residual herbage, which is mainly composed of dead leaf bases and stubble, has slightly higher organic matter contents, i.e. reciprocally lower ash contents, than available herbage which is mainly leafy regrowth (Watson, 1951). There were slight increases in contamination as the frequency or severity of defoliation was increased. Since the soil surface of the plots would become progressively more uneven as the defoliations were repeated, clean ground-level sampling would be more difficult and this would partly account for the increased contamination noted as the season progressed. Another contributory cause would be the higher rainfall normally experienced at Auchincruive during the later months of the season (Grainger, 1963) and which occurred in 1960 (Appendix 2). Wet weather can cause increased contamination directly by soil splash and indirectly by rendering the soil surface more susceptible to poaching, which causes admixture of the soil and herbage.

The extent of soil contamination in the experiments fully justifed the use of ash-free organic matter as the expression of herbage yield in place of the more customary dry matter. This conclusion accords with Green (1959), Alder and Richards (1962) and Bone and Tayler (1963). Past work has also shown the need to adjust herbage dry matter yields to account for soil contamination even at cutting heights of ½-¾ in. above ground level (Woodman and collaborators, 1926, 1927, 1928, 1929, 1931, 1932; Watson et al., 1932; Davies et al., 1950).

Crude protein contents of available and residual herbage were greater under grazing than under cutting in both experiments, results which can be attributed to the recirculation of nitrogen previously discussed. In accordance with many previous findings (Watson, 1951; Reid, 1959; Evans, 1960; Reid and MacLusky, 1960), crude protein contents were little affected by defoliation severity but decreased as the frequency of defoliation was reduced and the herbage became more mature at defoliation. The available herbage regrowths had consistently higher crude protein values than the residual stubble (Tables 6 and 12), as would be expected from the relative proportions of leaf and stem in the herbage (Fagan and Jones, 1924; Fagan and Milton, 1931; Waite and Sastry, 1949; Watson, 1951). The crude protein levels also showed typical seasonal variation (Heddle, 1965; Reith et al., 1964; Alexander, 1963) with highest levels always occurring in late season.

EXPERIMENTS 1 AND 2

Summary

1. Studies were made on two perennial ryegrass-dominant swards of the effects of various cutting and grazing systems on herbage production. Cutting was carried out by motor scythe and grazing by sheep enclosed either in movable aluminium alloy folds of 1/250 ac. (Experiment 1) or in individually-fenced plots of 1/100 ac. (Experiment 2).

2. Available herbage yields and residual herbage yields were determined by sampling the herbage to ground level with power-driven sheep shears. The weight of herbage removed by motor scythe or sheep was then given by the difference between these yields.

3. Utilized yields of herbage organic matter were increased by grazing compared with cutting. The increase is attributed to recirculation of nitrogen by the grazing animals. The yield relationship between cutting and grazing was 100:114 in Experiment 1 and 100:116 in Experiment 2. Utilized yields were also increased by infrequent defoliation relative to frequent and by severe defoliation in comparison with more lenient defoliation under both cutting and grazing.

4. Utilized yields of herbage crude protein were increased by grazing compared with cutting but neither frequency nor severity had any consistent effect.

5. The proportions of perennial ryegrass in the two swards were increased by grazing and frequent or severe cutting whereas infrequent cutting favoured cocksfoot, but the changes were small.

6. Organic matter contents were lower in residual herbage than in available herbage under both cutting and grazing. This effect is attributed to greater soil contamination as a result of the passage of machinery when applying cutting treatments and the treading of sheep in the grazing treatments.

7. Crude protein contents of both available and residual herbage were slightly higher under grazing treatment than under cutting. This effect is attributed to recirculation of nitrogen by the sheep.

EXPERIMENTS 3, 4, 5 AND 6

Experimental methods and materials

Field

The experiments were carried out in Donald's Thorn, a field of 4¾ acres. A report by the Macaulay Institute for Soil Science described the soil as an imperfectly-drained brown loam formed on reddish-brown clay (Thomson, 1960). A complete drainage system was laid into the field in 1958. Because of its proximity to the farm steading, the field had been intensively cropped especially by root cropping. From 1955 to 1959, four crops of mangolds and one of marrow-stem kale were taken. The manuring per acre per annum during this period was 15-23 tons farmyard manure, 36-103 lb N, 34-90 lb P_2O_5 and 43-150 lb K_2O. In 1960, after cultivations, the field was sown out with oats on 7th April; 90 lb P_2O_5 per acre was applied as superphosphate. The soil, sampled in February, 1961 to a depth of 5 in. with a soil-sampling auger had an analyses of: pH, 5.89; available P_2O_5, 5 mg/100 g soil; available K_2O, 7 mg/100 g soil; by the classification of Whittles (1952), the values indicated that the soil had 'medium' contents of available phosphate and potash.

Swards

On 6th May, 1960, the oats were undersown with two experimental grass seed mixtures, one to each half of the field. The seed was obtained direct from the Welsh Plant Breeding Station, Aberystwyth. The mixtures were:

		lb/ac
(a)	Aberystwyth S.24 perennial ryegrass	30
	Aberystwyth S.100 white clover	1
	Total	31
(b)	Aberystwyth S.23 perennial ryegrass	30
	Aberystwyth S.100 white clover	1
	Total	31

The oats were harvested by combine harvester in September under good weather conditions. The establishment of the grass swards was excellent.

Manuring

In 1961, 31 lb P_2O_5 and 45 lb K_2O per acre as potassic superphosphate (18% P_2O_5; 10% K_2O) were applied to the whole field in March. During the season, one half of each sward received no nitrogenous fertilizer ($S.24/N_o$, $S.23\ N_o$ swards) and the other half of each sward, 52 lb N as Nitro-chalk (15.5% N) in March and 52 lb N in July ($S.24/N_{104}$, $S.23/N_{104}$ swards). This manuring procedure was repeated in 1962.

Subdivision of field

In February, 1961, the experimental plot area of an acre in the centre of the field was trimmed by Allen motor scythe and raked to remove the straw stubble remaining from harvest time. Four experiments, one at each nitrogen manuring level on each sward, were laid out. The experiments were designated as follows:

Sward	Experiment No.
$S.24/N_o$	3
$S.23/N_o$	4
$S.24/N_{104}$	5
$S.23/N_{104}$	6

Each experiment consisted of an experimental plot area of ¼ acre with a contiguous holding paddock for sheep of just under 1 acre. The experimental areas, the individual grazing sub-plots (20ft x 10ft) within these areas and the holding paddocks were enclosed by permanent fencing, erected in March by contract at a cost of £362 for material and labour. Fence stobs at 5ft intervals and 3ft high, 4in. mesh, 16 gauge sheep netting, with a top and bottom plain wire were used. The total length of fencing was approximately 1100 yd. Gates with a 10ft x 3ft 3in. framework of aluminium alloy angle strips and covered with sheep netting wire were used to close off the fenced grazing treatment plots. Other gates of a simple sliding type, built of wooden slats, were made for various gateways on the network of paths in the experimental areas. A pen for handling the sheep was constructed for each experiment.

Experimental treatments

The experimental treatments, identical for each of the four experiments, were:

Defoliation method:

Cutting (C)

Grazing (G)

Defoliation intensity:

Frequency:	Monthly (M)		
	Variable (V)	7-9 in. herbage	
Severity:	Low (L)	$1-1\frac{1}{2}$ in.	from ground level.
	High (H)	$2-2\frac{1}{2}$ in.	from ground level.

An Allen motor scythe with a 2 ft wide cutter bar was used to apply the cutting (C) treatments and sheep to apply the grazing (G) treatments. These treatments were then applied at all combinations of defoliation frequency and severity, viz., ML, MH, VL and VH.

The monthly frequency (M) treatments were applied at calendar-monthly intervals. The defoliation dates for the experiments on the S.24 swards were fixed for the first week in each month starting in May whilst the dates for the experiments on the S.23 swards were fixed for the second week. Within each sward, the dates were fixed earlier for the experiment in which nitrogen fertilizer was applied. These monthly defoliation periods were chosen to coincide with those normally selected by the Grassland Committee of the Scottish Agricultural Improvement Council when evaluating herbage varieties by cutting in potentiality trials. The dates were also planned to allow the load of sampling and application of the treatments to be spread over a period and made physically manageable.

The variable frequency (V) treatments were applied independently under both cutting and grazing when the herbage reached a modal height per four replicate sub-plots of 8 in. from ground level. The herbage height was measured at ten randomly-selected positions per sub-plot by gathering a handful of herbage and judging the modal height against a ruler. To apply the low severity (L) cutting treatments, the motor scythe was fitted with a 'Universal' cutting assembly adjusted to leave a stubble height of 1-1½ in.; a 'Standard' cutting assembly, which left a stubble height of 2-2½ in., was fitted for the high severity (H) treatments (Plate 3). The severity of defoliation in the grazing treatments was controlled by varying the number of sheep enclosed and the time spent grazing in the individual sub-plots. These were determined on the basis of the experience gained in Experiments 1 and 2 as follows:

ML - 3 sheep for 2 days   VL - 3 sheep for 1½ days

MH - 2 sheep for 2 days   VH - 2 sheep for 1½ days

Plate 4 shows a grazing treatment (GVL) being applied.

Experimental design

In each experiment a split-plot statistical design was used with four replications of the defoliation methods as 20ft x 40ft main-plots and the defoliation intensities as 20ft x 10ft sub-plots (1/217.8 acre). The main-plot treatments were randomized independently within each block and the sub-plot treatments within each main-plot, giving a total of 32 sub-plots per

Plate 3

Allen motor scythes used to apply the cutting treatments. Fitted with 'Universal' cutting assembly (left) and 'Standard' cutting assembly (right).

Plate 4

Sheep used to apply the grazing treatments experiment. Replicates were treated concurrently. Access to the sub-plots was made by 5 ft paths between blocks I and II, and III and IV. Figure 7 illustrates the plot layout using Experiment 3 as an example while Plate 5 shows one of the replicates.

In choosing this statistical design, it was accepted that some precision would be lost in the measurement of defoliation method effects whereas precision would be increased in the measurement of the effects of defoliation intensities and their interactions with defoliation methods. However, the experience obtained in Experiments 1 and 2 indicated that the allocation of cutting versus grazing treatments as main-plots would be most suitable for simplification of the fencing network required and for convenience in the application of the treatments, particularly the cutting treatments.

Sheep management

From 60 Greyface ewe hoggs purchased early in April, 1961 at Ayr market, 52 were drawn out for similarity in age, weight and general condition. By random allocation, two flocks of 26 were made up, one for Experiments 3 and 4 (S.24/N_0, S.23/N_0 swards) and the other for Experiments 5 and 6 (S.24/N_{104}, S.23/N_{104} swards). The use of separate flocks for the two levels of fertilizer nitrogen was made to minimise fertility transference from the holding paddock swards to the experimental sub-plots, since the holding paddock and experimental area were under the same nitrogen treatment.

The sheep required to apply the grazing treatments within an experiment were randomly drawn from the flock of 26. Since replicates were grazed concurrently, the number of sheep required for a single grazing treatment was:

GML - 12 sheep	GVL - 12 sheep
GMH - 8 sheep	GVH - 8 sheep

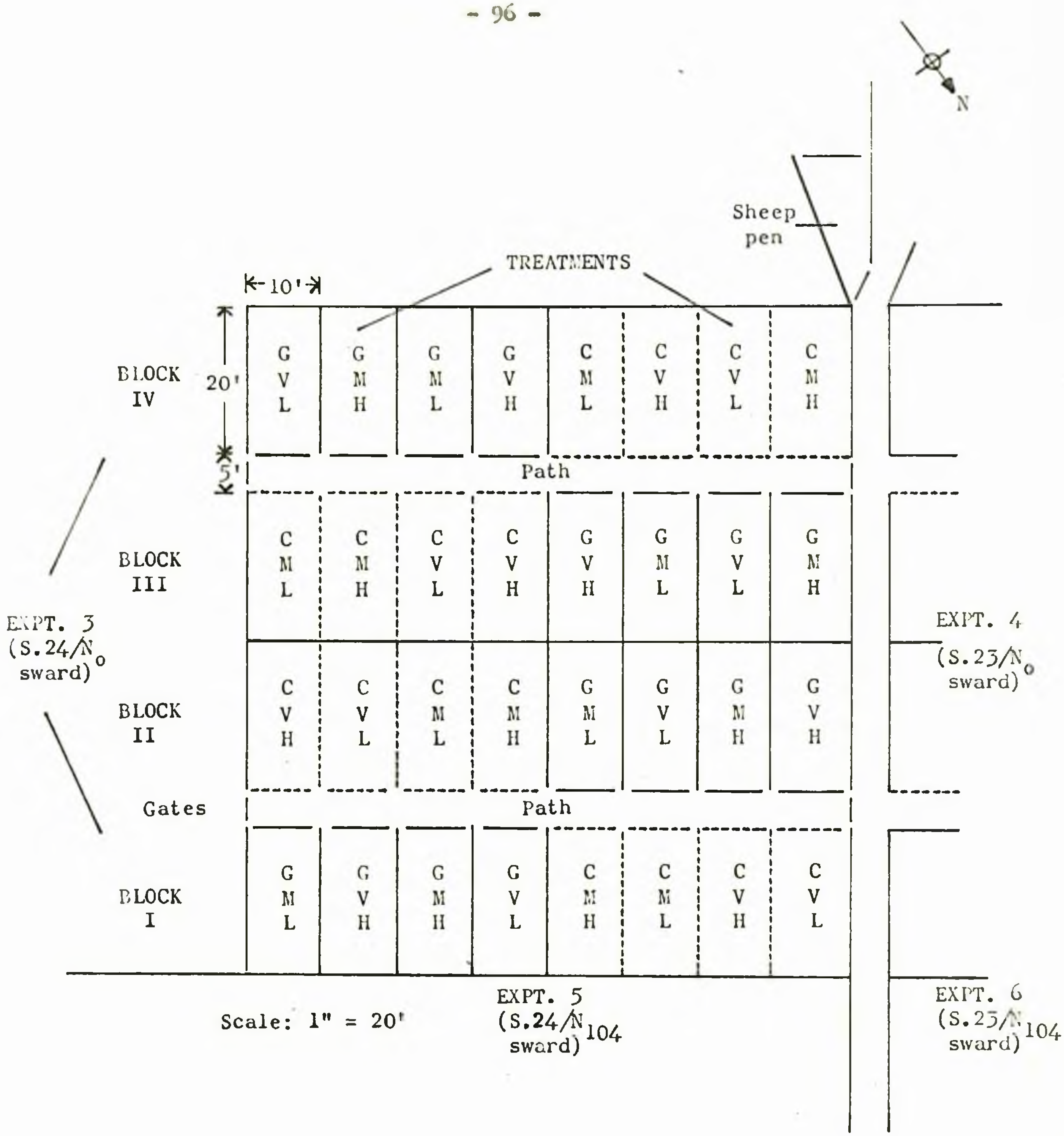


Figure 7 Illustration of part of experimental plot layout using Experiment 3 (S.24/N_0 sward) as example

Plate 5

Replicate in Experiment 3 (S.24/N_0 sward) showing cutting treatments (foreground) and grazing treatments (background).

P

Allen motor scythe fitted with Cooper-Stewart drive and Wolseley sheep shears.

The monthly treatments, GML and GMH, were also grazed concurrently, so that 20 sheep were required within an experiment to apply these two treatments at any one date. The variable frequency treatments, GVL and GVH, were rarely grazed concurrently since these treatments were applied independently when herbage growth was 7-9 in. Thus 12 or 8 sheep were usually needed at any one date. Sufficient sheep were available to apply simultaneously any two of the four variable frequency treatments from the two experiments within a particular nitrogenous fertilizer level e.g. 24 sheep needed if treatment GVL in Experiment 3 was ready for grazing at the same date as GVL in Experiment 4. In October, at the completion of grazing treatments for 1961, the sheep were sold at the local market.

In 1962, 60 Greyface ewe hoggs were again bought in April at Ayr market and 50 drawn out in the same manner as before. By random allocation, two flocks of 25 were made up, one for Experiment 3 (S.24/N_0 sward) and the other for Experiment 6 (S.23/N_{104} sward). Experiments 4 (S.23/N_0 sward) and 5 (S.24/N_{104} sward) were not continued into 1962, but the swards were used as additional holding paddocks. The application of the grazing treatments was similar to that described for 1961. The sheep were again sold at the local market in October, 1962 at the completion of the experiments.

Sampling machinery

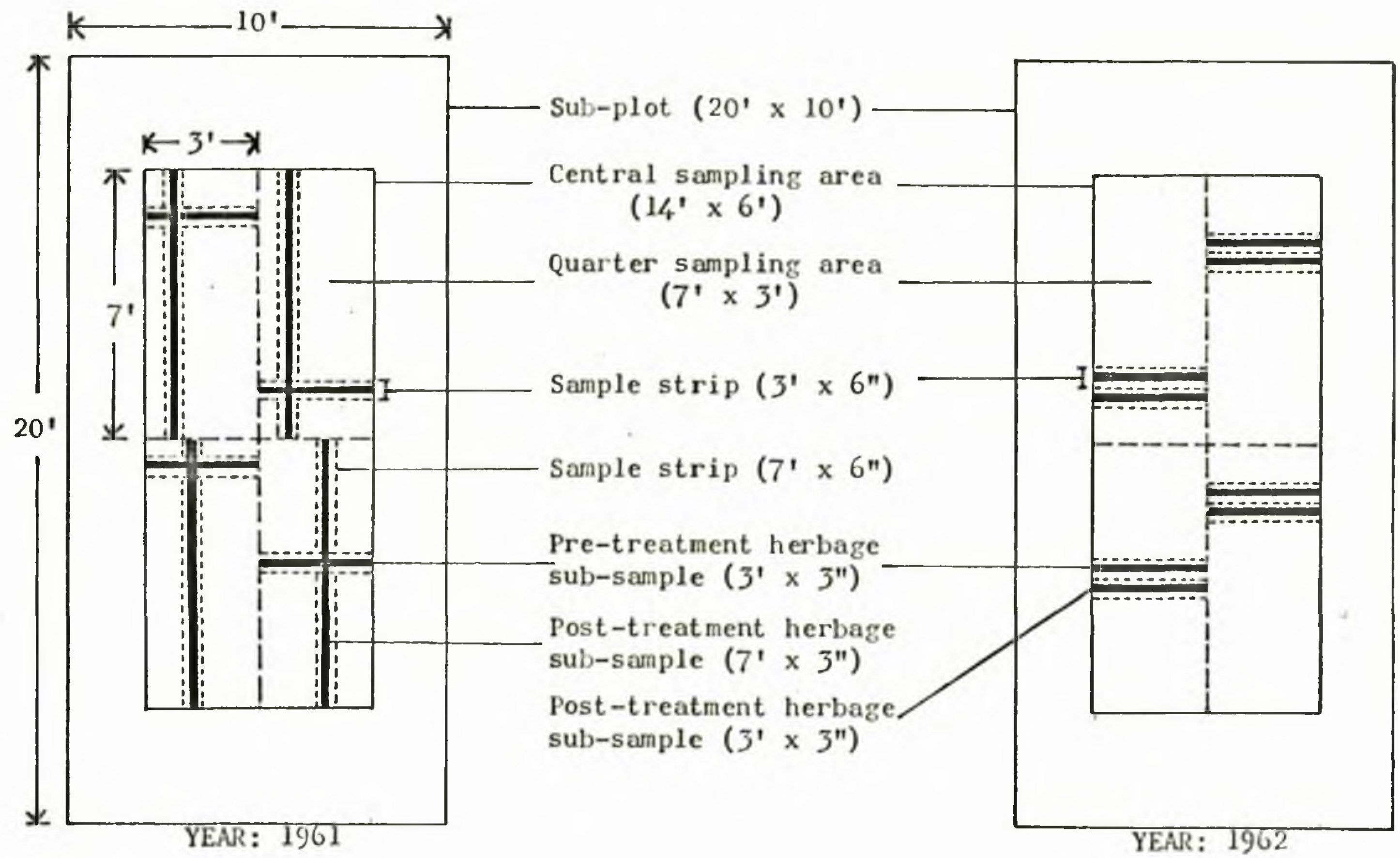
At each cutting and grazing, pre- and post-treatment herbage samples were taken by using power-driven Wolseley sheep shears ('Ringer' shearing head, Series II, wide pattern) with a special 3 in. grass-cutting comb to shear strips of herbage to ground level. Power was supplied by either a Brockhouse B.M.B. Hoe-mate light tractor (1¾ H.P.) or an Allen motor scythe (Villiers engine, 1.9 b.h.p.). The standard 6 ft Wolseley flexible driving shaft with slip clutch was used with the B.M.B. tractor, which meant that the machine had to pass over the sub-plots during sampling. To avoid this, the method finally developed was to attach a Cooper-Stewart twin drive with slip clutch to the power take-off of the motor scythe and use a 20 ft Cooper-Stewart flexible driving shaft (Plate 6).

Yield sampling : general

When sampling herbage within a plot to obtain an estimate of yield, it is necessary to devise a scheme of sampling which satisfactorily takes account of the variability of herbage growth within the plot. At the same time, sampling by any instrument is itself a treatment and it is necessary to devise a sampling scheme which allows the experimental treatment to affect the sward. These objects were achieved by a systematic scheme of sampling each part of the sub-plots and by keeping the sampling area down to a minimum. Sampling must also be applied to herbage which reflects the experimental treatment and not a previous sampling. This was achieved by using fresh sampling sites at each sampling period.

Yield sampling in cutting treatments

Available herbage (pre-treatment samples): In each sub-plot, peripheral areas, which had to bear the passage of cutting machinery, were discarded for sampling purposes and the sampling confined to a central sampling area, 14ft x 6ft, which was demarcated with pegs. Within each quarter of this sampling area, a herbage sub-sample, 3ft x 3in., was shorn from within a randomly-selected sample strip, 3ft x 6in. and the four sub-samples bulked to give a sub-plot sample (Figure 8). This sample was collected in a polythene bag and taken to the laboratories for yield and chemical composition determinations. Each sub-plot sample consisted of herbage from 3.6% of the central sampling area or 1.5% of the sub-plot area. The sample strips were located by placing



<u>Scale</u>: 1" = 5'

<u>Figure 8</u> Illustrations of experimental plots from Experiment 3 ($S.24/N_o$ sward) to show sampling for yield in the cutting treatments in 1961 and 1962

a 14 ft length of aluminium alloy angle, marked off in 6 in. divisions, along the edge of the sampling area and then placing a 3 ft length at right angles to this as a straight edge (Plate 7). Within each quarter there were fourteen potential sample strips of 3ft x 6in., each of which was used once only.

Utilized herbage: Two estimates of the herbage utilized (cut and removed) were made. The difference between pre- and post-cutting samples taken by sheep shears provided a 'shearhead' estimate comparable with the shearhead estimate of the herbage utilized by grazing which was obtained from the difference between pre- and post-grazing samples. The shearhead sampling method was thus the standard method used in the experiments. In addition, by taking a sample swath during the cutting treatment, a 'motor scythe' estimate of the herbage cut and removed was taken to act as a check on the shearhead estimate. Discard swaths of herbage were cut and removed at each end of the sub-plot and a sample swath, 14ft x 2ft 1½in., cut from the central sampling area. The swath was raked, collected in a polythene bag and taken to the laboratories for yield and chemical composition determinations. Yield was calculated on a swath length of 13ft 6in. to allow for the 3 in. pre-treatment sub-samples. The remainder of the sub-plot was trimmed down, and the cut herbage raked off and discarded to complete the cutting treatment.

Residual herbage (post-treatment samples): The procedure in 1961 was similar to that for available herbage described above except that the herbage sub-samples, each 7ft x 3in., were taken from sample strips at right angles across the pre-treatment sample strips (Figure 8) and a 7 ft straight edge used. For yield calculations, the sub-sample lengths were adjusted to 6ft 9in. to exclude the 3 in. crossed by the previously taken pre-treatment sub-samples. Each sub-plot sample consisted of 3.0% of the central sampling area or 3.4% of the sub-plot area. There were six potential sample strips of 7ft x 6in. within

Plate 7

Yield sampling of available herbage in the cutting treatments.

Plate 8

Yield sampling of available herbage in the grazing treatments.

each quarter and all were used if necessary before returning to previously-sampled areas.

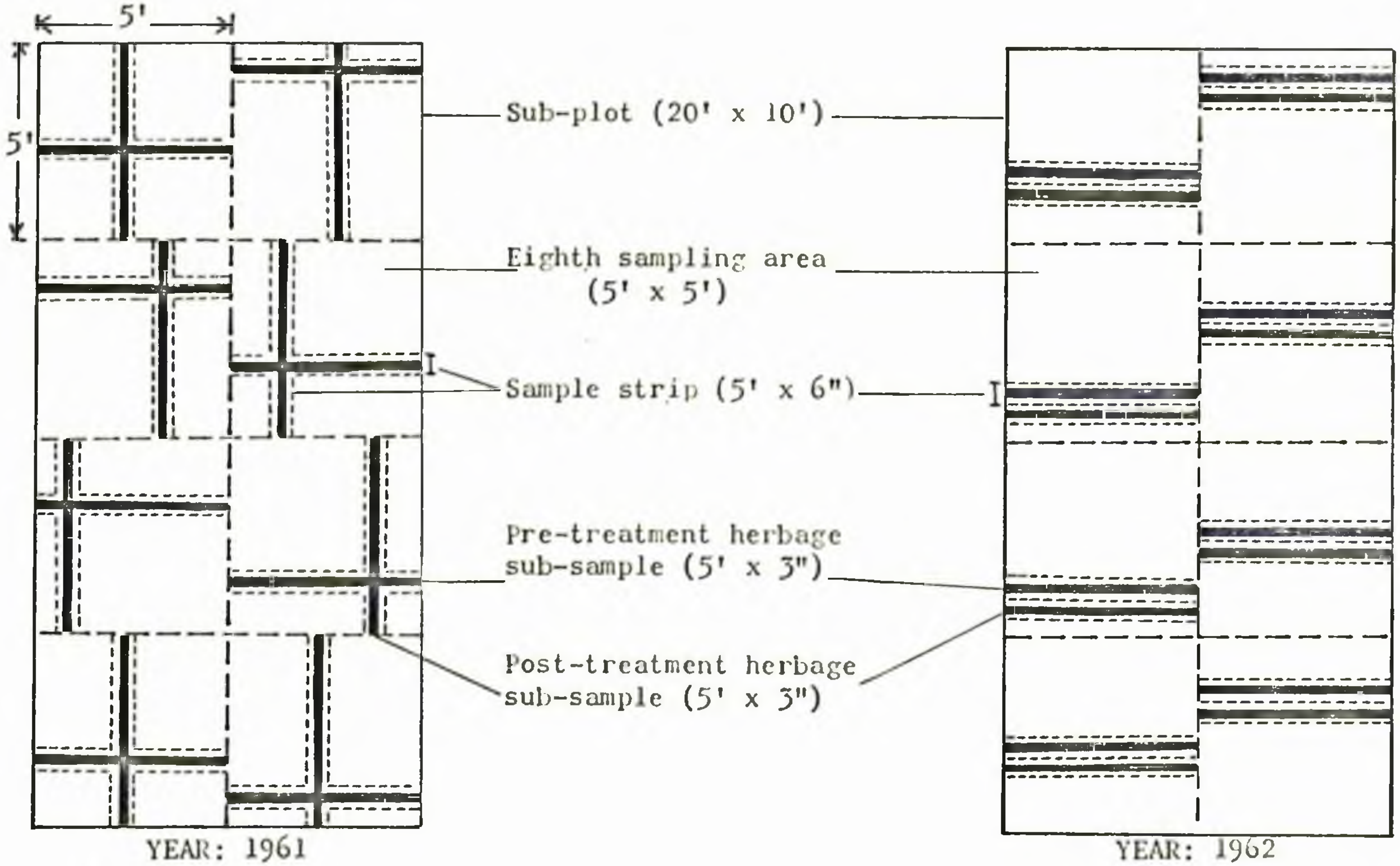
In 1962, sub-samples of 5ft x 3in. were taken adjacent and parallel to the pre-treatment sample strips (Figure 8). The sub-plot sample was thus reduced to 3.6% of the central sampling area or 1.5% of the sub-plot area. As there were fourteen potential sampling strips in a quarter sub-plot, it was possible to take the paired pre- and post-treatment samples seven times before returning to previously-selected positions.

Yield sampling in grazing treatments

Available herbage (pre-treatment samples): Experiments 1 and 2 showed that both herbage regrowths and herbage residues were more variable in grazing treatments than in comparable cutting treatments, therefore eight sub-samples were taken instead of four. Within each eighth of a 20ft x 10ft sub-plot, a herbage sub-sample, 5ft x 3in., was shorn from a randomly-selected position. These eight sub-samples were bulked to give a sub-plot sample (Figure 9). This sample consisted of 5% of the sub-plot area. The sample strips were located by placing a 20ft length of aluminium alloy angle along the edge of the sub-plot and at right angles to it, a 5ft length as straight edge (Plate 8). There were ten potential sample strips of 5ft x 6in. within each eighth.

Residual herbage (post-treatment samples): In 1961, eight sub-samples, each 5ft x 3in., were taken across the pre-treatment sub-sample positions (Figure 9) and the lengths corrected to 4ft 9in. to allow for pre-treatment samples;otherwise the procedure was similar to that for sampling available herbage.

In 1962, the procedure was changed slightly in that the 5ft x 3in. sub-samples were shorn from sample strips adjacent and parallel to the pre-treatment



Scale: 1" = 5'

Figure 9 Illustrations of experimental plots from Experiment 3 ($S.24/N_0$ sward) to show sampling for yield in the grazing treatments in 1961 and 1962 sample strips (Figure 9). Paired pre- and post-treatment sub-samples could thus be taken five times in each eighth of the sub-plot before returning to previously-sampled positions.

Sampling for botanical analyses

Botanical samples were taken from the pre-treatment herbage in each sub-plot whenever a cutting or grazing treatment was applied. Ten snips of herbage from random positions were shorn to ground level with the Wolseley sheep shears and bulked to give a sub-plot botanical sample. The sample was collected in a polythene bag and taken to the grassland laboratory for analysis.

Sampling for soil analyses

In February, 1962 and again in February, 1963, two soil samples were made up in each experiment, one from the sub-plots under cutting treatment and one from the sub-plots under grazing treatment. This was done by taking four random soil cores to a depth of 5 in. with a soil-sampling auger in each sub-plot. Within each experiment, the cores from all the cutting treatment sub-plots were bulked to give a soil sample and the procedure repeated for all the grazing treatment sub-plots. The samples were then taken to the analytical laboratory of the Chemistry Department for analyses.

Determination of herbage yield

Pre- and post-treatment herbage samples from the sub-plots were weighed to 0.1 g on a Mettler balance. Under both cutting and grazing treatments, herbage yield was calculated as the difference between pre-treatment available herbage yield and post-treatment residual herbage yield, i.e. the amount of herbage utilized whether cut by the motor scythe and removed or grazed and removed by the sheep. Thus, herbage yield is derived from the expression:

Available herbage yield minus residual herbage yield

Additional estimates of the amounts of herbage utilized under cutting treatments were obtained from the yield data provided by the swath samples cut by motor scythe which constituted the cutting treatments. These samples were weighed to 0.1 lb on a Gascoigne spring balance.

Determination of herbage botanical composition

The botanical samples were separated by hand as fresh herbage into perennial ryegrass, white clover, unsown grass and dicotyledonous weed constituents, weighed to 0.1 g on an Avery balance and the relative proportions calculated.

Determination of herbage chemical composition

Chemical analyses of the pre-treatment, post-treatment and sample swath herbages previously described, were carried out in the analytical laboratory of the Chemistry Department as follows:

Dry matter (D.M.): Laboratory samples of 300 g each were taken from the field sub-plot herbage samples and dried at 98-100°C for 16-18 hours in a Birmingham and Blackburn Unitherm Drier. The dried samples were weighed to 0.1 g and then ground through a 0.6 mm. screen in a laboratory mill and stored.

Organic matter (O.M.): Sub-samples, each 1 g of the re-dried, ground laboratory samples were ashed overnight at 480°C.

Digestibility of the organic matter (Dig.): The percentage digestibility of the organic matter was determined by the *in vitro* technique of Tilley *et al.* (1960) as modified by Alexander and McGowan (1961, 1966) and Armstrong *et al.* (1964). Sub-samples, each 0.5 g of the re-dried, ground laboratory samples, were inoculated with 50 ml. rumen liquor-buffer mixture, incubated in a water bath at 38-39°C. for 48 hours and then acidified by the addition of 4 ml. of (1+4) hydrochloric acid. After adjustment of the pH to 1.2, 5 ml. pepsin were added, the mixture incubated for a further 48 hours at 38-39°C. and then filtered using a filter aid. The residues were dried at 98-100°C. for 48 hours, cooled, weighed and ignited at 480°C. overnight and again cooled and weighed. The difference between dried and ignited residue weights after allowance for control-tube residues is taken as indigestible organic matter and used to calculate the digestibility coefficients of the organic matter.

Crude protein (C.P.): Sub-samples, each 1 g of the re-dried, ground laboratory samples, were analysed for crude protein content by a macro-Kjeldahl procedure.

Determination of soil chemical composition

The pH, available P_2O_5 and available K_2O of the soil were determined by the methods of Whittles (1952) as modified by Alexander (1963).

Summary of terminology

Main-plot: 20ft x 40ft defoliation method plot

Sub-plot: 20ft x 10ft defoliation intensity plot

Central sampling area: 14ft x 6ft sampling area in a cutting sub-plot.

Quarter sampling area: 7ft x 3ft sub-sampling area in the central sampling area.

Eighth sampling area: 5ft x 5ft sub-sampling area in a grazing sub-plot.

Sample strip: 6 in. wide herbage strip in a sub-sampling area from which 3 in. wide herbage sub-sample is shorn.

Herbage sub-sample: 3 in. wide strip of herbage shorn from within the 6 in. wide sample strip.

Sub-plot herbage sample: Bulked herbage sub-sample from a sub-plot. Used for yield and chemical composition determinations.

Pre-treatment sample: Sample of available herbage taken before defoliation treatment applied.

Available herbage yield (pre-treatment herbage yield): Synonymous terms for herbage yield on sub-plots before defoliation treatment applied.

Post-treatment sample: Sample of residual herbage taken after defoliation treatment applied

Residual herbage yield (post-treatment herbage yield): Synonymous terms for herbage yield on sub-plots after defoliation treatment applied.

Utilized herbage yield (shearhead estimate): Herbage removed by motor scythe in a cutting treatment or by sheep in a grazing treatment. Calculated from expression:

Available herbage yield minus residual herbage yield

(i.e. Pre-treatment herbage yield minus post-treatment herbage yield)

Standard yield estimate used in the experiments.

Swath sample: 2ft $1\frac{1}{2}$in. swath of herbage cut from the central sampling area of a sub-plot during the application of a cutting treatment. Used for yield and chemical determinations of the herbage removed.

Utilized herbage yield (motor scythe estimate): Herbage removed by motor scythe in a cutting treatment. Calculated from the swath sample and used as a check on the shearhead estimate of herbage yield.

Botanical sample: Representative sample of fresh herbage, usually around 100 g, taken from sub-plot to grassland laboratory for botanical analysis.

Laboratory sample: Representative sample of fresh herbage, usually 300 g, taken from sub-plot herbage sample in the analytical laboratory for dry matter analysis.

Laboratory sub-sample: Representative sub-sample, usually 0.5-1 g, taken from the dried, ground laboratory sample for chemical analysis in the analytical laboratory.

Meteorological data

A summary of the meteorological data for the 2-year period of the trials is shown in Appendix 2.

In 1961, soil and air temperatures were above normal in February, March and April but below in the summer months June, July and August. Weather conditions were therefore favourable for early spring growth. The rainfall was below average in May, June and July but mainly above during the rest of the year, especially from August to September.

Except for the months January, February and October, soil and air temperatures were below average in 1962 and especially so in March. There was more bright sunshine than normal and rainfall was average except for August and September, when there was more than average and October when there was less.

Presentation of results

As for the previous experiments, herbage yields are expressed as organic matter (O.M.) and are therefore corrected for soil contamination. Yields of digestible organic matter (D.O.M.) and yields of crude protein (C.P.) are also given. The yields are all expressed in 100 lb/ac and rounded off to the first decimal place. The percentage organic matter (% O.M.) of the herbage is shown on a dry matter basis, but both the percentage digestibility (% Dig.) and crude protein (% C.P.) are shown on an organic matter basis. Mean values are presented in the body of the thesis as tables together with statistical results from analyses of variance (Snedecor, 1956) where relevant. Some of the tabular data are also shown in graphs to aid interpretation. Tables of original data and detailed statistical analyses are lodged in the Grassland Husbandry Department, West of Scotland Agricultural College, Auchincruive, Ayr. The conventional statistical abbreviations listed in page 55 for Experiment 1 are again used.

The results are presented under the following sub-headings:

Dates of defoliations

Annual herbage yields

Mean annual botanical composition of the herbage

Mean annual chemical composition of the herbage

Seasonal distribution of herbage yields

Accumulative herbage yields

Seasonal botanical composition of the herbage

Seasonal chemical composition of the herbage

Comparison of motor scythe and shearhead sampling methods

Chemical composition of the soil

EXPERIMENT 3 (S.24/N SWARD)

Results (1961)

Dates of defoliations

During the season from April to October (Table 14) the herbage in the variable frequency grazing treatments (GVL, GVH) reached the required 8 in. height seven times compared to six times for comparable cutting treatments (CVL, CVH). Intervals between defoliations were thus shorter in the grazing treatments.

Table 14 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6	7
CML, GML) CMH, GMH)	4/5	5/6	6/7	5/8	4/9	5/10	
CVL	18/4	23/5	11/7	22/8	25/9	20/10	
GVL	19/4	16/5	21/6	24/7	11/8	9/9	11/10
CVH	18/4	22/5	6/7	10/8	8/9	11/10	
GVH	19/4	15/5	16/6	24/7	16/8	13/9	11/10

Annual herbage yields

Neither the method nor intensity of defoliation affected the annual utilised yields of organic matter, digestible organic matter or crude protein significantly (Table 15), although there were increases of 240-400 lb/ac for organic matter yields and 140-210 lb/ac for digestible organic matter yields as a result of grazing (G) in comparison with cutting (C), variable frequency defoliation (V) compared with monthly frequency (M), and low severity (L) relative to high severity defoliation (H). Low severity defoliation under both cutting and grazing resulted in significantly higher yields of organic matter and digestible organic matter than high severity defoliation when applied under the variable frequency regime. The differences in yield between the severity treatments were not significant with monthly defoliation but under cutting and grazing, low severity treatment gave the lower yield.

Table 15 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter C	Organic matter G	Organic matter Means	Digestible organic matter C	Digestible organic matter G	Digestible organic matter Means	Crude protein C	Crude protein G	Crude protein Means
Intensity									
ML	48.2	52.2	50.2	36.0	38.3	37.1	8.8	8.9	8.8
MH	50.5	54.2	52.3	37.8	40.3	39.0	9.8	9.2	9.5
VL	54.2	60.6	57.4	40.4	44.1	42.3	9.8	9.5	9.6
VH	48.9	50.7	49.8	36.7	36.7	36.7	8.7	9.1	8.9
Means	50.4	54.4		37.7	39.8		9.2	9.1	
Significant effects:									
Method		NS			NS			NS	
Intensity		NS			NS			NS	
Method x intensity		NS			NS			NS	
Frequency		NS			NS			NS	
Severity		NS			NS			NS	
Frequency x severity		*			*			NS	
C.V. (%)		11.1			11.6			16.3	

Differences between:	Sd̄	L.S.D.	Sd̄	L.S.D.	Sd̄	L.S.D.
Method means	3.11	-	2.21	-	0.82	-
Intensity means	2.90	-	2.24	-	0.77	-
Intensity means within a method	4.11	-	3.16	-	1.10	-
Method means within an intensity	4.72	-	3.52	-	1.26	-
Frequency/severity means	2.05	4.31	1.58	3.32	0.55	-

Mean annual botanical composition of the herbage

The method of defoliation had a much greater effect on the botanical composition than the intensity (Table 16). Perennial ryegrass made up 87.3% of the grazed herbage but only 61.6% of the cut herbage. In contrast, white clover was more plentiful under cutting. Varying the intensities of defoliation resulted in narrow differences. The proportion of ryegrass was greatest with variable frequency low severity defoliation (VL) and lowest with monthly frequency high severity defoliation (MH). Unsown species, chiefly annual meadow and bent grasses, dandelion and chickweed, contributed only a small part of the herbage.

Table 16 Weighted mean annual percentage botanical composition of the available herbage

Method	Perennial ryegrass			White clover			Unsown species		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	59.7	87.0	73.3	38.3	11.7	25.0	2.0	1.3	1.7
MH	57.3	81.3	69.3	41.2	16.4	28.8	1.5	2.3	1.9
VL	66.4	92.3	79.4	32.4	5.9	19.1	1.2	1.8	1.5
VH	62.9	83.5	75.7	35.8	9.6	22.7	1.4	1.9	1.7
Means	61.6	87.3		36.9	10.9		1.5	1.9	

Mean annual chemical composition of the herbage

Organic matter, digestibility and crude protein contents in the available herbage were not markedly affected by either the method or intensity of defoliation (Table 17).

Table 17 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter			Digestibility			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity				Available herbage					
ML	84.0	83.1	83.5	71.6	69.9	70.7	16.1	16.9	16.5
MH	83.4	83.9	83.6	71.1	69.7	70.4	16.3	16.3	16.3
VL	85.0	85.9	85.4	72.5	70.3	71.4	16.0	15.6	15.8
VH	84.2	85.8	85.0	70.8	69.4	70.1	15.1	15.3	15.2
Means	84.1	84.7		71.5	69.8		15.9	16.0	
				Residual herbage					
ML	73.6	72.5	73.0	67.9	66.4	67.1	13.4	16.8	15.1
MH	79.7	74.6	77.1	67.6	65.6	66.6	13.5	15.8	14.6
VL	75.2	74.6	74.9	69.1	67.4	68.2	12.7	15.6	14.1
VH	81.6	80.3	81.0	66.2	67.1	66.7	12.3	13.4	12.9
Means	77.5	75.5		67.7	66.6		13.0	15.4	

The greatest effect was the 1.7 percentage unit increase in digestibility with cutting relative to grazing and the high organic matter contents of herbage under variable frequency defoliation.

Similarly, the composition of the residual herbage was not markedly affected by treatment. The main differences were lower mean organic matter contents under low relative to high severity defoliation and lower crude protein contents under cutting relative to grazing.

With all the treatments, available herbage had consistently higher organic matter, digestibility and crude protein contents than residual herbage. The average differences are not great at 5-10, 3-4 and 1-3 percentage units respectively when it is considered that available herbage was mainly young leafy regrowth whereas residual herbage was chiefly stubble and dead leaf bases, especially after the cutting treatments; after grazing, residual herbage was usually a mixture of very short stubble and some ungrazed older leafage, which may have been fouled by dung or trodden by the hooves of the sheep and so rendered unpalatable. Since the organic matter content of pasture herbage is usually in the region of 88-91%, the organic matter contents in both herbages under cutting and grazing indicate that soil contamination has occurred, but particularly in the residual herbage.

Seasonal distribution of herbage yields

The seasonal distribution of utilized herbage yields for each treatment is shown in Table 18 while the yields of available and residual herbage from which the seasonal figures were derived by difference, are tabulated in Appendix 5. For all the treatments, the distribution of digestible organic matter yields closely followed that of the organic matter yields and both showed considerable fluctuation over the season. Crude protein yields varied similarly but within very narrow limits throughout.

Table 18 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defolia-tion No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			GML	
1	17.9	12.9	2.1	12.0	8.7	1.3
2	9.0	7.2	1.7	9.4	7.6	1.3
3	5.0	3.8	1.1	5.6	4.7	1.0
4	6.6	5.0	1.5	7.9	5.2	1.5
5	6.2	4.4	1.7	8.4	5.8	1.8
6	3.5	2.8	0.8	9.0	6.4	2.0
		CMH			GMH	
1	17.2	12.7	2.0	13.7	10.3	1.6
2	7.0	5.7	1.6	9.6	8.1	1.6
3	6.2	4.5	1.3	8.9	5.9	1.4
4	9.5	6.8	2.1	7.1	5.3	0.9
5	7.5	5.6	2.0	7.7	5.3	1.9
6	3.0	2.5	0.7	7.2	5.4	1.7
		CVL			GVL	
1	8.0	6.4	1.0	6.9	5.0	0.9
2	14.3	10.8	2.0	9.8	6.9	1.3
3	11.1	7.6	1.6	12.7	9.4	1.6
4	11.4	8.9	2.7	8.6	6.4	1.0
5	6.5	4.7	1.9	9.2	6.8	1.6
6	2.8	2.1	0.6	9.6	6.9	2.1
7				3.7	2.8	0.9
		CVH			GVH	
1	9.0	6.9	1.1	4.7	3.5	0.6
2	15.7	10.7	1.7	6.1	3.9	0.9
3	8.9	6.8	1.6	7.3	5.8	1.3
4	5.1	4.0	1.4	8.4	6.6	1.0
5	6.5	5.3	1.9	10.4	7.7	2.0
6	3.7	3.0	1.0	7.2	4.7	1.7
7				6.6	4.6	1.7

The effect of method of defoliation on the seasonality of organic matter and digestible organic matter yields is apparent from the range of yields. Maximum yields were higher and minimum yields lower under cutting. Range of yield between defoliations was greater with monthly than with variable frequency. In all the monthly treatments, highest yields were recorded at first defoliations. Top levels were 1790 lb/ac organic matter and 1290 lb/ac digestible organic matter under the CML treatment. Second defoliations also gave relatively high yields while the lowest yields were obtained at June and

October defoliations under cutting and at midseason under grazing. With variable frequency defoliation, top yields were recorded mainly in the first half of the season, particularly at second and third defoliations. The GVH treatment was an exception since its highest yield was at the fifth defoliation. Top organic matter yields were from 1430-1570 lb/ac under cutting and 1040-1270 lb/ac under grazing. Bottom yield levels were recorded at final defoliations, excepting the GVH treatment, in which the lowest level was at the first defoliation. The lowest yields were from 280-470 lb/ac organic matter and 210-350 lb/ac digestible organic matter. Relative to the other treatments, defoliation severity treatments had much smaller effects on the seasonality of yield and no general inferences can be drawn.

Accumulative herbage yields

Yields from comparable cutting and grazing treatments did not differ greatly and crude protein yields in particular were very closely matched (Figure 10). At early season and midseason, a yield advantage for both organic matter and digestible organic matter lay with the cutting treatments, but a slight superiority of yield under grazing developed by the end of the season.

Seasonal botanical composition of the herbage

Defoliation method had a far greater effect on the sown grass:clover ratio than defoliation intensity (Table 19; Figure 11). Consistently in each cutting treatment, the proportion of ryegrass was highest at the beginning and end of the season and lowest at midseason, whereas the converse of this held with the clover proportion. At their peaks, ryegrass values were between 72 to 94% and at their troughs, 38 to 57%. The high midseason clover values were between 52 to 61% while the lowest values ranged from 5-27%. In sharp contrast,

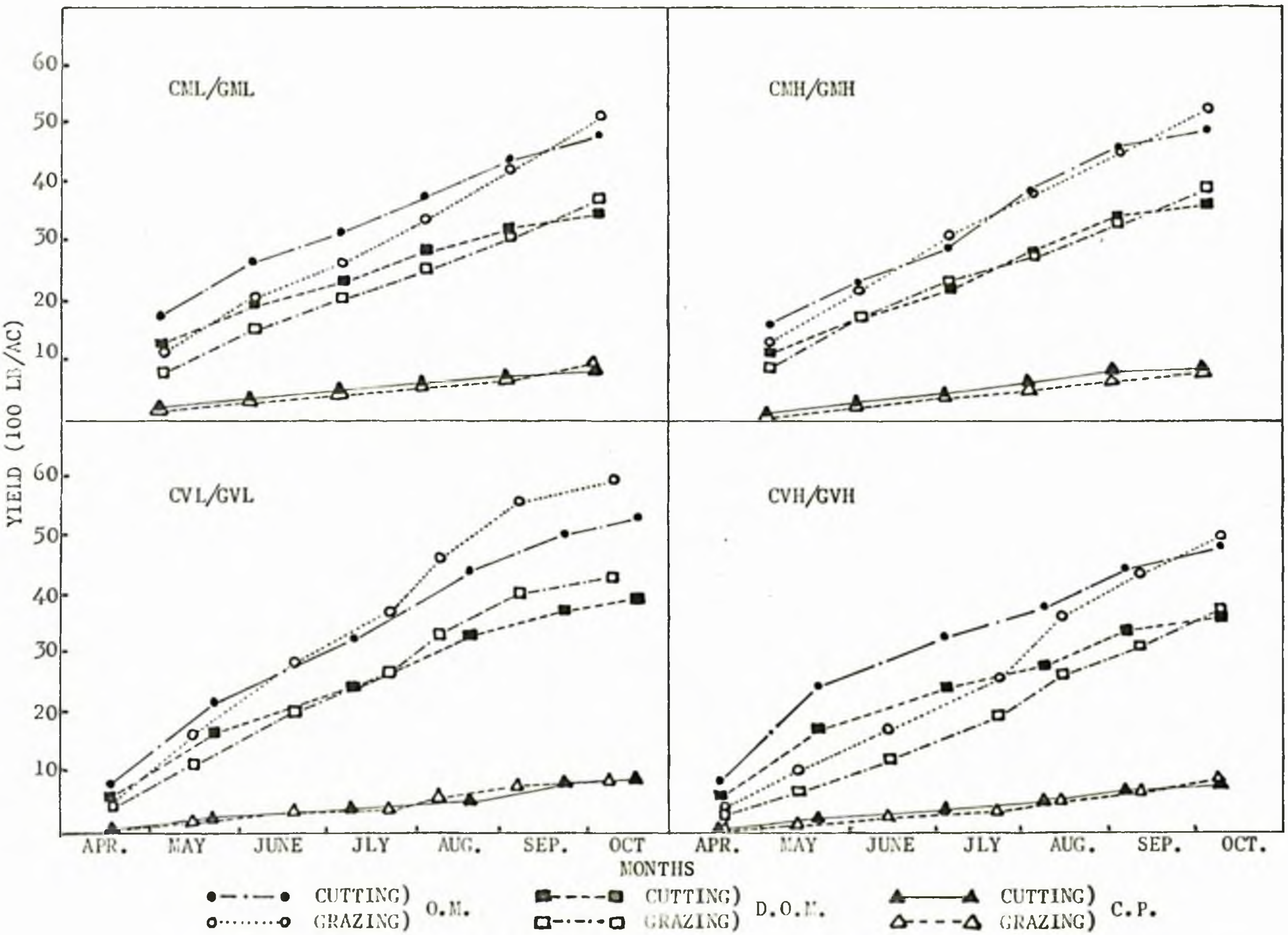


Figure 10 Accumulative utilized herbage yields for each treatment

ryegrass proportions under grazing lay mainly in the 80-95% range throughout the season, with little evidence of any consistent seasonal variation, whilst clover proportions lay between 5 to 18%.

Table 19 Seasonal percentage botanical composition of the available herbage for each treatment

Defoliation No.	Cutting: Perennial ryegrass	Cutting: White clover	Cutting: Unsown species	Grazing: Perennial ryegrass	Grazing: White clover	Grazing: Unsown species
		CML			GML	
1	82.0	14.4	3.5	83.5	14.5	2.0
2	58.2	39.4	2.5	80.6	16.9	2.8
3	50.9	45.9	3.2	88.0	10.8	1.2
4	44.3	55.1	0.7	92.2	7.2	0.7
5	59.3	48.6	1.2	79.0	19.0	2.0
6	84.3	15.5	0.4	96.2	3.4	0.5
		CMH			GMH	
1	72.0	26.7	1.3	82.3	12.0	5.8
2	67.1	30.1	2.9	72.3	26.3	1.4
3	56.0	42.6	1.4	81.8	16.4	1.9
4	37.5	61.3	1.2	79.9	18.9	1.2
5	49.3	49.8	1.0	83.0	14.7	2.3
6	73.3	25.7	1.1	89.5	9.7	0.8
		CVL			GVL	
1	91.8	7.2	1.0	93.4	4.9	1.7
2	73.5	25.1	1.5	93.6	4.1	2.3
3	45.8	52.4	1.8	92.6	5.5	2.0
4	57.3	42.3	0.5	91.1	5.5	3.4
5	69.3	29.1	1.6	91.9	7.5	0.6
6	82.3	17.4	0.4	89.3	9.1	1.6
7				97.1	2.6	0.4
		CVH			GVH	
1	94.0	5.1	1.0	93.5	4.8	1.8
2	73.8	24.1	2.2	87.3	10.6	2.2
3	53.6	44.6	1.8	87.7	10.7	1.6
4	46.4	52.4	1.2	85.6	10.6	3.8
5	48.1	51.2	0.8	86.5	12.7	0.8
6	78.4	21.0	0.7	87.5	11.7	0.9
7				93.1	6.5	0.4

Ryegrass values for both cutting and grazing were slightly greater with variable frequency than monthly defoliation and similarly with low than high severity defoliation. Unsown species were in small proportion so that clover contents were complementary to ryegrass contents.

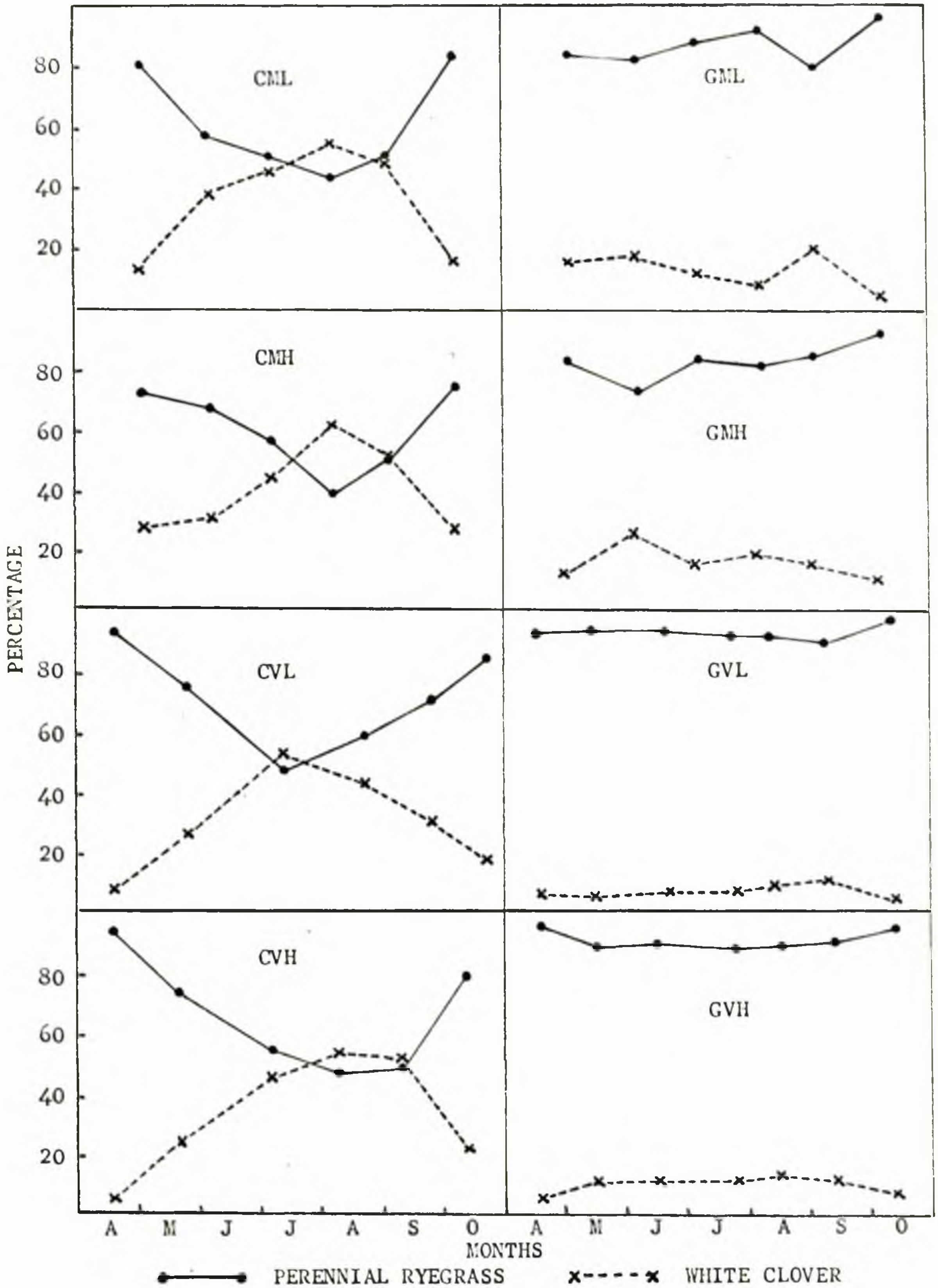


Figure 11 Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

Seasonal chemical composition of the herbage

Seasonal chemical composition data for the available and residual herbage in each treatment are shown fully in Table 20 while the percentage digestibility and crude protein data are further illustrated in Figure 12.

Available herbage: No consistent effect on organic matter content was evident from either the method or intensity of defoliation. It is likely that the contents were governed by the cleanliness of sampling the herbage in relation to the degree of soil contamination. Only at the first and occasionally the second defoliations when organic matter values were between 88-92% was there little sign of contamination.

Digestibility values were only marginally higher under cutting than under grazing. Both defoliation methods had a similar range of variation between the top and bottom levels, and the periods when levels were highest and lowest coincided (Figure 12). Frequency of defoliation had a greater effect with top values from 74-75% in June under the monthly treatments and 75-79% in April under the variable frequency defoliation treatments. The herbage at April was first growth of 8 in. leafy herbage whereas at June, the herbage was a month's regrowth. In early May when the first monthly defoliations were made, digestibilities were about 5 percentage units less than at the first variable frequency defoliations. Because of the high April values under variable frequency treatment,the range between top and bottom levels was slightly greater than the range under monthly defoliation. Little difference was discernible from the effects of defoliation severity treatments.

Neither the defoliation method nor intensity treatments had much effect on crude protein levels over the season, differences between top and bottom levels or the time of season when top or when bottom levels occurred. Thus the highest values, always obtained in late season, were 22-25% and the lowest, always in early season, 10-13%.

Residual herbage: Organic matter values were slightly lower over the season under grazing than under cutting. With both methods, the lowest levels were recorded in late season, particularly in the October grazings. Frequency of defoliation had little effect but severity caused considerable difference and lower values were associated with the low severity treatments (Table 20). This indicated that soil contamination was greater when the herbage was defoliated to 1-1½ in. than to 2-2½ in., an effect which could be expected on account of the higher stocking with sheep and consequently heavier treading under grazing and disturbance of the soil surface when applying the low cutting treatments. According to meteorological data (Appendix 2), the autumn of 1961 was very wet and this would intensify these effects.

Neither defoliation method nor severity had a marked effect on the digestibility values (Figure 12) but as in the available herbage, frequency of defoliation had considerable effect mainly because of high values in April under the variable frequency treatments. Thus under these treatments there was a greater range of values over the season than under monthly defoliation.

Apart from marginally higher levels with grazing than with cutting, the effect of treatment on the crude protein levels was not very marked. There was a seasonal trend in all treatments for values to be lowest in early season and highest in late season, with a wider range of values under grazing. Particularly high values were recorded after the final grazings in October.

Comparison of available and residual herbage: With few exceptions, available herbage had higher organic matter, digestibility and crude protein values. The magnitude of the differences varied, being greatest with organic matter and least with crude protein. Residual herbage showed greater seasonal variation in organic matter content mainly as a result of low late-season values

Over the season, variation in digestibility and crude protein levels in available herbage was closely matched by similar variation in residual herbage.

Table 20 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage: Cutting O.M.	Dig.	C.P.	Available herbage: Grazing O.M.	Dig.	C.P.	Residual herbage: Cutting O.M.	Dig.	C.P.	Residual herbage: Grazing O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	89.4	71.2	11.7	91.9	71.0	10.4	81.5	67.9	11.0	77.2	69.3	10.0
2	85.9	75.3	14.6	80.0	74.1	14.0	74.9	70.2	11.2	73.1	66.6	13.4
3	86.8	71.4	15.0	80.4	71.8	16.3	86.4	68.5	11.7	82.9	66.7	16.0
4	74.4	68.9	17.5	80.1	67.0	18.3	64.0	64.7	13.7	74.8	67.1	18.4
5	84.7	70.4	22.8	83.2	66.8	21.2	78.4	70.4	18.3	73.4	64.1	20.4
6	78.0	73.5	20.7	84.3	67.8	23.6	50.7	63.8	17.8	45.5	62.4	26.2
		CMH			GMH			CMH			GMH	
1	91.0	72.6	10.9	90.7	72.2	11.2	88.5	69.9	9.2	80.9	68.0	10.3
2	82.7	74.8	14.9	85.5	74.3	14.7	83.1	71.6	11.1	71.2	64.8	12.5
3	88.0	69.4	15.6	82.5	67.6	14.7	86.6	68.2	13.3	83.8	68.4	13.7
4	74.3	68.4	17.7	77.9	66.5	16.4	74.7	65.7	13.5	75.6	62.4	18.5
5	81.8	70.1	23.0	84.6	67.1	21.7	77.7	65.4	19.2	78.0	66.0	19.8
6	80.3	70.6	21.3	84.7	69.4	23.1	60.0	60.6	19.9	53.6	62.3	22.6
		CVL			GVL			CVL			GVL	
1	89.6	79.0	11.9	89.8	74.8	12.6	85.9	77.6	11.4	74.1	76.6	12.6
2	89.4	72.8	12.2	87.6	69.9	13.2	84.9	68.1	9.4	84.5	69.7	12.9
3	87.9	67.7	13.0	88.4	72.0	13.2	75.8	66.9	10.3	86.6	69.4	13.6
4	81.9	73.6	20.1	88.1	69.7	13.4	67.6	66.4	14.2	74.0	66.1	15.0
5	76.0	70.1	24.2	81.1	67.7	17.8	66.2	67.1	16.9	[illegible]	61.1	17.5
6	83.1	71.5	18.8	81.0	69.3	21.1	78.5	69.4	17.5	76.5	63.0	19.1
7				82.8	67.6	23.8				53.1	62.0	23.1
		CVH			GVH			CVH			GVH	
1	89.8	76.7	11.6	89.8	76.2	12.5	89.2	76.3	11.3	83.2	76.7	12.3
2	89.2	68.0	10.0	87.7	69.5	13.4	87.8	67.2	8.3	86.6	72.3	13.2
3	88.0	72.1	13.7	85.8	70.1	13.8	87.2	68.3	10.7	85.5	65.9	11.9
4	70.4	65.9	17.9	89.0	69.6	11.4	78.0	59.5	12.7	79.4	63.9	11.5
5	83.2	71.4	22.5	83.5	67.8	16.7	77.9	63.2	16.2	78.5	61.0	14.0
6	85.4	71.6	21.8	82.0	64.6	21.9	66.8	64.2	17.7	68.9	63.2	19.1
7				80.5	66.5	24.4				60.5	61.7	22.1

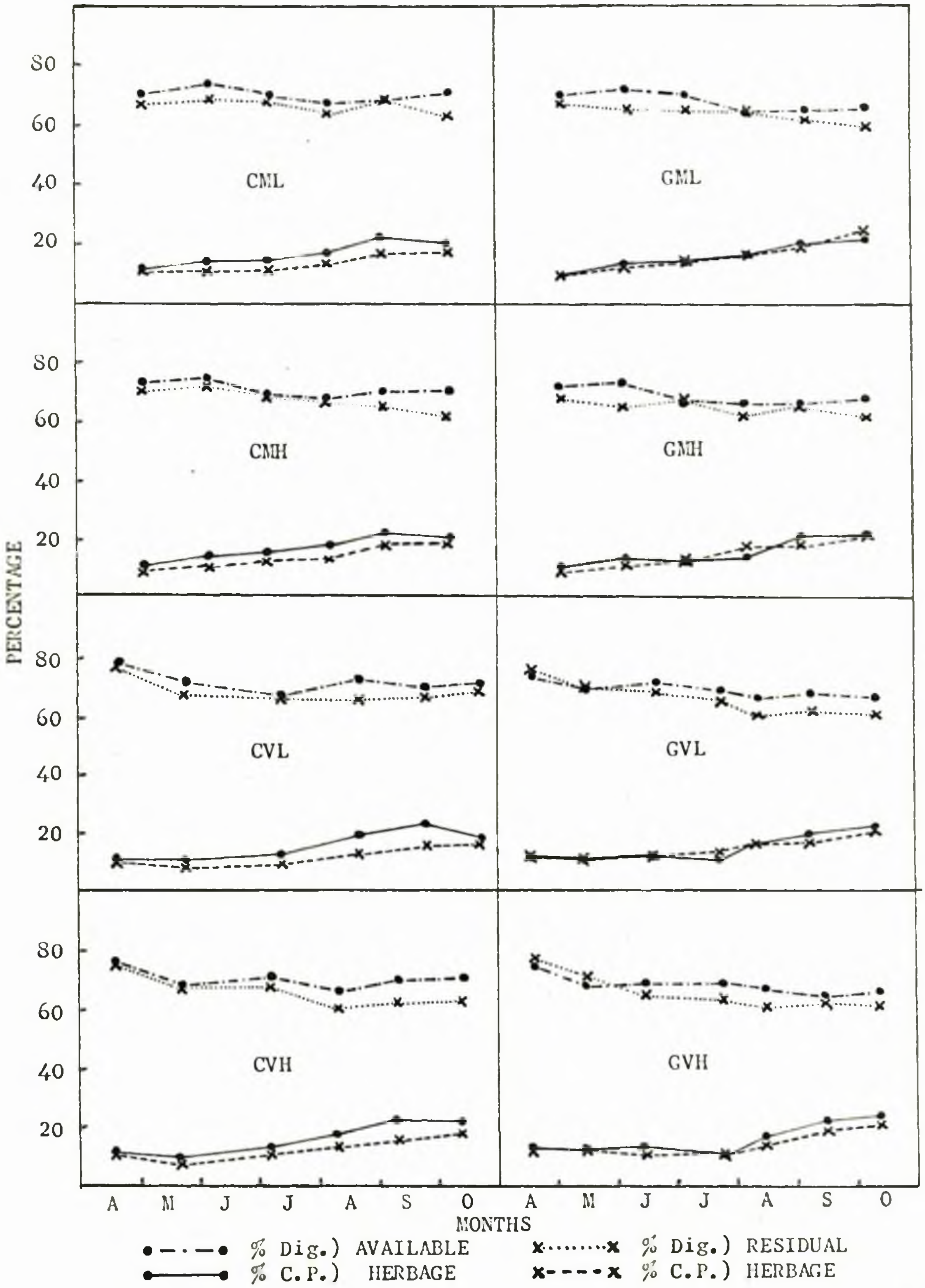


Figure 12 Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: The mean annual herbage yields for the cutting treatments as measured by the motor scythe sampling method are shown in Table 21 together with their relationship to yields from the shearhead sampling method. Also shown are the statistical results of analyses carried out to compare the differences between the two methods (i.e. shearhead estimate minus motor scythe estimate) among the four cutting treatments.

There were no significant treatment effects, thus showing that the yield relationship between the treatments was similar under both systems of measurement. However, the shearhead sampling method gave consistently higher estimates of herbage organic matter, digestible organic matter and crude protein and in each case this 'consistency' effect was significant.

Table 21 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	44.6	32.5	7.9	3.6	3.5	0.9
MH	45.1	33.3	8.4	5.4	4.5	1.4
VL	48.1	35.1	8.2	6.1	5.3	1.6
VH	44.2	32.1	7.5	4.7	4.6	1.2
Significant effects:						
Intensity				NS	NS	NS
Frequency				NS	NS	NS
Severity				NS	NS	NS
Frequency x severity				NS	NS	NS
Consistency				**	***	***
C.V. (%)				106.1	82.2	100.0
Differences between:				$s\bar{d}$	$s\bar{d}$	$s\bar{d}$
Intensity means				2.57	2.63	0.71
Frequency/severity means				3.63	1.87	0.50
Frequency means within a severity and vice versa				2.57	2.63	0.71

('Consistently higher' implies higher by a constant amount irrespective of which treatment is concerned; the statistical test for this effect is an F test of the correction factor divided by the error mean square, the correction factor having one degree of freedom).

Mean annual chemical composition of the herbage: The weighted mean annual chemical composition of the herbage cut and removed by the motor scythe in the cutting treatments is shown in Table 22.

The organic matter contents showed that little soil contamination of the herbage had taken place especially under variable frequency (V) and high severity (H) defoliation. Digestibility levels for the treatments were similar but crude protein contents were slightly higher under monthly frequency (M) and high severity defoliation.

Table 22 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digestibility	Crude protein
ML	85.1	73.0	17.8
MH	87.8	73.6	18.7
VL	87.8	73.0	17.0
VH	88.3	72.6	16.9

Seasonal distribution of herbage yields: The seasonal distribution of herbage yields for the cutting treatments as estimated by motor scythe, together with their relationship to yields from the shearhead sampling method (Table 23), show that apart from a few instances, mainly in the CVL and CVH treatments, individual shearhead estimates of organic matter, digestible organic matter and crude protein yields were greater than comparable motor scythe estimates. The widest differences between the two estimates were at the third and fourth defoliations in treatment CVL and the first and third defoliations in treatment CVH but otherwise the amounts by which the estimates differed was only 10-180 lb/ac organic matter, 10-15 lb/ac digestible organic matter and 0-30 lb/ac crude protein.

Table 23 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

Defoliation No.	Motor scythe: Organic matter	Motor scythe: Digestible organic matter	Motor scythe: Crude protein	Shearhead minus motor scythe: Organic matter	Shearhead minus motor scythe: Digestible organic matter	Shearhead minus motor scythe: Crude protein
		CML			CML	
1	16.8	11.9	2.0	1.1	1.0	0.1
2	8.1	6.1	1.4	0.9	1.1	0.3
3	5.1	3.7	1.0	-0.1	0.1	0.1
4	5.5	4.0	1.2	1.1	1.0	0.3
5	5.8	4.3	1.6	0.4	0.1	0.1
6	3.4	2.4	0.8	0.1	0.4	0.0
		CMH			CMH	
1	15.4	11.2	1.8	1.8	1.5	0.2
2	6.9	5.2	1.3	0.1	0.5	0.3
3	5.8	4.3	1.1	0.4	0.2	0.2
4	7.7	5.6	1.8	1.8	1.2	0.3
5	6.7	5.0	1.9	0.8	0.6	0.1
6	2.7	1.9	0.6	0.3	0.6	0.1
		CVL			CVL	
1	8.7	6.9	1.2	-0.7	-0.5	-0.2
2	14.9	10.5	1.8	-0.6	0.3	0.2
3	6.6	4.5	1.0	4.5	3.1	0.6
4	8.7	6.5	2.0	2.7	2.4	0.7
5	7.0	5.2	1.7	-0.5	-0.5	0.2
6	2.2	1.7	0.5	0.6	0.4	0.1
		CVH			CVH	
1	6.2	4.8	0.8	2.8	2.1	0.3
2	14.6	10.2	1.4	1.1	0.5	0.3
3	6.5	4.7	1.0	2.4	2.1	0.6
4	6.3	4.6	1.4	-1.2	-0.6	0.0
5	6.3	4.7	1.7	0.2	0.6	0.2
6	4.4	3.1	1.1	-0.7	-0.1	-0.1

Seasonal chemical composition of the herbage: The chemical composition data for the herbage removed by the motor scythe over the season are shown for the four cutting treatments in Table 24.

As shown by the high organic matter contents, there was little soil contamination of the herbage in any of the treatments in early season but later, varying degrees of contamination were evident as reflected in the lower organic matter contents. The contents were particularly low at the final defoliations in the CML and CMH treatments.

Digestibility levels under monthly frequency defoliation were highest in September and lowest at the beginning and end of the season. Under variable frequency defoliation, digestibilities were highest at the first defoliations in April which took place 15-16 days before the first monthly defoliations; the lowest digestibilities were at the second or third defoliations. Apart from these, little other effects of treatment were apparent.

There was a seasonal trend in all treatments for crude protein contents to be lowest in early season and highest in September with a gradual rise in between.

Table 24 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defoliation No.	Organic matter	Digestibility	Crude protein	Organic matter	Digestibility	Crude protein
		CML			CMH	
1	90.9	71.7	11.9	91.7	72.7	11.9
2	85.7	74.4	15.8	88.6	74.2	17.0
3	88.6	75.0	18.4	89.7	74.3	18.3
4	85.6	73.0	22.2	88.5	73.3	22.9
5	83.5	74.7	27.2	85.3	74.6	28.2
6	60.8	71.2	22.7	67.9	72.9	24.3
		CVL			CVH	
1	91.4	79.3	13.7	91.6	78.1	13.2
2	90.8	70.6	12.0	91.5	69.8	9.8
3	89.4	67.8	14.8	89.7	72.0	15.7
4	84.3	74.6	22.6	87.0	73.2	22.9
5	83.2	73.7	24.7	87.4	74.6	26.9
6	80.1	73.3	22.0	80.5	71.2	23.5

Chemical composition of the soil

Table 25 shows the chemical composition of the soil before and after the application of the cutting and grazing treatments. By the classification of Whittles (1952), the acidity has not changed from 'moderate' but the available phosphate has dropped from 'medium' to 'low' under both cutting and grazing. Available potash on the other hand has not changed from 'medium' under cutting, but under grazing it has risen from 'medium' to 'satisfactory'.

Table 25 Chemical composition of the soil before and after the application of cutting and grazing treatments

Date	Treatment	pH	mg/100 g soil	
			Available P_2O_5	Available K_2O
9.2.61	Nil	5.89	5	7
3.2.62	Cutting	5.84	3	6
	Grazing	5.82	3	12

EXPERIMENT 3 ($S.24/N_0$ SWARD)

Results (1962)

Dates of defoliations

The number and dates of defoliations for the treatments during the 1962 season (Table 26) show that herbage in the variable frequency grazing treatments reached the required 8 in. height more often than in comparable cutting treatments. There were thus more defoliations at shorter intervals in these grazing treatments.

Table 26 Number and dates of defoliations

	Defoliations						
Treatment	1	2	3	4	5	6	7
CML, GML) CMH, GMH)	1/5	1/6	2/7	3/8	4/9	5/10	
CVL	8/5	13/6	6/8	13/9	31/10		
GVL	7/5	1/6	2/7	30/7	24/8	14/9	15/10
CVH	8/5	13/6	27/7	4/9	15/10		
GVH	7/5	7/6	13/7	18/8	14/9	31/10	

Annual herbage yields

Mean annual utilized herbage yields of organic matter, digestible organic matter and crude protein for the main treatments and their interactions are shown in Table 27.

For organic matter and digestible organic matter yields, neither the differences due to method nor to intensity of defoliation were significant. Nevertheless there were appreciable yield increases from grazing compared with cutting treatments. Variable frequency cutting gave similar yields to monthly cutting but variable frequency grazing gave higher yields than monthly grazing.

Crude protein yields showed a significant 'method x intensity' interaction and significantly higher yields at low than at high severity defoliation.

Table 27 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter C	Organic matter G	Organic matter Means	Digestible organic matter C	Digestible organic matter G	Digestible organic matter Means	Crude protein C	Crude protein G	Crude protein Means
Intensity									
ML	53.4	57.6	55.5	42.8	45.4	44.1	10.3	10.3	10.3
MH	52.1	53.6	52.8	40.2	43.1	41.6	10.6	9.3	9.9
VL	52.6	60.4	56.5	41.2	47.5	44.3	9.3	11.4	10.4
VH	49.7	62.4	56.0	39.7	49.0	44.4	9.1	9.7	9.4
Means	52.0	58.5		40.9	46.2		9.8	10.2	

Significant effects:	Organic matter	Digestible organic matter	Crude protein
Method	NS	NS	NS
Intensity	NS	NS	NS
Method x intensity	NS	NS	**
Frequency	NS	NS	NS
Severity	NS	NS	*
Frequency x severity	NS	NS	NS
C.V. (%)	7.6	7.2	7.1

Differences between:	$S\bar{d}$	L.S.D.	$S\bar{d}$	L.S.D.	$S\bar{d}$	L.S.D.
Method means	3.03	-	2.49	-	0.33	-
Intensity means	2.10	-	1.58	-	0.36	-
Intensity means within a method	2.96	-	2.22	-	0.50	1.05
Method means within an intensity	4.01	-	3.15	-	0.55	0.73
Frequency/severity means	1.48	-	1.11	-	0.25	0.53

Mean annual botanical composition of the herbage

Since unsown species, mainly annual meadow and bent grasses, daisy and chickweed, formed only a tiny fraction of the herbage, the effect of treatment was limited to the sown grass:clover ratio. Perennial ryegrass averaged 91.4% under grazing but only 66.8% under cutting (Table 28). In contrast, white clover was much more abundant under cutting. Defoliation intensity treatments had small effects on the composition; ryegrass ranged from

76.7 - 81.8% and clover, 16.6 - 22.1%. Ryegrass was more plentiful with monthly than with variable frequency defoliation and with low severity than high severity defoliation whereas the clover proportion was greater with variable frequency and high severity defoliation.

Table 28 Weighted mean annual percentage botanical composition of the available herbage

Method	Perennial ryegrass			White clover			Unsown species		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	68.0	95.6	81.8	29.7	3.5	16.6	2.3	0.9	1.6
MH	69.9	89.4	79.6	28.3	9.5	18.9	1.8	1.1	1.4
VL	65.1	91.7	78.4	33.9	6.2	20.0	1.1	2.1	1.6
VH	64.4	89.1	76.7	34.9	9.3	22.1	0.8	1.7	1.2
Means	66.8	91.4		31.7	7.1		1.5	1.5	

Mean annual chemical composition of the herbage

Neither the method nor intensity of defoliation had an appreciable effect on organic matter, digestibility or crude protein values of the available herbage (Table 29). The main difference was a slight decrease in organic matter content under grazing relative to cutting. Similar small effects of treatments on the composition of the residual herbage were evident. Organic matter values were again slightly less under grazing, whilst crude protein values were slightly higher under grazing. There was also a mean difference of 2.0 percentage units digestibility in favour of variable frequency compared with monthly frequency defoliation.

Consistently greater levels of organic matter, digestibility and crude protein were recorded in available than in residual herbage. As in 1961, the composition reflects the higher feeding value of available herbage. Similarly, organic matter figures show that considerable soil contamination has taken place in all the treatments but especially in the residual herbage after grazing.

Table 29 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter			Digestibility			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
				Available herbage					
ML	85.9	81.5	83.7	75.0	75.1	75.0	16.8	17.7	17.2
MH	86.2	81.3	83.8	73.3	75.3	74.3	17.1	16.4	16.8
VL	85.8	81.6	83.7	75.4	74.4	74.9	16.4	18.9	17.6
VH	86.2	85.1	85.6	74.3	75.2	74.7	15.4	15.0	15.2
Means	86.0	82.4		74.5	75.0		16.4	17.0	
				Residual herbage					
ML	78.0	73.9	75.9	68.4	64.5	66.5	13.9	16.8	15.3
MH	79.5	75.7	77.6	69.4	65.7	67.5	13.8	14.9	14.3
VL	77.9	72.3	75.1	70.1	68.9	69.5	13.8	18.9	16.3
VH	82.0	77.9	80.0	68.6	69.2	68.9	12.3	14.1	13.2
Means	79.3	74.9		69.1	67.1		13.4	16.1	

Seasonal distribution of herbage yields

The seasonal distribution of available and residual herbage yields is shown in Appendix 6 while the utilized yields calculated from them are presented in Table 30. Organic matter and digestible organic matter yields varied considerably during the season and in similar fashion. Crude protein yields varied similarly but on a smaller scale.

Cutting treatments usually resulted in higher peak yields and lower bottom yields of organic matter and digestible organic matter than grazing treatments but the CVH treatment, with a top yield of 1460 lb/ac organic matter was an exception, since this was 320 lb/ac less than the top yield in treatment GVH. The general pattern was thus one of greater seasonal variation under cutting. With all the treatments, top yields were recorded at the first or second defoliations and lowest yields at the final defoliations in October. For organic matter, top yields were on average around 1400-1500 lb/ac and for digestible organic matter, 1200-1300 lb/ac whilst bottom yields were around 400-500 lb/ac and 300-400 lb/ac respectively. The effects of intensity treatments were not marked since seasonal variation was similar both in range and in the times when maximum and minimum yields were recorded for monthly defoliation relative to variable frequency defoliation and for low severity defoliation in comparison with high severity.

Table 30 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			CML	
1	9.3	8.0	1.3	14.2	11.9	2.1
2	15.5	12.3	2.3	10.1	8.5	1.5
3	9.5	7.9	2.2	9.7	7.8	1.6
4	7.6	5.8	1.5	7.3	5.4	1.5
5	7.1	5.4	1.9	9.9	7.2	2.2
6	4.4	3.4	1.1	6.4	4.7	1.6
		CMH			CMH	
1	7.4	6.3	1.2	13.2	11.3	1.9
2	14.4	11.7	2.4	10.7	9.0	1.8
3	12.8	9.0	2.6	11.2	8.7	1.6
4	5.2	3.9	1.2	6.8	5.2	1.3
5	8.5	6.4	2.3	7.3	5.5	1.6
6	3.9	3.0	1.0	4.4	3.3	1.1
		CVL			CVL	
1	14.9	12.4	2.3	13.1	11.0	1.4
2	10.9	8.7	1.7	11.3	9.0	1.9
3	14.6	10.4	2.6	8.8	7.3	1.6
4	8.0	6.3	1.9	7.9	6.2	1.6
5	4.2	3.4	0.8	6.8	5.3	1.6
6				7.1	5.0	1.8
7				5.4	3.7	1.6
		CVH			CVH	
1	14.6	12.8	2.3	11.5	9.9	1.4
2	10.5	8.9	1.8	17.8	13.9	2.3
3	10.7	7.5	1.7	12.6	9.9	1.7
4	9.4	7.0	2.2	7.0	5.6	1.3
5	4.5	3.5	1.2	8.1	5.8	1.7
6				5.3	4.0	1.4

Accumulative herbage yields

Figure 13 illustrates the way in which herbage yields under cutting and grazing accumulated as the season progressed. Digestible organic matter yields

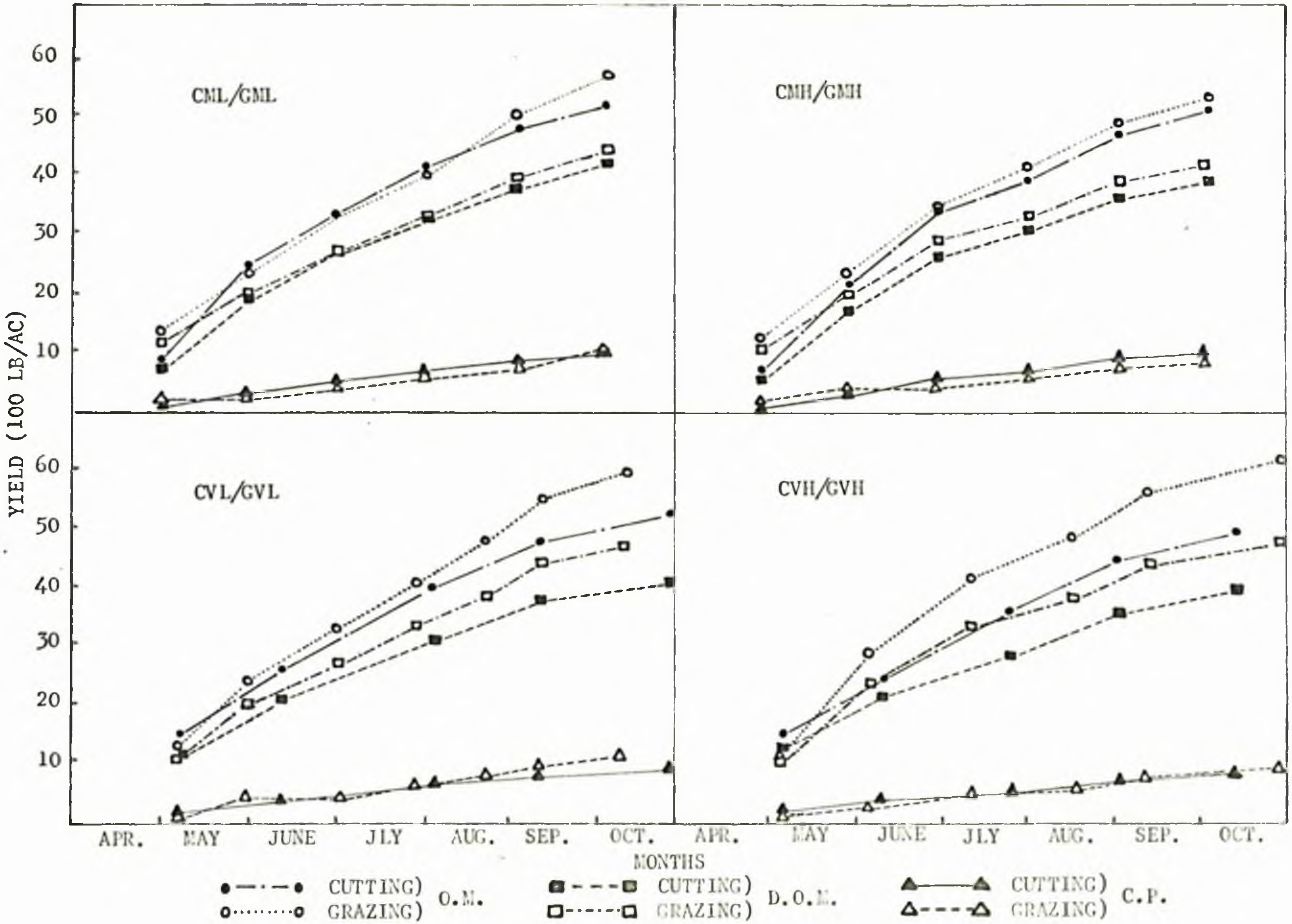


Figure 13 Accumulative utilized herbage yields for each treatment

developed similarly to organic matter yields. With monthly defoliation, yields under grazing were slightly greater than under cutting; with variable frequency defoliation, yields under grazing soon developed a yield advantage which became substantial by October. Crude protein yields developed along closely similar lines for both cutting and grazing.

Seasonal botanical composition of the herbage

Method of defoliation had a greater effect on the sown grass:clover ratio of the herbage than intensity (Table 31; Figure 14).

Table 31 Seasonal percentage botanical composition of the available herbage for each treatment

	Cutting			Grazing		
Defoliation No.	Perennial ryegrass	White clover	Unsown species	Perennial ryegrass	White clover	Unsown species
		CML			GML	
1	92.4	6.5	1.1	97.3	2.0	0.7
2	71.7	23.7	4.6	92.3	6.0	1.7
3	47.3	50.8	1.9	96.3	3.0	0.7
4	69.6	28.5	1.9	96.0	2.5	1.5
5	62.8	35.5	1.7	95.2	4.3	0.5
6	76.6	21.9	1.5	97.3	2.6	0.1
		CMH			GMH	
1	82.8	16.5	0.7	94.1	4.9	1.0
2	71.8	23.8	4.4	85.6	12.2	2.2
3	55.7	43.3	1.0	84.6	14.1	1.3
4	68.8	29.7	1.5	90.7	8.5	0.8
5	66.1	33.1	0.8	87.1	12.2	0.7
6	86.3	13.4	0.3	95.9	3.9	0.2
		CVL			GVL	
1	79.8	19.6	0.6	90.0	8.2	1.8
2	59.1	38.8	2.1	83.0	5.9	11.1
3	48.3	50.7	1.0	93.4	4.7	1.9
4	66.9	32.2	0.9	87.8	12.0	0.2
5	78.7	20.7	0.6	95.2	4.1	0.7
6				96.2	3.8	-
7				96.9	2.9	0.2
		CVH			GVH	
1	78.5	20.9	0.6	83.2	16.2	0.6
2	59.5	38.7	1.8	82.1	12.0	5.9
3	42.3	57.6	0.1	90.4	9.3	0.3
4	64.0	35.9	0.1	95.0	4.6	0.4
5	77.4	21.0	1.6	94.8	4.6	0.6
6				97.4	1.7	0.9

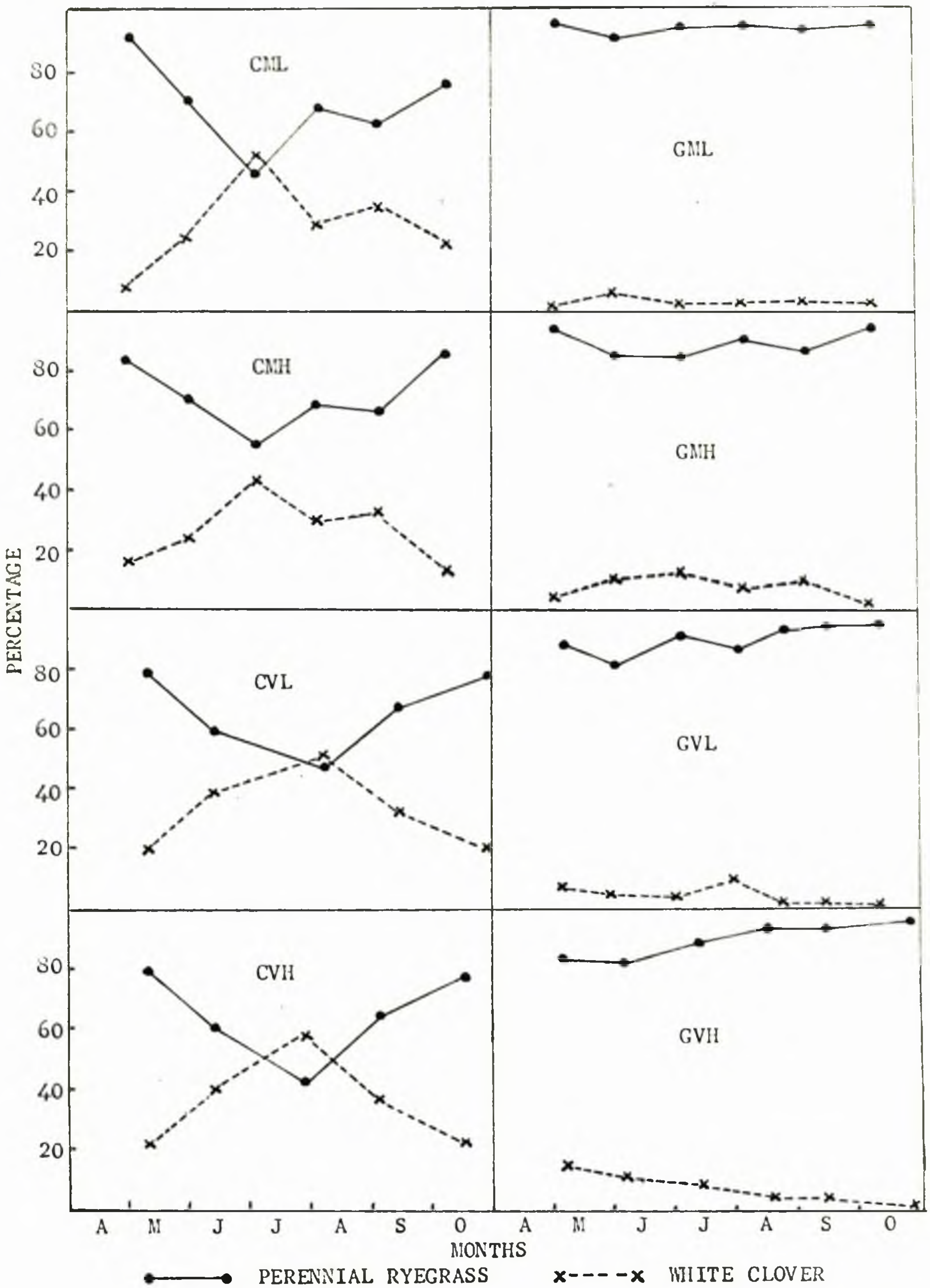


Figure 14 Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

Under cutting, the proportion of ryegrass was highest at the beginning and end of the season and lowest at midseason. Since unsown species made up such a small fraction of the herbage, changes in ryegrass proportions were matched by complementary changes in clover proportions.

Seasonal chemical composition of the herbage

The percentage chemical composition of the available and residual herbages over the season is presented in Table 32 and Figure 15.

Available herbage: At the beginning of the season, organic matter contents were close to normal (8[illegible]-91%) in all the treatments, but by the end of the season, the values had become much lower, especially under grazing in which figures as low as 70-75% were recorded. These figures indicate considerable soil contamination. Such contamination would be more likely under grazing because of the observed effects of treading, which rendered the soil surface more uneven than under cutting treatments. Little effect as a result of either frequency or severity of defoliation was evident.

Digestibility values behaved similarly under both method and intensity treatments (Figure 15). Levels were always highest at the first defoliation and lowest most frequently in September. Because of the late spring in 1962, the herbage in variable frequency defoliation treatments did not reach the required 8 in. height until early May, a few days after the fixed monthly defoliations were made. Differences between maximum and minimum values were also similar under all the treatments.

In all the treatments, crude protein contents were always lowest in early season and highest in late season, particularly at the final grazings in October. Differences between top and bottom levels were therefore larger under grazing.

Residual herbage: Organic matter contents were generally higher under cutting than under grazing and decreased as the season progressed under both these methods; the decrease was more marked under grazing (Table 32). Frequency of defoliation did not affect the values unduly but smaller values, indicating a greater degree of soil contamination, were associated with low severity in comparison with high severity defoliation.

Neither the method nor intensity of defoliation had a marked effect on digestibility values over the season. These followed the same pattern as in available herbage, with highest digestibilities in early season and lowest in late season. The only departure from this was the tendency in some of the variable frequency treatments, such as CVL, CVL and CVH, for values at the final defoliation to rise sharply.

Crude protein contents rose gradually as the season progressed. On average, the contents were around 13-14% in early season and 18-22% in late season, with slightly higher values under grazing than cutting.

Comparison of available and residual herbage: Residual herbage had invariably lower organic matter, digestibility and crude protein values than available herbage. The pattern of variation over the season in both types of herbage was similar for digestibility and crude protein attributes but with organic matter, the range between top and bottom levels was wider in the residual herbage due to very low values under grazing in late season. Wet weather in autumn (Appendix 2) no doubt contributed to this effect, which signifies increased soil contamination. Similarly, the cumulative effect of sheep treading, by rendering the soil surface uneven, would be a contributory cause.

Table 32/

Table 32 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage: Cutting O.M.	Dig.	C.P.	Grazing O.M.	Dig.	C.P.	Residual herbage: Cutting O.M.	Dig.	C.P.	Grazing O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	87.4	80.7	13.7	86.7	78.1	14.5	80.5	75.1	13.5	79.0	63.9	14.5
2	89.1	77.0	14.1	85.4	77.1	15.2	78.5	70.3	12.8	72.4	64.1	16.3
3	86.0	72.5	17.1	85.5	76.3	15.8	83.9	65.1	13.2	81.3	63.4	14.1
4	85.3	71.9	17.0	75.3	72.8	19.6	79.3	67.3	13.2	73.4	66.5	16.7
5	82.8	71.5	22.6	74.6	70.6	21.8	63.8	65.4	16.5	67.4	66.6	21.1
6	81.0	73.0	21.7	75.2	71.3	25.0	69.1	66.9	16.8	64.0	62.8	24.6
		CMH			GMH			CMH			GMH	
1	86.5	79.3	14.1	85.8	79.0	14.1	82.5	75.9	13.1	79.5	67.3	14.0
2	89.5	75.9	15.2	86.5	77.3	15.3	81.2	68.6	13.4	77.1	66.8	12.5
3	85.7	70.0	16.9	83.0	74.8	13.9	81.7	69.2	12.3	77.2	64.2	12.4
4	86.8	70.8	17.6	78.2	72.2	18.0	85.0	68.7	14.0	74.8	65.1	16.7
5	82.7	69.9	22.2	72.2	71.1	21.0	68.0	61.3	15.0	70.5	61.5	17.9
6	83.2	70.7	20.8	73.5	71.4	23.8	71.7	66.2	17.6	61.7	60.6	21.8
		CVL			GVL			CVL			GVL	
1	89.5	81.3	14.6	84.3	79.8	11.9	85.3	76.4	12.2	83.4	75.3	13.0
2	87.4	76.8	14.5	85.9	75.0	16.6	84.8	72.8	12.2	79.3	66.3	15.4
3	84.7	69.8	16.1	83.2	76.1	17.2	74.9	65.1	12.0	83.0	65.5	16.3
4	83.0	72.5	20.9	84.6	74.0	19.5	70.1	62.5	15.4	82.7	68.1	19.0
5	80.8	77.0	20.2	79.4	71.2	23.0	68.9	71.3	22.8	55.2	64.5	22.9
6				70.4	67.2	25.4				53.6	63.5	26.5
7				79.9	70.7	28.5				73.7	72.5	27.4
		CVH			GVH			CVH			GVH	
1	89.3	80.9	14.1	84.1	80.2	12.3	84.8	72.7	12.2	81.6	73.7	12.7
2	86.4	76.7	13.7	93.5	75.1	12.7	83.9	70.5	11.4	83.1	67.9	12.1
3	85.1	68.6	13.2	88.2	74.9	12.4	86.8	67.8	10.8	83.7	67.7	11.1
4	85.3	69.5	20.1	81.8	73.6	17.0	69.3	61.4	14.7	73.8	64.9	14.6
5	81.1	71.2	21.5	74.2	69.0	20.3	75.1	63.4	17.1	60.5	60.0	18.9
6				77.8	74.1	25.1				71.8	72.9	23.8

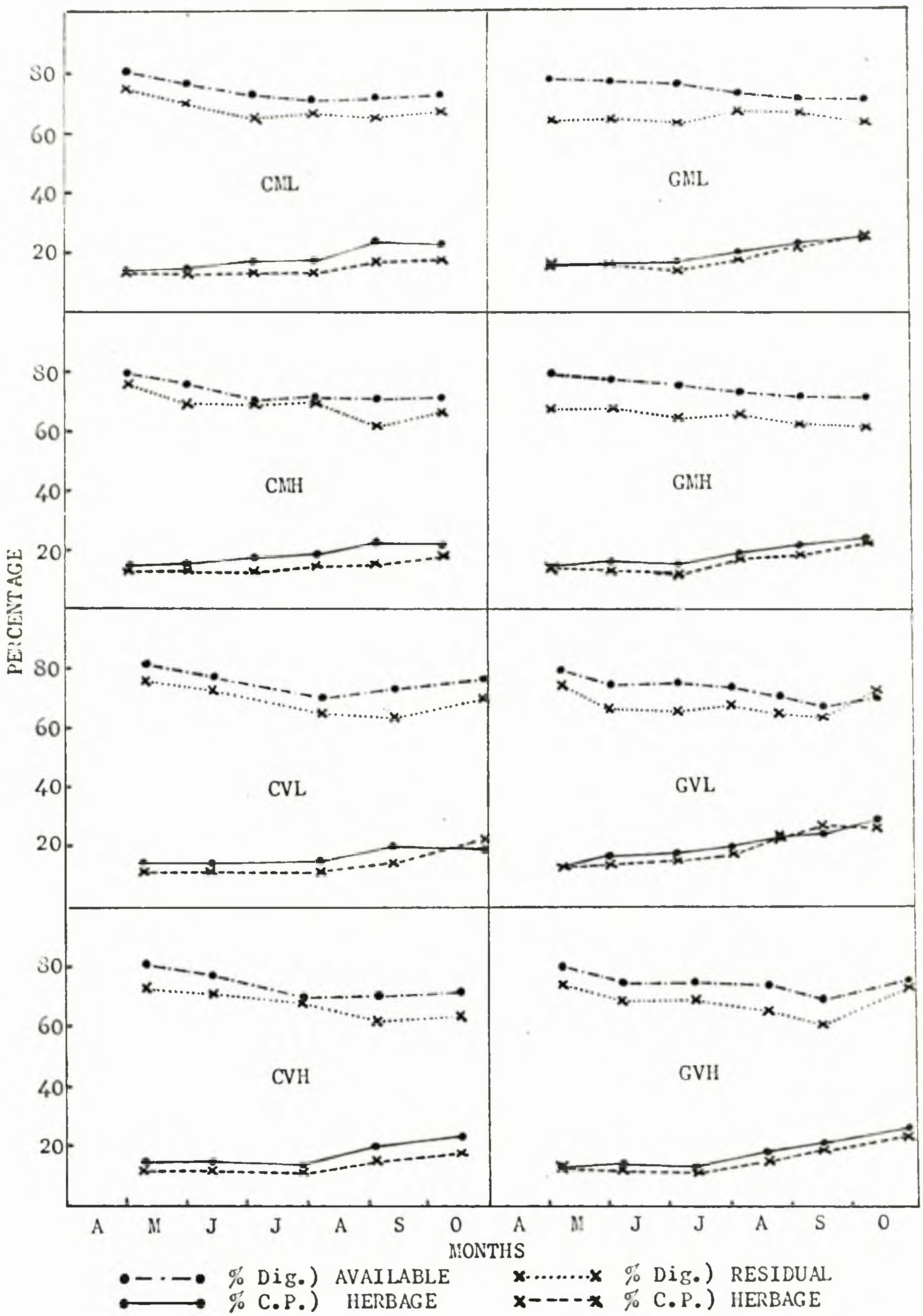


Figure 15 Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: Table 33 shows the motor scythe estimates of mean annual yield for the four cutting treatments and the relationship of these estimates to those from the shearhead sampling method. The results from the statistical examination of the differences between the two methods are also shown.

Treatment effects were not significant, showing that the yield relationship between the treatments was similar under both sampling methods. However, shearhead estimates resulted in consistently and significantly higher yields of organic matter, digestible organic matter and crude protein than the motor scythe estimates.

Table 33 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	52.0	40.2	9.4	1.4	2.6	0.8
MH	50.5	38.6	9.8	1.6	1.6	0.8
VL	49.4	37.9	8.6	3.2	3.3	0.8
VH	49.0	37.7	8.6	0.7	2.0	0.3
Significant effects:						
Intensity				NS	NS	NS
Frequency				NS	NS	NS
Severity				NS	NS	NS
Frequency x severity				NS	NS	NS
Consistency				*	**	**
C.V. (%)				170.6	91.7	114.3
Differences between:				$S\bar{d}$	$S\bar{d}$	$S\bar{d}$
Intensity means				2.05	1.58	0.55
Frequency/severity means				1.45	1.11	0.39
Frequency means within a severity and vice versa				2.05	1.58	0.55

Mean annual chemical composition of the herbage: The weighted mean annual chemical composition of the herbage cut and removed by motor scythe (Table 34) shows that organic matter contents were slightly smaller under monthly compared with variable frequency defoliation and under low compared with high severity defoliation. Digestibility was highest under treatment CML but the levels under the other three treatments were similar and only slightly lower than in CML. Crude protein contents were highest under monthly defoliation and high severity defoliation.

Table 34 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digest-ibility	Crude protein
ML	85.2	77.4	18.2
MH	87.7	76.4	19.4
VL	86.8	76.6	17.2
VH	88.4	76.9	17.4

Seasonal distribution of herbage yields: Table 35 shows the distribution of herbage yields over the season as estimated by motor scythe and the relationship of these yields to those as measured by shearhead.

Over all the treatments, the amounts by which the estimates differed were from 0-210 lb/ac organic matter, 0-140 lb/ac digestible organic matter and 0-50 lb/ac crude protein. In the majority of cases in each treatment, the shearhead method of sampling gave slightly higher estimates.

Table 35/

Table 35 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
Defoliation No.	Organic matter	Digestible organic matter	Crude protein	Organic matter	Digestible organic matter	Crude protein
		CML			CML	
1	9.0	7.6	1.2	0.3	0.4	0.1
2	15.4	12.2	2.3	0.1	0.1	0.0
3	9.1	6.8	1.7	0.4	1.1	0.5
4	7.0	5.2	1.3	0.6	0.6	0.2
5	7.4	5.5	1.9	-0.3	-0.1	0.0
6	4.1	3.0	1.1	0.3	0.4	0.0
		CMH			CMH	
1	5.7	4.9	0.9	1.7	1.4	0.3
2	16.5	12.7	2.6	-2.1	-1.0	-0.2
3	11.9	9.0	2.5	0.9	0.0	0.1
4	4.8	3.5	1.0	0.4	0.4	0.2
5	8.5	6.3	2.1	0.0	0.1	0.2
6	3.0	2.2	0.8	0.9	0.8	0.2
		CVL			CVL	
1	14.4	11.9	2.0	0.5	0.5	0.3
2	10.5	8.2	1.6	0.4	0.5	0.1
3	13.0	9.0	2.2	1.6	1.4	0.4
4	6.7	5.0	1.6	1.3	1.3	0.3
5	4.8	3.8	1.1	0.6	-0.4	-0.3
		CVH			CVH	
1	14.4	11.9	2.1	0.2	0.9	0.2
2	11.3	8.7	1.6	-0.8	0.2	0.2
3	10.7	7.7	1.7	0.0	-0.2	0.0
4	7.7	5.7	1.9	1.7	1.3	0.3
5	4.9	3.7	1.3	-0.4	-0.2	-0.1

Seasonal chemical composition of the herbage: The seasonal chemical composition data for the herbage removed by the motor scythe are shown in Table 36.

Organic matter contents were close to normal (88-91%) early in the season but fell in each treatment towards the end of the season.

The variable frequency treatments were defoliated 6-7 days later than the monthly frequency treatments because of the late spring and this is reflected in the digestibilities which were slightly higher under monthly treatment at the first defoliations. Digestibilities were usually lowest in August and September.

From their lowest levels around 14-15% at the start of the season, crude protein contents steadily increased throughout the season to levels around 24-26% by October.

Table 36 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defoliation No.	Organic matter	Digestibility	Crude protein	Organic matter	Digestibility	Crude protein
		CML			CMH	
1	89.7	84.6	13.6	89.0	84.5	15.4
2	89.8	79.1	14.8	90.4	77.3	15.5
3	86.4	74.3	19.0	89.4	75.1	20.6
4	88.0	74.4	18.3	88.2	71.7	21.1
5	74.7	73.4	25.3	82.2	74.3	24.5
6	76.7	74.2	25.9	80.2	73.9	26.0
		CVL			CVH	
1	90.5	82.7	14.1	90.9	82.9	14.7
2	89.6	77.7	15.2	88.9	76.8	14.5
3	86.8	69.8	16.9	90.0	71.7	16.0
4	83.5	74.4	23.7	83.4	74.0	24.0
5	75.4	78.8	23.5	84.7	75.1	25.5

Chemical composition of the soil

The chemical composition of the soil before and after the application of the cutting and grazing treatments for the second year (i.e. analyses in 1961 and 1962 respectively) are shown in Table 37.

Table 37 Chemical composition of the soil before and after the application of cutting and grazing treatments for the second year

Date	Treatment	pH	Available P_2O_5 (mg/100 g soil)	Available K_2O (mg/100 g soil)
3.2.62	Cutting	5.84	3	6
	Grazing	5.82	3	12
11.3.63	Cutting	5.74	4	7
	Grazing	5.60	3	18

According to Whittles (1952), the acidity of the soil fell slightly from 'moderate' to 'pronounced' under both cutting and grazing. There was no change in the classification of the available phosphate or potash although in the case of the potash, the level rose slightly from 12 to 18 mg/100 g soil under grazing.

EXPERIMENT 4 (S.23/N SWARD)

Results (1961)

Dates of defoliations

As shown in Table 38, there were six defoliations in each treatment during a season from approximately mid-May to mid-October. The intervals between defoliations in the variable frequency treatments were fairly similar except in the August-September period when they were shorter in the VH treatments than in the VL treatments and in the September-October period when the reverse occurred.

Table 38 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6
CML, GML) CMH, GMH)	14/5	13/6	13/7	13/8	15/9	16/10
CVL	17/5	23/6	21/7	22/8	27/9	19/10
GVL	18/5	21/6	20/7	15/8	18/9	13/10
CVH	18/5	22/6	20/7	16/8	13/9	18/10
GVH	19/5	16/6	20/7	15/8	9/9	13/10

Annual herbage yields

Annual utilized herbage yields for the treatments are shown in Table 39.

Organic matter: Grazing gave an increase of 720 lb/ac over cutting ($P<0.05$) while differences as a result of the intensity treatments were highly significant ($P<0.001$). Variable frequency defoliation gave an increase of 560 lb/ac over monthly ($P<0.001$) and low severity defoliation an increase of 520 lb/ac over high ($P<0.001$).

Digestible organic matter: The effects of the treatments were similar to those on the organic matter yields. Grazing gave an increase over cutting of 460 lb/ac and there were also differences due to the intensity treatments. Variable frequency defoliation gave an increase of 360 lb/ac over monthly ($P<0.01$) and low defoliation an increase of 400 lb/ac over high ($P<0.001$).

Crude protein: The defoliation method had no effect on the yields but the effect of the intensity of defoliation was significant ($P<0.05$). Variable frequency defoliation again gave an increase over monthly, this time of 130 lb/ac ($P<0.01$) but the severity of defoliation had little effect.

Table 39 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter			Digestible organic matter			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	53.8	54.6	54.2	42.0	42.4	42.2	11.1	10.4	10.7
MH	46.3	55.4	50.8	36.5	43.3	39.9	11.1	10.2	10.6
VL	56.9	66.3	61.6	44.5	50.8	47.6	12.2	12.3	12.2
VH	49.8	59.3	54.5	39.3	44.3	41.8	11.1	12.5	11.8
Means	51.7	58.9		40.6	45.2		11.3	11.3	
Significant effects:									
Method		*			*			NS	
Intensity		***			***			*	
Method x intensity		NS			NS			NS	
Frequency		***			**			**	
Severity		***			***			NS	
Frequency x severity		NS			NS			NS	
C.V. (%)		6.7			6.3			9.7	

Differences between:	$s\bar{d}$	L.S.D.	$s\bar{d}$	L.S.D.	$s\bar{d}$	L.S.D.
Method means	1.30	4.14	1.03	3.28	0.66	-
Intensity means	1.88	3.95	1.33	2.79	0.57	1.20
Intensity means within a method	2.65	-	1.88	-	0.81	-
Method means within an intensity	2.63	-	1.92	-	0.96	-
Frequency/severity means	1.32	2.77	0.94	1.97	0.40	0.84

Mean annual botanical composition of the herbage

Perennial ryegrass formed 66-69% of the herbage and white clover, 30-33% in all four intensity treatments (Table 40). In contrast, defoliation method had considerable effect on the sown grass:clover ratio, with mean values of 53.2% ryegrass under cutting and 81.6% under grazing; clover which comprised most of the balance of the herbage, was more abundant under cutting. The unsown species, consisting mainly of bent and annual meadow grasses, made up around 1% of the herbage in all the treatments.

Table 40 Weighted mean annual percentage botanical composition of the available herbage

	Perennial ryegrass			White clover			Unsown species		
Method	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	53.3	82.3	67.8	44.9	16.7	30.8	1.9	1.0	1.4
MH	53.1	80.9	67.0	45.8	18.3	32.0	1.1	0.9	1.0
VL	53.3	85.0	69.2	45.6	13.8	29.7	1.1	1.2	1.2
VH	53.0	78.3	65.7	45.7	20.9	33.3	1.3	0.8	1.0
Means	53.2	81.6		45.5	17.4		1.4	0.9	

Mean annual chemical composition of the herbage

In the available herbage, neither the method nor intensity of defoliation had much effect on organic matter, digestibility or crude protein contents (Table 41). The only differences were marginal increases in the digestibility and crude protein values with cutting in comparison with grazing. Similar comments may be made on the composition of residual herbage, excepting that crude protein contents were slightly greater under grazing than cutting.

In all the treatments, residual herbage had slightly but consistently lower contents of the composition attributes than available herbage. The lower organic matter contents in residual herbage reflect the greater degree of soil contamination associated with this herbage, since it has had to bear the application of the treatments, whether by grazing sheep or cutting machinery.

Table 41 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter C	Organic matter G	Organic matter Means	Digestibility C	Digestibility G	Digestibility Means	Crude protein C	Crude protein G	Crude protein Means
Intensity									
				Available herbage					
ML	83.6	84.8	84.2	74.7	71.7	73.2	17.7	15.1	16.4
MH	84.0	84.6	84.3	73.2	71.8	72.5	18.2	16.5	17.4
VL	84.4	83.3	83.8	74.2	73.2	73.7	17.9	17.3	17.6
VH	84.3	83.1	83.7	72.6	71.3	71.9	16.6	15.3	15.9
Means	84.1	83.9		73.6	72.0		17.6	16.0	
				Residual herbage					
ML	77.9	81.8	79.8	69.5	67.3	68.4	13.3	16.6	14.9
MH	78.9	83.5	81.2	68.6	67.3	68.0	13.6	15.3	14.4
VL	77.0	79.2	78.1	68.5	67.3	67.9	12.5	15.3	13.9
VH	82.2	80.6	81.4	67.6	67.1	67.4	12.0	14.1	13.0
Means	79.0	81.3		68.5	67.3		12.9	15.3	

Seasonal distribution of herbage yields

The seasonal yield distribution of available and residual herbages is shown in Appendix 7, while the utilized yields calculated from them are shown below in Table 42.

In general, organic matter and digestible organic matter yields under cutting showed a wider range of variation over the season than under grazing. The range was particularly narrow in the GML and GVH treatments where organic matter yields were from 710-1240 lb/ac and 760-1160 lb/ac respectively. With both methods, highest yields were recorded at the earlier defoliations and lowest in late season. Defoliation frequency treatments had little effect on the seasonality of yield apart from a slightly greater range between top and bottom levels with variable compared with monthly frequency defoliation. Similarly, little effect of the severity of defoliation was evident. Neither method nor intensity of defoliation had much effect on the crude protein yields and these showed little variation over the season in any of the treatments.

Table 42 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			GML	
1	16.4	13.8	2.4	9.6	8.1	1.2
2	12.0	9.1	2.3	10.9	9.7	1.9
3	8.1	5.5	2.0	12.4	8.7	1.8
4	8.3	6.6	2.1	7.8	6.3	1.9
5	5.8	4.6	1.7	6.8	5.1	2.0
6	3.1	2.4	0.8	7.1	4.6	1.6
		CMH			GMH	
1	12.6	10.4	2.3	11.9	9.7	1.7
2	10.2	8.1	2.1	10.6	9.6	1.6
3	5.5	4.5	1.8	12.7	9.1	2.1
4	8.6	6.4	2.2	7.4	6.1	1.5
5	5.7	4.2	1.7	4.2	3.5	1.4
6	3.8	2.9	0.9	8.6	5.5	1.9
		CVL			GVL	
1	13.6	11.3	2.3	18.3	14.6	2.6
2	14.7	11.5	2.8	15.3	12.2	2.5
3	8.0	5.8	1.8	9.4	6.7	1.8
4	11.6	8.7	3.0	10.3	7.7	2.2
5	5.4	4.4	1.6	9.1	7.1	2.2
6	3.6	2.8	0.8	4.0	2.4	0.9
		CVH			GVH	
1	16.8	13.4	2.8	11.6	9.2	1.8
2	13.0	10.2	2.3	11.4	9.5	2.2
3	8.1	6.0	2.2	10.3	7.3	2.0
4	4.9	3.8	1.5	8.4	6.0	1.7
5	3.2	2.9	1.3	7.6	5.6	2.2
6	3.8	2.9	0.9	9.9	6.8	2.5

Accumulative herbage yields

Figure 16 illustrates the development of accumulative yields over the season under both cutting and grazing. For all four intensity treatments, the final organic matter and digestible organic matter yields were greater under grazing, but only marginally so in the ML treatment. The superiority under grazing developed in early season in the MH and VL intensity treatments but in very late season in the remaining two. With crude protein yields, there was a marginal advantage to cutting in the treatments throughout most of the season.

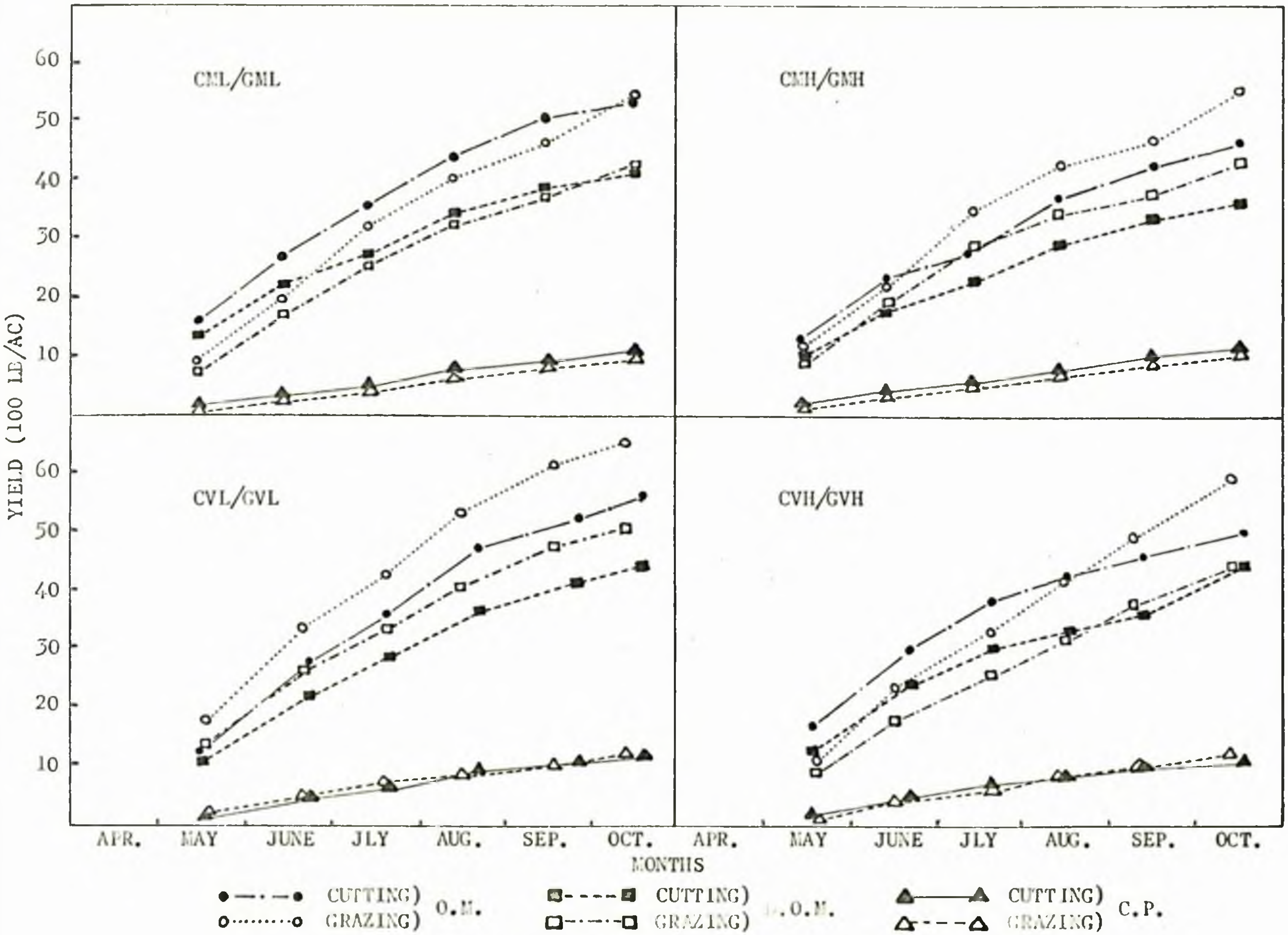


Figure 16 Accumulative utilized herbage yields for each treatment

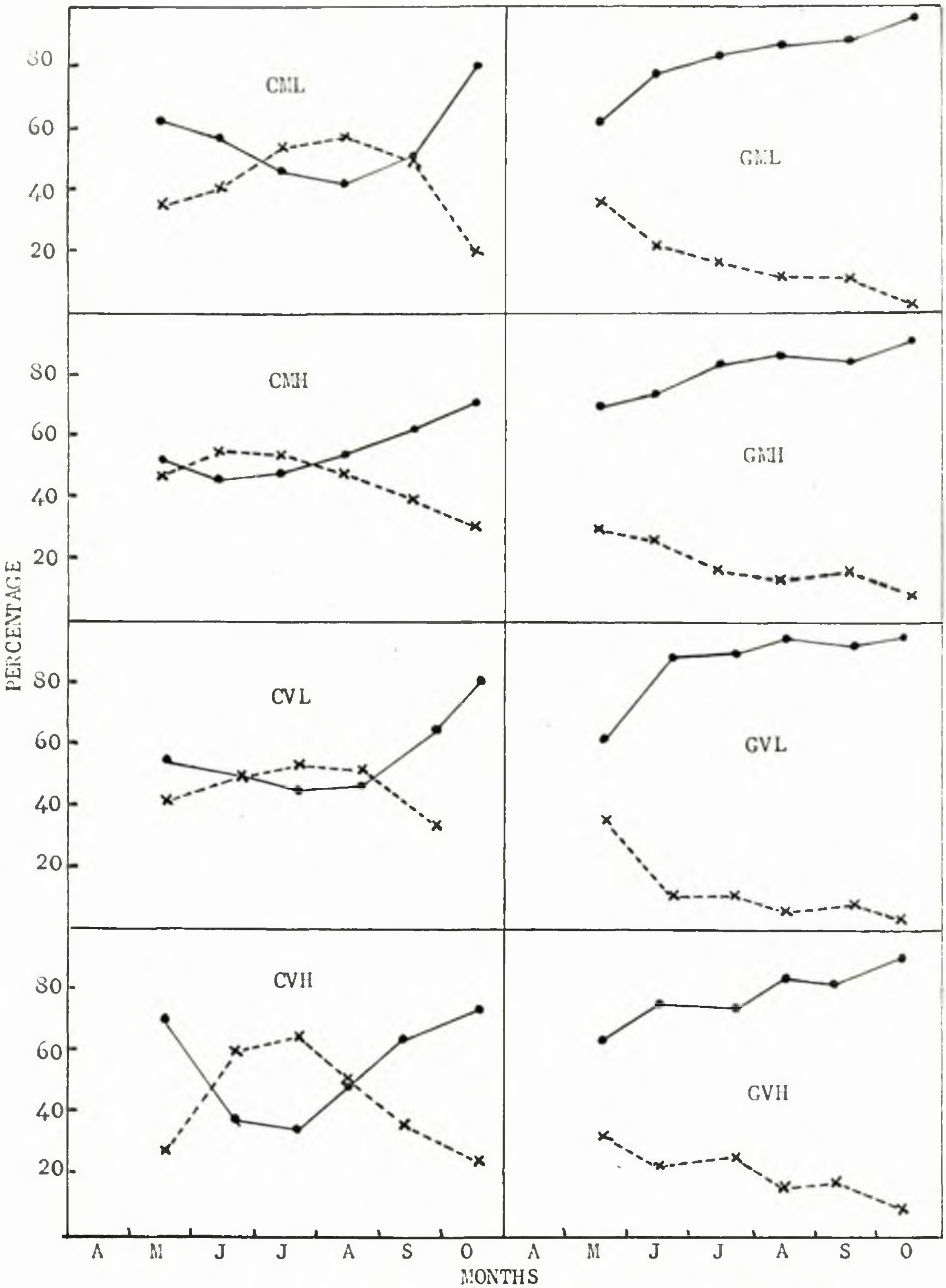
Seasonal botanical composition of the herbage

Considerable effect of defoliation method was evident but little effect of defoliation intensity (Table 43; Figure 17).

Table 43 Seasonal percentage botanical composition of the available herbage for each treatment

Defoliation No.	Cutting: Perennial ryegrass	Cutting: White clover	Cutting: Unsown species	Grazing: Perennial ryegrass	Grazing: White clover	Grazing: Unsown species
		CML			GML	
1	61.7	35.0	3.3	62.0	35.7	2.3
2	56.9	40.0	3.2	78.0	21.1	0.9
3	45.5	53.6	0.9	83.4	16.0	0.6
4	42.1	57.1	0.9	87.0	12.0	1.0
5	50.2	49.3	0.5	88.8	10.7	1.2
6	79.9	19.5	0.6	96.4	3.2	0.5
		CMH			GMH	
1	51.4	46.3	2.4	68.7	28.8	2.6
2	44.5	53.5	2.1	73.1	26.2	0.6
3	46.6	52.7	0.7	83.2	15.9	0.6
4	52.6	47.1	0.3	86.0	13.1	0.9
5	60.7	38.8	0.6	83.6	16.2	0.2
6	69.6	29.5	0.9	91.4	8.4	0.2
		CVL			GVL	
1	55.3	42.2	1.6	61.1	35.5	3.3
2	49.1	50.1	0.8	87.8	10.8	1.4
3	45.1	53.8	1.2	88.5	11.0	0.5
4	47.2	52.3	0.6	94.3	5.6	0.2
5	64.7	34.4	0.9	91.7	7.8	0.4
6	80.5	19.0	0.6	95.1	4.1	0.8
		CVH			GVH	
1	70.2	28.3	1.5	64.4	32.7	2.9
2	38.4	59.6	2.1	76.4	23.2	0.4
3	34.7	64.6	0.7	73.9	25.5	0.7
4	48.5	51.0	0.6	84.0	15.8	0.2
5	63.8	35.7	0.6	81.6	18.0	0.4
6	73.7	25.3	1.0	90.8	8.9	0.3

With cutting, the percentage of ryegrass in the herbage was high in early season, low in midseason and high again in late season. The values reached 70-80% in the treatments at the final defoliations after being as low as 35-45% in midseason. Vice versa, the proportion of clover reached approximately 55-65% at midseason but only 20-30% in late season. The bulk of the



PERENNIAL RYEGRASS   WHITE CLOVER

Figure 17   Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

herbage was made up of these two constituents in all the treatments since there was negligible incursion of unsown species. With grazing a different seasonal pattern emerged. Ryegrass and clover proportions at the first defoliation were fairly similar to those under cutting but thereafter the ryegrass gradually increased with each defoliation whereas the clover correspondingly decreased, until by the end of the season, the ryegrass made up over 90% and the clover less than 10% of the herbage.

Seasonal chemical composition of the herbage

The percentage chemical composition over the season of the available and residual herbages is shown in Table 44 and Figure 18.

Available herbage: In most treatments, organic matter contents were in the 88-89% range at first defoliations but thereafter fell irregularly as the season progressed until they reached as low as 55-69% under grazing. Because of this fall the range between top and bottom levels was usually greater under grazing than under cutting. Compared to these effects of defoliation method, the effects of intensity treatment were small and also irregular so that no general inferences can be drawn.

Similarly, little effect on the digestibility values can be attributed to the intensity treatments but defoliation method had fairly marked and consistent effects. With both cutting and grazing, top values of around 78-81% were always at the first defoliation in May, whereas bottom values were always in October under grazing treatment, and in midseason under cutting. These values were between 68 to 70% with cutting but only 62 to 65% with grazing.

Treatment had less effect on the crude protein values than season. The highest values were usually in September regardless of treatment and the lowest in May, with differences of between 10 to 12%.

Residual herbage: As the season progressed, there was a general though irregular fall in organic matter contents with all treatments until October, when the lowest values were recorded. The early season high values were alike for all the treatments but greater decreases generally occurred under grazing. There were particularly low values of around 54-57% in the CVL, CVL and CVH treatments.

There was little consistent effect on digestibility values from the intensity treatments but the range of values was greater under grazing than under cutting, mainly because of the sharp fall in digestibility values to 57-61% at the final defoliations (Figure 18). Cutting values lay in the 61-64% range at this defoliation. Top values under both cutting and grazing were around 75-79% and always at the first defoliations in May.

Season had a greater effect on crude protein contents than treatment. The lowest values, around 9-12%, were always at the first defoliations in May but gradually increased to reach peaks of 17-19% in September with cutting and 21-25% mainly in October with grazing. Neither frequency nor severity of defoliation had much effect.

Comparison of available and residual herbage: The levels of the three attributes described above were generally higher in available herbage. Differences between top and bottom levels of organic matter were greater in residual herbage because of lower late season values. Early-season values showed a marginal advantage in favour of available herbage. The pattern of seasonal variation in the digestibility and crude protein levels was essentially the same for both herbages (Figure 18).

Table 44/

Table 44 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage						Residual herbage					
	Cutting			Grazing			Cutting			Grazing		
	O.M.	Dig.	C.P.	O.M.	Dig.	C.P.	O.M.	Dig.	C.P.	O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	89.1	81.9	13.0	89.5	81.4	12.3	86.4	76.2	9.5	88.9	79.4	11.8
2	86.0	73.3	16.7	88.2	75.5	15.6	85.2	70.2	13.1	84.8	66.9	14.4
3	82.8	67.8	18.4	84.4	67.4	16.5	81.8	68.5	12.3	82.6	65.8	18.0
4	78.2	72.0	20.1	85.0	69.1	20.1	64.3	63.0	14.9	79.3	61.5	17.3
5	83.1	75.7	25.3	83.5	69.5	23.7	79.8	69.0	18.8	82.8	65.9	19.7
6	80.8	76.2	21.8	72.9	62.4	22.4	72.0	73.2	18.2	65.0	59.7	22.8
		CMH			GMH			CMH			GMH	
1	89.9	81.2	14.3	89.7	79.9	12.4	87.9	79.4	10.2	89.0	78.3	10.9
2	88.0	75.2	16.6	89.6	76.1	14.3	85.4	71.4	12.4	85.3	68.6	13.8
3	84.2	67.7	18.1	82.3	68.0	15.3	76.2	61.4	11.6	85.7	64.6	14.9
4	82.0	69.8	20.3	86.6	69.5	18.1	77.3	65.6	15.8	81.5	65.3	16.9
5	82.6	69.6	24.6	81.9	70.3	23.0	74.8	65.7	19.4	83.4	65.4	18.6
6	71.3	70.3	20.0	72.0	61.5	21.5	69.3	66.3	17.1	68.0	58.2	20.6
		CVL			GVL			CVL			GVL	
1	90.3	80.6	14.1	89.5	78.2	12.8	88.3	76.9	9.9	86.9	72.9	8.7
2	86.6	73.5	15.5	88.0	75.6	15.3	83.6	65.8	10.0	86.8	67.3	12.7
3	86.6	69.5	17.0	85.8	69.8	17.5	85.3	65.8	11.5	86.9	68.1	15.8
4	82.1	71.0	21.9	84.8	70.5	19.9	71.2	64.0	15.4	70.5	64.0	17.7
5	74.9	75.0	24.5	83.1	73.4	23.0	61.3	67.9	19.3	74.9	63.3	19.7
6	76.3	75.7	20.2	51.5	61.5	24.0	54.0	68.0	19.0	56.3	60.9	25.5
		CVH			GVH			CVH			GVH	
1	88.9	78.2	13.7	89.0	78.1	12.8	88.3	75.0	8.7	88.2	77.3	9.6
2	85.4	73.5	13.3	87.2	74.2	16.0	83.0	68.8	9.2	83.5	65.5	12.5
3	88.3	68.6	17.1	84.9	69.9	16.1	84.7	65.5	11.2	86.8	68.6	12.7
4	79.6	69.3	20.0	83.0	67.3	18.5	81.3	64.6	14.5	80.2	62.9	16.5
5	86.4	71.3	23.4	80.6	68.3	24.9	80.2	63.7	16.9	75.2	62.1	20.7
6	68.7	70.0	19.9	70.3	64.9	23.9	69.9	66.0	16.7	57.4	56.7	20.4

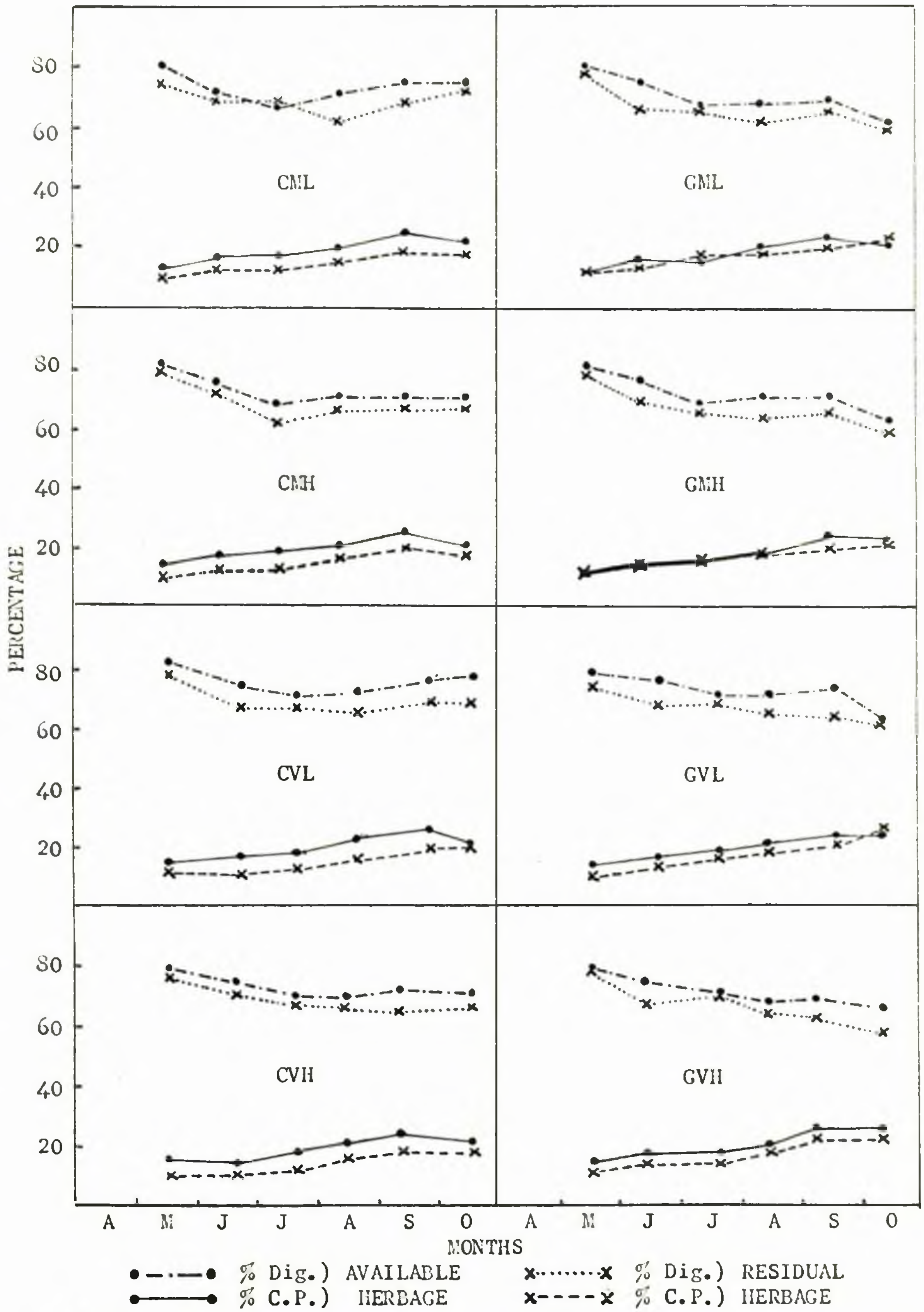


Figure 18 Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: The annual yields of herbage removed by the motor scythe sampling method in the four cutting treatments are shown in Table 45 along with the differences in yield between this method and the shearhead method.

Table 45 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	54.0	42.4	11.0	-0.2	-0.4	0.1
MH	47.5	36.9	10.3	-1.2	-0.4	0.8
VL	61.1	47.3	11.9	-4.2	-2.8	0.3
VH	49.7	38.2	9.7	0.1	1.1	1.4
Significant effects:						
Intensity				NS	NS	*
Frequency				NS	NS	NS
Severity				NS	NS	**
Frequency x severity				NS	NS	NS
Consistency				NS	NS	***
C.V. (%)				-264.3	-466.7	233.3
Differences between:				$s\bar{d}$	$s\bar{d}$	$s\bar{d}$(L.S.D.)
Intensity means				2.62	1.97	0.32(0.72)
Frequency/severity means				1.84	1.41	0.22(0.50)
Frequency means within a severity and vice versa				2.62	1.97	0.32

There were no significant treatment effects for either the organic matter or digestible organic matter yields. Both sampling methods therefore gave similar results as regards the yield relationship between the treatments. However, yields were greater when estimated by motor scythe in comparison with the shearhead under three of the four treatments; the reverse of this occurred in the fourth treatment (CVH). There was therefore no significant consistency effect.

Mean annual chemical composition of the herbage: The weighted mean annual chemical composition data for the herbage removed by motor scythe (Table 46), shows that while organic matter contents were at a high level in all the treatments, they were marginally greater under low than under high severity defoliation. Digestibility and crude protein contents were slightly higher under monthly than under variable frequency defoliation but whereas digestibility contents were slightly greater under low than under high severity defoliations, crude protein contents were slightly greater under high severity defoliation.

Table 46 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digestibility	Crude protein
ML	88.3	78.6	20.2
MH	89.2	77.7	21.8
VL	87.6	77.4	19.4
VH	89.4	76.9	19.5

Seasonal distribution of herbage yields: Table 47 shows the distribution of herbage yields over the season estimated by motor scythe and the relationship of these yields to those measured by shearhead.

In the main, the amounts by which the two estimates differed over the season were small but in one or two instances in each treatment, the estimates differed fairly widely. For organic matter and digestible organic matter yields, no one method outyielded the other consistently. For crude protein yields, the shearhead estimates were more often higher than the motor scythe estimates except in treatment CVL where the reverse occurred.

Table 47 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
Defoliation No.	Organic matter	Digestible organic matter	Crude protein	Organic matter	Digestible organic matter	Crude protein
		CML			CML	
1	19.8	16.4	2.8	-3.4	-2.6	-0.4
2	8.3	6.5	1.7	3.7	2.6	0.6
3	7.0	5.0	1.6	1.1	0.5	0.4
4	8.9	6.7	2.1	-0.6	-0.1	0.0
5	7.2	5.6	1.9	-1.4	-1.0	-0.2
6	2.9	2.2	0.8	0.2	0.2	0.0
		CMH			CMH	
1	13.2	11.0	2.2	-0.6	-0.6	0.1
2	8.5	6.7	1.8	1.7	1.4	0.3
3	8.2	5.8	1.8	-2.7	-1.3	0.0
4	9.1	6.9	2.2	-0.5	-0.5	0.0
5	5.6	4.3	1.7	0.1	-0.1	0.0
6	2.9	2.2	0.7	0.9	0.7	0.2
		CVL			CVL	
1	20.8	16.8	3.0	-7.2	-5.5	-0.7
2	12.1	9.3	2.1	2.6	2.2	0.7
3	9.8	7.2	2.0	-1.8	-1.4	-0.2
4	10.7	8.1	2.7	0.9	0.6	0.3
5	6.4	4.9	1.8	-1.0	-0.5	-0.2
6	1.3	1.0	0.3	2.3	1.8	-0.5
		CVH			CVH	
1	16.1	12.7	2.3	0.7	0.7	0.5
2	12.1	9.4	2.1	0.9	0.8	0.2
3	7.6	5.6	1.7	0.5	0.4	0.5
4	5.8	4.4	1.5	-0.9	-0.6	0.0
5	5.8	4.3	1.6	-2.6	-1.4	-0.3
6	2.4	1.9	0.6	1.4	1.0	0.3

Seasonal chemical composition of the herbage: The chemical composition data for the herbage removed by motor scythe over the season are shown in Table 48.

In early season, organic matter contents were high but there were slight though irregular decreases in each treatment as the season progressed and the lowest levels were recorded at the final defoliations. The final figure of 62.9% in the CVL treatment indicated a very high degree of soil contamination.

In all the treatments, digestibility contents were highest at the first defoliations in May and lowest at the third defoliations in July. The monthly treatments were defoliated 3-5 days in advance of the variable frequency treatments in May and this is reflected in the digestibilities then, which were 2-5% greater under monthly treatment.

In all the treatments, crude protein contents were lowest in May and highest in September with a range of 13-14%. At the final defoliations in October, the crude protein contents dropped by 1-5% compared with the levels in September.

Table 48 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defoliation No.	Organic matter	Digestibility	Crude protein	Organic matter	Digestibility	Crude protein
		CML			CMH	
1	90.5	82.9	14.0	90.5	83.5	16.6
2	89.2	79.0	20.4	89.9	79.0	20.3
3	86.2	71.6	23.1	89.5	70.6	22.5
4	87.7	74.9	23.8	89.2	75.8	24.2
5	87.2	78.1	27.2	86.6	76.4	29.6
6	81.0	77.4	26.0	85.7	76.5	24.5
		CVL			CVH	
1	90.6	80.9	14.4	90.2	78.9	14.3
2	89.7	76.8	17.1	89.9	77.3	16.9
3	88.4	73.0	20.8	90.2	73.5	21.8
4	87.9	76.2	25.3	88.9	76.9	25.5
5	80.2	76.5	27.3	88.1	74.4	28.0
6	62.9	73.9	24.2	83.6	77.3	24.7

Chemical composition of the soil

Table 49 shows the chemical composition of the soil before and after the application of the cutting and grazing treatments. By the classification of Whittles (1952), the acidity has not changed from 'moderate' or the available phosphate from 'low' but whereas under cutting the available potash has dropped from 'medium' to 'low', it has risen from 'medium' to 'satisfactory' under grazing.

Table 49 Chemical composition of the soil before and after the application of cutting and grazing treatments

Date	Treatment	pH	mg/100 g soil Available P_2O_5	Available K_2O
9.2.61	Nil	5.89	5	7
5.2.62	Cutting	5.95	4	5
	Grazing	5.97	3	13

EXPERIMENT 5 (S.24/N_{104} SWARD)

Results (1961)

Dates of defoliations

Herbage in the variable frequency grazing treatments, GVL and GVH, reached the required defoliation height nine and eight times respectively compared with six and seven times for the comparable cutting treatments, CVL and CVH (Table 50). The intervals between defoliations during the April-October season were thus shorter in the grazing treatments.

Table 50 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6	7	8	9
CML, GML) CMH, GMH)	3/5	2/6	4/7	4/8	2/9	3/10			
CVL	13/4	10/5	26/6	2/8	6/9	10/10			
GVL	16/4	8/5	7/6	4/7	26/7	14/8	9/9	30/9	21/10
CVH	15/4	9/5	22/6	26/7	17/8	14/9	12/10		
GVH	18/4	8/5	7/6	7/7	29/7	16/8	15/9	10/10	

Annual herbage yields

Mean annual utilized yields for the treatments together with statistical details are shown in Table 51.

Organic matter: Grazing gave an increase of 1660 lb/ac over cutting ($P<0.01$) while there was considerable variation due to the intensity treatments ($P<0.001$). Monthly defoliation raised yield by 680 lb/ac over variable frequency defoliation ($P<0.001$) and low severity defoliation by 360 lb/ac over high defoliation ($P<0.05$). There was also a significant 'defoliation method x intensity' interaction since the yields from monthly defoliation were appreciably greater than those from variable frequency defoliation with grazing whereas the corresponding differences were smaller or reversed with cutting.

Also, yields from low severity defoliation were greater than those from high severity with variable frequency cutting and monthly grazing but the corresponding differences were negligible with variable frequency grazing and monthly cutting.

Table 51 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter			Digestible organic matter			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	57.3	79.7	68.5	42.1	58.1	50.1	11.2	14.3	12.8
MH	56.1	75.4	65.8	41.8	53.8	47.8	11.3	13.8	12.5
VL	58.4	66.9	62.6	41.8	49.7	45.8	11.2	16.9	14.0
VH	50.0	66.1	58.0	38.2	48.0	43.1	10.3	13.6	11.9
Means	55.4	72.0		41.0	52.4		11.0	14.6	

Significant effects:	Organic matter	Digestible organic matter	Crude protein
Method	**	**	***
Intensity	***	**	*
Method x intensity	*	NS	NS
Frequency	***	***	NS
Severity	*	*	*
Frequency x severity	NS	NS	*
C.V. (%)	6.3	6.6	9.4

Differences between:	S$\bar{d}$	L.S.D.	S$\bar{d}$	L.S.D.	S$\bar{d}$	L.S.D.
Method means	2.52	8.02	1.66	5.28	0.14	0.45
Intensity means	2.01	4.22	1.54	3.24	0.62	1.30
Intensity means within a method	2.84	5.97	2.17	-	0.87	-
Method means within an intensity	3.52	9.36	2.51	-	0.77	-
Frequency/severity means	1.41	2.96	1.10	2.31	0.44	0.92

Digestible organic matter: Compared with cutting, grazing again gave an increased yield ($P<0.01$) while the intensity treatments again gave significant variation ($P<0.01$). There was an increase of 450 lb/ac from monthly over variable frequency defoliation ($P<0.001$) and an increase of 250 lb/ac from low severity defoliation over high ($P<0.05$). As with the organic matter yields, there was an increase from monthly over variable frequency defoliation with grazing but not with cutting; this interaction was not significant.

Crude protein: There was an increase from grazing relative to cutting of 360 lb/ac ($P<0.001$) and significant variation due to the intensity treatments ($P<0.05$). The frequency of defoliation had little effect but the severity had, with an increase of 120 lb/ac from low severity defoliation compared with high ($P<0.05$). The 'frequency x severity' interaction resulted because monthly defoliation gave a smaller yield than variable frequency with low defoliation but a greater yield than variable frequency with high defoliation.

Mean annual botanical composition of the herbage

The composition was affected by the method but hardly at all by the intensity of defoliation (Table 52).

Table 52 Weighted mean annual percentage botanical composition of the available herbage

Method	Perennial ryegrass C	G	Means	White clover C	G	Means	Unsown species C	G	Means
Intensity									
ML	78.0	93.8	85.9	20.4	4.5	12.5	1.6	1.7	1.7
MH	76.6	92.1	84.3	18.9	6.3	12.6	4.6	1.6	3.1
VL	80.8	96.0	88.4	17.2	2.7	9.9	2.1	1.3	1.7
VH	77.7	92.8	85.3	20.3	5.9	13.1	2.0	1.3	1.7
Means	78.3	93.6		19.2	4.9		2.6	1.5	

In cutting treatments, perennial ryegrass made up 76.6–80.8% of the herbage whereas under grazing, the proportion was 92.1-96.0%. The remainder of the herbage under these treatments was mostly white clover, which was therefore most abundant under cutting. Unsown species, mainly annual meadow and bent grasses, were present in the herbage only to a minor extent.

Mean annual chemical composition of the herbage

In available herbage, treatment had little effect on organic matter or digestibility values, but crude protein contents were greater under grazing than under cutting (Table 53). In residual herbage, crude protein was also greater under grazing, by a mean value of 5.4 percentage units. The digestibility of this herbage was little affected by treatment but there was a slight increase in organic matter under cutting compared with grazing and under variable frequency relative to monthly defoliation.

In general, the contents of the three attributes were at higher levels in the available herbage. Available herbage is chiefly leafy regrowth whereas residual herbage is either stubble after cutting or a mixture of stubble and rejected herbage after grazing. Soil contamination has occurred to a greater degree in the residual herbage, but this is not surprising since this herbage has had to bear the application of cutting or grazing treatments.

Table 53 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter			Digestibility			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
				Available herbage					
ML	86.1	86.5	86.3	70.2	68.5	69.3	17.4	18.8	18.1
MH	83.8	86.0	84.9	69.6	68.0	68.8	17.1	18.1	17.6
VL	85.3	81.3	83.3	69.1	69.8	69.5	17.0	22.6	19.8
VH	85.2	84.5	84.9	69.9	68.2	69.0	17.2	19.5	18.4
Means	85.1	84.6		69.7	68.6		17.2	19.7	
				Residual herbage					
ML	74.9	70.5	72.7	65.2	63.3	64.2	14.0	19.8	16.9
MH	79.0	77.0	78.0	64.5	64.6	64.5	14.1	18.0	16.0
VL	80.4	77.8	79.1	64.9	66.1	65.5	13.6	20.4	17.0
VH	77.2	75.1	76.3	64.8	64.1	64.5	14.7	18.6	16.0
Means	77.9	75.1		64.8	64.5		13.8	19.2	

Seasonal distribution of herbage yields

Utilized herbage yields over the season for each treatment are presented in Table 54 while the seasonal yields of available and residual herbage, from which the utilized yields were derived by difference, are tabulated in Appendix 8.

Table 54 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			GML	
1	21.8	15.7	3.9	17.6	11.1	3.2
2	10.0	7.4	1.4	10.8	8.3	1.7
3	4.0	3.0	0.7	17.7	12.5	2.8
4	9.7	7.6	2.7	14.3	11.2	2.1
5	6.5	4.5	1.5	11.4	9.2	2.5
6	5.3	4.0	1.0	7.9	5.8	2.1
		CMH			GMH	
1	22.0	16.0	3.9	15.0	9.4	2.7
2	10.5	8.1	1.7	14.7	11.4	2.2
3	4.6	3.2	0.9	14.4	9.9	2.5
4	7.0	5.9	2.1	14.8	10.2	2.4
5	9.0	6.5	2.1	9.5	8.0	2.5
6	3.0	2.2	0.7	7.1	4.9	1.6
		CVL			GVL	
1	5.9	4.8	1.4	5.1	4.3	1.1
2	13.4	9.5	2.2	6.6	4.6	1.5
3	11.8	8.0	1.4	8.6	7.2	1.5
4	11.9	8.7	2.9	10.3	7.9	2.0
5	8.5	6.1	2.0	12.3	9.8	3.3
6	6.9	4.8	1.3	7.8	4.0	3.2
7				8.4	6.3	2.2
8				5.7	3.8	1.5
9				2.2	1.8	0.6
		CVH			GVH	
1	8.7	7.4	2.1	4.9	3.9	1.2
2	11.3	8.2	1.8	7.5	6.8	1.4
3	7.9	5.9	1.0	13.3	9.5	2.0
4	7.5	5.8	1.9	9.0	5.7	1.4
5	7.6	5.7	1.8	6.9	4.6	1.7
6	4.1	3.5	1.2	9.5	7.1	1.8
7	2.8	1.8	0.5	8.6	6.2	2.2
8				6.4	4.4	1.9

The seasonal distribution of utilized yields showed differences according to the method of defoliation. Top yields of organic matter under cutting were always in May but the lowest yields occurred at various times. In contrast, top yields under grazing occurred at various times whereas bottom yields were usually obtained in October. The range of yields over the season was generally greater under cutting. Of the intensity treatments, frequency of defoliation exerted a much greater effect on yield than severity. The top yields under monthly defoliation were always at higher levels than under variable frequency defoliation. Under cutting, these levels in the monthly treatments reached 2180-2200 lb/ac and under grazing, 1500-1770 lb/ac. Comparable yields under variable frequency treatment were 1130-1340 lb/ac. Because of these differences and since frequency of defoliation caused little variation in the lowest yield levels, the range of seasonal variation in yield was greatest under monthly defoliation. Digestible organic matter yields followed a seasonal pattern essentially similar to that for organic matter yields. In turn, crude protein yields also followed a somewhat similar pattern but within much narrower limits because of the overall lower yield levels.

Accumulative herbage yields

Figure 19 shows the development of accumulative yields over the season under cutting and grazing treatment.

Although starting at lower levels, organic matter yields under grazing overtook yields under cutting by June or July. Thereafter, the gap between yields under these treatments widened until by October, substantial yield advantage had accrued to most of the grazing treatments. This advantage was not so great in the comparison between the CVL and GVL treatments as in the other comparisons. The development of digestible organic matter yields closely followed the pattern set by the organic matter yields. Similarly, with crude protein yields, advantage again lay with the grazing treatments.

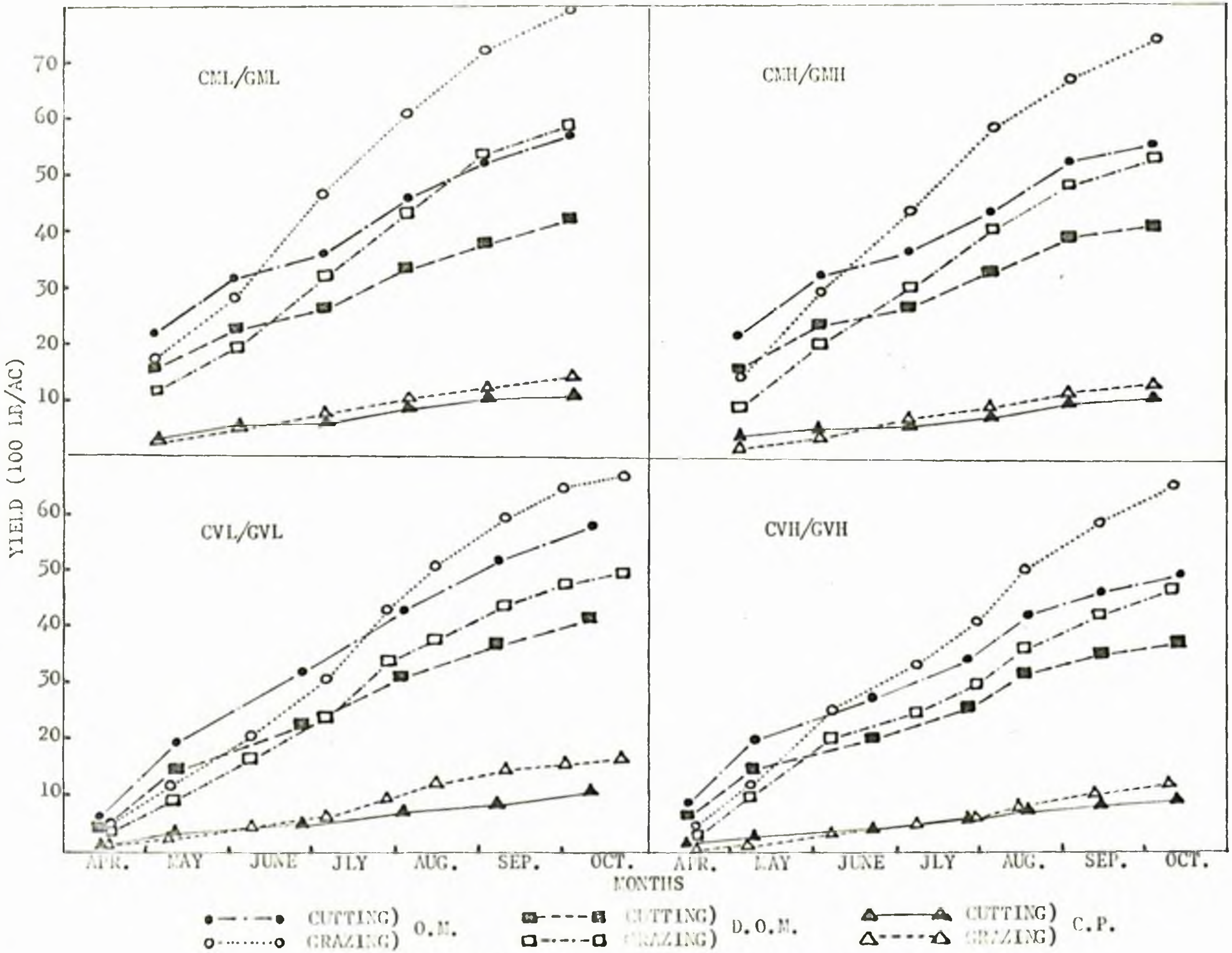


Figure 19 Accumulative utilized herbage yields for each treatment

Seasonal botanical composition of the herbage

Seasonal botanical composition data are presented in Table 55 and Figure 20.

Table 55 Seasonal percentage botanical composition of the available herbage for each treatment

Defoliation No.	Cutting: Perennial ryegrass	Cutting: White clover	Cutting: Unsown species	Grazing: Perennial ryegrass	Grazing: White clover	Grazing: Unsown species
	CML			GML		
1	86.3	11.4	2.3	86.3	9.9	3.8
2	75.0	22.3	2.8	94.9	3.3	1.8
3	67.2	29.5	3.3	96.4	3.1	0.5
4	72.2	27.5	0.3	93.6	5.0	1.5
5	73.6	25.4	1.0	94.9	3.4	1.7
6	82.1	17.0	1.0	98.3	1.3	0.4
	CMH			GMH		
1	87.3	8.8	3.8	90.1	6.5	3.4
2	71.3	25.1	3.8	84.9	13.0	2.2
3	63.0	34.6	2.3	92.7	6.2	1.2
4	77.2	22.6	0.2	93.4	5.4	1.2
5	72.0	26.6	1.4	93.7	5.5	0.8
6	80.6	16.9	2.7	98.2	1.4	0.4
	CVL			GVL		
1	93.8	4.4	0.6	92.8	6.4	0.9
2	90.7	6.1	3.3	89.1	7.0	4.0
3	78.1	19.5	2.4	94.0	4.1	1.9
4	78.3	20.4	1.3	97.2	2.6	0.3
5	67.2	30.4	2.4	96.5	1.9	1.6
6	85.5	13.3	1.2	98.5	0.7	0.8
7				98.9	1.0	0.1
8				99.5	0.4	0.1
9				99.4	0.3	0.3
	CVH			GVH		
1	91.9	7.3	0.9	91.3	5.8	3.0
2	85.7	9.7	4.6	91.5	5.8	2.7
3	76.2	20.8	3.1	91.7	7.1	1.3
4	66.9	32.2	0.9	91.9	6.6	1.5
5	76.4	21.9	1.8	92.5	6.8	0.8
6	72.1	26.1	1.8	94.2	4.5	1.2
7	84.6	13.9	1.5	95.1	4.8	0.1
8				93.6	5.5	0.9

Under cutting, ryegrass was most abundant at the first defoliation of the season in each treatment, making up 86-94% of the herbage. These proportions decreased to 63-67% usually by July before rising again towards the

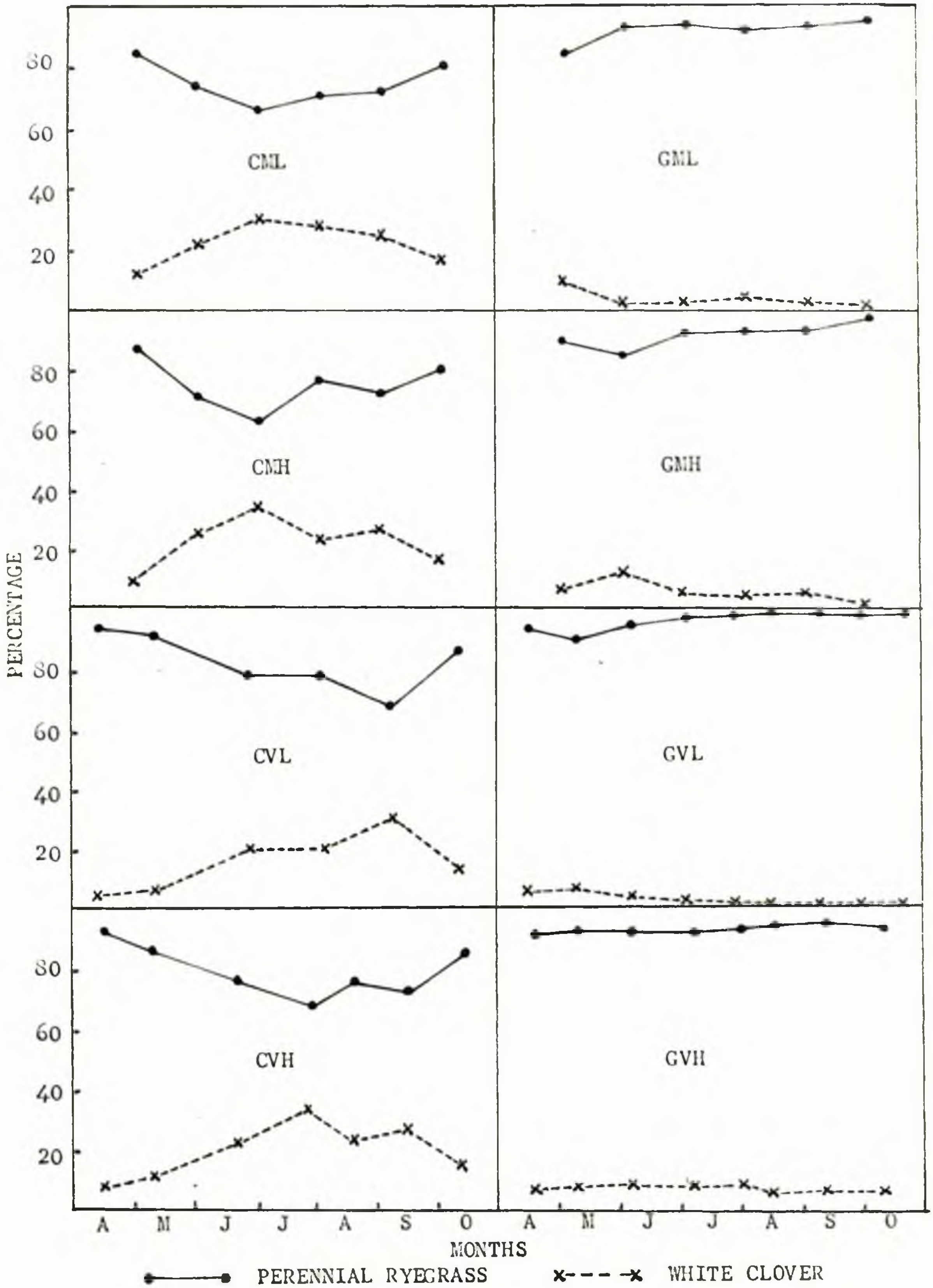


Figure 20 Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

end of the season. Since unsown species made up such small proportions of the herbage, most of the remaining herbage in these treatments was white clover, which was thus most plentiful in midseason and least so at the start. In contrast, under grazing, the relative proportions of ryegrass and clover did not vary so markedly since ryegrass, after making up 86-93% at the start of the season, steadily increased in most treatments. Clover was thus never abundant and by October, the proportions were negligible. Little effect on the composition could be ascribed to the defoliation intensity treatments.

Seasonal chemical composition of the herbage

Table 56 and Figure 21 show the chemical composition of the available and residual herbage throughout the season for each treatment.

Available herbage: There was little effect of either defoliation method or intensity on organic matter contents over the season. Contents were highest at the beginning of the season and lowest at the end, with a general though irregular trend of decreasing contents from start to finish. The values at the start, from 88-89%, showed little sign of soil contamination, but considerable contamination occurred later in the season.

Digestibility values were little affected by method of defoliation since under both cutting and grazing, the highest values were usually in the early part of the season and the lowest in midseason. Treatments GML and GMH were exceptions since the lowest values were obtained at the first defoliations Severity of defoliation had likewise little effect but marked changes were caused by frequency. Top values under monthly defoliation were usually in June but under variable frequency defoliation, the values, which were around 8 percentage units higher, were always in April. In both frequency treatments, the lowest values were at much the same levels, but with monthly defoliation they occurred mainly in July under cutting and in May under grazing, whereas with variable frequency defoliation, they occurred mainly in midseason.

Variation in crude protein contents was mainly due to the method of defoliation. Under cutting, the highest values were in April or July and the lowest in June. Under grazing, the lowest were also in June but the top values were usually at the end of the season. Top and bottom levels under grazing were at higher levels than their counterparts under cutting.

<u>Residual herbage</u>: With all the treatments, the highest organic matter contents were usually obtained in the early part of the season and the lowest in late season, particularly at the final defoliations. The differences between top and bottom levels were much greater under grazing than under cutting, due to the very low late-season levels, which were around 49-58%. Under cutting the comparable figures were 65-72%. Little effect due to the frequency of defoliation was discernible but under grazing, bottom levels were smaller under low severity than high severity defoliation.

There was little effect of either defoliation method or severity on digestibility values but frequency of defoliation had considerable effect because of the high values in April under variable frequency treatment (Figure 21). These values were around 75-79% whereas comparable values under monthly treatment were around 68-70%. Since there was little difference between treatments as regards the lowest values, which were usually in midseason, the overall seasonal variation was greater with variable frequency defoliation. The digestibility values generally rose slightly after midseason in all the treatments, but without reaching the heights obtained in early season.

The contents of crude protein were at distinctly higher levels throughout the season with grazing relative to cutting. The range in values was also greater under grazing. Under both cutting and grazing, the highest values occurred most frequently in August. Treatments CVL and CVH were exceptions, with highest values in April. The lowest values occurred consistently in June under cutting but in various months under grazing. Apart from the high values at the start of the season in the variable frequency treatments, the values generally were at higher levels in the second half of the season.

Table 56 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage: Cutting O.M.	Dig.	C.P.	Grazing O.M.	Dig.	C.P.	Residual herbage: Cutting O.M.	Dig.	C.P.	Grazing O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	87.1	70.6	16.9	89.2	65.1	16.2	76.6	65.5	12.7	83.6	68.6	13.0
2	88.4	71.9	13.1	87.4	70.6	14.4	85.9	67.6	10.5	84.0	65.7	13.5
3	85.2	68.2	13.1	87.4	66.8	15.5	71.5	65.3	11.1	75.4	60.3	14.8
4	83.5	69.9	22.5	83.5	70.2	23.0	71.9	59.5	16.5	49.0	58.0	35.2
5	86.3	68.3	20.5	84.9	71.9	22.8	73.6	69.1	18.2	80.0	63.7	23.4
6	85.3	70.8	17.6	85.7	66.4	25.2	78.6	65.0	15.2	56.3	60.3	24.4
		CMH			GMH			CMH			GMH	
1	83.8	71.9	17.2	88.7	65.7	16.5	71.8	67.5	13.6	85.2	70.2	14.4
2	88.7	72.3	13.5	87.7	70.9	13.8	87.1	66.9	10.5	86.2	65.2	12.9
3	85.8	65.0	12.9	88.9	65.7	15.7	86.3	63.5	11.1	80.7	62.1	14.5
4	80.3	70.2	22.4	83.0	66.6	20.2	72.7	61.7	18.4	66.7	63.7	26.1
5	82.2	67.5	19.8	81.9	71.9	23.4	80.8	63.8	16.3	80.1	62.6	21.4
6	80.0	68.7	17.5	83.6	66.9	23.7	70.8	66.6	15.1	58.3	63.9	24.9
		CVL			GVL			CVL			GVL	
1	89.0	80.9	23.0	88.6	79.6	20.7	87.7	78.7	21.6	81.8	76.7	20.4
2	89.1	68.7	15.0	85.4	70.1	20.6	86.2	63.4	11.4	84.1	69.5	19.2
3	88.5	65.2	10.1	83.4	72.9	17.6	87.2	62.8	8.6	83.3	64.4	17.4
4	81.1	68.2	21.0	87.7	67.9	17.6	76.5	60.7	15.0	79.7	61.5	16.7
5	86.2	69.9	19.9	81.2	69.8	25.5	76.6	67.0	15.8	69.7	58.3	24.1
6	77.3	67.3	17.4	62.6	60.6	30.3	68.9	63.6	15.3	84.7	69.4	18.7
7				84.4	71.7	25.7				80.1	66.7	25.1
8				80.6	66.3	25.3				74.8	66.4	24.5
9				80.7	69.1	27.2				50.5	61.5	26.9
		CVH			GVH			CVH			GVH	
1	88.5	81.5	21.8	83.2	76.7	23.1	88.4	77.3	16.9	71.4	74.5	22.0
2	88.4	70.4	14.6	87.9	77.0	18.3	86.8	66.0	11.7	84.2	65.8	17.4
3	88.2	67.1	10.6	87.7	70.0	14.2	84.9	65.3	9.4	85.7	68.5	13.6
4	80.9	66.7	19.8	87.8	62.0	14.4	67.6	60.7	17.1	80.6	61.1	14.0
5	85.8	70.6	19.7	83.2	63.8	21.0	73.7	67.2	16.6	80.3	62.4	19.3
6	85.5	69.2	20.5	82.5	68.0	22.4	81.4	60.0	16.1	56.0	59.1	27.7
7	75.9	63.6	17.6	83.8	67.5	25.0	65.3	64.1	17.0	69.9	59.6	23.5
8				74.7	64.9	26.6				56.3	59.5	23.3

Comparison of available and residual herbage: Apart from a few exceptions at individual defoliations, available herbage had higher organic matter,

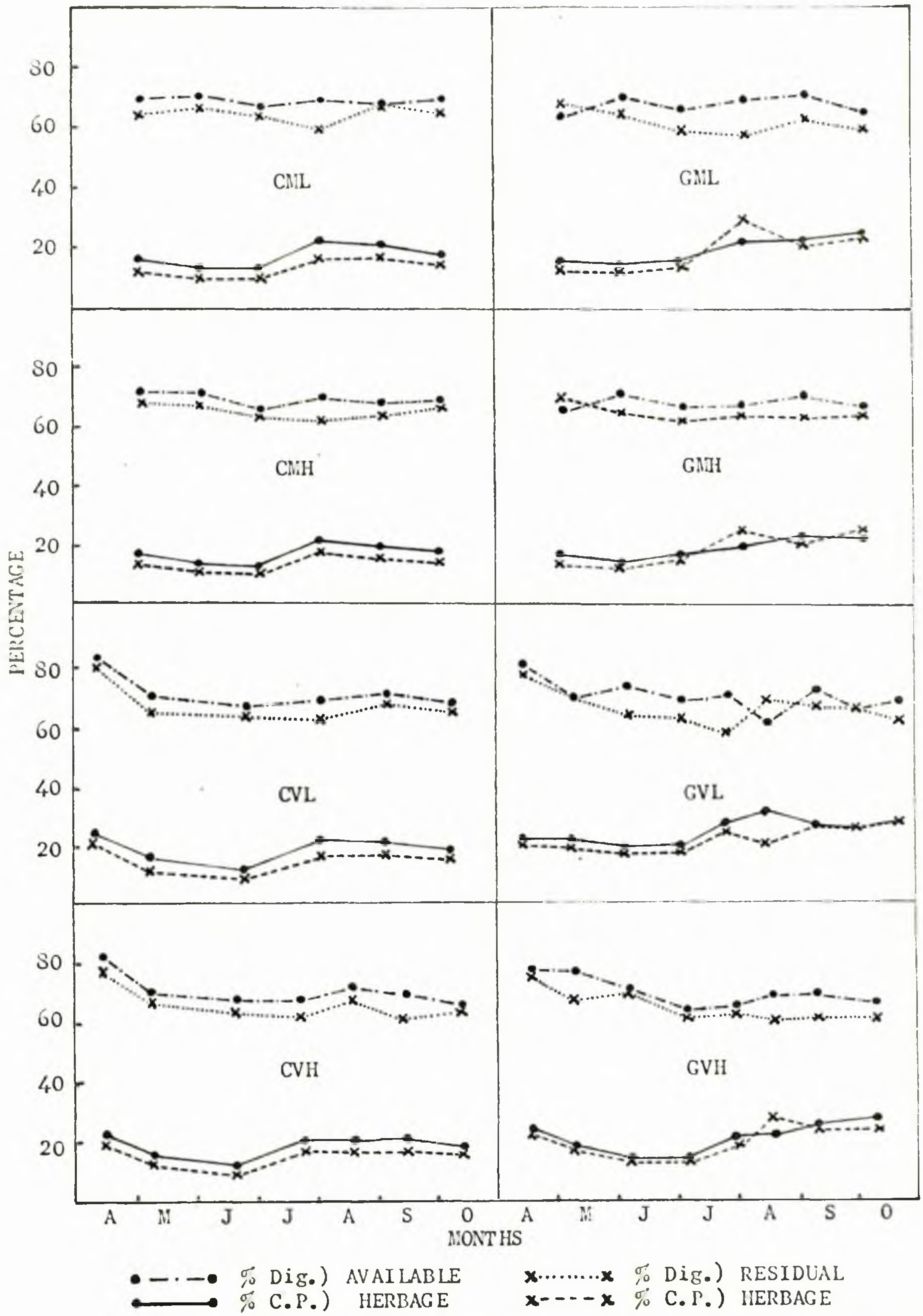


Figure 21 Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

digestibility and crude protein values than residual herbage. Organic matter contents varied over the season much more markedly in the residual herbage mainly as a result of the very low late-season values obtained after grazing but both herbages showed similar trends of decreasing percentages as the season progressed. The seasonality of digestibility values followed the same pattern in both herbages as did the seasonality of crude protein contents.

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: Table 57 shows the motor scythe estimates of annual yield for the four cutting treatments and the relationship of these estimates to those from the shearhead sampling method. The results from the statistical examination of the differences between the two methods are also shown.

Table 57 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	56.8	40.8	10.8	0.4	1.3	0.5
MH	54.8	40.1	10.9	1.3	1.8	0.4
VL	54.2	39.1	10.4	4.1	2.7	0.8
VH	47.4	33.3	9.7	2.6	4.9	0.6
Significant effects:						
Intensity				NS	NS	NS
Frequency				NS	NS	NS
Severity				NS	NS	NS
Frequency x severity				NS	NS	NS
Consistency				NS	*	NS
C.V. (%)				214.3	133.3	183.6
Differences between:				$S\bar{d}$	$S\bar{d}$	$S\bar{d}$
Intensity means				3.21	2.55	0.77
Frequency/severity means				2.28	1.79	0.55
Frequency means within a severity and vice versa				3.21	2.55	0.77

Treatment effects were not significant, showing that the yield relationship between the treatments was similar under both sampling methods. However, the shearhead estimates resulted in higher yields of organic matter, digestible organic matter and crude protein than the motor scythe estimates. This consistency effect was significant only for digestible organic matter yields ($P<0.05$).

Mean annual chemical composition of the herbage: Table 58 shows the weighted mean annual chemical composition of the herbage cut and removed by motor scythe in the four cutting treatments.

Organic matter and digestibility contents were slightly higher under monthly frequency and low severity defoliation than under variable frequency and high severity defoliation; of the individual treatments, the organic matter and digestibility contents were lowest in CVH. In contrast, crude protein levels were slightly higher under variable frequency and high severity defoliation.

Table 58 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digestibility	Crude protein
ML	87.6	71.8	18.9
MH	88.0	73.2	19.9
VL	87.0	72.1	19.2
VH	85.4	70.3	20.4

Seasonal distribution of herbage yields: The seasonal distribution of herbage yields for the cutting treatments as estimated by motor scythe are shown in Table 59 together with their relationship to yields from the shearhead sampling method.

The amounts of herbage yield by which the two estimates differed over the season mainly lay in ranges of from 0-170 lb/ac organic matter, 10-100 lb/ac digestible organic matter and 0-30 lb/ac crude protein. At the majority of the defoliations, shearhead estimates were greater than motor scythe estimates.

Table 59 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
Defoliation No.	Organic matter	Digestible organic matter	Crude protein	Organic matter	Digestible organic matter	Crude protein
		CML			CML	
1	23.3	16.3	3.6	-1.5	-0.6	0.3
2	8.9	6.8	1.2	1.1	0.6	0.2
3	3.8	2.6	0.6	0.2	0.4	0.1
4	10.5	7.8	2.8	-0.8	-0.2	-0.1
5	5.4	3.7	1.4	1.1	0.8	0.1
6	4.9	3.6	1.0	0.4	0.4	0.0
		CMH			CMH	
1	19.0	13.4	3.4	3.0	2.6	0.5
2	9.3	7.2	1.4	1.2	0.9	0.3
3	4.3	3.0	0.7	0.3	0.2	0.2
4	9.5	7.3	2.5	-2.5	-1.4	-0.4
5	8.7	6.3	2.0	0.3	0.2	0.1
6	4.1	3.0	0.9	-1.1	-0.8	-0.2
		CVL			CVL	
1	7.2	5.8	1.7	-1.3	-1.0	-0.3
2	14.3	10.0	2.1	-0.9	-0.5	0.1
3	8.7	5.7	1.0	3.1	2.3	0.4
4	11.4	8.6	2.7	0.5	0.1	0.2
5	7.9	5.8	1.8	0.6	0.3	0.2
6	4.8	3.3	1.1	2.1	1.5	0.2
		CVH			CVH	
1	5.5	4.5	1.2	3.2	2.9	0.9
2	11.3	7.6	1.7	0.0	0.6	0.1
3	8.0	5.3	1.9	-0.1	0.6	0.1
4	8.5	6.2	2.1	-1.0	-0.4	-0.2
5	6.2	3.9	1.8	1.4	1.8	0.0
6	5.8	4.3	1.5	-1.7	-0.8	-0.3
7	2.1	1.5	0.5	0.7	0.3	0.0

Seasonal chemical composition of the herbage: The chemical composition data for the herbage removed by motor scythe over the season are shown in Table 60.

Organic matter contents were close to normal (89-91%) early in the season in all the treatments but later fell to lower levels particularly at the end of the season.

Digestibility levels were highest in June under monthly defoliation but in April under variable frequency defoliation. Apart from this, little consistent effect of treatment was evident.

From their lowest levels around 14-15% at the start of the season, crude protein contents increased throughout the season to levels around 24-26% by the final defoliations in October in all the treatments.

Table 60 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defoliation No.	Organic matter	Digestibility	Crude protein	Organic matter	Digestibility	Crude protein
		CML			CMH	
1	89.8	70.0	15.5	90.1	70.9	18.2
2	90.5	76.3	13.8	90.6	77.9	14.9
3	87.7	69.2	16.1	89.7	69.6	16.1
4	88.2	74.4	26.8	87.6	76.4	26.0
5	79.0	67.8	26.1	86.8	72.7	23.6
6	83.9	73.0	21.2	75.3	72.3	21.4
		CVL			CVH	
1	88.1	80.4	24.6	90.3	81.3	22.3
2	90.3	70.3	14.7	90.4	67.5	15.0
3	90.6	65.4	11.7	91.5	65.6	11.7
4	88.7	75.0	23.8	89.0	73.6	24.8
5	85.0	73.7	22.7	67.7	63.7	29.6
6	72.1	68.4	22.1	87.3	74.0	25.1
7				72.7	70.0	22.8

Chemical composition of the soil

The chemical composition of the soil before and after the application of the cutting and grazing treatments is shown in Table 61. According to Whittles (1952), the acidity has not changed from a classification of 'moderate' or the available phosphate from 'medium' but whereas under cutting the available potash has not changed from 'medium', it has risen from 'medium' to 'satisfactory' under grazing.

Table 61 Chemical composition of the soil before and after the application of cutting and grazing treatments

Date	Treatment	pH	mg/100 g soil Available P_2O_5	Available K_2O
9.2.61	Nil	5.89	5	7
3.2.62	Cutting	5.82	7	7
	Grazing	5.91	8	13

EXPERIMENT 6 (S.23/N_{104} SWARD)

Results (1961)

Dates of defoliation

As Table 62 shows, there were the usual six defoliations at calendar-monthly intervals with monthly frequency treatments. With variable frequency treatments, the herbage reached the required 8 in. height six times under cutting (CVL and CVH) but nine and seven times respectively for the grazing treatments GVL and GVH. Intervals between defoliations were thus shorter under grazing, particularly in GVL after July.

Table 62 Number and dates of defoliations

Treatment	Defoliations 1	2	3	4	5	6	7	8	9
(CML, GML) CMH, GMH)	9/5	9/6	8/7	9/8	8/9	10/10			
CVL	29/4	8/6	10/7	5/8	11/9	19/10			
GVL	1/5	24/5	23/6	24/7	9/8	22/8	13/9	7/10	20/10
CVH	1/5	8/6	6/7	4/8	8/9	12/10			
GVH	1/5	24/5	23/6	24/7	11/8	13/9	10/10		

Annual herbage yields

Neither the method nor intensity of defoliation affected the yields of organic matter significantly (Table 63) although there were slight increases from grazing compared with cutting, monthly defoliation compared with variable frequency and low severity compared with high severity defoliation.

Grazing gave increases over cutting of 520 lb/ac digestible organic matter ($P<0.05$). Crude protein yields were affected similarly with an increase from grazing over cutting of 130 lb/ac.

Table 63 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter C	Organic matter G	Organic matter Means	Digestible organic matter C	Digestible organic matter G	Digestible organic matter Means	Crude protein C	Crude protein G	Crude protein Means
Intensity									
ML	66.9	68.8	67.8	49.7	52.1	50.9	13.5	13.8	13.6
MH	64.7	70.0	67.4	47.2	52.7	49.9	12.7	14.6	13.7
VL	64.2	68.4	66.3	49.5	54.8	52.1	13.0	15.1	14.0
VH	59.0	64.4	61.7	45.0	52.4	48.7	12.5	13.4	13.0
Means	63.7	67.9		47.8	53.0		12.9	14.2	

Significant effects:

	Organic matter	Digestible organic matter	Crude protein
Method	NS	*	*
Intensity	NS	NS	NS
Method x intensity	NS	NS	NS
Frequency	NS	NS	NS
Severity	NS	NS	NS
Frequency x severity	NS	NS	NS
C.V. (%)	10.5	10.1	11.8

Differences between:	$S_{\bar{d}}$	L.S.D.	$S_{\bar{d}}$	L.S.D.	$S_{\bar{d}}$	L.S.D.
Method means	1.74	-	1.46	4.65	0.35	1.11
Intensity means	3.46	-	2.55	-	0.81	-
Intensity means within a method	4.89	-	3.60	-	1.14	-
Method means within an intensity	4.58	-	3.44	-	1.05	-
Frequency/severity means	2.45	-	1.80	-	0.57	-

Mean annual botanical composition of the herbage

Defoliation method had considerable effect on the composition with mean values of 71.9% perennial ryegrass under cutting and 91.1% under grazing (Table 64). White clover made up the bulk of the remaining herbage and was thus more plentiful under cutting. In comparison, the intensity of defoliation had relatively little effect on the composition. Unsown species, mainly annual meadow and bent grasses, formed only a tiny fraction of the herbage and were unaffected.

Table 64 Weighted mean annual percentage botanical composition of the available herbage

Method	Perennial ryegrass			White clover			Unsown species		
	C	G	Means	C	G	Means	C	G	Means
intensity									
ML	68.7	90.9	79.8	30.2	7.5	18.8	1.1	1.7	1.4
MH	74.7	88.4	81.6	23.2	9.9	16.5	2.1	1.7	1.9
VL	74.6	94.3	84.5	23.8	4.3	14.1	1.6	1.4	1.5
VH	69.4	90.8	80.1	28.7	7.6	18.1	2.0	1.6	1.8
Means	71.9	91.1		26.5	7.3		1.7	1.6	

Mean annual chemical composition of the herbage

Neither the method nor intensity of defoliation had a marked effect on the composition of available herbage, apart from a slight increase in mean contents of organic matter and crude protein with grazing in comparison with cutting (Table 65). Differences in the composition of residual herbage as a result of treatment were confined to organic matter and crude protein levels. Organic matter contents were higher under monthly than under variable frequency defoliation and under high severity compared with low severity defoliation. Crude protein values were distinctly higher under grazing than under cutting.

Values for the three chemical attributes were consistently lower in residual herbage. These differences represent the differences between the leafy regrowth of available herbage and the stubble and dead leaf bases of residual herbage. However, since sampling is to ground level, stubble and dead leaf bases left after a defoliation treatment can be present in the sample of the regrowth taken at a later date. Vice versa, there may be a proportion of leafage in the residual herbage, since such leafage can be present below the height of defoliation on account of the prostrate habit of growth of S.23 ryegrass. In defoliation by grazing, any leafage in residual herbage is more likely to be that fouled by excreta or trampled and so uneaten rather than leafage below the prescribed defoliation height since sheep can graze leafage down to virtually ground level. The organic matter contents obtained are indicative of a fair degree of soil contamination, particularly in the residual herbage.

Table 65 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter			Digestibility			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
				Available herbage					
ML	78.4	84.2	81.3	71.0	70.9	71.0	17.8	19.8	18.8
MH	85.2	83.9	84.5	70.0	71.3	70.6	16.1	19.0	17.5
VL	81.0	83.5	82.2	72.2	72.2	72.2	17.4	21.5	19.5
VH	80.3	84.4	82.3	71.5	73.1	72.3	17.3	18.6	17.9
Means	81.2	84.0		71.2	71.9		17.1	19.7	
				Residual herbage					
ML	71.2	79.6	75.4	65.4	64.8	65.1	13.6	19.7	16.6
MH	83.6	80.1	81.8	66.6	65.4	66.0	12.1	16.1	14.1
VL	75.6	73.4	74.5	65.2	65.6	65.4	13.4	21.1	17.2
VH	76.0	76.1	76.0	66.8	65.0	65.9	13.5	16.3	14.9
Means	76.6	77.3		66.0	65.2		13.2	18.3	

Seasonal distribution of herbage yields

The distribution of available and residual herbage yields over the season is tabulated in Appendix 9, while the utilized yields derived from them by calculation are presented below in Table 66.

Organic matter and digestible organic matter yields showed a similar pattern of distribution and yields varied more widely under cutting than under grazing. Treatment CVL showed exceptional variation because of high yield at the second defoliation. Top yields were always obtained at the first defoliation with monthly cutting and at the second with variable frequency cutting, while the lowest yields were always at the final cutting in October. With grazing, the times when these values occurred were not so clear-cut, but top yields were still obtained in early season and lowest in late season. On account of larger yields in early season and smaller yields in late season, the seasonal range of yield was greater with variable frequency than monthly frequency defoliation.

Table 66 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defoliation No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			GML	
1	16.8	12.9	3.5	16.6	13.8	3.1
2	14.9	11.6	2.2	14.4	11.3	2.7
3	11.2	7.6	2.0	12.4	8.9	2.1
4	11.2	8.4	3.0	10.3	7.3	2.3
5	6.9	5.0	1.7	7.8	5.8	2.0
6	5.9	4.2	1.2	7.2	5.0	1.6
		CMH			GMH	
1	18.6	14.3	3.5	13.6	11.2	2.8
2	16.3	12.4	2.5	13.7	10.7	2.5
3	8.0	5.0	1.7	12.2	8.4	2.2
4	8.5	6.1	2.1	14.9	10.6	3.2
5	8.2	5.9	2.0	7.9	6.3	2.1
6	5.2	3.5	1.0	7.8	5.5	1.9
		CVL			GVL	
1	8.6	7.1	2.4	5.1	4.5	1.0
2	24.4	19.2	3.4	13.3	11.1	2.6
3	8.5	6.3	1.6	15.6	12.7	2.8
4	7.5	6.0	2.2	8.0	6.6	1.5
5	12.7	9.0	2.8	4.2	3.2	1.2
6	2.5	1.9	0.6	8.6	6.3	2.2
7				5.6	4.3	1.6
8				4.6	3.5	1.3
9				3.6	2.7	1.0
		CVH			GVH	
1	9.7	8.2	2.6	5.4	4.7	1.4
2	17.0	13.5	2.8	14.8	12.7	2.5
3	11.1	8.0	1.6	13.4	11.3	2.1
4	8.5	6.0	2.5	8.2	6.8	1.6
5	9.6	7.0	2.2	8.1	6.0	2.1
6	3.2	2.3	0.9	6.8	5.2	1.6
7				7.8	5.8	2.2

For similar reasons, the range was also generally wider with low severity defoliation than high defoliation. Crude protein yields in all the treatments varied in much the same manner as organic matter yields.

Accumulative herbage yields

Figure 22 illustrates the way in which organic matter, digestible organic matter and crude protein yields accumulated over the season. The effect of defoliation method was not marked under any of the intensity treatments but there was a slight divergence of the yields under cutting and grazing towards the end of the season, with a marginal final yield advantage to the grazing treatments.

Seasonal botanical composition of the herbage

Apart from extremely small quantities of unsown species, mainly annual meadow and bent grasses, the herbage was made up of sown ryegrass and clover. Neither the frequency nor severity of defoliation affected the botanical composition to any extent but the method of defoliation exerted consistent and clear-cut effects (Table 67; Figure 23). Ryegrass proportions under cutting treatment were high in early and late season but low in midseason and these fluctuations in ryegrass contents were matched by complementary fluctuations in clover contents. Thus clover made up 14-24% in May, 44-55% in July and 12-18% in October. Under grazing, ryegrass and clover fractions started off at similar levels to those under cutting but thereafter, ryegrass steadily increased to peak values of 96-98% at the end of the season, whereas clover correspondingly decreased to negligible proportions.

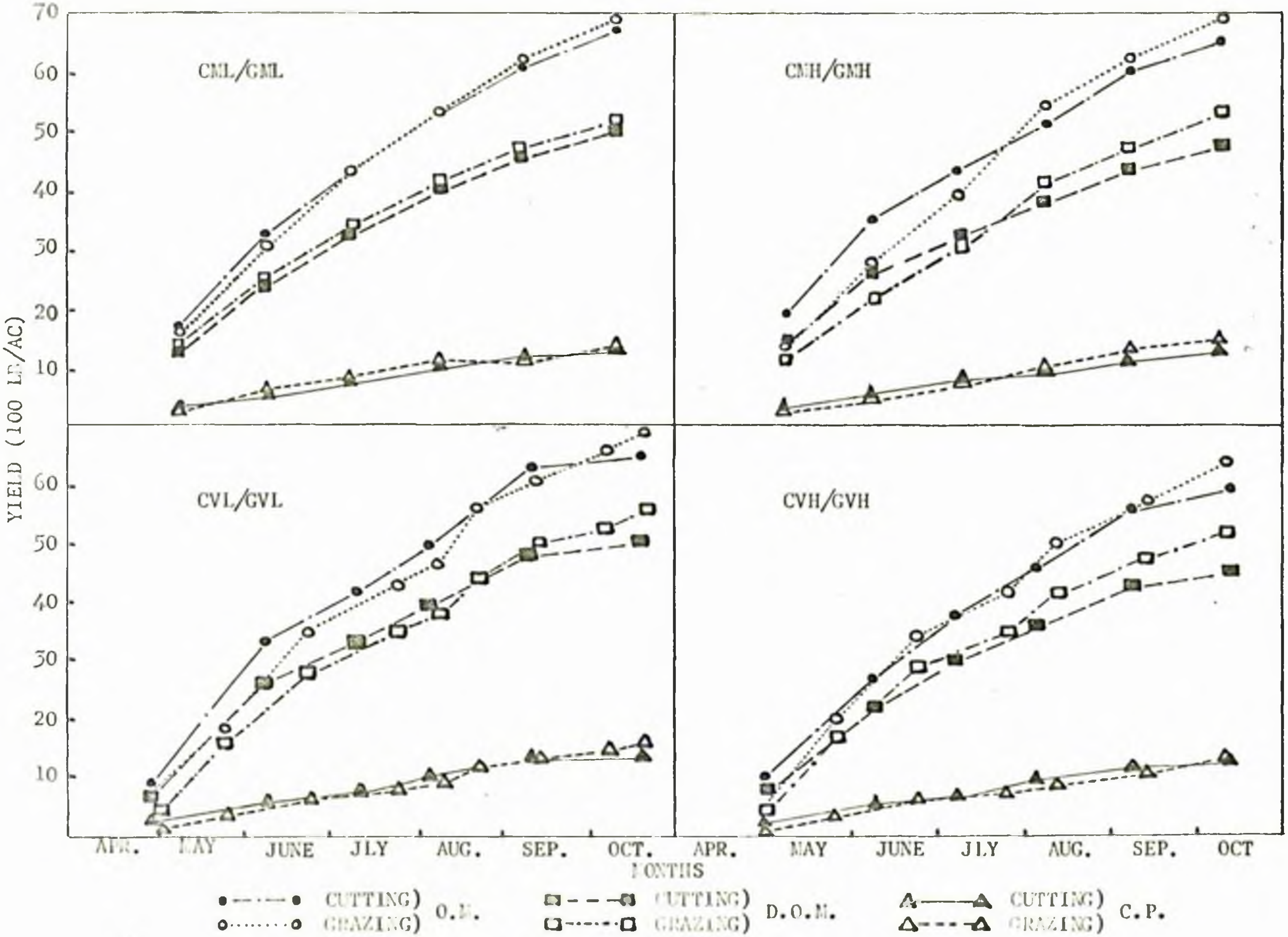


Figure 22 Accumulative utilized herbage yields for each treatment

Table 67 Seasonal percentage botanical composition of the available herbage for each treatment

Defoliation No.	Cutting: Perennial ryegrass	Cutting: White clover	Cutting: Unsown species	Grazing: Perennial ryegrass	Grazing: White clover	Grazing: Unsown species
		CML			GML	
1	75.0	23.8	1.3	83.0	13.6	3.4
2	65.5	32.4	2.1	85.5	11.5	3.0
3	44.5	54.8	0.7	93.1	5.4	1.5
4	69.9	29.6	0.1	93.8	5.4	0.8
5	74.0	25.1	0.9	95.9	3.7	0.5
6	80.8	18.3	0.9	96.9	2.6	0.6
		CMH			GMH	
1	81.8	14.6	3.8	81.0	16.4	2.6
2	71.5	26.1	2.4	82.7	15.5	1.8
3	48.7	49.2	2.2	88.8	6.9	2.1
4	81.8	16.8	1.5	90.9	8.7	0.4
5	72.4	26.3	1.3	92.4	7.2	0.4
6	85.8	13.3	0.9	96.1	3.2	0.7
		CVL			GVL	
1	82.4	14.0	3.7	83.8	11.0	5.2
2	75.3	22.4	2.3	90.1	8.8	1.2
3	48.5	50.8	0.8	94.1	3.8	2.2
4	79.9	19.0	1.0	95.4	3.9	0.7
5	74.7	24.8	1.2	97.8	1.7	0.5
6	86.9	12.4	1.4	97.6	1.9	0.5
7				97.7	2.0	0.3
8				98.0	1.4	0.6
9				98.3	1.2	0.5
		CVH			GVH	
1	76.5	20.9	2.6	79.5	13.1	7.5
2	56.3	41.3	2.5	90.3	9.3	0.4
3	54.2	44.1	1.7	92.8	5.6	1.7
4	72.3	27.1	0.7	91.2	8.6	0.2
5	83.7	14.2	2.1	93.3	6.4	0.3
6	80.9	16.2	3.0	95.2	4.4	0.4
7				96.4	3.4	0.3

Seasonal chemical composition of the herbage

Table 68 and Figure 24 show the seasonal chemical composition of available and residual herbages.

Available herbage: Organic matter values early in the season showed only slight signs of soil contamination assuming that soil-free values would be around 88-91%. However, as the season progressed, values generally but

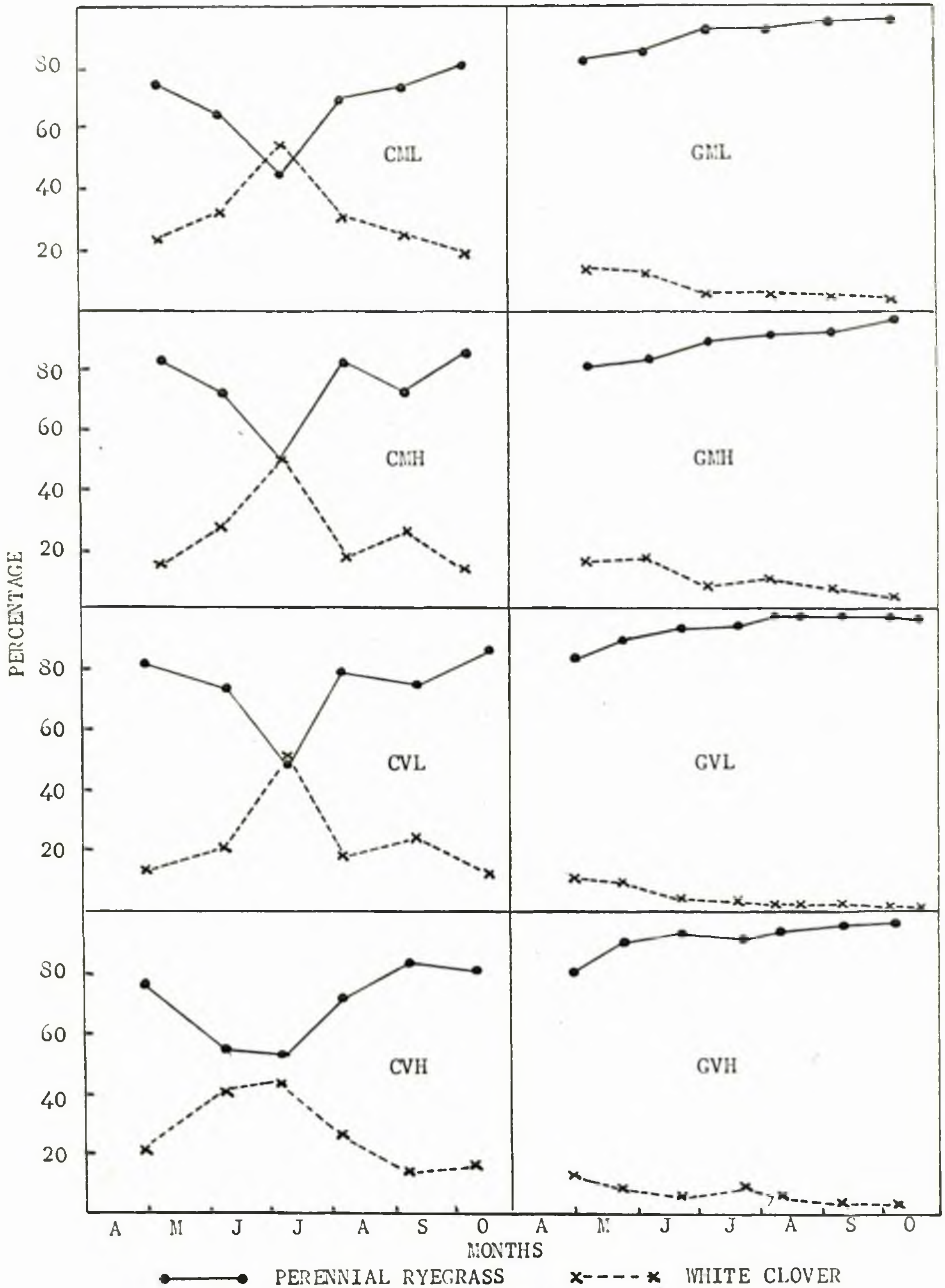


Figure 23 Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

irregularly became lower, indicating an increasing degree of contamination. This trend was evident in all the treatments and little consistent effect could be ascribed to either the method or intensity of defoliation. As indicated before, weather conditions and the cumulative effect on the soil surface of applying the treatments would be a major cause of variation in organic matter content.

Digestibility values were also little affected by method or intensity of defoliation. In all the treatments, the highest values of 76-80% were recorded at the first defoliations and the lowest generally in midseason. Levels at the first defoliations in the GML and GMH treatments were surprisingly similar to those in the GVL and GVH treatments although the former were sampled eight days earlier. Monthly cutting treatments on the other hand had slightly lower values than variable frequency cutting treatments.

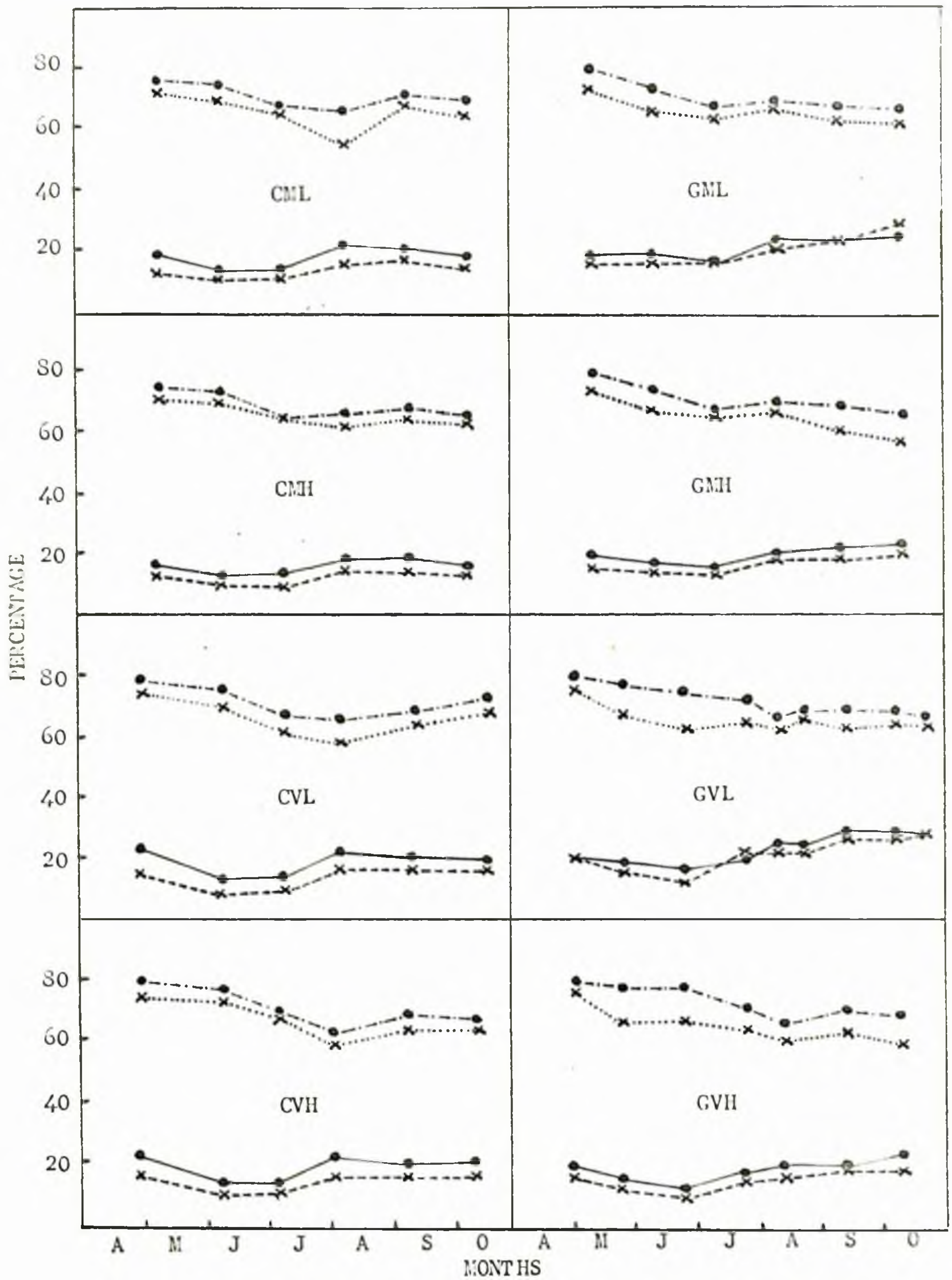
With crude protein, some effect of defoliation method but not of defoliation intensity was discernible. Both top and bottom values were smaller with cutting in comparison with grazing but the ranges between the values were similar. Under cutting, values dropped after the first defoliation, rose to peaks in August and then tailed off slightly until the final defoliation in October. Under grazing, the values behaved similarly to those under cutting at the beginning of the season but after reaching the lowest points, usually in July, rose gradually to peak values at the end of the season.

Residual herbage: Early-season levels of organic matter were similar for both cutting and grazing with the highest values occurring more often in July than any other time. Values then fell gradually though not consistently until the end of the season. A greater fall was recorded under grazing and the values in October were as low as 54-59%, indicating considerable soil contamination. Apart from these effects treatment caused little change in the organic matter contents.

Table 68 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage: Cutting O.M.	Dig.	C.P.	Available herbage: Grazing O.M.	Dig.	C.P.	Residual herbage: Cutting O.M.	Dig.	C.P.	Residual herbage: Grazing O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	87.4	75.8	19.2	86.5	80.3	18.0	85.8	72.5	13.0	84.4	73.0	15.9
2	83.5	74.7	13.4	86.1	73.2	17.8	80.5	68.9	10.7	83.4	65.3	16.0
3	83.3	67.5	14.7	84.7	67.3	16.4	88.7	66.2	10.5	85.4	62.7	15.7
4	65.4	66.6	22.0	82.4	68.9	21.6	51.2	55.1	15.6	82.7	67.2	21.0
5	77.1	70.9	21.1	83.5	66.6	23.4	75.3	68.5	17.5	77.5	61.9	22.6
6	76.7	68.6	17.8	80.1	66.4	24.2	64.9	65.3	15.4	59.5	60.7	27.6
		CMH			GMH			CMH			GMH	
1	86.7	75.5	17.0	88.6	80.4	18.7	85.1	71.9	13.1	84.3	74.3	14.5
2	83.1	73.8	12.7	87.6	73.9	16.5	84.9	70.7	9.7	84.5	67.4	13.9
3	87.0	64.2	13.7	85.1	67.0	15.6	88.4	65.3	9.1	88.8	64.5	12.5
4	85.5	66.6	19.4	79.4	69.5	20.3	78.2	61.7	15.2	84.4	66.9	18.6
5	83.6	68.5	19.0	82.9	68.7	22.2	85.7	64.9	13.8	77.0	60.6	18.3
6	81.7	65.8	16.3	78.6	66.4	23.1	76.7	63.9	14.4	58.4	57.2	19.6
		CVL			GVL			CVL			GVL	
1	86.0	79.3	22.8	83.5	79.8	20.1	77.5	75.4	16.3	79.2	75.6	20.0
2	82.7	76.4	12.6	84.8	76.6	18.0	83.2	70.3	9.0	82.1	67.0	15.1
3	80.2	67.1	14.0	89.0	75.0	15.9	84.1	62.0	9.8	81.8	62.6	12.1
4	74.5	67.3	22.3	87.5	71.4	20.0	64.8	57.7	17.0	81.3	64.5	20.8
5	81.9	69.0	20.1	82.6	66.0	23.6	73.1	64.5	15.7	80.2	62.4	22.3
6	85.2	72.5	18.9	82.9	69.4	23.9	75.8	68.2	16.0	77.8	65.2	22.2
7				82.5	68.8	28.1				58.8	62.3	27.4
8				80.8	69.1	27.7				57.2	63.8	27.2
9				68.7	67.4	26.6				54.9	63.4	26.5
		CVH			GVH			CVH			GVH	
1	84.8	80.3	22.2	79.8	79.3	19.7	73.0	74.8	16.5	82.4	75.8	16.8
2	85.4	76.6	13.4	86.7	77.0	16.0	81.6	72.8	9.7	80.6	64.5	13.8
3	87.2	70.2	12.4	89.3	76.7	13.6	88.1	68.7	11.0	85.0	66.8	11.1
4	75.9	62.9	21.8	87.8	70.4	18.1	70.1	57.6	16.2	79.4	63.1	17.2
5	78.6	68.4	19.9	84.2	66.1	21.5	75.2	62.7	16.0	76.6	58.9	17.9
6	62.1	66.6	19.5	81.9	69.7	22.2	64.1	63.7	15.5	65.8	62.0	21.0
7				75.1	68.1	24.8				54.2	57.9	19.5

Defoliation method but not intensity had some effect on the digestibility values. In all the treatments, top levels occurred always at the first defoliations and only ranged from 72-76%. There was a greater difference between the treatments as regards the lowest levels. These ranged from 55-62% and occurred in August under cutting but generally at final defoliations under



●—·—● % Dig.) AVAILABLE   ×·······× % Dig.) RESIDUAL
●———● % C.P.) HERBAGE   ×-----× % C.P.) HERBAGE

Figure 24   Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

grazing. Thus, whereas there was a gradual lowering of values over the season with grazing, values under cutting decreased until August and rose slightly afterwards.

The effect of treatment on crude protein contents was limited to the method of defoliation. Bottom values were lower and peak values higher under grazing in comparison with cutting so that seasonal variation was greatest with the former. Under cutting, values fell after the second or third defoliations to their lowest points and then rose sharply to peaks usually in August before dropping slightly again. With grazing, values were lowest in July and then rose gradually towards the end of the season.

Comparison of available and residual herbage: Organic matter contents of available herbage were generally greater than those in residual herbage and although they fell in both types of herbage as the season progressed, the fall was greatest with residual herbage, particularly under the grazing treatments. Digestibility and crude protein values were generally higher in the available herbage, but apart from this, the seasonal variation for each attribute was the same in both herbages.

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: The annual yields of herbage removed by the motor scythe sampling method in the four cutting treatments are shown in Table 69 along with the differences in yield between this method and the shearhead method.

Among the organic matter yields, monthly defoliation resulted in significantly higher yields than variable frequency defoliation. The two sampling methods have thus given different results when treatments are compared, with the motor scythe having given a relatively lower estimate than the shearhead when defoliated monthly in comparison with defoliation at variable frequencies.

However, higher estimates were usually associated with the shearhead method and this consistency effect was significant (P<0.05). The consistency effect was also significant for digestible organic matter but not crude protein yields, but for both these yield attributes, there were no significant treatment effects. Thus, both the digestible organic matter and crude protein yield relationship between the treatments was similar under both sampling methods.

Table 69 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	60.1	45.2	13.0	6.7	4.5	0.5
MH	57.2	43.0	11.9	7.6	4.2	0.8
VL	66.2	50.7	12.9	-2.0	-1.3	0.0
VH	55.9	42.6	12.1	3.2	2.4	0.4
Significant effects:						
Intensity				NS	NS	NS
Frequency				*	NS	NS
Severity				NS	NS	NS
Frequency x severity				NS	NS	NS
Consistency				*	*	NS
C.V. (%)				135.9	156.0	325.0
Differences between:				Sd̄(L.S.D.)	Sd̄	Sd̄
Intensity means				3.71	2.77	0.95
Frequency/severity means				2.63(5.95)	1.97	0.67
Frequency means within a severity and vice versa				3.71	2.77	0.95

Mean annual chemical composition of the herbage: Table 70 shows the weighted mean annual chemical composition of the herbage cut and removed by the motor scythe in the cutting treatments.

There was no marked effect of treatment on the organic matter contents, but the contents were marginally greater under variable compared with monthly frequency defoliation and under high relative to low severity defoliation. With digestibility levels, a marginal advantage lay with variable frequency and low severity defoliation while the reverse held for crude protein contents.

Table 70 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digest-ibility	Crude protein
ML	87.4	75.2	21.7
MH	88.2	75.2	20.8
VL	88.3	76.7	19.5
VH	88.7	76.2	21.6

Seasonal distribution of herbage yields: Table 71 shows the distribution of herbage yields over the season as estimated by motor scythe and the relationship of these yields to those as measured by shearhead.

For organic matter yields, no one sampling method consistently outyielded the other but for digestible organic matter and crude protein yields, the shearhead estimate outyielded the motor scythe estimate at the majority of the defoliations. Over all the treatments, the amounts by which the estimates differed were from 10-390 lb/ac organic matter, 0-280 lb/ac digestible organic matter and 0-30 lb/ac crude protein.

Table 71/

Table 71 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
Defoliation No.	Organic matter	Digestible organic matter	Crude protein	Organic matter	Digestible organic matter	Crude protein
		CML			CML	
1	20.2	15.7	4.3	-3.4	-2.8	-0.8
2	11.2	8.8	2.0	3.7	2.8	0.2
3	7.4	5.3	1.4	3.8	2.3	0.6
4	12.0	8.8	3.1	-0.8	-0.4	-0.1
5	5.6	4.1	1.5	1.3	0.9	0.2
6	3.7	2.6	0.8	-2.2	1.6	0.4
		CMH			CMH	
1	16.8	13.3	3.5	1.8	1.0	0.0
2	12.4	9.7	2.0	3.9	2.7	0.5
3	6.3	4.4	1.1	1.7	0.6	0.6
4	9.7	7.0	2.5	-1.2	-0.9	-0.4
5	8.8	6.4	2.0	-0.6	-0.5	0.0
6	3.1	2.1	0.7	2.1	1.4	0.3
		CVL			CVL	
1	11.1	8.8	2.7	-2.5	-1.7	-0.3
2	24.5	19.7	3.1	-0.1	-0.5	0.3
3	7.0	5.0	1.3	1.5	1.3	0.3
4	8.2	6.0	2.3	-0.7	0.0	-0.1
5	12.1	8.8	2.8	0.6	0.2	0.0
6	3.2	2.4	0.7	-0.7	-0.5	-0.1
		CVH			CVH	
1	10.1	8.1	2.6	-0.4	0.1	0.0
2	17.3	13.7	2.7	-0.3	-0.2	0.1
3	7.6	5.4	1.4	3.5	2.6	0.2
4	10.2	7.5	2.7	-1.7	-1.5	-0.2
5	7.5	5.6	2.0	2.1	1.4	0.2
6	3.1	2.3	0.8	0.1	0.0	0.1

Seasonal chemical composition of the herbage: Table 72 shows the seasonal chemical composition data for the herbage removed by motor scythe.

As shown by the high organic matter contents, there was little soil contamination of the herbage in any of the treatments in the first half of the season, but later, varying degrees of contamination were evident as reflected in the lower organic matter contents. The contents were particularly low at the final defoliations in the CML and CMH treatments.

Digestibilities followed the same seasonal pattern in each treatment. The highest levels, ranging from 77-81%, were obtained at the first two defoliations usually in May and June while thereafter, levels were mainly in the 69-74% range.

Treatment had also little effect on the crude protein contents since in all the treatments, these contents were high at the first defoliations, dipped to their lowest levels at the second defoliations and then gradually increased until August or September before dipping again in October. The highest levels were around 25-28%.

Table 72 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defoliation No.	Organic matter	Digestibility	Crude protein	Organic matter	Digestibility	Crude protein
		CML			CMH	
1	89.3	77.3	21.1	89.4	79.4	21.1
2	89.8	79.3	17.5	90.1	78.4	16.2
3	90.2	71.0	18.7	90.0	69.7	17.1
4	86.0	72.7	25.8	87.4	71.8	25.4
5	84.3	73.4	26.5	87.6	72.7	23.1
6	76.4	70.0	22.3	77.5	68.6	23.7
		CVL			CVH	
1	88.7	79.1	24.8	88.6	79.9	25.9
2	90.7	80.8	12.7	90.4	79.2	15.7
3	89.8	71.2	18.1	89.5	72.2	17.9
4	86.3	72.5	27.7	88.7	73.2	26.3
5	85.6	73.0	22.9	87.9	73.7	26.1
6	82.7	74.0	23.0	80.7	74.3	24.1

Chemical composition of the soil

Table 73 shows the chemical composition of the soil before and after the application of the cutting and grazing treatments. By the classification of Whittles (1952), the acidity has remained 'moderate' while the available phosphate and potash have both remained at 'medium' levels, though the available potash almost attained a 'satisfactory' level under grazing, i.e. a level of 12 mg/100 g soil.

Table 73 Chemical composition of the soil before and after the application of cutting and grazing treatments

Date	Treatment	pH	mg/100 g soil Available P_2O_5	mg/100 g soil Available K_2O
9.2.61	Nil	5.89	5	7
3.2.62	Cutting	5.96	6	6
	Grazing	5.98	5	11

EXPERIMENT 6 (S.23/N$_{104}$ SWARD)

Results (1962)

Dates of defoliations

The number and dates of defoliations for the treatments during the season May to October (Table 74) show that herbage in the variable frequency grazing treatments (GVL, GVH) reached the required 8 in. height more often than in comparable cutting treatments (CVL, CVH). There were thus more defoliations at shorter intervals under grazing. In the cutting treatments, the defoliation intervals were usually in the region of six weeks.

Table 74 Number and dates of defoliations

Treatment:	Defoliations 1	2	3	4	5	6	7
CML, GML) CMH, GMH)	4/5	4/6	5/7	6/8	7/9	10/10	
CVL	11/5	20/6	8/8	19/9	31/10		
GVL	7/5	6/6	9/7	30/7	20/8	14/9	15/10
CVH	11/5	13/6	27/7	5/9	15/10		
GVH	7/5	7/6	11/7	4/8	28/8	8/10	

Annual herbage yields

Mean annual utilized herbage yields for the main treatments and their interactions are shown in Table 75.

Organic matter: Grazing gave an increase of 1760 lb/ac over cutting ($P<0.001$) while there was also considerable variation as a result of the intensity treatments ($P<0.001$). Monthly defoliation gave an increase of 980 lb/ac over variable frequency defoliation ($P<0.001$) and low defoliation an increase of 560 lb/ac over high defoliation ($P<0.01$). There was an interaction ($P<0.001$). The yields from monthly defoliation were appreciably greater than those from variable frequency defoliation under grazing but the corresponding differences were negligible under cutting. Also, yields from low defoliation were considerably greater than those from high except at variable frequency grazing where there was little difference.

Table 75 Annual utilized herbage yields (100 lb/ac)

Method	Organic matter			Digestible organic matter			Crude protein		
	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	60.3	87.0	73.6	47.9	68.5	58.2	11.3	18.2	14.7
MH	53.5	80.8	67.2	44.3	63.9	54.1	11.1	16.7	13.9
VL	60.8	65.1	62.9	47.4	52.8	50.1	10.6	13.3	11.9
VH	52.2	64.2	58.2	42.3	53.7	48.0	11.0	13.8	12.4
Means	56.7	74.3		45.5	59.7		11.0	15.5	

Significant effects:	Organic matter	Digestible organic matter	Crude protein
Method	***	***	***
Intensity	***	***	***
Method x intensity	***	***	**
Frequency	***	***	***
Severity	**	*	NS
Frequency x severity	NS	NS	NS
C.V. (%)	7.0	6.5	10.6

Differences between:	Sd	L.S.D.	Sd	L.S.D.	Sd	L.S.D.
Method means	0.77	2.45	0.93	2.96	0.27	0.86
Intensity means	2.31	4.85	1.71	3.59	0.52	1.09
Intensity means within a method	3.27	6.87	2.42	5.08	0.74	1.55
Method means within an intensity	2.94	6.41	2.29	5.22	0.71	1.58
Frequency/severity means	1.64	3.45	1.21	2.54	0.37	0.78

Digestible organic matter: The effects of the treatments on yield were the same as for the organic matter yields above and the statistical relationships were also identical except that the increased yield from low defoliation relative to high was significant at the 5% level in place of the 1% level.

Crude protein: The effects of the treatments were again similar to those described above with considerable variation due to method (P<0.001) and intensity (P<0.001). Monthly defoliation gave an increase of 210 lb/ac over variable frequency defoliation (P<0.001) but the severity of defoliation had little effect. There was again an interaction (P<0.001) mainly because while there was little difference between the cutting treatments, monthly grazing gave greater yields on average than variable frequency grazing.

Mean annual botanical composition of the herbage

The botanical composition was affected by the method but not by the intensity of defoliation (Table 76).

Table 76 Weighted mean annual percentage botanical composition of the available herbage

	Perennial ryegrass			White clover			Unsown species		
Method	C	G	Means	C	G	Means	C	G	Means
Intensity									
ML	82.0	97.9	89.9	17.1	1.8	9.5	1.0	0.3	0.6
MH	80.6	96.7	88.7	18.0	2.5	10.3	1.4	0.8	1.1
VL	85.6	98.6	92.1	13.7	0.8	7.2	0.8	0.6	0.7
VH	81.8	97.3	89.5	17.4	2.1	9.8	0.8	0.6	0.7
Means	82.5	97.6		16.6	1.8		1.0	0.6	

Under both cutting and grazing, perennial ryegrass made up the bulk of the herbage, but there was a mean difference of 15.1 percentage units in favour of grazing. White clover was almost absent under grazing but made up 16-18% under cutting treatment. Only minute quantities of unsown species, mainly annual meadow and bent grasses, were present.

Mean annual chemical composition of the herbage

In the available and residual herbages, neither the method nor intensity of defoliation had any marked effect upon organic matter or digestibility values (Table 77). Some effect of treatment was evident in the crude protein contents since these were slightly higher under grazing than under cutting in both types of herbages.

Consistently lower levels of the attributes were recorded in residual herbage. As in the previous year, the composition data reflect the lower feeding value of the residual herbage. Similarly, the organic matter contents show that soil contamination, whilst appreciable for both types of herbage, is higher in residual herbage.

Table 77 Weighted mean annual percentage chemical composition of the available and residual herbage

Method	Organic matter C	Organic matter G	Organic matter Means	Digestibility C	Digestibility G	Digestibility Means	Crude protein C	Crude protein G	Crude protein Means
Intensity									
				Available herbage					
ML	83.6	84.7	84.1	74.1	75.1	74.6	15.4	19.5	17.5
MH	83.2	83.7	83.4	72.1	75.3	73.7	15.2	18.7	16.9
VL	83.8	82.2	83.0	74.4	73.7	74.0	15.5	18.7	17.1
VH	84.9	85.1	85.0	73.1	75.5	74.3	16.0	17.6	16.8
Means	83.9	83.9		73.4	74.9		15.5	18.6	
				Residual herbage					
ML	79.7	76.4	78.0	68.4	68.1	68.2	11.8	17.0	14.4
MH	80.2	78.0	79.1	65.5	69.0	67.2	11.6	15.3	13.4
VL	76.5	77.3	76.9	68.1	67.0	67.6	12.1	17.1	14.6
VH	80.1	80.6	80.4	66.5	66.4	66.5	11.8	13.4	12.6
Means	79.1	78.1		67.1	67.6		11.8	15.7	

Seasonal distribution of herbage yields.

The seasonal distribution of utilized herbage yields (Table 78) was derived from available and residual herbage yields (Appendix 10). As before, the seasonality of digestible organic matter yields matched that of organic matter yields; crude protein yields showed a similar pattern but varied within narrower limits. Considerable range in yields was evident with the cutting treatments, which usually had peak yields at the second defoliation and extremely low final yields in October. This pattern was repeated under grazing but since late-season yields did not dip to such low levels, the range between top and bottom yields was less. Apart from peak yields in early season which were slightly greater with monthly than with variable frequency defoliation, frequency treatments did not affect the seasonality of yield unduly. There was also little effect due to severity of defoliation.

Table 78 Seasonal distribution of utilized herbage yields for each treatment (100 lb/ac)

Defolia-tion No.	Cutting O.M.	Cutting D.O.M.	Cutting C.P.	Grazing O.M.	Grazing D.O.M.	Grazing C.P.
		CML			GML	
1	11.7	8.8	2.7	11.1	9.6	1.9
2	20.3	17.2	2.7	22.5	18.7	3.9
3	8.5	6.6	1.5	17.4	12.8	3.1
4	7.6	5.9	1.9	10.7	7.6	2.6
5	9.0	6.9	1.8	15.8	12.4	4.2
6	3.2	2.4	0.7	9.6	7.4	2.6
		CMH			GMH	
1	4.7	3.6	1.5	9.2	8.6	1.9
2	20.0	17.5	3.2	19.1	15.8	3.0
3	9.1	7.3	1.7	17.0	12.6	3.3
4	6.9	5.8	2.0	12.1	8.6	2.7
5	8.6	6.8	1.8	14.7	11.7	3.7
6	4.3	3.4	1.0	8.7	6.6	2.1
		CVL			GVL	
1	14.7	11.9	3.0	12.4	10.8	2.2
2	19.3	15.2	2.4	16.4	13.8	3.0
3	16.4	12.2	3.3	10.8	8.8	1.6
4	8.5	6.5	1.4	6.6	5.4	1.5
5	2.0	1.7	0.5	8.0	6.0	1.9
6				5.2	4.0	1.3
7				5.7	4.1	1.6
		CVH			GVH	
1	16.5	13.5	3.8	14.7	12.8	3.0
2	15.9	13.3	2.5	14.8	13.3	2.9
3	10.3	7.3	2.4	16.3	12.5	2.6
4	6.3	5.7	1.5	5.1	4.2	1.8
5	3.2	2.5	0.9	6.0	5.2	1.7
6				7.5	5.8	1.9

Accumulative herbage yields

Figure 25 shows the accumulation of utilized herbage yields under cutting and grazing over the season. Under all the intensity treatments except VL, yields of organic matter, digestible organic matter and crude

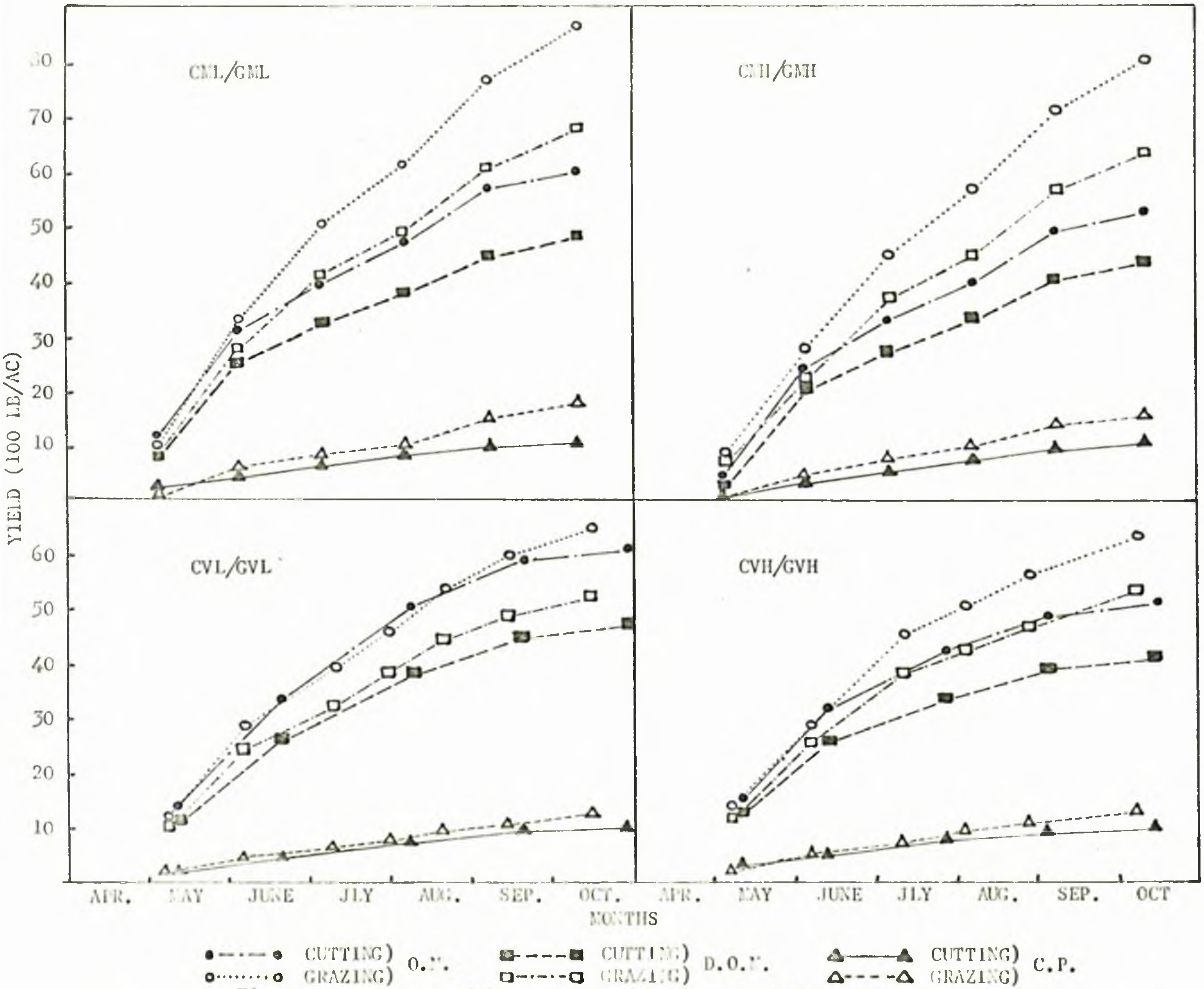


Figure 25 Accumulative utilized herbage yields for each treatment

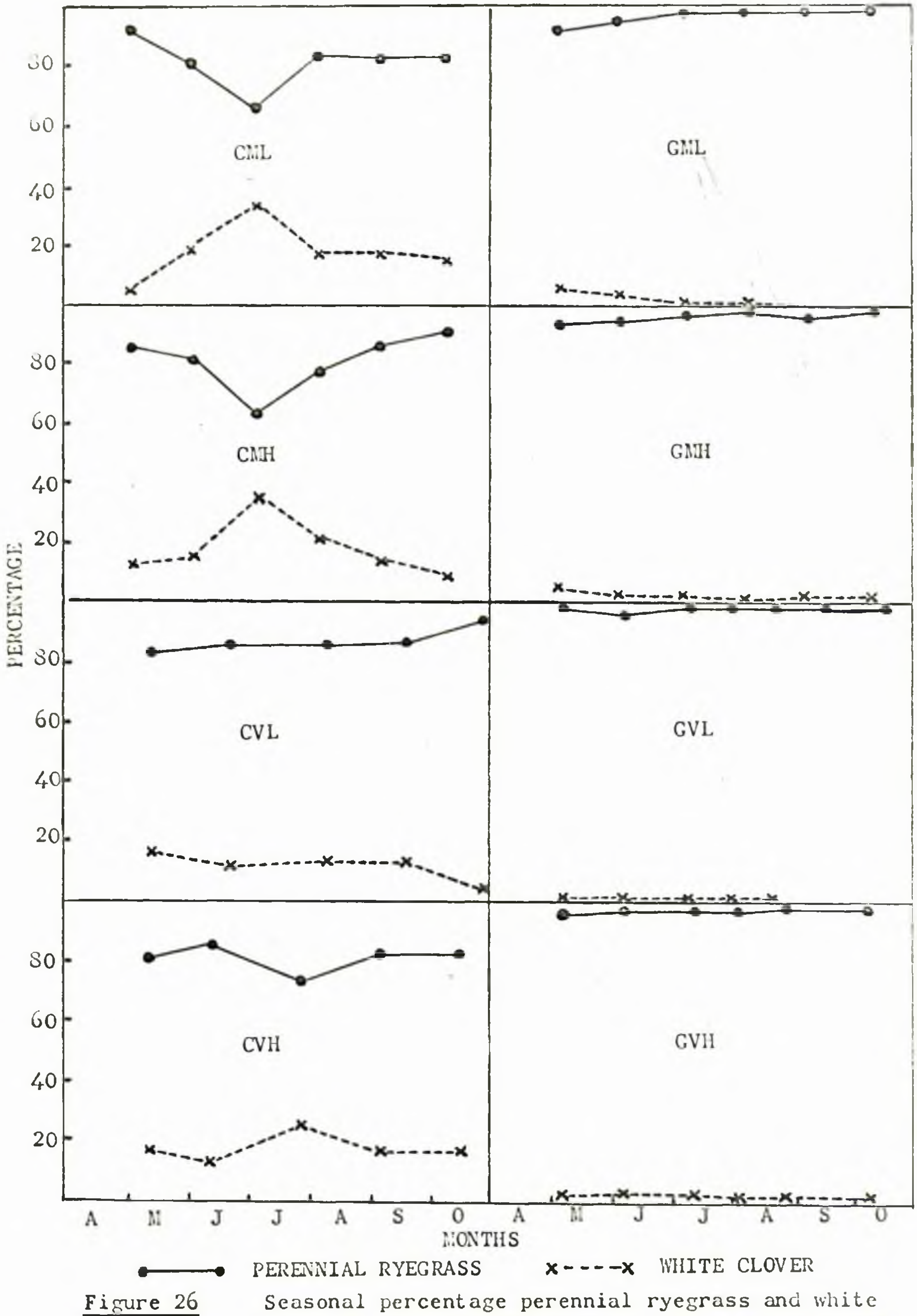
protein soon outstripped those under cutting until by the end of the season, considerable differences had emerged. With the VL treatment, yield superiority under grazing was slower to develop and the final differences were relatively small.

Seasonal botanical composition of the herbage

Some effect of method and of frequency of defoliation was evident (Table 79, Figure 26).

Table 79 Seasonal percentage botanical composition of the available herbage for each treatment

Defoliation No.	Cutting: Perennial ryegrass	Cutting: White clover	Cutting: Unsown species	Grazing: Perennial ryegrass	Grazing: White clover	Grazing: Unsown species
		CML			CML	
1	92.0	5.7	2.3	93.1	6.2	0.7
2	81.1	18.6	0.3	95.6	3.6	0.8
3	65.6	34.1	0.3	98.6	1.2	0.2
4	82.8	16.5	0.7	99.5	0.5	-
5	82.4	17.1	0.5	99.9	0.1	-
6	83.2	15.0	1.9	100.0	-	-
		CMH			CMH	
1	86.1	12.9	1.0	93.5	5.3	1.2
2	81.6	16.3	2.1	95.1	3.3	1.6
3	62.5	35.1	2.4	96.9	2.5	0.6
4	78.3	20.9	0.8	99.7	0.3	-
5	85.7	13.5	0.8	96.3	2.7	1.0
6	89.9	9.2	0.9	98.5	1.5	-
		CVL			CVL	
1	83.0	16.5	0.5	99.3	0.5	0.2
2	85.5	12.4	2.1	96.2	1.0	2.8
3	85.5	14.2	0.3	98.8	1.0	0.2
4	87.3	12.5	0.2	98.7	1.3	-
5	94.6	5.2	0.2	98.8	1.0	0.2
6				99.7	0.2	0.1
7				100.0	-	-
		CVH			CVH	
1	82.2	17.4	0.5	95.9	2.4	1.7
2	85.6	13.4	1.1	97.5	2.5	-
3	74.3	25.1	0.7	97.3	2.5	0.2
4	82.7	16.1	1.3	97.4	1.4	1.2
5	83.4	16.0	0.6	98.2	1.6	0.2
6				97.8	2.2	-



<u>Figure 26</u> Seasonal percentage perennial ryegrass and white clover of the available herbage for each treatment

With cutting, ryegrass made up over 80% of the herbage in May, then generally decreased in midseason before rising again to 85-95% in late season. Since unsown species made up negligible proportions, the remainder of the herbage at these periods was clover. Thus, at its most abundant in July, clover made up 25-35%. With grazing, over 90% of the herbage in early season consisted of ryegrass and this proportion increased steadily until finally in October, the figure was between 98-100% in all the grazing treatments. Clover was therefore very sparse. The frequency effect under cutting was confined to midseason where ryegrass proportions dipped and clover increased to a greater extent with monthly than with variable frequency defoliation; under grazing, slightly lower ryegrass proportions and greater clover proportions were evident at the start of the season with monthly defoliation.

Seasonal chemical composition of the herbage

The seasonal chemical composition of the available and residual herbage is presented in Table 30 and Figure 27.

Available herbage: Organic matter contents varied over the season but not in a regular manner which could be ascribed to treatment. In all the treatments, levels were highest at the second defoliations when they showed little sign of soil contamination. At most of the other defoliations, the levels indicated varying degrees of contamination. This was usually greatest in the second half of the season.

Treatment had also apparently little effect on digestibility values, since these followed the same pattern in each treatment. Levels were highest at the beginning of the season and lowest in midseason, after which they rose slightly towards the end of the season.

Crude protein values were affected by defoliation method but not by intensity (Figure 27). Under cutting, the contents were highest in May, lowest at second defoliations and generally rose slightly towards the end of the season. Top values were from 19-21% and bottom values, 11-21%. In comparison, under grazing, top values were from 24-26% and bottom values 13-15%; the lowest values occurred at the same time, but the top values at the opposite end of the season.

Residual herbage: At practically every defoliation, some degree of soil contamination occurred as indicated by the organic matter contents (Table 80), which became lower as the season progressed, although the falls were not regular. The falls were greater under grazing than under cutting. Little effect was discernible as a result of the defoliation intensity treatments.

In all the treatments, the seasonal variation of the digestibility values followed a similar pattern, so that neither method nor intensity of defoliation appeared to have had much effect. Values were generally highest in early season, lowest in midseason and somewhere in between at the end.

With crude protein contents, the seasonal pattern varied according to the method but not intensity of defoliation. Under cutting, the highest levels, around 16-17%, were obtained at the first defoliations. These were immediately followed by the lowest levels. Thereafter, crude protein contents rose slightly. Under grazing, the highest values were always recorded in late season but the lowest were most frequently at second defoliations as in the cutting treatments. Due to high top values of around 21-25%, the range of seasonal variation was greatest under grazing.

Comparison of available and residual herbages: Values of the three chemical attributes reported were at higher levels in available herbage fairly consistently throughout the season. Organic matter contents decreased in an irregular fashion in both herbages as the season progressed, but the decrease was greatest in residual herbage particularly under grazing treatment. The pattern of seasonal variability of digestibility and crude protein values was similar for both herbages.

Table 80 Seasonal percentage chemical composition of the available and residual herbage for each treatment

Defoliation No.	Available herbage: Cutting O.M.	Dig.	C.P.	Available herbage: Grazing O.M.	Dig.	C.P.	Residual herbage: Cutting O.M.	Dig.	C.P.	Residual herbage: Grazing O.M.	Dig.	C.P.
		CML			GML			CML			GML	
1	80.8	76.1	19.9	86.4	80.3	18.2	80.9	76.8	16.4	74.6	74.1	18.9
2	89.8	80.6	11.9	88.0	77.7	15.0	83.2	72.7	9.1	84.3	68.4	11.1
3	86.4	69.7	12.5	85.5	70.0	16.3	85.2	63.8	9.1	87.0	58.4	12.7
4	79.5	69.3	18.6	77.3	70.2	23.8	72.0	61.8	12.6	80.8	68.4	25.6
5	80.1	70.9	15.6	84.6	75.0	25.4	73.6	64.5	10.7	59.6	65.2	22.5
6	81.0	70.6	16.7	83.4	75.0	25.9	81.3	68.0	13.6	68.0	65.9	22.9
		CMH			GMH			CMH			GMH	
1	75.7	75.5	20.7	84.0	82.0	18.8	79.1	75.5	17.5	72.5	74.0	17.8
2	88.8	78.9	12.6	87.6	78.1	13.4	84.3	69.4	8.9	85.3	71.8	10.1
3	86.1	67.8	12.1	83.7	70.7	17.4	81.6	62.2	9.1	85.9	59.3	10.3
4	82.0	67.6	18.2	80.0	69.3	21.5	75.0	58.9	12.3	80.7	66.3	20.1
5	78.8	67.8	14.9	82.3	75.1	23.3	78.2	58.[illegible]	9.9	72.6	64.1	18.7
6	84.6	69.3	16.1	82.3	73.3	23.7	82.9	63.9	12.5	66.1	65.3	21.2
		CVL			GVL			CVL			GVL	
1	81.1	77.2	19.2	84.1	80.4	17.7	74.8	70.3	17.1	78.3	73.4	17.5
2	87.4	76.5	11.0	85.1	76.9	15.4	81.1	71.7	8.4	83.1	69.2	12.1
3	85.5	71.0	17.5	89.0	72.1	13.2	74.6	63.0	11.1	84.4	63.5	11.4
4	82.2	72.6	14.3	83.6	68.2	19.8	81.4	68.0	10.9	82.2	60.6	18.0
5	77.6	71.2	17.9	76.2	70.9	23.8	69.9	65.7	13.9	67.6	68.3	23.6
6				76.3	70.2	25.0				64.8	65.1	24.7
7				73.0	70.5	26.2				74.9	67.6	21.7
		CVH			GVH			CVH			GVH	
1	83.5	77.1	19.8	84.4	79.6	18.1	73.3	71.3	16.0	77.3	70.1	15.4
2	87.3	76.8	11.7	87.1	78.4	13.5	85.6	70.9	8.3	83.6	67.6	7.6
3	87.3	65.9	16.4	86.7	72.0	13.6	88.0	62.6	11.8	86.1	64.4	10.1
4	84.4	71.8	15.9	83.5	69.0	23.8	74.0	61.2	11.2	77.5	61.0	17.0
5	77.1	68.4	18.2	82.0	74.7	22.8	77.5	63.9	14.0	74.7	61.4	17.7
6				83.3	75.3	22.9				83.6	72.5	20.9

Comparison of motor scythe and shearhead sampling methods

Annual herbage yields: Table 81 shows the motor scythe estimates of annual yield for the four cutting treatments and the relationship of these estimates to those from the shearhead sampling method. The results from the statistical examination of the differences between the two methods are also shown.

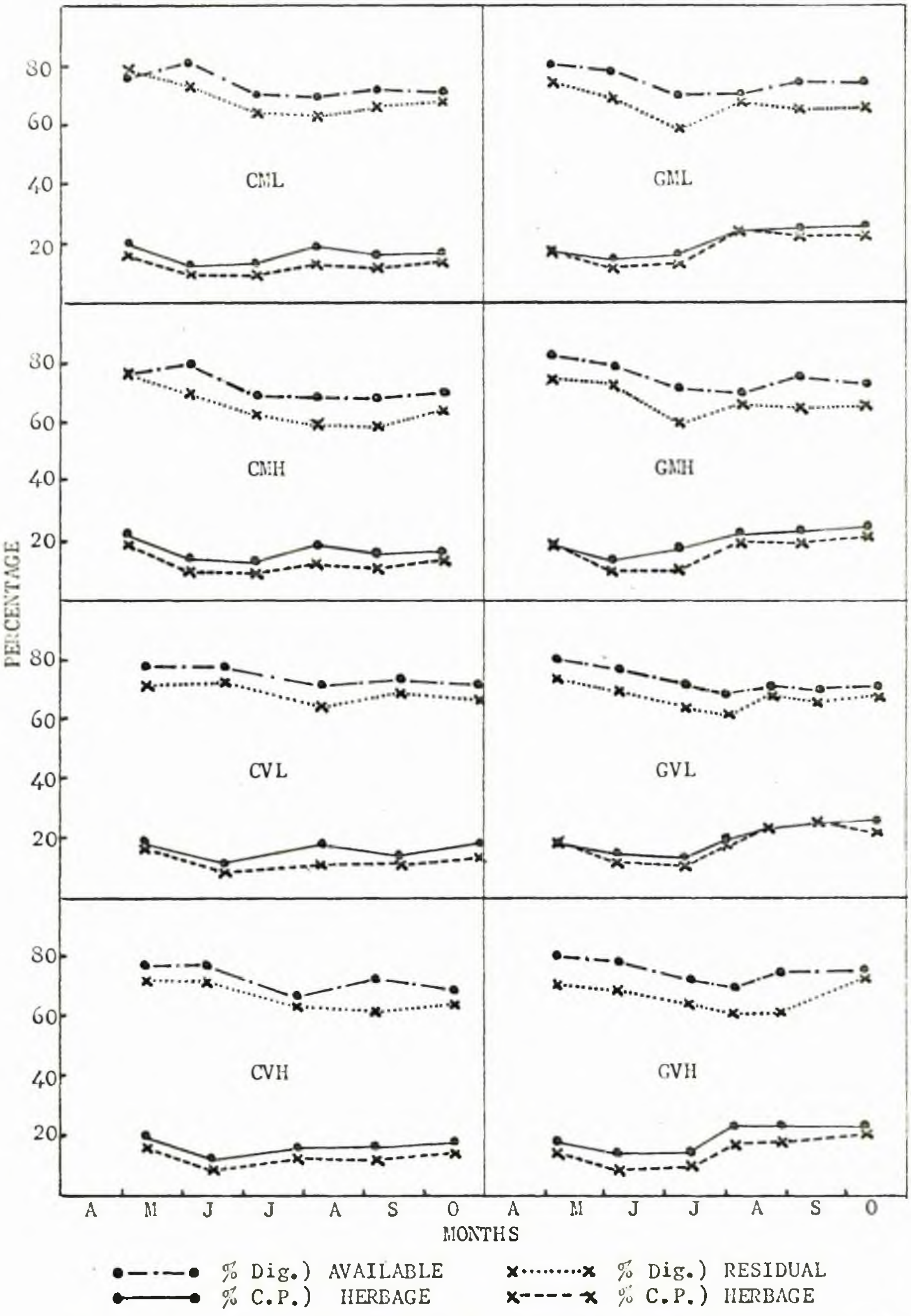


Figure 27 Seasonal percentage digestibility and crude protein of the available and residual herbage for each treatment

There were no significant treatment effects on either the organic matter or digestible organic matter yields. The yield relationship between the treatments was therefore similar under both sampling methods. The shearhead estimates resulted in consistently higher yields and this effect was significant.

Among the crude protein yields, monthly and high severity defoliation gave significantly greater yields than variable frequency and low severity defoliation. The two sampling methods have thus given different results, with relatively low estimates from the motor scythe in comparison with the shearhead under monthly and high severity defoliation but there was a significant consistency effect since shearhead estimates were always slightly greater.

Table 81 Annual herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
Intensity						
ML	57.7	46.1	10.3	2.6	1.7	1.0
MH	51.7	40.7	9.2	1.9	3.6	1.9
VL	58.4	46.3	10.2	2.4	1.1	0.4
VH	51.1	40.2	9.8	1.0	2.1	1.2
Significant effects:						
Intensity				NS	NS	*
Frequency				NS	NS	*
Severity				NS	NS	*
Frequency x severity				NS	NS	NS
Consistency				***	***	***
C.V. (%)				84.2	71.4	45.5
Differences between:				$S\bar{d}$	$S\bar{d}$	$S\bar{d}$(L.S.D.)
Intensity means				1.14	1.10	0.39(0.88)
Frequency/severity means				0.81	0.77	0.32(0.72)
Frequency means within a severity and vice versa				1.14	1.10	0.39

Mean annual chemical composition of the herbage: The weighted mean annual chemical composition data for the herbage removed by motor scythe (Table 82) show that organic matter and digestibility contents were marginally greater under high in comparison with low severity defoliation. Crude protein contents were at similar levels in three of the treatments. In the fourth (CVH), crude protein was at a higher level than the others.

Table 82 Weighted mean annual percentage chemical composition of the herbage removed by the motor scythe

Intensity	Organic matter	Digestibility	Crude protein
ML	88.1	80.0	17.8
MH	89.5	78.7	17.9
VL	87.3	79.1	17.6
VH	90.2	78.7	19.1

Seasonal distribution of herbage yields: Table 83 shows the distribution of herbage yields over the season estimated by motor scythe and the relationship of these yields to those measured by shearhead.

The amounts by which the two estimates differed over the season were generally very small apart from one or two instances in each treatment. At the majority of defoliations, the shearhead estimates were greater than the motor scythe estimates. Differences mainly lay in ranges from 0-180 lb/ac organic matter, 10-130 lb/ac digestible organic matter and 0-70 lb/ac crude protein.

Table 83/

Table 83 Seasonal herbage yields from the motor scythe sampling method and their relationship to yields from the shearhead sampling method for each cutting treatment (100 lb/ac)

	Motor scythe			Shearhead minus motor scythe		
Defoliation No.	Organic matter	Digestible organic matter	Crude protein	Organic matter	Digestible organic matter	Crude protein
		CML			CML	
1	11.1	9.2	2.6	0.6	-0.4	0.1
2	22.1	18.2	2.9	-1.8	-1.0	-0.2
3	5.7	4.3	0.9	2.8	2.3	0.6
4	8.3	6.3	1.9	-0.7	-0.4	0.0
5	8.0	6.2	1.5	1.0	0.7	0.3
6	2.6	1.9	0.6	0.6	0.5	0.1
		CMH			CMH	
1	4.7	3.9	1.1	0.0	-0.3	0.4
2	20.5	16.7	2.9	-0.5	0.8	0.3
3	6.7	5.1	1.1	2.4	2.2	0.6
4	8.4	6.3	1.8	-1.5	-0.5	0.2
5	8.2	6.3	1.6	0.4	0.5	0.2
6	3.1	2.4	0.7	1.2	1.0	0.3
		CVL			CVL	
1	17.0	13.8	3.8	-2.3	-1.9	-0.8
2	19.0	15.1	2.4	0.3	0.1	0.0
3	14.7	11.4	2.6	1.7	0.8	0.7
4	5.3	4.1	0.9	3.2	2.4	0.5
5	2.5	1.8	0.5	-0.5	-0.1	0.0
		CVH			CVH	
1	14.8	12.2	3.3	1.7	1.3	0.5
2	16.3	13.1	2.3	-0.4	0.2	0.2
3	9.0	6.4	1.8	1.3	0.9	0.6
4	8.1	6.3	1.6	-1.8	-0.6	-0.1
5	2.9	2.2	0.7	0.3	0.3	0.2

Seasonal chemical composition of the herbage: Table 84 shows the seasonal chemical composition data for the herbage removed by motor scythe.

Organic matter contents were close to normal (88-91%) in early season but generally decreased later. The values were particularly low at the final defoliations in treatments CML and CVL.

Digestibilities followed the same seasonal pattern in each treatment. The highest levels, ranging from 80-84%, were obtained at the first two defoliations in May and June while thereafter, levels were mainly in the 74-78% range.

Crude protein contents were similarly little affected by treatment. Levels were high initially in May then dropped to their lowest levels around 13-14% in June. Thereafter the contents increased until by late season, the levels approached or exceeded those in May.

Table 84 Seasonal percentage chemical composition of the herbage removed by the motor scythe for each cutting treatment

Defolia-tion No.	Organic matter	Digest-ibility	Crude protein	Organic matter	Digest-ibility	Crude protein
		CML			CMH	
1	90.0	83.6	23.4	90.4	84.1	24.4
2	91.2	82.3	13.2	90.7	81.5	14.1
3	88.8	75.9	15.5	90.1	75.8	16.1
4	87.1	76.1	22.5	88.3	74.8	22.1
5	82.3	77.3	18.7	87.8	76.7	19.5
6	76.5	74.8	21.8	85.6	75.7	21.9
		CVL			CVL	
1	86.5	81.6	22.4	90.5	82.1	22.5
2	89.8	79.6	12.5	91.3	80.4	14.1
3	90.2	77.7	18.0	91.2	72.0	20.0
4	83.2	76.7	17.7	88.9	77.7	20.1
5	68.9	73.8	21.4	84.2	75.6	24.9

Chemical composition of the soil

The chemical composition of the soil before and after the application of the cutting and grazing treatments for the second year (i.e. analyses in 1962 and 1963 respectively) is shown in Table 85.

Table 85 Chemical composition of the soil before and after the application of cutting and grazing treatments for the second year

Date	Treatment	pH	mg/100 g soil Available P_2O_5	Available K_2O
3.2.62	Cutting	5.96	6	6
	Grazing	5.98	5	11
11.3.63	Cutting	5.83	6	6
	Grazing	5.80	4	13

According to the classification of Whittles (1952), the acidity of the soil remained 'moderate'. Under cutting, the available phosphate was unchanged at a 'medium' level but under grazing, it dropped to 'low'. In contrast, whereas available potash remained at 'medium' under cutting, it rose to a 'satisfactory' level under grazing.

EXPERIMENTS 3, 4, 5 AND 6

Discussion

Experimental layout

The layout proved very satisfactory for the conduct of the experiments on the four swards and no practical difficulties were encountered in applying the cutting and grazing treatments. Since the four 20ft x 10ft sub-plots within a cutting main-plot were not individually fenced, there were no obstacles to manoeuvring the motor scythe when cutting, but peripheral areas of the sub-plots, over which the motor scythe passed frequently, were discarded for sampling, which was confined to the 14ft x 6ft central area. Within the grazing main-plots, sub-plots were individually enclosed by permanent fencing and the resultant network of fencing, including sheep pens, gates and paths was adequate for the assembly, handling and allocation of sheep to the sub-plots.

Williams (1951) recorded amelioration of the microenvironment inside hurdle-type enclosures compared with outside and attributed it to the higher temperatures and relative humidities which developed because of a reduction in wind force. Thus because of the fencing in the present experiments, some amelioration of the microclimate will have taken place inside the sub-plots with resultant favourable effects on herbage yield as noted by Cowlishaw (1951), but presumably not so great since wire netting with a more open mesh was used. Slight microclimatic advantages in favour of grazing may have occurred since in each block, the cutting sub-plots were within a 20ft x 40ft fenced enclosure open at one end, whereas the grazing sub-plots were separately fenced 20ft x 10ft enclosures with gates at one end (Figure 7).

The split-plot design proved satisfactory and the number of replicates was sufficient to allow reasonable yield differences between the treatments to be detected by the statistical analyses. Standard errors of the annual herbage yields were fairly low indicating that variation in the herbage growth between replicates was not marked. One of the advantages of agronomic small-plot grazing trials is that they permit replication and statistical design without requiring excessively large numbers of grazing animals or areas of land.

Chemical composition of the soil

Analyses of the soil after cutting and grazing treatment of the herbage showed that in comparison with the analyses before treatment, the main change in composition was in the level of available potash, which was classified as 'medium' at the start of the experiments (Whittles, 1951). Under cutting treatment, it remained at this classification in all the experiments except Experiment 4, where it fell slightly to a 'low' level. Under grazing, the available potash rose in all the experiments to a 'satisfactory' level. Similar results were obtained under cutting and grazing by Bryant and Blaser (1961). The increase under grazing is attributable to the return of excretal potassium mainly in the urine (Sears and Newbold, 1942; Herriott et al., 1959; Herriott and Wells, 1963; Mundy, 1961). Under intensive sheep grazing, Sears and Evans (1953), Watson and Hurst (1953), Wolton (1955) and Herriott and Wells (1963) found that available potassium in the soil increased under conditions in which urine or urine and dung were returned relative to when the excreta were withheld.

Sampling machinery

Throughout the experiments, Wolseley sheep-shearing equipment was used to sample the pre-treatment and post-treatment herbage. Initially, a B.M.B. Hoe-mate light tractor with the standard 6ft Wolseley flexible driving shaft with slip clutch was used to drive the sheep shears but the use of such a short shaft meant that the machine had to be parked on the sub-plots during sampling. Available herbage was pressed down by the wheels and proper application of the cutting treatments made difficult. In wet weather, the passage of the wheels undoubtedly caused soil contamination of the herbage. Consequently, this method of sampling was replaced by one in which a Cooper-Stewart twin drive with slip clutch was attached to the power take-off of an Allen motor scythe and the sheep shears driven by a 20ft Cooper-Stewart flexible shaft. The motor scythe was parked on the pathways so that damage to the herbage during sampling was limited to any effects of trampling by the operator of the equipment. Routine careful maintenance of the sampling equipment was strictly carried out throughout the experiments and the equipment remained fully serviceable.

The shearhead is classified by Brown (1954) as a versatile instrument capable of cutting short or tall herbage and capable of cutting over even or uneven surfaces. This was confirmed in the experiments and no difficulties were encountered in sampling herbage which varied between dense, tall, monthly regrowths and 1-1½ in. residual stubble. Because of the narrow cutting width (3 in.) great care has to be taken to avoid edge effects when cutting strips and this was done in the experiments by cutting along a straight edge. Alder and Richards (1962) and Bone and Tayler (1963) noted that the shearhead is best suited for sampling short herbage, although when sampling very short herbage, care must be taken to avoid the herbage being flicked away by vibration from the cutters.

Apart from the use of the shearhead to estimate the herbage utilized in cutting and grazing treatments, i.e. difference between pre- and post-cutting or grazing samples, the Allen motor scythe was used to take sample swaths during the application of cutting treatments in order to provide additional estimates of the herbage utilized. The Allen is widely used as a mowing machine in grassland experiments (Brown, 1954; Linehan and Lowe, 1946; Hunt, 1963). On the whole, its use in the experiments was satisfactory although there were occasions when clean cutting of moist, dense, S.23 ryegrass swards proved difficult.

Comparison of sampling methods

The shearhead sampling method was the standard method employed in the experiments for making estimates of the herbage utilized in both cutting and grazing treatments so that the sources of random sampling error would be the same for all the treatments. Sampford (1960) has discussed these and other sources of error which may affect the estimated yields of utilized herbage when measured by the difference between pre- and post-treatment samples. Hitherto, the use of pre- and post-treatment samples for estimating herbage utilized has been limited to grazing treatments (Jones, 1932, 1937; Waite et al., 1950; MacLusky, 1955; Line, 1959; Bone and Tayler, 1963 and others). The motor scythe estimates of the herbage utilized in the cutting treatments served as checks on the shearhead estimates.

Herbage yields: In Experiments 3 and 5 conducted on the S.24 ryegrass swards, the herbage yield relationship among the cutting treatments was similar under both the shearhead and motor scythe sampling methods. Over all the cutting treatments there was an increase in annual herbage yield from the shearhead method of 40 to 610 lb/ac organic matter, 130 to 490 lb/ac digestible organic matter and 30 to 160 lb/ac crude protein. These increases accumulated from smaller yield differences between the two systems at individual defoliations over the season since most of the differences were in favour of the shearhead method. There was less consistency between the two sampling methods in Experiments 4 and 6, which were conducted on S.23 ryegrass swards. In the two years of Experiment 6, the relationship between the cutting treatments was similar for both sampling methods for all the yield attributes except organic matter the first year and crude protein the second year. These anomalies appeared to result from low estimates of yield under monthly treatment by the motor scythe relative to the shearhead. The majority of the differences in yield between the two methods were in favour of the shearhead estimates both annually and seasonally. The yield relationship between treatments was again similar for both methods in Experiment 4 but in contrast to the other experiments the annual yields of organic matter and digestible organic matter in three of the four treatments were slightly greater with the motor scythe sampling method.

Thus, in the main, the yield relationship among the cutting treatments has proved to be the same for both sampling methods whilst in general, shearhead estimates of yield have been greater by varying degrees than motor scythe estimates. A comparison of the effects of the two sampling methods on the annual herbage yields is summarized in Table 86.

Table 86 Mean annual herbage yields (100 lb/ac) from the motor scythe sampling method and relative relationship to yields from the shearhead sampling method (motor scythe estimate = 100)

Experiment	Motor scythe			Percentage change		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
3 (S.24/N_o sward, 1961)	45.5	33.2	8.0	+ 11	+ 14	+ 15
3 (S.24/N_o sward, 1962)	50.2	38.6	9.1	+ 4	+ 6	+ 8
4 (S.23/N_o sward, 1961)	53.1	41.2	10.7	- 3	- 1	+ 6
5 (S.24/N_{104} sward, 1961)	53.3	38.3	10.4	+ 4	+ 7	+ 6
6 (S.23/N_{104} sward, 1961)	59.8	45.4	12.5	+ 7	+ 5	+ 3
6 (S.23/N_{104} sward, 1962)	54.7	43.3	9.9	+ 4	+ 5	+ 11

The different random sampling errors associated with the two sampling methods would be partly responsible for the differences in yield but the major factor was probably the method of sampling pre- and post-treatment herbage. To ensure that these herbage samples were from plot areas affected by treatment and not by previous sampling, they were always taken from fresh areas. Thus the area from which the swath sample was cut by motor scythe included a proportion previously cut to ground level and as the season progressed this proportion would increase. At the second sampling, approximately 8% of the swath sample would have been cut to ground level, and by the sixth sampling, approximately 40%. By the time the later samplings were reached any detrimental effects on yield of the earlier ground-level samplings would have worn off. Visual observations showed that during the early-season flush of growth, regrowth on areas cut to ground level was rapid and it was difficult to see where the sampling had been by the time of the next sampling but during midseason and late season, recovery was less rapid and the outlines of the strips sampled to ground level were obvious at later samplings. Stapledon (1924) and Stapledon and Milton (1930) have noted that cutting to ground level resulted in reduced herbage yield relative to a more lenient severity of defoliation.

<u>Chemical composition of the herbage</u>: The effects of defoliation frequency or severity treatments on the chemical composition of the herbage utilized by motor scythe were not marked in any of the experiments apart from a slight but inconsistent trend of greater digestibility and crude protein contents under low relative to high severity defoliation. The organic matter, digestibility and crude protein contents of this herbage were at higher levels than in the shearhead samples of available or residual herbages, a result in keeping with the different morphological make-up of the three types of herbage.

As might be expected, the chemical composition of the utilized and available herbages was particularly close under the low severity defoliation treatments, since the utilized herbage in these treatments consisted of the available herbage less only a 1 in. stubble. Seasonally the composition of the utilized herbage followed a similar pattern to that of the available and residual herbages. Organic matter contents were highest in early season and lowest in late season. Digestibilities were affected mainly by defoliation frequency treatment at the start of the season and were highest under whichever treatment, monthly or variable frequency, was defoliated earliest. Crude protein contents were usually lowest in early season and highest in late season.

Application of treatments

The mean available and residual herbage yields of organic matter per defoliation in Experiments 3, 4, 5 and 6 (Table 87) show that the various intensities of defoliation under cutting and grazing were satisfactorily applied.

The yields of available herbage mainly reflect the effect of the different frequencies of defoliation. The mean amounts by which these yields under cutting and grazing differed over the four experiments were much greater under monthly defoliation (160-890 lb/ac) than under variable frequency defoliation (0-290 lb/ac). These effects are not surprising since under variable frequency defoliation, the herbage was defoliated at 7-9 in. whereas under monthly defoliation, the herbage was defoliated according to a fixed time schedule.

Residual herbage yields under cutting and grazing differed over the four experiments by 130-520 lb/ac with monthly defoliation but by 20-360 lb/ac with variable frequency defoliation. Residual yields mainly reflect the effect of the different severities of defoliation. Under cutting, yields from defoliation to 1-1½ in. were always less than yields from defoliation to 2-2½ in. Low severity grazing also usually left a smaller yield of residual stubble than high severity grazing although the differences were not nearly so clear-cut as under cutting.

Table 87 Mean available and residual herbage yields of organic matter per defoliation in experiments 3, 4, 5 and 6 (100 lb/ac)

Experiment	Defoliation intensity	Available herbage Cutting	Available herbage Grazing	Residual herbage Cutting	Residual herbage Grazing
3 ($S.24/N_o$ sward, 1961)	ML	14.7	18.0	6.6	9.3
	MH	17.1	19.7	8.7	10.7
	VL	14.5	16.1	5.5	7.4
	VH	15.6	17.1	7.5	9.8
	Means	15.5	17.7	7.1	9.3
3 ($S.24/N_o$ sward, 1962)	ML	16.1	13.1	7.2	3.5
	MH	16.9	13.7	8.2	4.8
	VL	15.7	15.2	5.2	6.6
	VH	19.4	16.5	9.5	6.1
	Means	17.0	14.6	7.5	5.2
4 ($S.23/N_o$ sward, 1961)	ML	14.7	21.5	5.8	12.4
	MH	17.1	22.6	9.4	13.3
	VL	16.0	17.4	6.5	6.3
	VH	18.4	18.4	10.1	8.5
	Means	16.6	20.0	7.9	10.2
5 ($S.24/N_{104}$ sward, 1961)	ML	16.0	24.9	6.5	11.7
	MH	18.5	24.8	9.2	12.2
	VL	15.7	16.2	6.0	8.8
	VH	16.4	18.0	9.3	9.7
	Means	16.7	21.0	7.7	10.6
6 ($S.23/N_{104}$ sward, 1961)	ML	17.6	20.7	6.4	9.2
	MH	20.0	19.6	9.2	7.9
	VL	18.1	16.7	7.4	9.1
	VH	19.8	18.7	9.9	9.5
	Means	18.9	18.9	8.3	8.9
6 ($S.23/N_{104}$ sward, 1962)	ML	19.5	22.1	9.4	7.6
	MH	23.0	21.4	14.1	8.0
	VL	19.0	19.7	6.8	10.4
	VH	23.0	20.4	12.6	9.7
	Means	21.1	20.9	10.7	8.9

These results reflect the difficulties inherent in trying to match cutting and grazing systems of defoliation. The limitations are well recognized

(Stapledon *et al.*, 1924; Klapp, 1937; Sears, 1951; Jameson, 1963 and many others). Under a cutting system, it is possible to defoliate herbage uniformly to a required severity e.g. close cutting to 1-1½ in. from ground level but there are differences between herbage species and varieties as regards the ease and accuracy of defoliation to such precise levels. In Experiments 3 and 5, little difficulty was encountered in cutting down the S.24 ryegrass sward cleanly and evenly at the required severities with the motor scythe, but in Experiments 4 and 6, the dense, leafy growth typical of an S.23 ryegrass sward, was less easy to defoliate so precisely, particularly when the herbage was damp with dew or wet from a shower of rain. Under a grazing system it is difficult to defoliate herbage down to a pre-determined level so precisely as under cutting. Stock neglect herbage fouled by dung or by excessive trampling and also defoliate plants and parts of plants selectively. In the experiments, there was little selective grazing by the sheep at the first or second grazings when the herbage was fresh and clean but inter-area selectivity took place at the later grazings with the result that residual herbage usually consisted of a patchwork of herbage grazed to the required level, herbage grazed beneath the required level and undergrazed herbage. The undergrazed herbage was mainly material contaminated by dung or excessively trampled; wet weather intensified these effects. Sheep dung droppings, on account of their small size and physical nature, usually disintegrated rapidly and fouled areas of herbage were only temporarily neglected during the season. Urine-contaminated herbage was not rejected. The margins of the grazing plots, which were rarely fouled, were invariably grazed closer than the desired levels. Herbage regrowths after grazing were thus uneven in comparison with the regrowths after cutting. These findings are in broad agreement with those of Stapledon and Jones (1927), Jones (1937), Beruldsen and Morgan (1938), Sears and Newbold (1942), Sears et al. (1943), Brown (1954) and the American Joint Committee Report (1962).

Defoliations

In the monthly frequency treatments, there were 6 defoliations at calendar-monthly intervals, usually 30-32 days apart, starting in May and finishing in October.

In 1961, when weather conditions were suitable for early spring growth (Appendix 2), the herbage in the variable frequency treatments in the $S.24/N_{104}$ sward (Experiment 5) reached the required 8 in. defoliation height by the second week in April while in the $S.24/N_0$ sward (Experiment 3), it reached 8 in. by the third week. The variable frequency treatments in the $S.23/N_{104}$ sward (Experiment 6) were ready for defoliation by late April-early May, but the treatments in the $S.23/N_0$ sward were not ready until the third week of May. Spring growth was later in 1962 and herbage in the variable frequency treatments in both the $S.24/N_0$ sward (Experiment 3) and the $S.23/N_{104}$ sward (Experiment 6) did not attain the required defoliation height until the second week in May. The final defoliations of the season took place in October. The number of defoliations over the season in the variable frequency treatments was 5-6 under cutting and 6-9 under grazing. Intervals between defoliations were therefore usually shorter under grazing (Table 88). The intervals between grazings cited in the table are calculated from the start of one grazing to the start of the next and so include the 1½- to 2-day periods of grazing when regrowths can be interrupted by defoliation. The intervals of uninterrupted regrowth between grazings will therefore be 1½-2 days less than those cited. There were generally an extra 1 or 2 defoliations under low compared with high severity grazing but the same number of defoliations under low and high severity cutting.

Table 38 Range of intervals between variable frequency defoliations in experiments 3, 4, 5 and 6

Experiment	Range between defoliations	
	Cutting	Grazing
3 (S.24/N_0 sward 1961)	25-49	18-38
3 (S.24/N_0 sward 1962)	36-54	21-47
4 (S.23/N_0 sward, 1961)	22-37	25-34
5 (S.24/N_{104} sward, 1961)	22-47	18-30
6 (S.23/N_{104} sward 1961)	26-40	13-33
6 (S.23/N_{104} sward 1962)	33-49	21-34

In accord with the results obtained in Experiments 1 and 2, the growth rate of the swards was generally faster after defoliation by grazing than by cutting; this effect was particularly evident in the swards which received fertilizer nitrogen (Experiments 5 and 6). Two main causal factors may be operating, namely, the return of excreta to the grazed swards and the relative photosynthetic efficiencies of the residual herbage after cutting and after grazing.

Many studies (Sears and Newbold, 1942; Sears et al., 1948; Sears, 1953b; Doak, 1951; Herriott et al., 1959; Herriott and Wells, 1963; Mundy, 1961) have shown that the dung and urine of grazing sheep contain a large proportion of the nutrients ingested from the herbage. Most of the excretal nitrogen and potassium is in the urine and most of the phosphorus in the dung. Because of the solubility and ready availability of the nutrients in the urine, stimulus to herbage growth will come from this source rather than the dung, which requires breakdown by soil micro-organisms to render the nutrients available. Some of the urinary nitrogen is lost by volatilization and leaching but after taking account of these losses, Walker et al. (1954) estimated that 50-60% of the total ingested nitrogen was again available for use by the sward. Similarly, although loss of urinary potassium by leaching occurs, a proportion of the excreted potassium is also available for re-utilization by the sward.

The finding that the faster growth rate of herbage after grazing relative to cutting was most marked in the swards receiving fertilizer nitrogen is probably related to an interaction between excretal and clover sources of nitrogen. This interaction would operate most strongly in the swards not receiving fertilizer nitrogen (Experiments 3 and 4) where excretal nitrogen would cause depression of clover with subsequent loss of symbiotic nitrogen (Watkin, 1954; Wheeler, 1958), so that in effect, the input of excretal nitrogen would merely substitute for the clover nitrogen (Wetson and Hurst, 1953). The excretal nitrogen may only become effective in stimulating growth once the grass/clover balance has swung to grass dominance (Green and Cowling, 1960; Mundy, 1961; Herriot and Wells, 1963). Where there is additional input of fertilizer nitrogen as in Experiments 5 and 6, the recirculated excretal nitrogen may rapidly become effective in stimulating growth since the combined input of fertilizer and excretal nitrogen will more than compensate for the loss of clover nitrogen and the change to grass dominance will be accelerated.

The rate of herbage regrowth will also be partly determined by the photosynthetic efficiency of the material left after defoliation. After cutting, residual herbage consists mainly of old, non-functional material and stubble. This plant material will have poor light interception and low photosynthetic efficiency (Donald, 1956, 1963). On the other hand, after grazing there is a certain amount of ungrazed and partially grazed herbage capable of continued light interception and photosynthetic activity, apart from stubble and dead material. Brougham (1956) obtained faster rates of regrowth <u>immediately</u> after high defoliation (cutting) to 5 in. than after defoliation to 3 in. or 1 in., an effect which he attributed to the greater amounts of photosynthetic tissue left after lax defoliation.

Botanical composition of the herbage

Table 89 summarizes the effects of defoliation method and intensity treatments on the annual sown grass:clover ratios of the available herbage in Experiments 3, 4, 5 and 6.

Table 89 Weighted mean annual percentage perennial ryegrass and white clover of the available herbage for the defoliation method, frequency and severity treatments in experiments 3, 4, 5 and 6

Experiment	Constituent	Method C	Method G	Frequency H	Frequency V	Severity L	Severity H
3 ($S.24/N_0$ sward, 1961)	Ryegrass	61.6	87.3	71.3	77.5	76.4	72.5
	Clover	36.9	10.9	26.9	20.9	22.1	25.7
3 ($S.24/N_0$ sward, 1962)	Ryegrass	66.8	91.4	80.7	77.5	80.1	78.2
	Clover	31.7	7.1	17.8	21.1	18.3	20.5
4 ($S.23/N_0$ sward, 1961)	Ryegrass	53.2	81.6	67.4	67.4	68.5	66.3
	Clover	45.5	17.4	31.4	31.5	30.3	32.7
5 ($S.24/N_{104}$ sward, 1961)	Ryegrass	78.3	93.6	85.1	86.8	87.1	84.8
	Clover	19.2	4.9	12.5	11.5	11.2	12.8
6 ($S.23/N_{104}$ sward, 1961)	Ryegrass	71.9	91.1	80.7	82.3	82.1	80.8
	Clover	26.5	7.3	17.7	16.1	16.4	17.3
6 ($S.23/N_{104}$ sward, 1962)	Ryegrass	82.5	97.6	89.3	90.8	91.0	89.1
	Clover	16.6	1.8	9.9	8.5	8.4	10.0

The annual ryegrass:clover ratios in the experiments were affected markedly by the method but only slightly by the intensity of defoliation. Under cutting treatment, ryegrass made up 53.2-66.8% in Experiments 3 and 4 and 71.9-82.5% in Experiments 5 and 6 while under grazing, the proportions were 81.6-91.4% and 91.1-97.6% respectively. Clover proportions were complementary to these since the ingress of unsown species was negligible.

Defoliation method was also the main influence on botanical composition during the seasons. In Experiment 3, clover made up 5-25% of the herbage at the start of each season. Under cutting, it increased to peak proportions of 30-60% by midseason before falling to 10-25% by the end of the season. In contrast, under grazing it declined rapidly during the season until by the end it made up only 3-10%. Ryegrass proportions were largely complementary to these proportions. Similar seasonal variation in composition was evident in Experiment 4 but with the difference that there were 20-25 percentage units more clover at the start of the season whilst at the midseason, clover made up 50-65% of the herbage under cutting treatment. In Experiments 5 and 6, there was 5-20% clover at the beginning of each season. By the finish, there was less than 6% after grazing treatment but under cutting, the proportion rose to 20-50% by midseason and then declined to 5-15% by the end.

The reduction of clover under the grazing systems in the experiments relative to the cutting systems is in accord with Richardson and Callus (1932), Sears (1953a), Sears <u>et al</u>. (1953), Brockman and Wolton (1963) and Wolton (1963). Under grazing, recirculated excretal nitrogen with its stimulus to grass growth would be a major factor in the decline of clover because of increased shading by the grass on the clover (Blackman and Templeman, 1938; Donald, 1963). Treading by the sheep would also contribute towards a reduction in clover content (Klečka, 1937; Thomas, 1949; Edmond, 1958a, 1963). In agreement with Davies (1925), Stapledon and Milton (1932) and Ivins (1952), white clover was observed to be highly acceptable to the sheep and was selectively grazed before the ryegrass. This selectivity would also be partly responsible for its decline.

The effects of defoliation frequency and severity treatments on the swards were not marked. There was only marginally more ryegrass and less clover with variable frequency relative to monthly defoliation and with low relative to high severity defoliation.

Hughes and Davis (1951), Williams (1952), Reid (1959, 1962), Reid and MacLusky (1960), Appadurai and Holmes (1964) and Gervais (1960) also obtained little effect of defoliation frequency and/or severity on the grass:clover ratios in their swards although in common with the present experiments, these workers investigated a fairly narrow range of defoliation intensities. Where a wider range of defoliation frequencies and/or severities was studied, it was generally found that white clover proportions were increased and grass proportions correspondingly decreased by frequent relative to infrequent defoliation and with severe compared with lax defoliation (Kennedy, 1950; Wagner, 1952; Hamblyn, 1954; Burger et al., 1958; Brougham, 1959; Hunt and Wagner, 1963; Langille and Warren, 1965; Weeda, 1965 and others). This effect is attributable to competition among pasture plants for light. Environmental factors such as the supply of moisture and nutrients will also affect the relative competitive abilities of grass and clover in mixture but Donald (1956, 1963) in his reviews has stressed that the proportion of clover in grass/clover swards is largely dependent upon the direct and indirect effects from the shading of the clover by the taller grass. Defoliation of the sward reduces the competition for light suffered by the clover and improves its ability to compete. However, exceptions to this generalization can occur where defoliation is very severe or very frequent (Brown, 1939; Dodd, 1942; Tesar and Ahlgren, 1950), probably because removal of all the clover laminas represents virtually complete removal of its photosynthetic surface whereas grass usually retains some photosynthetic tissue (Donald, 1963).

Chemical composition of the herbage

The effects of defoliation method and intensity treatments on the annual chemical composition of the available herbage in Experiments 3, 4, 5 and 6 are summarized in Table 90. Equivalent data for the residual herbage are presented in Table 91.

Table 90 Weighted mean annual chemical composition of the available herbage for the defoliation method, frequency and severity treatments in experiments 3, 4, 5 and 6

Experiment	Attribute	Method C	Method G	Frequency M	Frequency V	Severity L	Severity H
3 ($S.24/N_0$ sward, 1961)	O.M.	84.1	84.7	83.6	85.2	84.5	84.3
	Dig.	71.5	69.8	70.6	70.7	71.1	70.2
	C.P.	15.9	16.0	16.4	15.5	16.1	15.7
3 ($S.24/N_0$ sward, 1962)	O.M.	86.0	82.4	83.7	84.6	83.7	84.7
	Dig.	74.5	75.0	74.7	74.8	74.9	74.5
	C.P.	16.4	17.0	17.0	16.4	17.4	16.0
4 ($S.23/N_0$ sward, 1961)	O.M.	84.1	83.9	84.2	83.8	84.0	84.0
	Dig.	73.6	72.0	72.8	72.8	73.5	72.2
	C.P.	17.6	16.0	16.9	16.8	17.0	16.6
5 ($S.24/N_{104}$ sward, 1961)	O.M.	85.1	84.6	85.6	84.1	84.8	84.9
	Dig.	69.7	68.6	69.0	69.2	69.4	68.9
	C.P.	17.2	19.7	17.8	19.1	18.9	18.0
6 ($S.23/N_{104}$ sward, 1961)	O.M.	81.2	84.0	82.9	82.3	81.8	83.4
	Dig.	71.2	71.9	70.8	72.2	71.6	71.4
	C.P.	17.1	19.7	18.2	18.7	19.1	17.7
6 ($S.23/N_{104}$ sward, 1962)	O.M.	83.9	83.9	83.8	84.0	83.6	84.2
	Dig.	73.4	74.9	74.1	74.2	74.3	74.0
	C.P.	15.5	18.6	17.2	16.9	17.3	16.9

The effect of treatment on the chemical composition of the available herbage was not marked in any of the experiments. This is illustrated by the narrow range of mean values for the chemical attributes; over all the experiments, values for the various treatments were within a range of 81.2-86.0% for organic matter content, 68.6-75.0% for digestibility and 15.5-19.7% for crude protein percentage. Within the individual experiments, the ranges were much narrower. Defoliation method had little consistent effect on the organic matter contents or digestibilities of the available herbage in any of the experiments, but within the limits of the narrow ranges mentioned above, crude protein contents were usually slightly greater under grazing than under cutting. The effects of defoliation frequency in the experiments were small and inconsistent but there was a consistent though slight effect of increased digestibilities and crude protein contents from low severity in comparison with high severity defoliation.

With all the treatments in the experiments, residual herbage had consistently lower organic matter, digestibility and crude protein contents than available herbage.

Table 91 Weighted mean annual chemical composition of the residual herbage for the defoliation method, frequency and severity treatments in experiments 3, 4, 5 and 6.

Experiment	Attribute	Method		Frequency		Severity	
		C	G	N	V	L	H
3 ($S.24/N_0$ sward, 1961)	O.M.	77.5	75.5	75.1	77.9	74.0	79.0
	Dig.	67.7	66.6	66.9	67.5	67.7	66.6
	C.P.	13.0	15.4	14.8	13.5	14.6	13.7
3 ($S.24/N_0$ sward, 1962)	O.M.	79.3	74.9	76.8	77.5	75.5	78.8
	Dig.	69.1	67.1	67.0	69.2	68.0	68.2
	C.P.	13.4	16.1	14.8	14.8	15.8	13.8
4 ($S.23/N_0$ sward, 1961)	O.M.	79.0	81.3	80.5	79.7	79.0	81.3
	Dig.	68.5	67.3	68.2	67.6	68.1	67.7
	C.P.	12.9	15.3	14.7	13.5	14.4	13.7
5 ($S.24/N_{104}$ sward, 1961)	O.M.	77.9	75.1	75.3	77.7	75.9	77.1
	Dig.	64.8	64.5	64.4	65.0	64.9	64.5
	C.P.	13.8	19.2	16.5	16.5	16.9	16.0
6 ($S.23/N_{104}$ sward, 1961)	O.M.	76.6	77.3	78.6	75.3	74.9	78.9
	Dig.	66.0	65.2	65.5	65.6	65.2	65.9
	C.P.	13.2	18.3	15.4	16.1	16.9	14.5
6 ($S.23/N_{104}$ sward, 1962)	O.M.	79.1	78.1	78.6	78.6	77.5	79.7
	Dig.	67.1	67.6	67.7	67.0	67.9	66.8
	C.P.	11.8	15.7	13.9	13.6	14.5	13.0

Over all the experiments, mean values for the various treatments were within a range of 74.0-81.3% for organic matter content, 64.4-69.2% for digestibility and 11.8-19.2% for crude protein percentage. Organic matter and digestibility values were generally slightly higher under cutting in comparison with grazing, but in contrast, crude protein contents were always greater under grazing. There was no consistent effect of defoliation frequency on chemical composition although digestibilities were usually slightly greater under variable relative to monthly frequency defoliation. Defoliation severity treatment had small but reasonably clear-cut effects on composition. Organic matter contents were consistently greater under high compared with low severity defoliation whilst digestibility and crude protein contents were generally greater under low severity defoliation.

Organic matter, digestibility and crude protein contents in the available herbage were invariably at higher levels than in the residual herbage during the season but the pattern of variation was similar for both herbages. Organic matter contents were highest in early season and thereafter decreased irregularly to their lowest levels in late season. Little consistent effect of treatment was apparent except in the residual herbage where, as shown by the lower organic matter values, soil contamination was greater under grazing than cutting and under low than high severity defoliation. The main treatment effect on the seasonal digestibilities of the herbages was exerted by the frequency of defoliation in early season. When the herbage in the variable frequency defoliation treatments reached 8 in. in April as it did in Experiments 3, 5 and 6 in 1961, digestibility was higher than in the herbage under monthly defoliation, which was first defoliated in May. In Experiment 4 in 1961 and Experiments 3 and 6 in 1962, herbage under monthly frequency treatment had higher digestibility than herbage under variable frequency treatment in early season, because herbage in the latter treatment did not reach the required 8 in. until after the fixed dates of the first monthly defoliations. The main treatment effect on crude protein content was that contents were higher under grazing than under cutting throughout the season. In all the treatments, crude protein values were invariably lowest in early season and highest in late season.

From average chemical composition values for herbage at various stages of growth listed by Watson (1951) and Evans (1960), the available herbage in the experiments would have organic matter contents of around 88-91% when free of soil contamination; the residual herbage, which was largely stubble, would normally have higher contents but only very slightly so. The organic matter values actually obtained thus show that, apart from some of the defoliations in early season, varying and sometimes considerable soil contamination took place in both available and residual herbages in the treatments. The degree of contamination was greater in the residual herbage since this bore the load of cutting equipment or the hooves of grazing sheep during the application of the defoliation treatments. These effects are intensified in wet weather due to the increased susceptibility of the soil surface to poaching or puddling and to soil splash. Since the rainfall at Auchincruive usually increases as the season progresses (Grainger, 1963) and did so in both 1961 and 1962 (Appendix 2), the consequent increase observed in poaching was undoubtedly largely responsible for the progressive increase in soil contamination as reflected by the lower organic matter contents. The gradual increase in contamination would also be partly caused by cumulative wear and tear of the soil surface in the treatment plots due to the repeated defoliations. Clean ground-level sampling of the herbages thus became increasingly more difficult, particularly in the grazing plots where the trampling effects of the sheep induced considerable surface unevenness. Greater contamination in the herbage was evident after low than after high severity defoliation probably because the causal factors described above would be intensified; in the low severity cutting treatments, where the Universal cutting assembly was used, the fingers of the swath board are tilted slightly downwards so that they sometimes gouged shallow furrows when the soil surface was uneven; in the low severity grazing treatments, the high stocking rate used of 3 sheep per plot meant that considerable trampling with its consequent disturbance of the soil surface was inevitable.

The extent and variability of the soil contamination found in the experiments fully justified the further use of ash-free organic matter as the most satisfactory expression of herbage yield when yields are determined from herbage samples sheared to ground level. Green (1959), Alder and Richards (1962) and Bone and Tayler (1963) came to a similar conclusion. Earlier workers cutting herbage down to ½-¾ in. above ground level also used to correct dry matter yields for soil contamination (Woodman and collaborators, 1926, 1927, 1928, 1929, 1931, 1932; Watson *et al.*, 1932; Davies *et al.*, 1930) although contemporary workers, even when cutting to similar heights, generally use dry matter as their yield basis (Kennedy, 1950; Chestnutt, 1960; Reid and Maclusky, 1960; Bryant and Blaser, 1961 and others).

The differences in digestibility between the available and residual herbages reflect the differences in type of herbage, although considering the marked differences in morphological make-up, the superiority in digestibility of the available herbage was not unduly large. Available herbage consisted mainly of leafy regrowth whereas residual herbage was mainly comprised of stem stubble, leaf bases and leaf sheaths. The high levels of digestibility in the herbages are in accord with the work of Minson *et al.* (1960a, b, 1964), Pritchard *et al.* (1963) and Terry and Tilley (1964), who found that all parts of grass herbage had high digestibility at early stages of growth. Only after emergence of the flower heads did the digestibility of the herbage fall rapidly; stem and to a lesser extent, leaf sheath, fell at a fast rate relative to leaf lamina. Because of the monthly and variable frequency treatments adopted in the present experiments, the herbage in the various treatments was prevented from maturing en masse to a flowering stage of growth. Only a few individual plants, in which the flowering initials presumably escaped defoliation, managed to send up flowering stems, usually in June or July. It has also been noted that white clover, which made up a considerable proportion of the herbage in the cutting treatments, has a high digestibility and that this digestibility falls off with maturity at a much slower rate than grasses (Harkess, 1962, 1963a, b). No references in the literature were found pertaining to digestibility comparisons between herbages similar to those examined in the experiments. Most of the detailed herbage digestibility studies have been conducted on first-growth herbage cut at increasing stages of maturity or on herbage cut at monthly or two-monthly intervals; in addition, the herbage was usually cut at 1-2 in. above ground level and little cognizance taken of the residual stubble (Minson et al., 1960a, 1964; Harkess, 1962, 1963b, 1964; Terry and Tilley, 1964; Ashford and Troelsen, 1965). These workers noted that digestibilities of the regrowths did not show marked variability, a finding confirmed by the results obtained in the present experiments under both monthly and variable frequency defoliation. The results also showed that there was no marked difference between cutting and grazing or between low and high severity defoliation, as regards their effects on the digestibilities of the available and residual herbages. No references pertaining to the effects of defoliation method and severity on herbage digestibility were found in the literature with which to compare these results.

Increasing interest has been taken in the use of digestibility as a major criterion of the nutritive value of herbage to ruminants (Kennedy, 1950; Blaxter, 1960; Miller, 1961a, b). A main reason for this is that digestibility is an inherent attribute of the herbage whereas traditional grassland evaluation methods involving animal output can be influenced by such factors as the quality of the livestock, the stocking density and the standard of management (Ivins et al., 1958; Ivins, 1960; Harkess, 1962, 1963a). Digestible organic matter as an index of output has thus been increasingly used (Kennedy, 1950; Ivins, 1960; Corbett, 1960; Brundage, 1961; Harkess, 1962, 1963a; Minson et al., 1964; Ashford and Troelsen, 1965). The use of organic matter digestibility of the herbage as an index of nutritive value and digestible organic matter as an index of herbage output in the experiments was therefore fully justified. By using the digestibility of the organic matter rather than the digestibility of the dry matter or the percentage digestible organic matter in the herbage dry matter, account was taken of the variability in ash contents of the herbages, most of which would be due to soil contamination.

The determination of herbage digestibility by laboratory in vitro techniques has only recently become widespread and has been reviewed by Shelton and Reid (1960) and Homb (1963). In comparison with in vivo techniques, in vitro fermentation techniques allow rapid estimates of the digestibility of large numbers of herbages. Since only very small samples of herbage are required, the digestibility of component parts of herbage plants such as leaf blade or sheath can be carried out (Pritchard et al., 1963; Terry and Tilley, 1964), whilst plant breeders can examine large numbers of individual genotypes and incorporate the selected plants quickly into their breeding programmes (Cooper et al., 1960; Thomas, 1963; Rogers and Whitmore, 1966). Rapid estimates of nutritive value can also be made on large numbers of herbage varieties in variety evaluation programmes (Hunt, 1963; Dent, 1963;

Dent and Aldrich, 1963; Heddle, 1965). The technique developed in the analytical laboratories of the Chemistry Department at Auchincruive for analyses of the herbages in the experiments and for use in herbage evaluation trials, including the procedure and equipment necessary to produce a continuous output of 250-300 determinations per week, have been described by Alexander and McGowan (1961, 1966) and Armstrong et al. (1964).

The finding that crude protein contents were higher in the available than in the residual herbage is in accord with a large volume of work which showed that high levels of crude protein are usually associated with a high proportion of leaf relative to stem in the herbage (Fagan and Jones, 1924; Fagan and Milton, 1931; Waite and Sastry, 1949; Watson, 1951; Blaser et al., 1960). Available and residual herbages usually had higher crude protein contents under grazing than under cutting treatment, an effect attributable to the recirculation of nitrogen under grazing previously discussed. The effect was most marked in the residual herbage and this is probably mainly due to differences between cutting and grazing as regards the nature of the material left after defoliation. Cutting normally left an even, residual stubble with little leafage whereas after grazing, the residual material consisted of both stubble and ungrazed leafy herbage. Some of this ungrazed material may also have been impregnated by nitrogen-rich urine. In the experiments, intervals between defoliation as a result of the frequency treatments lay mainly in a 3 to 5 week range. In agreement with Woodman et al. (1928, 1931), Woodman and Norman (1932), Kennedy (1950) and Peterson and Hagan (1953), these frequencies did not differ markedly in their effect upon the crude protein contents of the herbages but under a wider range of defoliation intervals it has been shown that there is a general trend of decreasing protein content with increasing interval between defoliations (Woodman et al., 1926, 1927; Shutt et al., 1930; Watson and Horton, 1936; Kennedy, 1950; Williams, 1952; Chestnutt, 1960; Ashford and Troelsen, 1965). These effects of frequency are related to the maturity and associated leaf to stem ratio of the herbage; with frequent defoliation, herbage material will be young, leafy and high in protein relative to the more mature and less leafy herbage which develops under infrequent defoliation (Wilson, 1886, 1889; Fagan and Jones, 1924; Fagan and Milton, 1931; Waite and Sastry, 1949; Watson, 1951; Evans, 1960). Crude protein contents under low and high severity defoliation did not differ markedly in the experiments but in general there was a slight superiority under low severity treatment. In comparable comparisons of defoliation severity on perennial ryegrass/ white clover swards, Reid (1959, 1962) and Appadurai and Holmes (1964) also noted little marked effect on crude protein content but Reid and MacLusky (1960) found that herbage cut to ¾ in. had slightly higher crude protein contents than herbage cut to 1 in. They attributed this effect to a higher leaf to stem ratio in the more closely cut swards since Cooper and Saeed (1949) and Langer (1957) had shown that severe defoliation stimulated the production of leaf at the expense of flowering stem. In the experiments, variation in the crude protein contents over the season under all the treatments was similar in that contents were lowest in early season and highest in late season. This pattern of variation has been noted by many workers including Fagan and Jones (1924), Linehan et al. (1947), Kennedy (1950), Alexander (1963), Heddle et al. (1963), Heddle (1965) and Keith et al. (1964).

In the past, crude protein content has been regarded as a major index of the nutritive value of herbage (Fagan and Jones, 1924; Woodman et al., 1926, 1932; Watson and Horton, 1926), but with advances in knowledge of animal nutrition, emphasis has shifted to more appropriate expressions of nutritive value such as percentage digestibility, starch equivalent or net energy. However, in his critique on the evaluation of forage crops by chemical analyses, Sullivan (1962) still considered that within limits, crude protein content was an acceptable criterion of herbage quality. As such it is still widely used in grassland experiments, being usually quoted on a dry matter basis; yields of crude protein are also usually cited (Holmes, 1948; Brown, 1954; Hunt and Gardner, 1956; Reid, 1959; Dent and Aldrich, 1963; Reith et al., 1964; Hunt and Frame, 1965 and others). In the experiments, crude protein content was expressed as a percentage of the organic matter to take account of the varying degrees of soil contamination from ground-level sampling.

Herbage yields

Individual periods of grazing during the application of the grazing treatments were only 1½-2 days and no measurements were made of herbage growth during these periods. Over the season in each experiment, these periods totalled 12 days in the monthly grazing treatments. Under variable frequency defoliation, the totals, depending upon the treatments, were 9-10½ days in each year of Experiment 3, 9 days in Experiment 4 and 12-13½ days in Experiment 5; in Experiment 6, the totals were 10½-13½ days the first year and 9-10½ days the second year. This feature of the 'difference' technique used in the experiments is not regarded as a serious objection to the method, partly because the high stocking rates used (equivalent to 436-653 sheep per acre per day during the application of the treatments) ensured that the herbage was rapidly grazed down with almost machine-like precision and growth was therefore limited in amount. Applications of this difference technique have been satisfactorily made by Jones (1932), Jones (1937), Waite et al. (1952), MacLusky (1960), Lowe (1959), Line (1959), Davison (1959), Huokuna (1960b), Bone and Tayler (1963) and Campbell (1964). Another technique which makes use of short grazing periods and does not measure growth during the periods is 'grazing to mower height', a technique used by Stapledon and Milton (1932), Sears (1944, 1951a, 1953a), Sears et al. (1953), Muokuna (1960b) and Bryant and Blaser (1961).

Effects of defoliation method: The effects of defoliation method on the herbage yields of organic matter, digestible organic matter and crude protein in the four experiments are summarized in Table 92.

Table 92 Mean annual herbage yields (100 lb/ac) and relative relationship between yields from cutting (C) and grazing (G) defoliation systems (C = 100) for experiments 3, 4, 5 and 6

Experiment	Organic matter			Digestible organic matter			Crude protein		
	C	G	% change	C	G	% change	C	G	% change
3 (S.24/N_0 sward, 1961)	50.4	54.4	+ 8	37.7	39.8	+ 6	9.2	9.1	- 1
3 (S.24/N_0 sward, 1962)	52.0	58.5	+ 13	40.9	46.2	+ 13	9.8	10.2	+ 4
4 (S.23/N_0 sward, 1961)	51.7	58.9	+ 14	40.6	45.2	+ 11	11.3	11.3	0
5 (S.24/N_{104} sward, 1961)	55.4	72.0	+ 30	41.0	52.4	+ 28	11.0	14.6	+ 33
6 (S.23/N_{104} sward, 1961)	63.7	67.9	+ 7	47.8	53.0	+ 11	12.9	14.2	+ 10
6 (S.23/N_{104} sward, 1962)	56.7	74.3	+ 31	45.5	59.7	+ 31	11.0	15.5	+ 41

In Experiment 3, organic matter and digestible organic matter yields were between 6 to 13% greater under grazing than cutting; the increases were higher in the second year. Crude protein yields were closely similar the first year and only 4% greater with grazing the second year. In Experiment 4, there were yield increases from grazing of 14% for organic matter, 11% for digestible organic matter but crude protein yields were the same under both cutting and grazing.

These results are in agreement with those from other workers who compared the effects of cutting and grazing systems on herbage yields from grass/clover swards receiving no fertilizer nitrogen. In trials lasting 3-5 years, Sears (1953a) and Sears et al. (1953) obtained a 4-6% increase in dry matter yield from grazing on dominantly perennial ryegrass/white clover swards. Taylor et al. (1960) working with a cocksfoot/white clover sward obtained a 6% increase from cutting. However, since grazing times were only 1-4 hours, it is doubtful if the return of excreta was proportional to the amounts of herbage removed. These workers used an interesting technique in which the grazed swards were defoliated from 4-6 in. and 10-12 in. down to 2 in. in 1-, 7- and 14-day periods and this method of defoliation likewise simulated on the cut swards by progressive mowing down to 2 in. over the same periods. Also on grass/clover swards, Jones (1958) and Miles (1960) obtained slightly greater yields from cutting on cocksfoot and italian ryegrass swards but on perennial ryegrass and timothy swards, a slight yield advantage was obtained under grazing.

In Experiment 5 on the S.24/N_{104} sward, the yield of organic matter was 30% greater under grazing than cutting. Similar increases were recorded for yields of digestible organic matter and crude protein. In the first year of Experiment 6 (S.23/N_{104} sward), there were small increases in yields of the three attributes under grazing but in the second year, the increases were substantial. The increase in organic matter yield rose from 7% in the first year to 31% the second year, in digestible organic matter from 11 to 31% and in crude protein, 31 to 41%.

Other workers have recorded somewhat similar results to these. On grass/clover swards receiving fertilizer nitrogen, yield advantages under grazing relative to cutting of 4-3% were obtained on permanent pasture by Klapp (1959) and Wolton (1963) and on ryegrass, timothy and meadow fescue swards by Scheijgrond and Vos (1960). Similar effects can be inferred from work carried out by Brockman and Wolton (1963) and Armitage and Templeman (1964).

Differences between cutting and grazing as regards their effects on herbage yield have been largely attributed to the return of dung and urine under grazing and consequent recirculation of sward nutrients, whilst treading and selective grazing by the sheep will also contribute to the differences.

The quantities of nutrients returned by sheep on intensively-grazed small plots have been calculated by Sears and Newbold (1942) and Sears <u>et al.</u> (1948) in New Zealand and by Herriott <u>et al.</u> (1959) and Herriott and Wells (1963) in Scotland. Under conditions akin to those in Experiments 3, 4, 5 and 6, the Scottish workers calculated that during the grazing season, the nutrient return per acre was 130-140 lb nitrogen, 115-120 lb potassium, 15 lb phosphorus and 15 lb calcium. They also calculated that under their conditions, the sward received urinary cover six times whereas the frequency of cover of dung was only 0.02. Since most of the nitrogen and potassium are in the urine, these elements will be distributed more uniformly than the phosphorus and calcium, most of which is in the dung. This evenness of urinary return is only possible under intensive grazing. Under extensive and semi-intensive grazing with cattle or sheep, the distribution of nutrients in both urine and dung could be very uneven and would be concentrated in local patches which in total would make up only a small proportion of the sward over the season

(Petersen et al., 1956a, b; Saunders and Metson, 1959; MacLusky, 1960; Elliot, 1962; Hilder, 1964).

The availability of the nutrients in dung is low but in the urine which has the major influence on herbage growth, the nitrogen and potassium are almost immediately available to the plants (Sears and Newbold, 1942; Jewitt and Barlow, 1949; Doak, 1951, 1952; Watkin, 1957; Barrow, 1961). Under grazing, the most important means of transfer of clover nitrogen to grass is by the return of excreta (Sears, 1953a; Walker, 1956; MacLusky, 1956). Some value has also been ascribed to trace elements in the excreta (Gisiger, 1950) and to growth-promoting hormones in the urine (Salter and Schollenberger, 1938; Sauerlandt, 1948; Doak, 1954). However, some of the urinary nitrogen is lost by hydrolysis or leaching of the urea and by leaching of the nitrogenous products from ammonia nitrification (Doak, 1951, 1952; Walker, 1956) so that only 50-60% of the nitrogen ingested is effectively recirculated after excretion (Walker et al., 1954).

Several workers have obtained increased yield from grass/clover swards where dung and urine were applied separately or together (Nevens, 1951; Sears and Newbold, 1942; Sears, 1944; Sears et al., 1948; Mundy, 1961; Herriott and Wells (1963). However, other workers found that the application of excreta did not lead to increased yield (Sears and Thurston, 1952; Watkin, 1954; Wheeler, 1958). The probable cause of these contradictory results is the antagonism between clover and excretal sources of nitrogen (Sears and Thurston, 1952; Metson and Hurst, 1953; Watkin, 1954; Young, 1958; Mundy, 1961; Herriott and Wells, 1963; Watson and Lapins, 1964), an antagonism already briefly discussed as regards its effect on the rate of regrowth and botanical composition of the swards after grazing. Excretal nitrogen causes suppression of clover growth and hence a reduction in the supply of clover nitrogen so that any gain in yield from the input of excretal nitrogen may be offset by the loss in yield resulting from the reduced supply of clover nitrogen. The similarity in annual crude protein yields under cutting and grazing in the first year of Experiment 3 and in Experiment 4 (Table 92) support this inference and herbage yields under cutting and grazing did not differ markedly in these experiments although a slight final yield superiority gradually developed under grazing (Figures 10, 16). Once grass/clover swards attain grass dominance, this antagonism is reduced and yield response to excretal nitrogen more likely (Green and Cowling, 1960). This hypothesis is supported by the results presented by Sears (1953a), Mundy (1961) and Herriott and Wells (1963). To a limited extent it is also supported by the annual yield data shown for the second year of Experiment 3 (Table 92) since there is slightly more crude protein under grazing than cutting and organic matter and digestible organic matter yields are also greater under grazing. As shown by the accumulative herbage yields (Figure 13), the excretal nitrogen was cumulatively effective in the development of yield superiority under grazing. Support may also be adduced from the data presented by Watkin (1954) and Wheeler (1958), which showed that the return of dung and urine or urine alone increased yields from grass/clover swards only when fertilizer nitrogen was also applied. Input of fertilizer nitrogen in addition to the excretal nitrogen would speed up the botanical change to grass dominance through the direct and indirect effects of shading on the clover of the grasses (Blackman and Templeman, 1938; Donald, 1963). Support for the inference that excretal nitrogen is effective on grass-dominant swards is given by the results already presented and discussed for Experiments 1 and 2 and from the results of Sears (1953a), Sears <u>et al.</u> (1953) and Wolton (1963). The results shown in Table 92 for Experiments 5 and 6 also support this inference since the annual crude protein yields were 10-41% greater under grazing than cutting showing that more nitrogen was available under grazing. The accumulative yields (Figures 19, 22, 25) indicated that the recirculated nitrogen was cumulatively effective in increasing herbage yields. The botanical composition data showed that ryegrass soon made up over 90% of the herbage in the grazed swards.

Because of the high stocking rates used in the experiments, the yield and botanical composition of the grazed swards will undoubtedly have been affected by the treading of the sheep. At an individual grazing the daily stocking rates varied between 436 and 653 sheep per acre. Taking account of the number of grazings in the various treatments in the experiments and assuming a normal grazing season of 200 days, the treatment swards carried the equivalent of the following stocking rates over the season:

Treatment	Sheep/acre
CML	39
CMH	26
CVL	30-44
CVH	20-26

The sheep would spend less time walking and more time standing or lying in the plots relative to normal grazing but even so, considerable treading pressure will have been exerted. Several studies have shown that treading can cause reduction in herbage yield by direct injury to the plants and reduction in growth vigour and density of grass tillers and clover nodes (Bates, 1930; Klečka, 1937; Lieth, 1954; Edmond, 1958a, c, 1964; Schaaf, 1965). Treading can also depress herbage growth indirectly by compaction of the soil which reduces water infiltration into the soil, causes puddling of the soil surface, impedes oxygen diffusion and mechanically impedes root and shoot development (Bates, 1935; Alderfer and Robinson, 1947; Lutz, 1952; Lieth, 1954; Edmond, 1958a, b; Rosenberg, 1964; Gradwell, 1965, 1966). Treading damage is increased in wet compared with dry conditions (Tanner and

Mamaril, 1959; Edmond, 1962, 1963; Schothorst, 1963a, b; Wind and Schothorst, 1965). Since the rainfall at Auchincruive normally increases as the season progresses (Grainger, 1963) and did so in 1961 and 1962 (Appendix 2) it is conceivable that damage by treading was greatest in late season. Although no measurements of treading effects were made, observations showed that treading damage was more apparent in late summer and autumn than earlier in the season. Poaching was particularly evident if there had been wet weather during the application of the treatments. Plant species differ in their tolerance to treading and perennial ryegrass, which was the major constituent in the experimental swards has been classified as one of the grasses most tolerant to treading (Bates, 1930; Ellenberg, 1952; Sears, 1953a; Edmond, 1964). White clover, the other major constituent of the swards, is regarded as medium-tolerant and its stems are particularly susceptible to injury (Klečka, 1937; Thomas, 1949; Edmond, 1958a, 1963). In view of this, treading damage to white clover would be partly responsible for its rapid reduction to relatively small proportions in the grazed relative to the cutting treatments.

It is recognised that sheep have naturally very selective grazing habits but also that this selectivity is largely dependent upon stocking rate. Under extensive grazing systems, there is ample opportunity for selective grazing but under intensive grazing, opportunity is restricted (Martin Jones, 1933d; Tribe, 1948; Jones, 1952; Alcock, 1964b). The high stocking rates used in the experiments undoubtedly restricted selectivity by the sheep and both the ryegrass and white clover were well-grazed. However, it was observed that white clover was invariably grazed before the ryegrass. This selectivity could be partly responsible for the rapid decline of clover in the grazing treatments. Since there was little ingress of unsown species, sown perennial ryegrass soon became dominant in all the grazed swards. A degree of inter-area selectivity took place in the swards. In agreement with Nevens (1941), Norman and Green (1958) and Voisin (1959) it was observed that urine did not diminish the acceptability of herbage but in accord with Sears and Newbold (1942) Johnstone-Wallace and Kennedy (1944), Norman and Green (1958) and MacLusky (1960), herbage fouled by dung droppings and herbage trampled into the soil were rejected or only partially grazed. Although mosaics of neglected and grazed herbage were usually visible after grazings, the areas of rejected herbage never made up unduly large proportions of the plots. Under the humid conditions of the west of Scotland, areas soiled by dung soon become 'clean' again because of the rapid disintegration and disappearance of the dung droppings.

The net effect of inter-area selective grazing on the estimates of utilized herbage yield is difficult to assess. Where herbage is neglected and therefore not grazed down to the required level, the utilized herbage will be low. This will be offset to some degree where the herbage is grazed beneath the desired level. In a comparison of cutting and grazing effects on herbage yield from a cocksfoot sward, Bryant and Blaser (1961) partly attributed the lower yields from grazing to over-close grazing below the required height and concurrent removal of stubble and organic food reserves. The difficulty of grazing down to a pre-determined level has been recorded by Stapledon and Milton (1932), Sears (1944, 1951a) and Huokuna (1964b). These workers used the 'grazing to mower height' technique in which herbage samples were cut from treatment plots and the plots stocked sufficiently heavy to ensure that the herbage was grazed down to the level of the cuts in 2-3 days. It is usual in this technique to mow herbage neglected after grazing to the level of the sample cuts so as to prevent overestimates of the succeeding growth. Where herbage has been grazed below the level of the cuts, succeeding regrowth will be underestimated.

Effects of defoliation frequency: Table 93 summarizes the effects of defoliation frequency treatment on annual herbage yields of organic matter, digestible organic matter and crude protein in the four experiments.

Table 93 Mean annual herbage yields (100 lb/ac) and relative relationship between yields from monthly (M) and variable (V) frequency defoliation systems (M = 100) for experiments 3, 4, 5 and 6

Experiment	Organic matter M	Organic matter V	Organic matter % change	Digestible organic matter M	Digestible organic matter V	Digestible organic matter % change	Crude protein M	Crude protein V	Crude protein % change
3 (S.24/N_0 sward, 1961)	51.2	53.6	+ 5	38.1	39.5	+ 4	9.1	9.2	+ 1
3 (S.24/N_0 sward, 1962)	54.2	56.3	+ 4	42.9	44.3	+ 3	10.1	9.9	- 2
4 (S.23/N_0 sward, 1961)	52.5	58.1	+ 11	41.1	44.7	+ 9	10.7	12.0	+ 12
5 (S.24/N_{104} sward, 1961)	67.1	60.3	- 10	48.9	44.4	- 9	12.7	13.0	+ 2
6 (S.23/N_{104} sward, 1961)	67.6	64.0	- 5	50.4	50.4	0	13.6	13.5	- 1
6 (S.23/N_{104} sward, 1962)	70.4	60.6	- 14	56.1	49.0	- 13	14.3	12.2	- 15

There was no consistent yield relationship between the defoliation frequencies in the experiments. In both years of Experiment 3 and the first year of Experiment 6, herbage yields under monthly and variable frequency defoliation treatment were closely similar but in Experiment 4, yields were greater under variable frequency defoliation whilst in Experiment 5 and the second year of Experiment 6, yields were greater under monthly frequency defoliation.

Various studies have shown that frequency of defoliation usually has clear-cut effects on herbage yield, with the general result that yield increased as the interval between defoliations lengthened. This finding has been obtained in cutting experiments both with time scales such as 2-, 4- and 6-weekly defoliation intervals and stage of growth scales such as 3-5 in., 7-9 in. and 11-13 in. herbage (Woodman et al., 1926, 1927, 1928, 1929, 1931; Woodman and Norman, 1932; Kennedy, 1950; Brougham, 1959; Reid, 1959; Taylor et al., 1960; Bryant and Blaser, 1961; Appadurai and Holmes, 1964; Huokuna, 1964 and many others). Similarly, increased yields have been obtained in grazing studies with increased length of recovery period between grazings (Jones and Jones, 1930; Hughes and Davies, 1951; Williams, 1952; Maclean, 1953, Brougham, 1959, 1960; Taylor et al., 1960; Bryant and Blaser, 1961; Weeda, 1965).

The results in the experiments are not at variance with the results of these workers. In the experiments, the two frequencies are not treatments within a common frequency scale. Instead, the monthly treatment is on a time scale whilst the variable treatment is on a stage of growth scale. In Experiments 3 and 4, the number of defoliations over the season under monthly treatment varied little from the number under variable frequency treatment. However the intervals between the defoliations varied (Table 83) since under monthly frequency, the intervals were 30-33 days whereas under variable frequency they ranged between 18-54 days. In Experiment 4 over all the treatments, organic matter yields were 11% greater on average with 24 defoliations under variable frequency defoliation than with 24 monthly defoliations. In the two years of Experiment 3, the equivalent increases were 4% and 5% with 26 and 23 defoliations respectively under variable frequency treatment. Since herbage production is ultimately dependent upon the leaf area per unit of land, i.e. Leaf Area Index (L.A.I.), available to intercept light energy (Watson, 1947; Donald and Black, 1958), the herbage in the variable frequency treatments may have intercepted light energy more efficiently than the herbage in the monthly treatments. Differences in efficiency could conceivably happen since first growths and successive regrowths were always allowed to reach 7-9 in. regardless of time interval before defoliation in the variable frequency treatments whereas under monthly frequency, the fixed time interval may have been more than adequate for efficient light interception during periods of flush growth in early season and less than adequate in periods of slow growth such as midsummer or very late season. Over-frequent defoliation by reducing leaf area can depress yield because of poor light interception and accompanying low rate of growth (Donald, 1956, 1963) whilst an adequate length of recovery period is particularly important between close defoliations (Reid, 1959, 1962; Brougham, 1959).

In Experiments 5 and 6, the number of defoliations under variable frequency cutting was 10-14 over the season compared with 12 under monthly treatment, but under variable frequency grazing, there were 13-17 defoliations relative to the 12 monthly grazings. Organic matter yields under variable frequency defoliation were 5-14% less than under monthly treatment, an effect probably related to the differences in frequency of defoliation; this effect was particularly marked under grazing in comparison with cutting in Experiment 5 (Table 51) and the second year of Experiment 6 (Table 75); as a result, there was a 'method x intensity' interaction in each experiment.

Effects of defoliation severity: The effects of defoliation severity on the annual herbage yields in the four experiments are summarized in Table 94.

Table 94 /

Table 94 Mean annual herbage yields (100 lb/ac) and relative relationship between yields from low (L) and high (H) severity defoliation systems (L = 100) for experiments 3, 4, 5 and 6

Experiment	Organic matter			Digestible organic matter			Crude protein		
	L	H	% change	L	H	% change	L	H	% change
3 (S.24/N_0 sward, 1961)	53.8	51.0	- 5	39.7	37.9	- 5	9.2	9.2	0
3 (S.24/N_0 sward, 1962)	56.0	54.4	- 3	44.2	43.0	- 3	10.3	9.7	- 6
4 (S.23/N_0 sward, 1961)	57.9	52.7	- 9	44.9	40.9	- 9	11.5	11.2	- 3
5 (S.24/N_{104} sward, 1961	65.5	61.9	- 5	47.9	45.4	- 5	13.4	12.2	- 9
6 (S.23/N_{104} sward, 1961)	67.1	64.5	- 4	51.5	49.3	- 4	13.8	13.3	- 4
6 (S.23/N_{104} sward, 1962)	68.3	62.7	- 8	54.1	51.0	- 6	13.3	13.1	- 2

In general, herbage yields of organic matter, digestible organic matter and crude protein were reduced by high in comparison with low severity defoliation. The reductions were only between 0 to 6% in both years of Experiment 3 and in the first year of Experiment 6, but in the remaining experiments and in the second year of Experiment 6, the reductions were 2-9%. These findings are in broad agreement with those from other experiments in Britain and elsewhere in which the effects of various degrees of defoliation severity were compared on a variety of grass and grass/clover swards, although herbage yields were generally expressed as dry matter and sometimes with crude protein in addition. In Britain, Reid (1959, 1962), Reid and MacLusky (1960), Chestnutt (1960), G.R.I. (1960, 1961), MacLusky and Morris (1964) and Appadurai and Holmes (1964), working with ryegrass swards cut to severities ranging between ¾ to 4½ in., consistently obtained increased yields from close compared with lax defoliation; similar results were obtained on timothy and cocksfoot swards (Jones, 1959; G.R.I., 1960; Reid, 1960). Workers abroad using cocksfoot, timothy, tall fescue, bromegrass or Kentucky bluegrass swards also found increased yield with increasing closeness of cut (Kennedy, 1950; Burger et al., 1958; Gervais, 1960; Huokuna, 1960a, 1964; Wilson and McGuire, 1961; Bryant and Blaser, 1961; Hunt and Wagner, 1963). However, it was noted by Drake et al. (1963) and Appadurai and Holmes (1964) that there was little advantage in close relative to lax defoliation under hot, dry conditions where soil moisture was a limiting factor.

Relatively few studies on defoliation severity have been conducted under grazing conditions but increased herbage yields from close relative to lax grazing were reported by Brougham (1959) and Bryant and Blaser (1961). Weeda (1965) obtained greater yield from grazing to 1-2 in. than 3-4 in. in the early years of his trial but later, lax grazing gave the greatest yield.

Increased yield from severe defoliation has been attributed to the removal of flowering shoots and consequent stimulus to the initiation and growth of tillers and leaves (Cooper and Saeed, 1949; Langer, 1957; Reid, 1959, 1962). It has also been suggested that close defoliation stimulates initiation of regrowth by permitting a high light intensity at the base of the sward; it may do this partly by preventing a build-up of old, dead material which would shade younger, functional material (Mitchell and Coles, 1955; Wilson and McGuire, 1961; Campbell, 1963, 1964; Hunt, 1965).

Treatment interactions: There were relatively few 'method x intensity' interactions in the experiments. In the second year of Experiment 3, the interaction was confined to crude protein yields and in Experiment 5 to the organic matter yields. However, there were interactions for the three yield attributes in the second year of Experiment 6. There were also few 'frequency x severity' interactions, these being limited to the organic matter and digestible organic matter yields in the first year of Experiment 3 and the crude protein yield in Experiment 5.

The differing natures of the interactions in the experiments makes it difficult to ascribe them to any single cause but two main factors seem likely. Firstly, although the severity of grazing was controlled by varying the number of sheep and the time they spent grazing in the plots, it is possible for two sheep, e.g. in a GVH treatment, to utilize as much herbage in the same time as three sheep, e.g. in a GVL treatment, since they will exert less treading pressure and possibly reject less herbage on account of spoilage by trampling; as a result, the herbage may be grazed below the desired 2-2½in. severity. This may have been the main cause of the interaction in Experiments 5 and 6 since the increase in yield from low relative to high severity defoliation was least marked under grazing, particularly variable frequency grazing. Although the data shown in Table 87 indicate that differing severities were satisfactorily applied on the whole, there were individual cases where the application of the grazing swards was not so clear-cut as, for instance, the GVL and GVH treatments in the second year of Experiment 6. On the other hand, under cutting, the use of 'Standard' and 'Universal' cutting assemblies ensured that the cutting severities of defoliation were satisfactorily applied and that there was always less residual yield after 1-1½ in. defoliation than after 2-2½ in. defoliation.

Secondly, the effect of the frequency of defoliation on herbage yields can lead to interactions. In Experiments 5 and 6, yields under monthly grazing were greater than under variable frequency grazing but under cutting, frequency had little effect on the yields. These results may have arisen because under variable frequency grazing, there were 8-9 grazings in Experiment 5 and 6-7 in Experiment 6 over the season relative to the usual 6 monthly grazings and as previously discussed, several studies have shown that increased herbage yield results when the intervals between defoliations are lengthened. Monthly grazing with its longer intervals would therefore be expected to lead to an increase in yield relative to variable frequency grazing. Under variable frequency cutting there were 6-7 cuttings in Experiment 5 and 5 in Experiment 6 relative to the 6 monthly cuttings. There was thus little difference between the two frequencies as regards the number of cuttings over the season and consequently little difference in yield.

EXPERIMENTS 3, 4, 5 AND 6

Summary

1. From all combinations of two perennial ryegrass/white clover swards (S.24/S.100 and S.23/S.100) and two levels of application of fertilizer nitrogen per annum (0 and 104 lb N/ac), four different swards were created. Four identical experiments, one at each nitrogen manuring level on each sward, were conducted to determine the herbage yield relationships between various systems of cutting and grazing. Experiments 3 and 6 were carried out for two years and Experiments 4 and 5 for one year.

2. The experimental treatments were cutting (C) and grazing (G) methods of defoliation applied at all combinations of four defoliation intensities viz., two defoliation frequencies and two defoliation severities. The frequencies were monthly (M) and variable (V). Monthly treatments were applied at calendar-monthly intervals whilst variable frequency treatments were applied independently under both cutting and grazing when the herbage reached 7-9 in. The severities were low (L) and high (H). Under low severity treatment, the herbage was closely defoliated to 1-1½ in. from ground level and under high severity, 2-2½ in. from ground level. Cutting treatments were applied with a motor scythe and grazing treatments with sheep.

3. In each of the four experiments, a split-plot statistical design was used with four replications of the two defoliation methods as main-plots and the four defoliation intensities as sub-plots. Replicates were treated concurrently.

4. Under both cutting and grazing treatments, yields of available and residual herbage were determined by shearing sample strips of herbage to ground level with power-driven sheep shears. The difference between these yields provided shearhead estimates of the herbage utilized, whether cut by motor scythe and removed, or grazed and removed by sheep. Sample swaths of herbage cut by motor scythe during the application of the cutting treatments provided additional estimates of the herbage utilized under cutting for comparison with the shearhead estimates. Yields were expressed as organic matter, digestible organic matter and crude protein.

5. The level of available potash in the soil remained virtually unchanged after cutting treatment but increased after grazing.

6. The herbage yield relationship among the cutting treatments was similar for both the shearhead and motor scythe sampling methods.

7. In the monthly frequency treatments there were 6 defoliations, usually 30-32 days apart, starting in May and finishing in October. In the variable frequency treatments, there were 5-7 cuttings at intervals of 22-54 days and 6-9 grazings at intervals of 13-47 days during seasons from April to October in 1961 and May to October in 1962. The faster growth rate of swards after grazing relative to cutting was attributed chiefly to the recirculation of nutrients in the excreta, particularly urinary nitrogen.

8. The method of defoliation was the main influence on the botanical composition of the swards. Under grazing, perennial ryegrass rapidly became the dominant constituent of the herbage while white clover

declined to very small proportions. The decline of clover was ascribed largely to the return of excretal nitrogen with its stimulus to grass growth and resultant increased shading by the grass on the clover; treading and selective grazing by the sheep would also contribute to its decline. Under cutting, both ryegrass and clover made up considerable proportions of the herbage.

9. There were no marked effects of treatment on the mean annual chemical composition of the available herbage. The chemical composition of the residual herbage was mainly affected by the method of defoliation; organic matter contents were smaller and crude protein contents greater under grazing.

10. Organic matter, digestibility and crude protein contents in the available herbage were at higher levels than in the residual herbage both annually and seasonally, although over the season the pattern of variation was similar for both.

11. Organic matter contents were highest in early season and lowest in late season. The main effect of treatment was in the residual herbage where organic matter contents were lower under grazing relative to cutting and under low relative to high severity defoliation.

12. At the start of the season, digestibilities were highest under whichever defoliation frequency treatment, monthly or variable, was defoliated earliest, but apart from this, treatment had little effect.

13. Crude protein contents were lowest in early season and highest in late season and were greater under grazing than under cutting, especially in the residual herbage.

14. The organic matter values showed that soil contamination took place in both available and residual herbages in all treatments and was considerable under grazing and low severity defoliation treatment. Contamination was intensified in wet weather due to soil splash and increased poaching of the soil surface and was greatest in the residual herbage. The extent and variability of the soil contamination justified the use of ash-free organic matter as the most satisfactory expression of herbage yield under the ground-level sampling technique used.

15. Both available and residual herbages had high digestibilities throughout the season. The higher digestibilities in the available herbage reflected the leafy nature of this herbage compared with the stem stubble and leaf bases of the residual herbage. By expressing the digestibility as a percentage of the organic matter, account was taken of soil contamination in the herbages.

16. Crude protein contents were higher under grazing than cutting, particularly in the residual herbage, an effect attributable to the recirculation of urinary nitrogen. Crude protein was also expressed as a percentage of the organic matter to take account of soil contamination in the herbages.

17. On the perennial ryegrass/white clover swards receiving no fertilizer nitrogen (Experiments 3 and 4), there were herbage yield increases under grazing relative to cutting of 8-14% for organic matter and 6-13% for digestible organic matter, but crude protein yields under cutting and grazing were similar. On the ryegrass/clover swards receiving fertilizer nitrogen (Experiments 5 and 6), there were herbage yield increases of

7-13% for organic matter, 11-31% for digestible organic matter and 10-41% for crude protein.

18. Herbage yields under grazing would be slightly underestimated since no account was taken of growth during the individual periods of grazing. These periods totalled 9-13½ days over the season for each of the various treatments in 1961 and 9-10½ days in 1962.

19. Increased herbage yields under grazing relative to cutting were attributed principally to the return of excreta and consequent recirculation of sward nutrients, particularly nitrogen. This excretal nitrogen was cumulatively effective in the development of yield superiority under grazing. The effectiveness was most marked in grass-dominant swards. In grass/clover swards, it was suggested that the effectiveness was less marked because of antagonism between excretal and clover sources of nitrogen; excretal nitrogen would cause depression of clover growth and hence a reduction in the supply of clover nitrogen, so that any gain in yield from the input of excretal nitrogen would be offset by the loss in yield resulting from the reduced supply of clover nitrogen.

20. Because of the high stocking rates, herbage yields under grazing would be influenced by the treading effect of the sheep, since treading can reduce herbage yield directly by injury to the plants and indirectly by its adverse effects upon the soil environment, especially in wet weather.

21. Selective grazing by the sheep was minimised because of the high stocking rates, but a degree of inter-area selectivity took place since herbage fouled by dung droppings or trampled into the soil was temporarily

rejected or only partially grazed.

22. Since the two defoliation frequencies were not treatments within a common frequency scale, there was no consistent yield relationship between the monthly and variable frequency treatments, but in general, herbage yield increased as the interval between defoliations lengthened.

23. In the experiments, there were reductions in herbage yield under high severity relative to low severity defoliation of 3-9% for organic matter and digestible organic matter and 0-9% for crude protein.

24. The increased yield from low severity defoliation was ascribed to the removal of flowering stems and consequent stimulus to tiller production.

25. Treatment interactions on herbage yield were few and relatively unimportant so that in general the effects of defoliation intensity treatments on herbage yield were similar under cutting and grazing.

EXPERIMENTS 1, 2, 3, 4, 5 AND 6

General discussion and conclusions

The use of sheep to defoliate the swards and to supply the effects of treading, selective grazing and return of excreta, combined with ground-level shearing to measure herbage yields offers a practical technique of grassland evaluation. By using the sheep simply as defoliation 'machines' on small plots, the agronomic assessment of herbage production becomes possible under grazing conditions whilst still retaining the advantages of cutting techniques in economy of land, equipment, labour and finance, and also the use of replication and statistical design. Herbage production from grass and grass/clover swards was satisfactorily assessed by this grazing technique using 2-3 sheep for short periods, usually 1½-2 days, in movable aluminium alloy folds of 1/250 ac. in Experiment 1, and in individually fenced plots of 1/100 ac. or 1/218 ac. in Experiments 2, 3, 4, 5 and 6.

Although initially expensive, the non-rust aluminium alloy folds can be used repeatedly, allow considerable flexibility of grazing management and are easily manoeuvrable. Because the plots are enclosed only during grazing, modification of the plot microenvironment is minimised and they offer a degree of versatility which is lacking in permanent fencing. The folds are thus suitable for widespread use in the measurement of herbage production under grazing conditions and Miles (1960) has reported on their application for these purposes at the Welsh Plant Breeding Station, Aberystwyth. They are also suitable for simulating various systems of grazing management and were successfully used (Frame, 1965b) to determine the effects of time and frequency of grazing pasture in winter by ewe hoggs on subsequent spring and summer herbage production.

The plot size in such grazing experiments must be large enough to avoid the areas sampled from being an unduly large proportion of the plot, otherwise the sampling becomes part of the treatment. The sub-plots in the experiments were at or near the minimal size since by late-season, considerable areas of the sub-plots had been sampled previously. Motor scythe estimates of herbage yield were slightly lower than corresponding shearhead estimates since the sample swaths included areas previously sampled whereas the shearhead estimates were always sampled from fresh areas. Despite this, the herbage yield relationship among the cutting treatments was similar for both sampling methods. The shearhead method of sampling herbage was efficient as a means of sampling pre- and post-treatment herbage down to ground level to provide yield estimates of available and residual herbage. It was more laborious than motor scythe sampling and strict routine maintenance was necessary to keep the equipment serviceable.

The use of satisfactory electronic techniques of measuring herbage yield (Campbell et al., 1962) could nullify any effects of sampling on subsequent yield and be less laborious than the shearhead technique. Since large numbers of estimates could be made at short intervals, grazing could be started and finished at precise levels of herbage yield. This would represent a major advance in grazing experimental technique since the amount of herbage available and the number of sheep required to utilize it over a given period of time could be closely matched. At present, it is common for grazing to be carried out at particular stages of herbage growth, usually judged by the height of the herbage, or at fixed time intervals. These criteria have the disadvantage that for a given height or after a given interval, the amount of herbage present is not constant over the season. In spite of these difficulties, the various grazing intensity treatments were satisfactorily applied in the experiments and were comparable with those under equivalent cutting intensities.

The plots must also be large enough to provide forage for a minimum of two sheep over a period of not less than 24 hours, so that they will settle down to a reasonably normal pattern of grazing, mastication and rest. By using short 1-2 day periods of grazing, there is no need to measure growth during the periods. If shorter periods are used, the return of nutrients in the excreta will not be proportional to the intake of nutrients from the herbage utilized (Herriott and Wells, 1963). In addition, an adequate period of conditioning on swards treated similarly to those of the plots is necessary to ensure that the excretal return is related to the herbage ingested.

Perennial ryegrass proportions were increased under grazing in comparison with cutting in all the experiments. In the dominantly grass swards of Experiments 1 and 2, this increase was at the expense of cocksfoot and in the remaining experiments at the expense of white clover. The rapid decline of clover to negligible proportions in Experiments 3, 4, 5 and 6 makes the introduction of grazing techniques in the evaluation of grass/clover swards particularly relevant. Defoliation intensity treatments had little effect on the botanical composition of the swards.

The organic matter contents demonstrated that considerable soil contamination of the available and residual herbage had taken place under both cutting and grazing, but more so under grazing. Contamination is unavoidable with ground-level sampling and is intensified by the trampling of stock, particularly in wet weather. Varying degrees of contamination also occurred in the sample swaths cut by motor scythe at 1-1½ in. or 2-2½ in. from ground level in treatments CML, CMH, CVL and CVH. Contamination was greater under low (L) severity defoliation. In the co-ordinated herbage variety potentiality trials carried out by the three Scottish agricultural colleges, the CML and CMH treatments are commonly used and the yields expressed as dry matter. Similar cutting techniques are widely used elsewhere to measure herbage production in a wide range of grassland evaluation work and the yields also normally expressed as dry matter. Contamination is likely to be greater on open than on closely-knit swards, under severe defoliation than under lax defoliation, on uneven than level soil surface conditions and in wet than in dry weather. Additional and substantial contamination undoubtedly takes place during the raking-up of the herbage due to disturbance of the soil surface by the rake tines. Serious doubts must therefore be cast upon the continued universal use of dry matter as an expression of yield in cutting techniques. Organic matter is a more satisfactory and logical basic criterion of yield. In view of this, herbage nutritive value indices such as digestibility and those of herbage quality such as crude protein are best expressed as percentages of the organic matter rather than the dry matter.

The pre- and post-treatment herbage cut by shearhead and the herbage cut by motor scythe were always at high levels of digestibility. Differences in digestibility between these three types of herbage were not great in spite of their different morphological make-up. Apart from the variation in digestibility values due to date of first cut,treatment had little effect upon the digestibilities. The use of in vitro fermentation to determine the digestibility of large numbers of herbages as developed by Alexander and McGowan (1966) offers a valuable technique of assessing the nutritive status of herbage in varietal evaluation and other types of grassland research.

The differences in crude protein content between the three types of herbage were also small. Crude protein contents were increased by grazing compared with cutting treatment because of the recirculation of excretal nitrogen. Crude protein as an index of nutritive value is being replaced by more suitable indices such as digestibility but despite this, it is still useful as a general-purpose measure of herbage quality, particularly in grassland experiments concerned with the nitrogen economy of pastures. Even here it may and probably should be ousted by the adoption of straightforward percentage nitrogen in the herbage.

Under both cutting and grazing, herbage yields were greater under infrequent relative to frequent defoliation and under low compared with high severity defoliation, but in the experiments, the greatest response to treatment was the increase in herbage yield under grazing relative to cutting. This yield response was attributed principally to the recirculation of sward nutrients, especially urinary nitrogen. This recirculated nitrogen was more effective on grass swards than on grass/clover swards because of antagonism between clover and excretal sources of nitrogen. Initially, external sources of nitrogen, whether excretal or fertilizer, suppressed clover and merely substituted for clover nitrogen. Once grass dominance was achieved, the external input of nitrogen became effective in increasing yield. Yields from grazing treatments would be slightly underestimated since no account was taken of growth during the short grazing periods. Yields were also subject to the effects of trampling and inter-area selective grazing.

In the monthly cutting regimes used in the co-ordinated variety potentiality trials, fairly rigid adherence to fixed cutting schedules is carried out. This allows forward planning of experimental work and advance organisation of labour and equipment both in the field and in the laboratories where chemical analyses are conducted. The scheme is thus geared to physical rather than biological demands. Biologically, either the CVL or CVH treatments, where the herbage is defoliated at pre-determined stages of growth, would appear to be more logical than defoliation at fixed time intervals and more readily interpreted in relation to farming practice.

In the experiments, the differences among monthly and variable frequency cutting treatments as regards the way they reflected annual or seasonal distribution of yield, or botanical or chemical composition, were not large. Similarly, the differences among monthly and variable frequency grazing treatments were not unduly large. In contrast, there were considerable yield differences between cutting and grazing systems, with a marked yield advantage to grazing.

Table 95 summarises the relative relationship of the annual herbage yields among the eight treatments averaged over Experiments 3, 4, 5 and 6. Treatment CMH, which is the customary cutting treatment used at Auchincruive in varietal potentiality trials, is taken as the standard.

Table 95 Relative relationship of annual herbage yields among the eight treatments (CMH = 100*) averaged over experiments 3, 4, 5 and 6

Treatment	Organic matter	Digestible organic matter	Crude protein
Cutting:			
CML	105	105	99
CMH	100	100	100
CVL	107	107	99
CVH	96	98	94
Grazing:			
GML	124	122	114
GMH	120	120	110
GVL	120	121	118
GVH	114	115	108

(* Average annual herbage yields (100 lb/ac) for treatment CMH are: O.M. = 53.9; D.O.M. = 41.3; C.P. = 11.1)

In view of these results, it may be concluded that there is need to measure herbage production under grazing conditions in grassland evaluation programmes, whether in the assessment of varieties or in the evaluation of seed mixtures, fertilizers or other management factors. Since the various grazing treatments did not differ markedly in their effects on yield or composition, it could be contended that any one of these treatments could be adopted. However, in spite of the advantages of fixed monthly defoliation previously discussed, monthly grazing would have disadvantages not apparent in monthly cutting. In heavy crops of grass during flush periods of growth or after heavy nitrogenous fertilization, utilization may not be satisfactory because of wastage by trampling and fouling. Therefore, of the grazing treatments examined, the GVL or GVH treatments are the obvious choices. In view of the seasonal variation in herbage yield, even when cut at particular stages of growth e.g. 7-9 in. herbage, it may be desirable to modify these particular treatments by adjusting the stocking rate according to the amount of growth present so that utilization to the desired level is completed in a short period. Any adjustment would need to be within the limits of 2-3 sheep and 1-2 days in view of the size of plot. These limits still allow a considerable range of grazing pressures. As previously discussed, such objective managements could be more accurately selected with improved sampling methods which may be developed, for example by the introduction of electronics.

Although the widespread incorporation of grazing into grassland evaluation work is advisable, the volume of work necessary to assess herbage varieties or measure herbage production under various conditions of management makes it impossible to adopt grazing widely in place of cutting techniques. Work on yield relationships under various cutting and grazing systems is therefore fully warranted so that the simpler cutting techniques can be retained and the results under particular grazing managements predicted. The finding that herbage yield responded to defoliation intensity treatments in a similar manner under both cutting and grazing has important implications in future studies on the yield relationships. Studies can be concentrated on a few selected intensities, knowing that the direction of yield response to other intensities is predictable.

Herbage production under cattle grazing probably differs from that under sheep grazing on account of the different patterns of trampling, selective grazing and excretal return between these two classes of stock. Further studies along the lines of the experiments reported in the thesis are therefore desirable using young or even mature cattle as sward conditioners. The main drawback would be the high cost of cattle, land and fencing.

In grass/clover swards, the yield relationship between comparable cutting and grazing regimes is modified chiefly by interaction between symbiotic nitrogen and excretal nitrogen or excretal and fertilizer nitrogen. The yield relationship is more straightforward on grass swards but since most herbage species and varieties in the United Kingdom are used in grass/legume mixtures, it is logical to seek relationships in grass/clover swards also. From similar types of study reported by Miles (1960), Scheijgrond and Vos (1960) and Bryant and Blaser (1961), it can be inferred that the relationship will vary between different herbage genera and species. However, it may be possible to establish relationships within individual genera or within varieties of individual species, since the results from the six experiments showed that the various perennial ryegrasses under study responded similarly to method of defoliation by always producing more herbage under grazing treatment. Miles (1960) and Scheijgrond and Vos (1960) also obtained yield responses from perennial ryegrass varieties under grazing. In contrast, Miles (1960) and Bryant and Blaser (1961) found that the yield response from cocksfoot varieties was greater under cutting. There is therefore need to establish yield relationships between cutting and grazing using different grass genera, species and varieties with and without clover as a companion and with and without the application of fertilizer nitrogen, since the results appear to be most strongly influenced by these factors.

EXPERIMENTS 1, 2, 3, 4, 5 AND 6

Summary

1. The measurement of herbage production under grazing, using sheep to condition the swards, is a practical technique of grassland evaluation.

2. Compared with permanent fencing, movable aluminium alloy folds are more versatile and allow considerable flexibility in grazing management.

3. The size of plot in agronomic grazing experiments must be large enough to permit adequate sampling without interfering with the treatment and to provide forage for a minimum of two sheep over a period not less than 24 hours.

4. Ideally, the number of sheep used to graze the herbage in a plot over a given period should be closely matched to the amount of herbage available. This matching would be simpler with electronic techniques of measurement than with shearing techniques.

5. The universal use of organic matter as the basic index of yield is recommended in preference to dry matter in grassland experimentation.

6. Herbage yield responded to defoliation intensity in a similar manner under both cutting and grazing but the effects of intensity treatment on yield, botanical and chemical composition were small in comparison with the effects of defoliation method.

7. There was a considerable yield advantage under grazing relative to cutting at all intensities. In the grass/clover swards, there was a substantial increase in perennial ryegrass and concomitant decrease in white clover under grazing.

8. There is need to measure herbage production under grazing conditions in varietal evaluation and other forms of grassland research.

9. The most suitable grazing management would be variable frequency grazing, e.g. grazing at 7-9 in. herbage, with stock numbers matched to the available herbage so that utilization would be completed to the desired level in 1-2 days.

10. Because of cost, it will be impossible to adopt grazing techniques widely in place of cutting. It is therefore desirable to establish yield relationships between various cutting and grazing systems, so that the simpler cutting techniques can be retained and the results under particular grazing managements predicted.

11. Yield relationships were satisfactorily established in the six experiments for perennial ryegrass and perennial ryegrass/white clover swards.

12. There is need to establish yield relationships between cutting and grazing using different grass genera, species and varieties with and without clover and with and without fertilizer nitrogen, since the results are most strongly influenced by these factors.

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Appendix 1 List of common and scientific names of grasses, legumes and other plants mentioned in the thesis

Common names	Scientific names
Annual meadow grass	Poa annua L.
Bent grass	Agrostis tenuis Sibth.
Blueberry	Vaccinium myrtillus L.
Bog myrtle	Myrica gale L.
Bracken	Pteridium aquilinum (L.) Kuhn
Bracken fern	Pteridium esculentum (Forst.) Diels
Bromegrass	Bromus inermis Leyss.
Browntop	Agrostis tenuis Sibth.
Chewing's fescue	Festuca rubra L. subsp. commutata Gaud.
Chickweed	Stellaria media Vill.
Cocksfoot	Dactylis glomerata L.
Creeping bent	Agrostis stolonifera L.
Daisy	Bellis perennis L.
Dandelion	Taraxacum officinale Weber
Dock	Rumex obtusifolius L.
Italian ryegrass	Lolium multiflorum Lam.
Kentucky bluegrass	Poa pratensis L.
Meadow fescue	Festuca pratensis Huds.
Ox-eye daisy	Chrysanthemum leucanthemum L.
Perennial ryegrass	Lolium perenne L.
Ragwort	Senecio jacobaea L.
Red clover	Trifolium pratense L.
Red fescue	Festuca rubra L. subsp. rubra
Rough-stalked meadow grass	Poa trivialis L.
Short-rotation ryegrass	Lolium perenne L. x Lolium multiflorum Lam.
Smooth-stalked meadow grass	Poa pratensis L.
Tall fescue	Festuca arundinacea Schreb.
Timothy	Phleum pratense L.
White clover	Trifolium repens L.
Yorkshire fog	Holcus lanatus L.

Appendix 2 Monthly meteorological data, 1960-62

Month	Rainfall (in.) 1960	Rainfall (in.) 1961	Rainfall (in.) 1962	Sunshine (hr) 1960	Sunshine (hr) 1961	Sunshine (hr) 1962
January	3.70	2.14	5.24	61.2	68.0	50.0
February	2.62	2.74	2.22	98.0	73.8	85.0
March	1.70	1.91	1.36	100.1	96.4	106.5
April	2.16	2.91	2.16	143.6	108.1	209.7
May	1.44	0.82	2.02	205.1	200.1	213.3
June	1.68	1.65	1.44	251.5	153.0	203.0
July	2.66	2.99	3.35	140.7	139.1	151.9
August	3.38	5.11	5.99	192.3	149.8	155.4
September	2.76	6.47	7.20	161.7	109.0	85.1
October	2.15	5.73	1.39	73.9	106.5	90.7
November	5.04	4.41	1.83	81.5	61.8	41.4
December	4.95	2.78	3.65	45.0	56.3	45.2
Total	34.24	39.66	37.85	1554.6	1321.9	1437.2

Month	Mean grass minimum temperature (°F) 1960	1961	1962	Mean soil temperatures 4 in. below surface (°F) 1960	1961	1962
January	27.4	26.0	29.0*	37.0	35.4	37.1
February	26.7	32.9	27.8	35.9	40.5	38.1
March	33.3	36.0	20.9	40.0	43.9	34.9
April	36.5	36.0	29.2	46.5	46.6	42.9
May	39.2	35.1	35.8	53.7	52.7	50.4
June	45.7	44.0	41.7	60.2	56.0	55.7
July	48.0	45.4	45.5	58.8	57.4	56.8
August	43.6	46.2	47.7	58.4	56.4	55.6
September	40.4	46.4	43.1	53.2	55.2	52.6
October	38.1	40.3	40.3	47.7	48.5	49.4
November	32.4	33.5	31.4	41.9	41.8	41.8
December	26.5	24.8	28.1	36.4	36.3	38.0

* Reading would be lower than this had not the thermometers been covered by snow on 1st and 2nd January

Appendix 3 Seasonal and annual herbage yields of the available and residual herbage for each treatment in experiment 1 (100 lb/ac*)

Defoliation No.	Available herbage O.M.	C.P.	O.M.	C.P.	Residual herbage O.M.	C.P.	O.M.	C.P.
	C(4-1)		C(4-1)		C(4-1)		C(4-1)	
1	10.5	2.4	9.2	2.0	3.7	0.8	3.2	0.7
2	10.4	2.6	8.6	2.3	3.4	0.7	3.8	0.8
3	9.7	2.3	10.7	3.0	6.8	1.3	7.0	1.7
4	10.2	2.1	9.8	2.7	7.0	1.3	3.1	0.7
5	8.9	1.6	7.8	2.0	5.6	1.0	3.1	0.7
6	9.7	2.0	8.7	2.4	5.0	0.8	5.5	1.2
7	11.8	2.8	9.0	2.4	2.2	0.4	4.0	0.9
8			7.3	2.1			5.0	1.2
9			4.9	1.4			1.4	0.4
Annual yield	71.1	15.9	75.9	20.2	33.6	6.3	36.1	8.2
	C(8-1)		C(8-1)		C(8-1)		C(8-1)	
1	17.1	3.3	15.8	2.9	2.8	0.4	3.9	0.7
2	13.6	2.4	14.3	3.4	5.8	0.8	4.3	0.8
3	15.3	2.9	10.7	2.6	5.3	0.8	7.2	1.4
4	12.9	2.6	12.1	2.8	3.2	0.5	3.9	0.8
5			10.9	2.9			6.6	1.6
6			13.4	3.6			4.6	1.2
Annual yield	59.0	11.0	77.2	18.2	17.2	2.6	30.4	6.5
	C(8-2)		C(8-2)		C(8-2)		C(8-2)	
1	15.5	2.7	19.0	3.4	6.8	1.1	7.2	1.3
2	14.9	3.0	12.0	2.7	7.5	1.3	5.6	1.1
3	15.6	3.2	11.7	3.1	11.8	2.1	7.8	1.8
4	16.2	2.7	8.9	2.2	7.5	1.2	7.1	1.6
5	13.1	2.5	12.6	3.2	7.5	1.4	7.0	1.4
6	9.5	2.1	14.0	3.7	6.7	1.3	5.6	1.2
7			10.4	3.0			3.3	0.8
Annual yield	84.8	16.1	88.5	21.2	47.8	8.3	43.6	9.5
	C(12-2)		C(12-2)		C(12-2)		C(12-2)	
1	24.9	3.8	22.0	3.4	7.9	1.0	5.7	0.9
2	21.2	4.1	17.1	4.0	12.7	2.1	9.0	1.7
3	16.5	3.0	18.8	4.3	9.8	1.5	11.3	2.3
4	15.2	2.9	18.5	4.3	6.8	1.0	7.8	1.7
5	9.3	2.2	11.3	3.2	5.5	1.2	2.7	0.6
Annual yield	87.2	16.1	87.7	19.2	42.5	6.7	36.5	7.2

* In this and equivalent tables for the experiments in the thesis, annual yield is the total of seasonal yields summed in lb/ac and then rounded off to 100 lb/ac, so may differ slightly from the sum of individual yields above since each of these yields has been rounded off to 100 lb/ac

Appendix 4 **Seasonal and annual herbage yields of the available and residual herbage for each treatment in experiment 2 (100 lb/ac)**

Defoliation No.	Available herbage O.M.	C.P.	O.M.	C.P.	Residual herbage O.M.	C.P.	O.M.	C.P.
	CM		GM		CM		GM	
1	17.2	3.1	17.9	3.6	3.5	0.6	6.2	1.1
2	17.3	3.3	24.7	4.7	6.4	1.0	9.5	1.5
3	19.3	2.7	26.4	4.4	9.1	1.2	13.6	2.3
4	14.7	2.5	19.3	4.0	7.6	1.1	13.2	2.3
5	13.7	2.4	17.6	4.0	7.8	1.1	10.2	2.1
6	12.2	2.4	18.5	4.8	4.9	0.9	8.5	1.9
Annual yield	94.4	16.3	124.4	25.5	39.3	5.9	61.1	11.2
	CV		GV		CV		GV	
1	10.5	2.9	10.3	3.1	2.8	0.7	4.0	1.1
2	17.4	3.5	14.3	3.9	3.8	0.7	4.5	1.1
3	14.8	2.8	16.5	4.1	7.9	1.3	11.1	2.5
4	16.1	2.6	14.5	3.5	9.1	1.3	9.0	1.8
5	11.1	1.7	18.1	3.6	8.9	1.2	9.7	1.7
6	11.0	2.0	12.4	3.0	7.5	1.2	6.4	1.3
7	13.7	2.7	17.4	4.3	6.4	1.3	7.4	1.4
8	10.9	2.5	12.3	3.5	6.2	1.2	5.3	1.5
9	7.3	1.8	9.5	2.8	4.8	1.2	2.7	0.7
Annual yield	112.7	22.6	125.3	31.8	57.4	10.1	60.1	12.7
	GCV		GVT		GCV		GVT	
1	10.4	2.9	11.1	3.1	4.1	1.1	2.3	0.6
2	14.0	3.7	11.3	3.0	4.2	0.9	4.2	0.9
3	16.3	3.6	15.0	3.5	6.7	1.2	5.7	1.3
4	16.8	3.6	16.2	3.6	6.0	1.1	5.6	1.1
5	14.6	2.5	16.0	3.3	8.1	1.3	6.0	1.1
6	16.3	4.0	14.1	3.4	8.2	1.6	5.6	1.2
7	10.9	2.4	13.8	3.8	6.6	1.3	6.4	1.5
8	9.8	2.7	10.8	3.0	7.1	1.7	3.1	0.7
9	12.0	3.4	4.4	1.2	4.3	1.1	1.7	0.4
Annual yield	121.0	2[illegible].7	112.7	27.8	55.2	11.3	40.7	8.8

Appendix 5 Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 3, 1961 (100 lb/ac)

Defoliation No.	Available herbage: Cutting O.M.	D.O.M.	C.P.	Available herbage: Grazing O.M.	D.O.M.	C.P.	Residual herbage: Cutting O.M.	D.O.M.	C.P.	Residual herbage: Grazing O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	24.5	17.4	2.8	20.3	14.4	2.1	6.6	4.5	0.7	8.3	5.7	0.8
2	15.6	11.8	2.4	18.0	13.3	2.5	6.6	4.6	0.7	8.6	5.7	1.2
3	13.9	10.0	2.1	19.0	13.7	3.1	9.0	6.1	1.1	13.5	9.0	2.1
4	15.3	10.5	2.7	19.9	13.3	3.6	8.6	5.6	1.2	12.0	8.1	2.1
5	12.8	9.0	2.9	17.2	11.5	3.6	6.6	4.6	1.2	8.8	5.7	1.8
6	5.9	4.3	1.2	13.7	9.3	3.2	2.4	1.5	0.4	4.7	2.9	1.2
Annual Yield	87.9	63.0	14.1	108.0	75.4	18.2	39.8	27.0	5.3	55.9	37.1	9.3
		CMH			GMH			CMH			GMH	
1	25.0	18.1	2.7	24.0	17.3	2.7	7.8	5.5	0.7	10.3	7.0	1.1
2	16.5	12.5	2.7	21.0	15.6	3.0	9.5	6.8	1.1	11.5	7.5	1.4
3	20.3	14.1	3.2	21.6	14.6	3.2	14.0	9.6	1.8	12.7	8.7	1.7
4	19.9	13.6	3.5	20.4	13.6	3.4	10.4	6.8	1.4	13.3	8.3	2.5
5	13.7	9.6	3.1	18.1	12.1	3.9	6.2	4.0	1.2	10.4	6.9	2.1
6	7.1	5.0	1.5	13.1	9.1	3.0	4.1	2.5	0.8	5.9	3.7	1.3
Annual Yield	102.5	72.9	16.8	118.2	82.2	19.2	52.0	35.1	7.0	64.0	42.0	10.1
		CVL			GVL			CVL			GVL	
1	13.9	11.0	1.7	14.4	10.7	1.8	6.0	4.6	0.7	7.5	5.7	0.9
2	20.3	14.8	2.5	17.3	12.1	2.3	5.9	4.0	0.6	7.4	5.2	1.0
3	18.1	12.2	2.4	20.9	15.1	2.8	6.9	4.6	0.7	8.2	5.7	1.1
4	18.3	13.4	3.7	20.4	14.2	2.8	6.9	4.6	1.0	11.8	7.9	1.8
5	11.9	8.3	2.8	16.9	11.4	3.0	5.4	3.6	0.9	7.6	4.7	1.3
6	4.9	3.5	0.9	14.1	9.8	3.0	2.1	1.4	0.4	4.5	2.8	0.9
7				8.4	5.7	2.0				4.7	2.9	1.1
Annual Yield	87.2	63.2	14.0	112.4	79.0	17.5	33.1	22.8	4.2	51.8	34.9	8.1
		CVH			GVH			CVH			GVH	
1	15.4	11.8	1.8	15.4	10.2	1.7	6.4	4.9	0.7	8.7	6.7	1.1
2	22.9	15.6	2.3	20.3	14.1	2.8	7.2	4.8	0.6	14.2	10.3	1.9
3	19.5	14.1	2.7	22.7	15.9	3.1	10.6	7.3	1.1	15.4	10.2	1.8
4	14.7	9.7	2.6	21.2	14.8	2.4	9.6	5.7	1.2	12.8	8.2	1.5
5	13.6	9.7	3.1	20.3	13.7	3.4	7.0	4.4	1.1	9.8	6.0	1.4
6	7.9	5.6	1.7	11.6	7.5	2.6	4.2	2.7	0.8	4.5	2.8	0.9
7				9.9	6.6	2.4				3.3	2.0	0.7
Annual Yield	93.9	66.5	14.2	119.4	82.8	18.3	45.0	29.8	5.5	68.7	46.1	9.2

Appendix 6 Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 3, 1962 (100 lb/ac)

Defoliation No.	Available herbage						Residual herbage					
	Cutting			Grazing			Cutting			Grazing		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	18.6	15.0	2.5	20.3	15.8	2.9	9.3	7.0	1.3	6.1	3.9	0.9
2	20.7	15.9	2.9	15.0	11.6	2.3	5.2	3.7	0.7	4.9	3.1	0.8
3	23.7	17.2	4.0	12.5	9.5	2.0	14.2	9.3	1.9	2.8	1.7	0.4
4	14.0	10.1	2.4	9.7	7.1	1.9	6.4	4.3	0.8	2.5	1.7	0.4
5	11.6	8.3	2.6	13.1	9.3	2.8	4.5	2.9	0.7	3.2	2.1	0.7
6	7.9	5.7	1.7	7.7	5.5	1.9	3.5	2.3	0.6	1.3	0.8	0.3
Annual Yield	96.5	72.2	16.2	78.3	58.8	13.8	43.1	29.5	6.0	20.7	13.3	3.5
		CMH			GMH			CMH			GMH	
1	18.6	14.7	2.6	21.3	16.8	3.0	11.2	8.4	1.5	8.1	5.5	1.1
2	24.9	18.9	3.8	18.8	14.5	2.9	10.6	7.2	1.4	8.1	5.4	1.0
3	21.3	14.9	3.6	14.3	10.7	2.0	8.6	5.9	1.1	3.1	2.0	0.4
4	14.0	9.9	2.5	11.9	8.5	2.1	8.8	6.0	1.2	5.1	3.3	0.9
5	13.6	9.5	3.0	10.1	7.2	2.1	5.1	3.2	0.8	2.8	1.7	0.5
6	8.7	6.2	1.8	6.1	4.4	1.5	4.8	3.2	0.8	1.8	1.1	0.4
Annual Yield	101.1	74.1	17.3	82.5	62.1	13.5	49.0	34.0	6.8	28.9	19.0	4.3
		CVL			GVL			CVL			GVL	
1	20.5	16.6	2.9	24.7	19.7	2.9	5.6	4.2	0.7	11.6	8.7	1.5
2	18.5	14.2	2.7	17.8	15.4	2.9	7.7	5.6	0.9	6.6	4.3	1.0
3	20.4	14.3	3.3	14.2	10.8	2.4	5.9	3.8	0.7	5.4	3.5	0.9
4	12.4	9.0	2.6	14.1	10.5	2.8	4.3	2.7	0.7	6.2	4.2	1.2
5	6.9	5.3	1.4	13.5	9.6	3.1	2.7	1.9	0.6	6.7	4.4	1.6
6				11.9	8.0	3.0				4.8	3.0	1.3
7				10.2	7.2	2.9				4.9	3.5	1.3
Annual Yield	78.7	59.4	12.9	106.5	79.2	20.1	26.0	18.2	3.6	46.1	31.7	8.7
		CVH			GVH			CVH			GVH	
1	26.6	21.5	3.8	22.2	17.8	2.7	12.0	8.7	1.5	10.7	7.9	1.4
2	23.8	18.2	3.3	26.3	19.7	3.4	13.2	9.3	1.5	8.5	5.8	1.0
3	22.9	15.7	3.0	19.1	14.3	2.4	12.2	8.3	1.3	6.5	4.5	0.7
4	15.0	10.4	3.0	11.7	8.6	2.0	5.5	3.4	0.8	4.7	3.0	0.7
5	8.9	6.3	1.9	10.9	7.5	2.2	4.4	2.8	0.7	2.8	1.7	0.5
6				8.6	6.4	2.2				3.3	2.4	0.8
Annual Yield	97.1	72.2	15.0	98.9	74.3	14.8	47.4	32.5	5.9	36.6	25.3	5.1

Appendix 7 Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 4, 1961 (100 lb/ac)

Defoliation No.	Available herbage: Cutting O.M.	D.O.M.	C.P.	Grazing O.M.	D.O.M.	C.P.	Residual herbage: Cutting O.M.	D.O.M.	C.P.	Grazing O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	23.4	19.2	3.1	22.5	18.4	2.8	7.0	5.4	0.7	15.0	10.3	1.5
2	19.4	14.2	3.2	28.9	21.8	4.5	7.4	5.2	1.0	18.0	12.1	2.6
3	15.7	10.6	2.9	28.8	19.4	4.8	7.5	5.2	0.9	16.4	10.8	2.9
4	15.8	11.4	3.2	20.4	14.0	4.1	7.5	4.7	1.1	12.6	7.8	2.2
5	8.7	6.6	2.2	15.5	10.8	3.7	2.9	2.0	0.6	8.6	5.7	1.7
6	5.3	4.0	1.2	13.0	8.1	2.9	2.2	1.6	0.4	5.8	3.5	1.3
Annual Yield	88.4	66.0	15.7	129.0	92.4	22.7	34.6	24.0	4.6	74.4	50.1	12.3
		CMH			GMH			CMH			GMH	
1	23.7	19.2	3.4	24.0	19.2	3.0	11.1	8.8	1.1	12.1	9.3	1.3
2	21.3	16.0	3.5	32.3	24.5	4.6	11.1	7.9	1.4	21.7	14.9	3.0
3	17.3	11.7	3.1	27.6	18.7	4.2	11.8	7.2	1.4	14.9	9.7	2.2
4	19.2	13.4	3.9	22.5	15.7	4.1	10.6	6.9	1.7	15.2	9.6	2.6
5	11.4	7.9	2.8	14.8	10.4	3.4	5.7	3.7	1.1	10.6	6.9	2.0
6	9.9	7.0	2.0	14.1	8.7	3.0	6.2	4.1	1.1	5.5	3.2	1.1
Annual Yield	102.6	75.1	18.7	135.3	97.2	22.3	56.3	38.6	7.7	80.0	53.9	12.1
		CVL			GVL			CVL			GVL	
1	21.9	17.7	3.1	25.4	19.8	3.3	8.3	6.4	0.8	7.1	5.2	0.6
2	24.3	17.8	3.8	23.5	17.7	3.5	9.6	6.3	1.0	8.2	5.5	1.0
3	15.9	11.0	2.7	18.4	12.8	3.2	7.9	5.2	0.9	9.0	6.2	1.4
4	17.9	12.7	3.9	17.3	12.2	3.4	6.3	4.0	1.0	7.0	4.5	1.2
5	10.9	8.2	2.7	13.6	10.0	3.1	5.5	3.7	1.1	4.5	2.9	0.9
6	4.8	3.7	1.0	6.2	3.8	1.5	1.2	0.8	0.2	2.2	1.4	0.6
Annual Yield	95.7	71.1	17.1	104.3	76.3	18.0	38.8	26.5	5.0	38.0	25.6	5.8
		CVH			GVH			CVH			GVH	
1	27.3	21.3	3.8	22.2	17.4	2.8	10.5	7.9	0.9	10.6	8.2	1.0
2	27.2	20.0	3.6	23.3	17.3	3.7	14.2	9.8	1.3	11.9	7.8	1.5
3	21.3	14.6	3.6	21.0	14.7	3.4	13.2	8.7	1.4	10.8	7.4	1.4
4	14.5	10.0	2.9	16.6	11.2	3.1	9.6	6.2	1.4	8.2	5.2	1.4
5	11.4	8.1	2.7	13.9	9.5	3.5	8.2	5.2	1.4	6.3	3.9	1.3
6	8.8	6.2	1.8	13.5	8.7	3.2	5.0	3.3	0.8	3.5	2.0	0.7
Annual Yield	110.5	80.2	18.3	110.5	78.8	19.7	60.7	41.1	7.3	51.2	34.4	7.3

Appendix 8 **Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 5, 1961 (100 lb/ac)**

Defoliation No.	Available herbage: Cutting O.M.	D.O.M.	C.P.	Grazing O.M.	D.O.M.	C.P.	Residual herbage: Cutting O.M.	D.O.M.	C.P.	Grazing O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	26.6	18.8	4.5	28.5	18.6	4.6	4.8	3.1	0.6	10.9	7.5	1.4
2	15.6	11.2	2.0	27.1	19.1	3.9	5.6	3.8	0.6	16.3	10.8	2.2
3	13.1	8.9	1.7	29.0	19.4	4.5	9.1	5.9	1.0	11.4	6.8	1.7
4	17.5	12.2	3.9	24.4	17.1	5.6	7.7	4.6	1.3	10.1	5.9	3.5
5	13.5	9.3	2.7	23.4	16.9	5.3	7.0	4.9	1.3	12.1	7.7	2.8
6	9.8	6.9	1.7	17.1	11.4	4.3	4.5	2.9	0.7	9.2	5.6	2.2
Annual Yield	96.0	67.3	16.7	149.6	102.4	28.2	38.7	25.2	5.4	70.0	44.3	13.9
		CMH			GMH			CMH			GMH	
1	27.5	19.7	4.6	26.1	17.2	4.3	5.5	3.7	0.7	11.2	7.8	1.6
2	19.1	13.8	2.6	31.9	22.6	4.4	8.6	5.8	0.9	17.2	11.2	2.2
3	19.3	12.5	2.5	29.3	19.3	4.7	14.7	9.3	1.6	14.9	9.3	2.2
4	19.1	13.4	4.3	26.7	17.8	5.4	12.2	7.5	2.2	11.9	7.6	3.0
5	17.5	11.9	3.5	21.6	15.6	5.0	8.5	5.4	1.4	12.1	7.6	2.6
6	8.8	6.1	1.5	13.0	8.7	3.1	5.8	3.9	0.9	5.9	3.7	1.5
Annual Yield	111.3	77.4	19.1	148.6	101.0	26.9	55.2	35.6	7.8	73.1	47.2	13.1
		CVL			GVL			CVL			GVL	
1	9.5	7.7	2.1	14.9	11.8	3.1	3.6	2.8	0.8	9.8	7.5	2.0
2	18.2	12.5	2.8	18.1	12.7	3.8	4.8	3.0	0.6	11.6	8.0	2.3
3	21.3	13.9	2.2	19.2	14.0	3.4	9.6	6.0	0.8	10.6	6.8	1.9
4	19.3	13.1	4.0	25.1	17.0	4.4	7.4	4.5	1.1	14.8	9.1	2.5
5	15.4	10.8	3.1	22.6	15.8	5.8	6.9	4.7	1.1	10.3	6.0	2.5
6	10.7	7.2	1.9	15.6	9.5	4.7	3.8	2.4	0.6	7.8	5.4	1.4
7				13.9	9.9	3.6				5.4	3.6	1.4
8				10.9	7.2	2.8				5.2	3.4	1.3
9				5.6	3.9	1.5				3.4	2.1	0.9
Annual Yield	94.3	65.2	16.0	145.7	101.7	32.9	36.0	23.4	4.9	78.9	52.1	16.1
		CVH			GVH			CVH			GVH	
1	15.8	12.9	3.4	12.3	9.4	2.8	7.0	5.4	1.3	7.4	5.5	1.6
2	17.6	12.4	2.6	16.7	12.8	3.0	6.4	4.2	0.8	9.2	6.1	1.6
3	23.5	15.8	2.5	25.5	17.9	3.6	15.6	9.9	1.5	12.3	8.4	1.7
4	21.2	14.1	4.2	24.4	15.1	3.5	13.7	8.3	2.3	15.4	9.4	2.1
5	16.4	11.5	3.2	23.8	15.1	4.9	8.7	5.9	1.4	17.0	10.6	3.8
6	11.6	8.1	2.4	17.0	11.5	3.8	7.6	4.6	1.2	7.5	4.5	2.0
7	8.8	5.6	1.6	13.3	9.0	3.3	6.0	3.9	1.0	4.7	2.8	1.1
8				10.7	6.9	2.9				4.3	2.5	1.0
Annual Yield	114.9	80.3	19.8	143.7	97.7	27.9	65.0	42.1	9.5	77.7	49.8	14.3

Appendix 9 **Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 6, 1961 (100 lb/ac)**

	Available herbage						Residual herbage					
	Cutting			Grazing			Cutting			Grazing		
Defoliation No.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	21.6	16.4	4.2	22.3	17.9	4.0	4.8	3.5	0.6	5.7	4.1	0.9
2	22.0	16.4	2.9	23.7	17.4	4.2	7.1	4.9	0.8	9.3	6.1	1.5
3	19.1	12.9	2.8	24.1	16.2	4.0	8.0	5.3	0.8	11.7	7.3	1.8
4	19.2	12.8	4.2	21.3	14.7	4.6	8.0	4.4	1.2	11.0	7.4	2.3
5	13.8	9.7	2.9	20.8	13.9	4.9	6.9	4.7	1.2	13.0	8.1	3.0
6	9.8	6.7	1.8	11.9	7.9	2.9	3.9	2.5	0.6	4.7	2.9	1.3
Annual Yield	105.4	74.9	18.8	124.1	88.0	24.6	38.6	25.3	5.3	55.3	35.8	10.8
		CMH			GMH			CMH			GMH	
1	26.7	20.1	4.6	19.5	15.7	3.6	8.1	5.9	1.1	5.9	4.5	0.9
2	28.0	20.7	3.6	23.1	17.1	3.8	11.7	8.3	1.1	9.4	6.4	1.3
3	20.3	13.1	2.8	21.1	14.1	3.3	12.4	8.1	1.1	9.0	5.8	1.1
4	18.3	12.2	3.6	23.5	16.3	4.8	9.8	6.1	1.5	8.6	5.7	1.6
5	15.7	10.8	3.0	18.7	12.9	4.1	7.6	4.9	1.1	10.7	6.5	2.0
6	11.0	7.3	1.8	11.7	7.8	2.7	5.9	3.8	0.8	4.0	2.3	0.8
Annual Yield	120.1	84.1	19.3	117.6	83.8	22.3	55.4	36.9	6.7	47.6	31.1	7.7
		CVL			GVL			CVL			GVL	
1	14.8	11.8	3.4	16.8	13.4	3.4	6.2	4.7	1.0	11.7	8.8	2.3
2	32.8	25.1	4.1	22.8	17.5	4.1	8.4	5.9	0.8	9.5	6.4	1.5
3	19.5	13.0	2.7	23.1	17.3	3.7	10.9	6.8	1.1	7.5	4.7	0.9
4	17.8	12.0	4.0	21.5	15.4	4.3	10.3	5.9	1.8	13.5	8.7	2.8
5	17.8	12.3	3.6	16.8	11.0	4.0	5.2	3.5	0.8	12.6	7.9	2.8
6	5.8	4.2	1.1	16.4	11.4	3.9	3.3	2.3	0.5	7.9	5.1	1.7
7				12.7	8.8	3.6				7.2	4.5	2.0
8				10.8	7.5	3.0				6.3	4.0	1.7
9				9.2	6.2	2.4				5.6	3.5	1.5
Annual Yield	108.5	78.4	18.9	150.1	108.4	32.3	44.4	28.9	5.9	81.7	53.6	17.2
		CVH			GVH			CVH			GVH	
1	17.0	13.6	3.8	16.4	13.0	3.2	7.3	5.5	1.2	10.9	8.3	1.8
2	29.3	22.4	4.0	25.3	19.5	4.0	12.3	9.0	1.2	10.5	6.8	1.5
3	25.1	17.7	3.1	23.7	18.2	3.2	14.0	9.6	1.5	10.3	6.9	1.1
4	20.2	12.7	4.4	21.8	15.4	3.9	11.7	6.7	1.9	13.6	8.6	2.4
5	17.3	11.9	3.4	17.3	11.5	3.7	7.8	4.9	1.2	9.3	5.5	1.7
6	9.6	6.4	1.9	13.8	9.6	3.1	6.4	4.1	1.0	7.0	4.4	1.5
7				12.8	8.7	3.2				5.0	2.9	1.0
Annual Yield	118.6	84.7	20.6	131.1	95.8	24.3	59.6	39.8	8.1	66.7	43.4	10.9

Appendix 10 Seasonal and annual herbage yields for the available and residual herbage for each treatment in experiment 6, 1962 (100 lb/ac)

Defoliation No.	Available herbage						Residual herbage					
	Cutting			Grazing			Cutting			Grazing		
	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.	O.M.	D.O.M.	C.P.
		CML			GML			CML			GML	
1	22.9	17.4	4.6	23.6	18.9	4.3	11.2	8.6	1.8	12.6	9.3	2.4
2	31.7	25.5	3.8	36.1	28.0	5.4	11.4	8.3	1.0	13.6	9.3	1.5
3	20.7	14.4	2.6	23.3	16.2	3.8	12.2	7.8	1.1	5.9	3.4	0.8
4	16.3	11.3	3.0	17.1	12.0	4.1	8.7	5.4	1.1	6.5	4.4	1.5
5	15.8	11.2	2.5	21.1	15.8	5.4	6.7	4.3	0.7	5.3	3.4	1.2
6	9.3	6.6	1.6	11.6	8.7	3.0	6.2	4.2	0.8	2.1	1.4	0.5
Annual Yield	116.7	86.4	18.0	152.8	99.7	25.9	56.4	38.6	6.6	45.8	31.2	7.8
		CMH			GMH			CMH			GMH	
1	21.7	16.4	4.5	22.5	18.4	4.3	17.0	12.9	3.0	13.3	9.9	2.4
2	37.5	29.6	4.7	33.2	26.0	4.5	17.5	12.1	1.6	14.2	10.2	1.4
3	28.4	19.2	3.4	22.6	16.0	3.9	19.3	12.0	1.7	5.7	3.4	0.6
4	20.0	13.5	3.6	18.1	12.6	3.9	13.1	7.7	1.6	6.0	4.0	1.2
5	18.7	12.7	2.8	20.5	15.4	4.8	10.1	5.9	1.0	5.8	3.7	1.1
6	11.7	8.1	1.9	11.5	8.4	2.7	7.4	4.7	0.9	2.7	1.8	0.6
Annual Yield	138.0	99.5	20.9	128.5	96.7	24.0	84.5	55.3	9.8	47.7	32.9	7.3
		CVL			GVL			CVL			GVL	
1	22.3	17.3	4.3	23.8	19.1	4.2	7.7	5.4	1.3	11.3	8.3	2.0
2	27.9	21.3	3.1	32.6	25.0	5.0	8.6	6.2	0.7	16.2	11.3	2.0
3	23.0	16.3	4.0	23.3	16.7	3.1	6.6	4.2	0.7	12.5	7.9	1.4
4	14.8	10.8	2.1	17.9	12.2	3.5	6.3	4.3	0.7	11.3	6.8	2.0
5	6.9	4.9	1.2	19.5	13.8	4.6	4.9	3.2	0.7	11.5	7.8	2.7
6				11.5	8.1	2.9				6.4	4.1	1.6
7				9.3	6.5	2.4				3.6	2.5	0.8
Annual Yield	94.9	70.6	14.7	137.8	101.5	25.8	34.1	23.3	4.1	72.7	48.7	12.5
		CVH			GVH			CVH			GVH	
1	29.4	22.7	5.8	25.9	20.6	4.7	13.0	9.2	2.1	11.2	7.8	1.7
2	33.6	25.8	3.9	30.5	23.9	4.1	17.6	12.5	1.5	15.8	10.7	1.2
3	25.1	16.5	4.1	26.4	19.0	3.6	14.7	9.2	1.7	10.1	6.5	1.0
4	17.5	12.6	2.8	14.5	9.9	3.4	11.2	6.9	1.3	9.4	5.7	1.6
5	9.5	6.5	1.7	11.5	8.6	2.6	6.3	4.0	0.9	5.5	3.4	1.0
6				13.5	10.2	3.1				6.1	4.4	1.3
Annual Yield	115.0	84.1	18.4	122.3	92.3	21.6	62.8	41.8	7.4	5[illegible].1	38.6	7.8

Appendix 11 Paper presented at the 9th International Grassland Congress, São Paulo, Brazil on 7th - 20th January, 1965. (Session 17 - Experimental techniques in pasture research)

THE EFFECTS OF CUTTING AND GRAZING TECHNIQUES ON PRODUCTIVITY OF GRASS/CLOVER SWARDS

Summary

The productivities of perennial ryegrass/white clover swards were measured under eight different techniques of cutting and grazing. Herbage yields were increased by grazing compared to cutting, particularly when fertiliser nitrogen was applied, by low compared to high defoliation and by infrequent compared to frequent defoliation. The percentage white clover was reduced by grazing and further depressed by fertiliser nitrogen. The results indicate the practicability and desirability of using grazing animals in the agronomic evaluation of herbage varieties.

Resumo

Os premios das produtividades do centeio falso/trêvo branco foram medidos sob tecnicos de visáo differentes ceifar e de pastar os produtos de verdura foram aumentados pela pastagem comparada com a cortadura, particularmente quando se apiicava o fertilizador nitrogeneo, por baixo antes que por alto desfolhaments e por infrequente em comparação com desfolhamento frequente. A porcentagem do trêvo branco foi reduzida por pastagem e deprimido além disso por fertilizador nitrogenio. Indicam os resultados a praticalabilidade a ánsia de empregar animais de pasto na avaliação agronomica das variedades de verdura.

Introduction

In spite of the fact that grassland in the world is chiefly utilised by grazing animals (6) the agronomic value of herbage varieties is commonly assessed by some form of cutting technique. Such techniques have virtues of speed, ease and economy but may be criticised in that the grazing animal, with its effects on the sward of treading, selective grazing and excretion, is ignored. The expenditure required in time, effort and money to make large-scale use of grazing animals in variety-testing is prohibitive, and more so if it is ultimately desired to express the productivities of the varieties in terms of animal output. The use of grazing animals to 'condition' varieties combined with cutting schedules to measure their herbage yields under this conditioning offers a compromise. This technique has been studied experimentally at the West of Scotland Agricultural College over the past few years by comparing the productivity of grass/clover swards under different regimes of cutting and grazing (7). Some data from experiments in 1961 are presented below.

Experimental/

Experimental

Two swards were established by sowing seed mixtures (a) 30 lb S.24 perennial ryegrass (Lolium perenne L.) and (b) 30 lb S.23 perennial ryegrass per acre, each with 1 lb S.100 white clover (Trifolium repens L.) per acre under oats in 1960. Four identical trials, two in each sward, were conducted in 1961. One trial in each sward received no fertiliser nitrogen (N) during the season (S.24/N_0; S.23/N_0) and the other, 52 lb N per acre in early spring and 52 lb N per acre in mid-summer (S.24/N_1; S.23/N_1). Each trial had an experimental area of ¼ acre and a holding paddock of 1 acre which carried a flock of 13 sheep. The experimental treatments were:

(A) Defoliation method

Cutting (C)
Grazing (G)

(B) Severity

Low (L)	1-1½ in.)	from ground level
High (H)	2-2½ in.)	

(C) Frequency

Monthly (M)
Variable (V) 7-9 in. tall herbage

A split-plot statistical design was used, with the defoliation method in 20 x 40 ft main-plots and the frequency-severity treatments in 20 x 10 ft sub-plots. There were four replications. The variable frequency sub-plots were defoliated independently as the herbage reached 7-9 inches tall. An auto-scythe was used to impose the cutting treatments. The grazed plots were individually fenced and grazed as follows:

ML - 3 sheep for 2 days	VL - 3 sheep for 1½ days
MH - 2 sheep for 2 days	VH - 2 sheep for 1½ days

Sub-plot yields were calculated from the difference between pre- and post-treatment cuts, using power-driven Wolseley sheep shears with a 3-inch cutting comb to shear randomly-distributed sample strips of herbage to ground level. From analyses of these pre- and post-treatment cuts, yields (i.e. utilised herbage) were determined as organic matter (O.M.), digestible organic matter (D.O.M.) and crude protein (C.P.). Digestibility was estimated by the *in vitro* method of Tilley *et al.* (12) as modified by Alexander and McGowan (1). The botanical composition of fresh pre-treatment herbage was analysed at each defoliation by hand separation.

Results

Defoliation

The number of defoliations during a season lasting from April to October under the various treatments in each sward are shown in Table 1.

Table 1 Number of defoliations in each trial during season

Treatment	Trial $S.24/N_0$	$S.24/N_1$	$S.23/N_0$	$S.23/N_1$
MCL	6	6	6	6
MCH	6	6	6	6
VCL	6	6	6	6
VCH	6	7	6	6
MGL	6	6	6	6
MGH	6	6	6	6
VGL	7	9	6	9
VGH	7	8	6	7

Herbage yields

Annual herbage yields for the two trials on the S.24 perennial ryegrass/ S.100 white clover sward are shown in Table 2.

Table 2 Yields of organic matter, digestible organic matter and crude protein (100 lb/ac.) for trials $S.24/N_0$ and $S.24/N_1$

Treatment	$S.24/N_0$ O.M.	D.O.M.	C.P.	$S.24/N_1$ O.M.	D.O.M.	C.P.
Defoliation method						
Cutting	50.4	37.7	9.2	55.4	41.0	11.0
Grazing	54.4	39.8	9.1	72.0	52.4	14.6
S.E. of difference	± 3.1	± 2.2	±0.8	± 2.5	± 1.7	± 0.1
P	NS	NS	NS	< 0.01	< 0.01	< 0.001
Severity						
Low	53.8	39.7	9.2	65.5	47.9	13.4
High	51.0	37.9	9.2	61.9	45.4	12.2
S.E. of difference	± 2.1	± 1.6	±0.5	± 1.4	± 1.1	± 0.4
P	NS	NS	NS	< 0.05	< 0.05	< 0.05
Frequency						
Monthly	51.2	38.1	9.1	67.1	48.9	12.7
Variable	53.6	39.5	9.2	60.3	44.4	13.0
S.E. of difference	± 2.1	± 1.6	±0.5	± 1.4	± 1.1	± 0.4
P	NS	NS	NS	< 0.001	< 0.001	NS

NS = Not significant

In the $S.24/N_0$ trial, differences in the yields of organic matter, digestible organic matter and crude protein, as a result of the treatments, were not significant. In the $S.24/N_1$ trial, grazing significantly increased yields compared to cutting, whilst the yields were also significantly increased by low compared to high defoliation, and with the exception of crude protein, by monthly compared to variable frequency defoliation.

The annual organic matter, digestible organic matter and crude protein yields for the S.23/N_0 and S.23/N_1 trials are shown in Table 3.

Table 3 Yields of organic matter, digestible organic matter and crude protein (100 lb/ac.) for trials S.23/N_0 and S.23/N_1

Treatment	S.23/N_0 O.M.	S.23/N_0 D.O.M.	S.23/N_0 C.P.	S.23/N_1 O.M.	S.23/N_1 D.O.M.	S.23/N_1 C.P.
Defoliation method						
Cutting	51.7	40.6	11.3	63.7	47.8	12.9
Grazing	58.9	45.2	11.3	67.9	53.0	14.2
S.E. of difference	± 1.3	± 1.0	± 0.6	± 1.7	± 1.5	± 0.3
P	< 0.05	< 0.05	NS	NS	< 0.05	< 0.05
Severity						
Low	57.9	44.9	11.5	67.1	51.5	13.8
High	52.7	40.9	11.2	64.5	49.3	13.3
S.E. of difference	± 1.3	± 0.9	± 0.4	± 2.4	± 1.8	± 0.6
P	< 0.001	< 0.001	NS	NS	NS	NS
Frequency						
Monthly	52.5	41.1	10.7	67.6	50.4	13.6
Variable	58.1	44.7	12.0	64.0	50.4	13.5
S.E. of difference	± 1.3	± 0.9	± 0.4	± 2.4	± 1.8	± 0.6
P	< 0.001	< 0.01	< 0.01	NS	NS	NS

NS = Not significant

Yields of organic matter and digestible organic matter but not crude protein, were significantly increased by grazing compared to cutting in the S.23/N_0 trial. Variable frequency defoliation significantly increased yields of organic matter, digestible organic matter and crude protein relative to monthly and low defoliation increased yields relative to high.

In the S.23/N_1 trial, organic matter, digestible organic matter and crude protein yields were increased, the latter significantly so, by grazing compared to cutting. The yields did not differ significantly as a result of the frequency-severity treatments, although the trends were similar to those of the S.24/N_1 trial.

The effect of grazing on seasonal yields in all the trials was to partly offset the midsummer slump, typical of cut, especially monthly cut, swards. Figure 1 illustrates this in trial S.24/N_1 using four of the treatments as examples.

Herbage composition

Post-treatment herbage samples had consistently lower organic matter

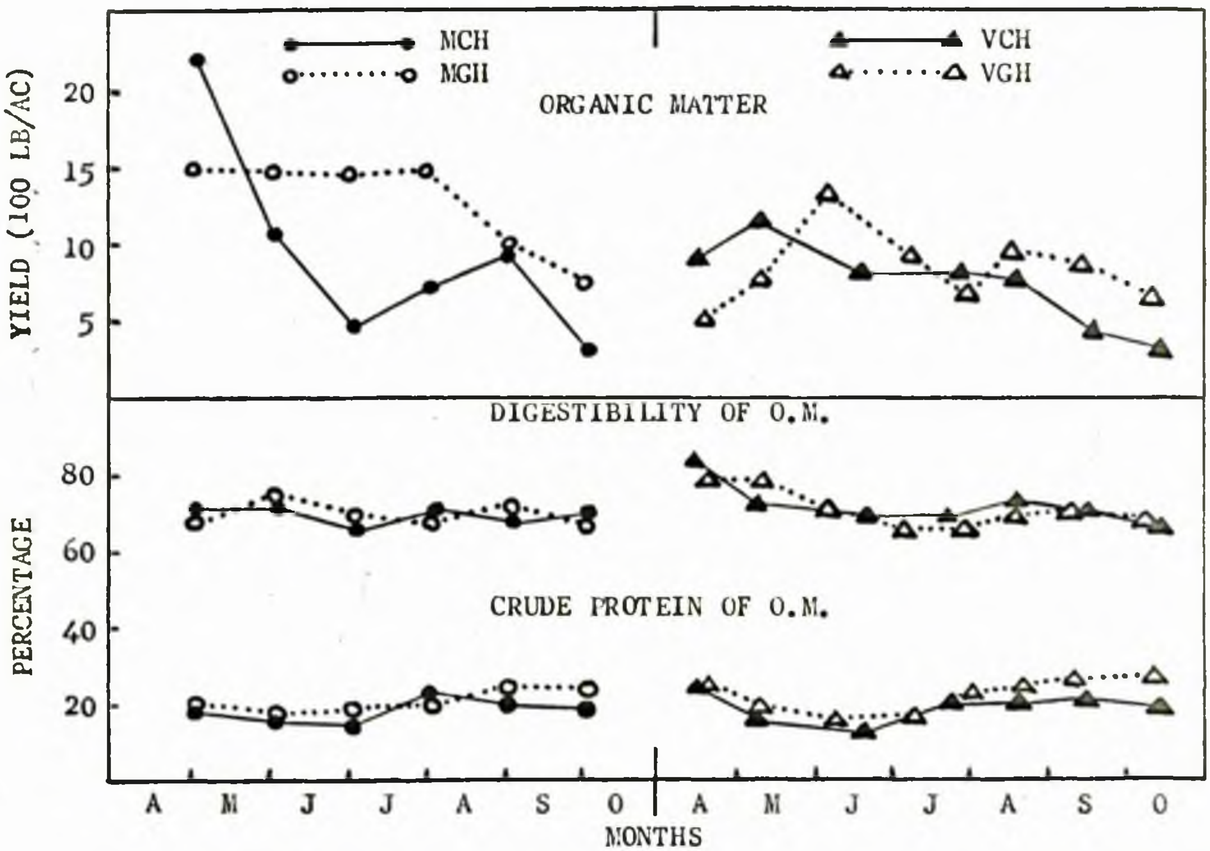

Figure 1 Seasonal distribution of (1) organic matter yield and (2) percentage digestibility and percentage crude protein of organic matter in pre-treatment herbage from treatments MCH:MCH and VCH:VGH of Trial S.24/N$_1$.

percentage than pre-treatment samples in the four trials (Table 4).

Table 4 Mean organic matter percentages in the total herbage dry matter in each trial

Trial	Cutting Pre-cuts	Cutting Post-cuts	Grazing Pre-cuts	Grazing Post-cuts
S.24/N_o	83.8	77.2	84.6	74.2
S.24/N_1	84.9	78.3	84.4	74.3
S.23/N_o	83.0	78.0	82.7	79.6
S.23/N_1	81.1	77.3	83.4	76.4

The percentage digestibilities of the organic matter in the various treatments of the four trials were very similar. Herbage regrowths lay chiefly in the 68 to 72% range. The percentages in post-treatment herbage stubble were usually 3 to 5% lower than in pre-treatment herbages. Figure 1 shows examples of the percentages in the latter for trial S.24/N_1.

The pattern of crude protein percentages in the organic matter was similar in all the trials, although the level of percentages was slightly higher in the two trials receiving fertiliser nitrogen. Herbage regrowths ranged mainly from 17 to 22% and post-treatment herbage, 14 to 20%. Differences between pre- and post-treatment herbage were less marked under grazing. Figure 1 illustrates the pattern in the S.24/N_1 trial.

Sward botanical composition

As the incursion of unsown species was negligible, the main botanical changes occurred in the balance between sown grass and clover. Perennial ryegrass fractions were increased and clover fractions decreased by the application of fertiliser nitrogen compared to no application between the trials and by grazing compared to cutting within each trial. These effects, which were similar in all treatments, are illustrated by Figure 2 which shows the seasonal distribution of clover in the four trials, using MCH and MGH treatments as examples. The frequency-severity treatments caused slight but consistent changes in each trial in that perennial ryegrass proportions were raised and white clover proportions lowered by low compared to high defoliation and by variable frequency compared to monthly defoliation.

Discussion

Organic matter and digestible organic matter yields were higher under grazing than cutting, although the differences were not always significant (Tables 2 and 3). Similar responses, on the basis of dry matter, were found by Jones (9) and Brockman and Wolton (2), using different sampling techniques.

Yield responses under grazing have been attributed to recirculation of sward nutrients, especially nitrogen, by the grazing animal (11). The effect appears to be cumulative (2). The effectiveness of recirculated nitrogen in increasing yield is low in grass/clover swards with no added fertiliser nitrogen, but high when nitrogen is applied (13, 14). Green and Cowling (8)

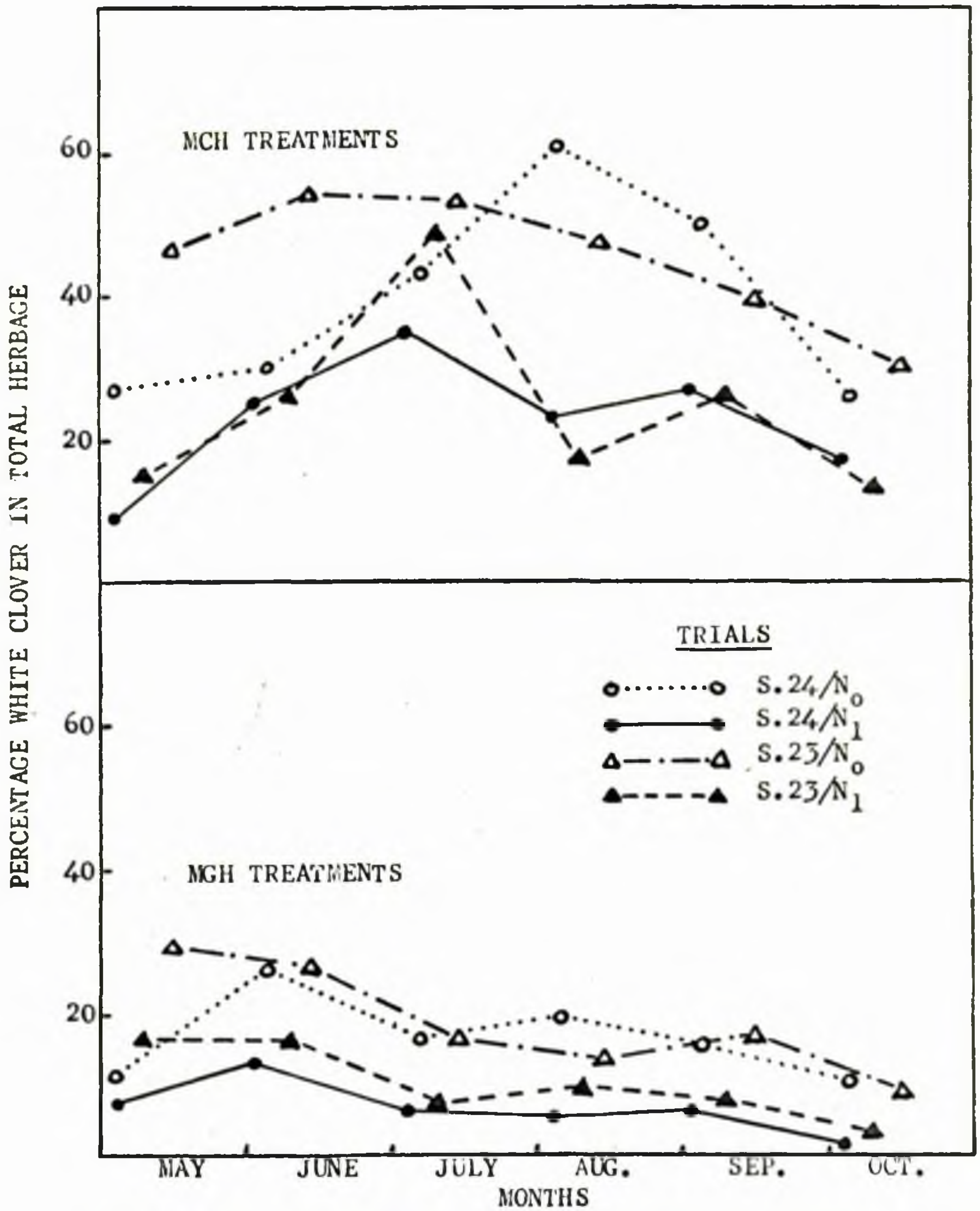

Figure 2 Effects of MCH and MGH treatments on the seasonal distribution of white clover in the four trials

THE EFFECTS OF DEFOLIATION SYSTEMS
ON THE PRODUCTIVITY OF
PERENNIAL RYEGRASS/WHITE CLOVER SWARDS

by

JOHN FRAME

Ph.D. Thesis Summary

There is need for accurate techniques to evaluate the large numbers of herbage varieties being released by plant breeders. There is also need for suitable techniques to measure and compare grassland productivity under various conditions of management. It would be logical to measure productivity under grazing systems because grazing is the most important method of grassland utilization. Since experimental resources of land, animals, equipment, labour and finance are usually limited, there is widespread reliance upon cutting systems, even although subject to the criticism that the grazing effects of trampling, selective grazing and return of excreta are absent. The shortcomings of present evaluation techniques are recognized in the United Kingdom and consequently there are no official lists of recommended herbage varieties.

The six experiments in this thesis were designed to determine the productivity of perennial ryegrass and perennial ryegrass/white clover swards under various cutting and grazing systems and to establish herbage yield relationships among the systems. The experimental treatments were cutting and grazing applied at various frequencies and severities of defoliation. Cutting treatments were applied by motor scythe and grazing treatments by sheep. The sheep, enclosed in movable aluminium alloy folds or in individually-fenced plots, were used simply to defoliate the swards and to supply the grazing effects. Yields of pre- and post-treatment herbage were

determined by a technique of shearing sample strips of herbage to ground level with power-driven sheep shears. The difference between these yields provided estimates of the herbage utilized. Yields were expressed as organic matter, digestible organic matter and crude protein.

Botanically, there was a rapid increase in perennial ryegrass proportions and a concomitant decline in white clover under grazing relative to cutting. Chemically, organic matter, digestibility and crude protein contents in pre-treatment herbage were at higher levels than in post-treatment herbage, both annually and seasonally. Organic matter contents were lower under grazing relative to cutting and under severe compared with more lenient defoliation because of soil contamination. Contamination was intensified in wet weather and was greatest in herbage residues. Herbage digestibilities were little affected by treatment apart from early-season variation due to date of first cut. Crude protein contents were increased by grazing in comparison with cutting.

Under both cutting and grazing, utilized herbage yields were increased by infrequent compared with frequent defoliation and by severe relative to more lenient defoliation. These responses were small in relation to the yield superiority under grazing compared with cutting systems. On the ryegrass swards given fertilizer nitrogen, there were herbage yield increases under grazing of 14-16% for organic matter and 36-45% for crude protein. On ryegrass/clover swards given no fertilizer nitrogen, the yield advantages under grazing were 8-14% for organic matter and 6-13% for digestible organic matter but crude protein yields under cutting and grazing were similar. On the ryegrass/clover swards given fertilizer nitrogen, there were herbage yield increases under grazing of 7-13% for organic matter, 11-31% for digestible organic matter and 10-41% for crude protein.

The herbage yield increases under grazing systems were attributed principally to the recirculation of excretal nutrients, particularly urinary nitrogen. This recirculated nitrogen was more effective on grass swards than grass/clover swards because of antagonism between clover and excretal sources of nitrogen. Initially, external sources of nitrogen, whether excretal or fertilizer, suppressed clover and merely substituted for symbiotic clover nitrogen. Once grass dominance was achieved, the external input of nitrogen became more effective in increasing yield.

It is concluded that there is need to measure herbage productivity under grazing conditions in varietal evaluation and other forms of grassland research. The universal use of organic matter as the basic index of herbage yield is recommended in preference to dry matter in grassland experimentation, since it takes account of variable soil contamination of herbage. The agronomic small-plot grazing system used in the experiments is a practical technique of grassland evaluation. Because of cost, it will be impossible to adopt grazing techniques widely in place of cutting. It is therefore desirable to establish yield relationships between various cutting and grazing systems, so that the simpler cutting techniques can be retained and the results under particular grazing managements predicted. Relationships were satisfactorily established for perennial ryegrass and perennial ryegrass/white clover swards but there is need to establish further yield relationships using different grass genera, species and varieties with and without clover and with and without fertilizer nitrogen, since the results are most strongly influenced by these factors.

concluded that the extra grass yield from excretal nitrogen was counterbalanced by suppression of clover in grass/clover swards and suggested that excretal nitrogen would be more effective in grass-dominant swards. This inference is supported by Frame (7) and Bolton (15). From the yields of crude protein in the S.24/N_o and S.23/N_o trials (Tables 2 and 3) it may be inferred that the quantity of nitrogen available under cutting was equal to that under grazing. The yield responses of organic matter to grazing in these trials may have been related to differences in the degrees of utilisation of the herbage between the two defoliation systems. In the S.24/N_1 and S.23/N_1 trials, the quantity of nitrogen available under grazing was greater than under cutting and this is reflected in the organic matter yield responses.

The yields from low defoliation treatments were consistently greater than those from high in agreement with Reid (10). In the two trials which received fertiliser nitrogen, yields were greater under monthly defoliation than under variable frequency. Opposite results were obtained in the other two N_o trials. This can be explained on the basis of the greater number of defoliations under variable frequency in the N_1 trials (Table 1), as in general, increased frequency of cutting or grazing results in decreased yields (3).

The soil contamination associated with ground-level herbage sampling renders dry matter unsatisfactory as a measure of yield. Herbage yields were therefore calculated on the basis of organic matter. Contamination was greater in post-treatment than pre-treatment herbage due to treading by sheep and cutting machinery in the interim.

The percentage digestibilities in the organic matter of the herbage regrowths maintained a range of 6 to 72% throughout the season, after April defoliations in the variable frequency treatments, which were 78 to 82%. In spite of variation in clover content between equivalent treatments in the N_o and N_1 trials and in spite of the greater number of defoliations in the latter trials due to the application of fertiliser nitrogen, the level of digestibility percentages in the treatments in all the trials were very similar.

The changes in botanical composition as a result of treatment were typical and in general agreement with work elsewhere. Clover was suppressed by grazing, an effect mainly attributed to excretal nitrogen in the urine (2, 13, 14). Competition in a grass/clover sward, particularly in terms of nitrogen status and light relationships, has been reviewed by Donald (4). White clover is also susceptible to treading (5) and to selective grazing.

The results from these trials indicate the need to introduce grazing animals at some stage in the agronomic assessment of herbage varieties. Cutting can not simulate grazing and although it may prove possible to devise a cutting technique from which the effects of a particular grazing management can be predicted, the limitations are obvious when all the possible variations in grazing management are considered. Grazing effects are particularly important in the grass/clover sward due to their influence on botanical composition, and although it is simpler to test varieties in the pure grass sward, it is logical to assess them in grass/clover swards in the United Kingdom where most herbage species and varieties are used in grass/clover mixtures. The use of simple grazing techniques with stock to condition the sward, coupled with a suitable method of determining herbage yields would seem to be a promising basis from which to incorporate grazing into herbage variety evaluation and predict the effects of various systems of grazing management.

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Appendix 12 Paper presented at the 10th International Grassland Congress, Helsinki, Finland on 7th - 16th July, 1966 (Section 1 - Grassland production)

THE EVALUATION OF HERBAGE PRODUCTION UNDER CUTTING AND GRAZING REGIMES

Summary

The relationship between yields from comparable cutting- and grazing-regimes varied according to whether the sward was of pure grass or grass/clover. Interactions between excretal-, clover- and fertilizer-nitrogen were the main influences on herbage production in these swards. Trampling and selective grazing modified the influences. Since a general relationship is unlikely to be established for all swards, it will be more profitable to seek relationships within certain classes of sward and treatment. Because of the volume of grassland evaluation work, it is improbable that grazing techniques will replace cutting techniques. Further study on relationships is therefore justified.

Introduction

There is need for accurate techniques to evaluate the large numbers of herbage varieties being released by plant breeders. In the O.E.C.D. scheme (10) for varietal certification of the herbage seed moving in international trade, 873 cultivars were listed. There is also need for suitable techniques to measure and compare grassland production under various conditions of management.

It would be logical to measure herbage production under grazing regimes because grazing is the most important method of grassland utilization. Since experimental resources in land, animals, equipment, labour and finance are usually limited, cutting regimes are preferred, even though subject to the criticism that the effects of return of excreta, trampling and selective defoliation are absent. There is widespread reliance upon cutting to measure herbage production in the assessment of varieties (11) and in the evaluation of seed mixtures, fertilizers and other management factors (8).

The shortcomings of present evaluation techniques are recognized in the United Kingdom and consequently there are no official lists of recommended varieties. Instead, the National Institute of Agricultural Botany issue Farmers' Leaflets which list the herbage varieties most likely to be satisfactory for general use. For grass varieties, assessment is made on the basis of lateness of heading, early spring growth, hay yield, aftermath yield, autumn growth, persistency and winter hardiness.

Studies have been initiated at Auchincruive on the yield relationships under various cutting- and grazing-systems. Few studies of this nature have been conducted (1, 15), although relationships can be inferred from other studies (12, 18). If relationships could be shown to exist, the simpler cutting techniques could be retained and the results under grazing predicted. Preliminary data from grass and grass/clover swards have been published (4, 5). Further data from grass/clover swards are presented below.

Experimental

Two grass/clover swards were established in 1960 by sowing these seed mixtures: (i) 30 lb S.24 perennial ryegrass (Lolium perenne L.) and (ii) 30 lb S.23 perennial ryegrass per acre, each with 1 lb S.100 white clover (Trifolium repens L.) per acre. Two experiments, one in each sward, designated $S.24/N_0$ and $S.23/N_{104}$ were conducted over a period of 2 years after the year of sowing. The S.24 sward received no fertilizer N whilst the S.23 sward was given 52 lb N per acre in early spring and again in midsummer each year. Both swards received 81 lb P_2O_5 and 45 lb K_2O per acre each spring.

The experimental treatments were:

Defoliation methods

Cutting (C)
Grazing (G)

Defoliation intensities

Severity	Low (L)	1-1½ in.	from ground level
	High (H)	2-2½ in.	from ground level
Frequency	Monthly (M)		
	Variable (V)	7-9 in. herbage.	

In each experiment, a split-plot statistical design was used with 4 concurrently treated replications of the 2 defoliation methods as 20 x 40 ft main-plots and defoliation intensity treatments as 20 x 10 ft sub-plots.

Variable-frequency treatments were defoliated independently when the herbage reached a modal height per 4 replicates of 8 in. Cutting treatments, CLM, CHM, CLV and CHV, were applied by using a motor scythe with a cutting assembly which could be adjusted for cutting height. The grazing-intensity treatments were applied to single sub-plots as follows:

GLM - 3 sheep for 2 days   GHM - 2 sheep for 2 days
GLV - 3 sheep for 1½ days   GHV - 2 sheep for 1½ days

Each experiment had its own holding paddock of similar sward type on which the sheep were kept when not being used for the treatments.

At each cutting and grazing, pre-treatment herbage samples measuring available herbage and post-treatment samples measuring residual herbage were taken with power-driven sheep shears from randomly-chosen strips. The residual herbage strips were adjacent and parallel to the available herbage strips. Four sample pairs were taken from each cutting sub-plot but, because of higher variation, 8 sample pairs were taken in each grazing sub-plot.

The yields (i.e. utilized herbage) from the treatments were expressed as organic matter (O.M.), digestible organic matter (D.O.M.) and crude protein (C.P.). Organic matter was chosen as the yield basis since it takes account of the soil contamination of herbage from ground-level sampling. Adjustment of dry-matter data for the soil contamination, shown to occur even at cutting heights of ½-¾ in., was practised by earlier workers (2, 19). Digestibility was measured by the *in vitro* method. Botanical analyses were made by hand separation on samples of fresh pre-treatment herbage.

Results

Number of defoliations

In both growing seasons lasting from April to October, there were 6 defoliations under monthly treatments. Variable-frequency treatments resulted in 6-9 grazings, compared with 5-6 cuttings, since herbage reached the required height more often with grazing.

Annual herbage yields

Treatment differences in annual yield from either year, or from the sum of both years, on $S.24/N_0$ were small and not significant, except for the increase of 60 lb/ac crude protein from low defoliation over high defoliation in the second year (Table 1). Where differences occurred, they favoured grazing rather than cutting, low- compared with high-defoliation and variable rather than monthly frequency defoliation.

In experiment $S.23/N_{104}$, there were increases in yield from grazing over cutting, low- over high-defoliation and monthly over variable frequency defoliation. These increases generally reached significance in the second year. The development of yield under cutting and under grazing during the course of the 2 seasons is illustrated for 2 treatments, CHV and GHV, in Figure 1.

Botanical composition

Grazing caused a reduction of clover and a corresponding increase in rye-grass, relative to cutting (Table 2). Severity and frequency of defoliation had less effect.

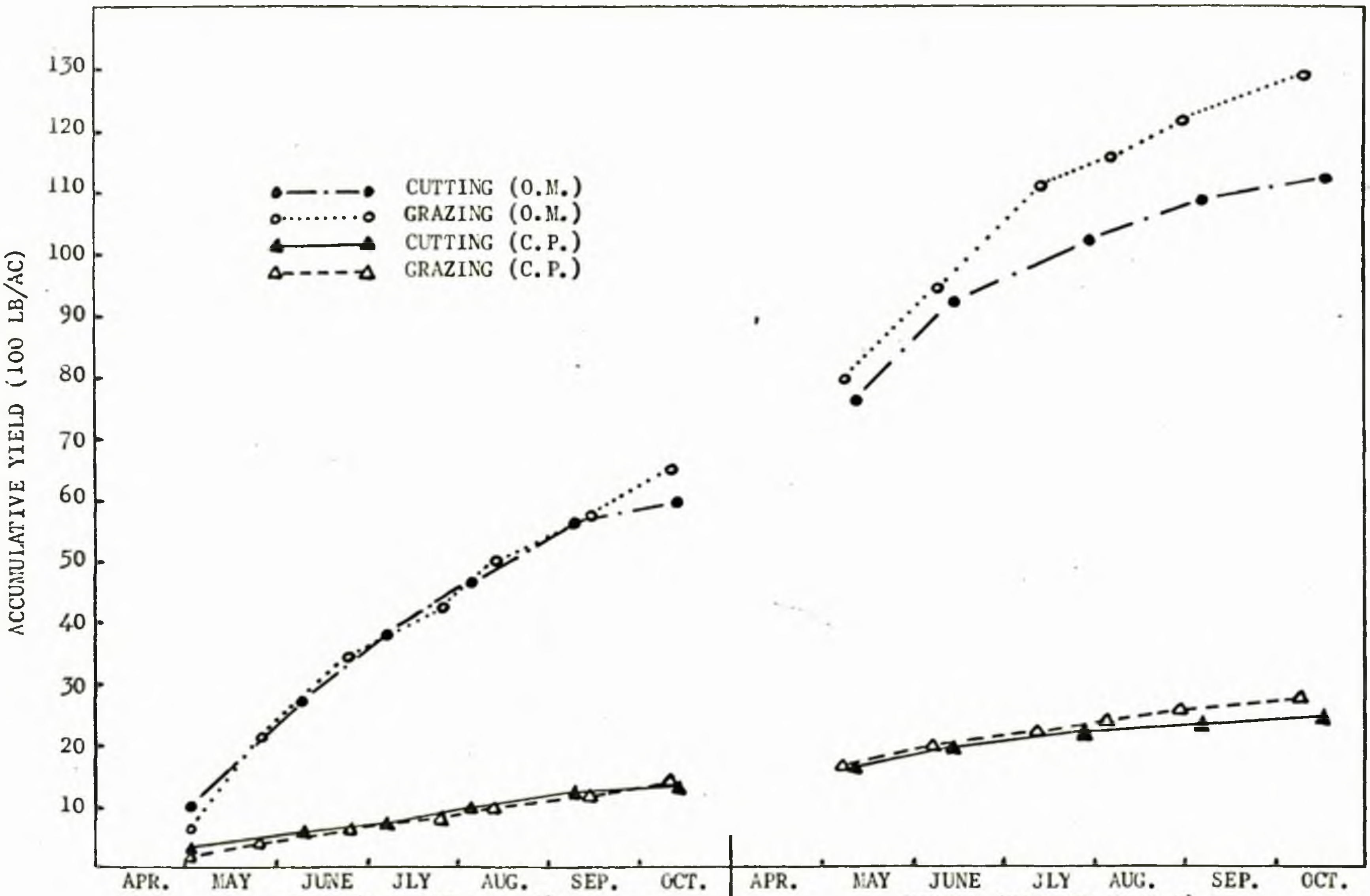
Treatment differences were evident in botanical composition figures during seasons. In $S.24/N_0$, grazing reduced the clover to 5-20% of the sward throughout each season, whereas with cutting, clover made up 5-20% at the start and finish, but 40-60% at the midseason. In $S.23/N_{104}$, clover was reduced to 1-5% by grazing, but with cutting, made up 10-20% at the beginning and end, and 20-40% at the midseason.

Table 1/

Table 1 Annual herbage yields in experiments S.24/N_5 and S.23/N_{104} (100 lb/ac)

Harvest year :-	Organic matter 1	Organic matter 2	Digestible organic matter 1	Digestible organic matter 2	Crude protein 1	Crude protein 2
Experiment S.24/N_5						
Method						
Cutting	50.4	52.0	37.7	40.9	9.2	9.8
Grazing	54.4	58.5	39.8	46.2	9.1	10.2
Sd	± 3.1	± 3.0	± 2.2	± 2.5	± 0.8	± 0.3
P	NS	NS	NS	NS	NS	NS
Severity						
Low	53.8	56.0	39.7	44.2	9.2	10.3
High	51.0	54.4	37.9	43.0	9.2	9.7
Sd	± 2.1	± 1.5	± 1.6	± 1.1	± 0.5	± 0.3
P	NS	NS	NS	NS	NS	< 0.05
Frequency						
Monthly	51.2	54.2	38.1	42.9	9.1	10.1
Variable	53.6	56.3	39.5	44.3	9.2	9.9
Sd	± 2.1	± 1.5	± 1.6	± 1.1	± 0.5	± 0.3
P	NS	NS	NS	NS	NS	NS
Experiment S.23/N_{104}						
Method						
Cutting	63.7	56.7	47.8	45.5	12.9	11.0
Grazing	67.9	74.3	53.8	59.7	14.2	15.5
Sd	± 1.7	± 0.8	± 1.5	± 3.0	± 0.3	± 0.9
P	NS	< 0.001	< 0.05	< 0.001	< 0.05	< 0.001
Severity						
Low	67.1	68.3	51.5	54.1	13.8	13.3
High	64.5	62.7	49.3	51.0	13.3	13.1
Sd	± 2.4	± 1.6	± 1.8	± 2.5	± 0.6	± 0.8
P	NS	< 0.01	NS	< 0.05	NS	NS
Frequency						
Monthly	67.6	70.4	50.4	56.1	13.6	14.5
Variable	64.0	60.6	50.4	49.0	13.5	12.2
Sd	± 2.4	± 1.6	± 1.8	± 2.5	± 0.6	± 0.8
P	NS	< 0.001	NS	< 0.001	NS	< 0.001

Sd = Standard error of difference between means
NS = Not significant



<u>Figure 1</u> Accumulative herbage yields from treatments CHV and GHV in harvest years 1 and 2 of Experiment $S.23/N_{104}$

Table 2 Weighted mean percentage botanical composition data in experiments $S.24/N_0$ and $S.23/N_{104}$

	Experiment $S.24/N_0$				Experiment $S.23/N_{104}$			
	Harvest year 1		Harvest year 2		Harvest year 1		Harvest year 2	
	Ryegrass	Clover	Ryegrass	Clover	Ryegrass	Clover	Ryegrass	Clover
Method								
Cutting	61.6	36.9	66.8	31.7	71.9	26.5	82.5	16.6
Grazing	87.3	10.9	91.4	7.1	91.1	7.3	97.6	1.8
Severity								
Low	76.4	22.1	80.1	18.3	82.1	16.4	91.0	8.4
High	72.5	25.7	78.2	20.5	80.8	17.3	89.1	10.0
Frequency								
Monthly	71.3	26.9	80.7	17.8	80.7	17.7	89.3	9.9
Variable	77.5	20.9	77.5	21.1	82.3	16.1	90.8	8.5

Chemical composition

In both experiments pre-treatment herbage had consistently higher contents of organic matter, digestible organic matter and crude protein than post-treatment herbage (Table 3).

Table 3 Weighted mean chemical composition for pre- and post-treatment herbage in experiments $S.24/N_0$ and $S.23/N_{104}$

	Harvest year 1						Harvest year 2					
	% O.M.		% Dy* (O.M.)		% C.P.** (O.M.)		% O.M.		% Dy (O.M.)		% C.P. (O.M.)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Experiment $S.24/N_0$												
Method												
Cutting	84.1	77.5	71.5	67.7	15.9	13.0	86.0	79.3	74.5	69.1	16.4	13.4
Grazing	84.7	75.5	69.8	66.6	16.0	15.4	82.4	74.9	75.0	67.1	17.0	16.1
Severity												
Low	84.5	74.0	71.1	67.7	16.1	14.6	83.7	75.5	74.9	68.0	17.4	15.8
High	84.3	79.0	70.2	66.6	15.7	13.7	84.7	78.8	74.5	68.2	16.0	13.8
Frequency												
Monthly	83.6	75.1	70.6	66.9	16.4	14.8	83.7	76.8	74.7	67.0	17.0	14.8
Variable	85.2	77.9	70.7	67.5	15.5	13.5	84.6	77.5	74.8	69.2	16.4	14.8
Experiment $S.23/N_{104}$												
Method												
Cutting	81.2	76.6	71.2	66.0	17.1	13.2	83.9	79.1	73.4	67.1	15.5	11.8
Grazing	84.0	77.3	71.9	65.2	19.7	18.3	83.9	78.1	74.9	67.6	18.6	15.7
Severity												
Low	81.8	74.9	71.6	65.2	19.1	16.9	83.6	77.5	74.3	67.9	17.3	14.5
High	83.4	78.9	71.4	65.9	17.7	14.5	84.2	79.7	74.0	66.8	16.9	13.0
Frequency												
Monthly	82.9	78.6	70.8	65.5	18.2	15.4	83.8	78.6	74.1	67.7	17.2	13.9
Variable	82.3	75.3	72.2	65.6	18.7	16.1	84.0	78.6	74.2	67.0	16.9	13.6

* % Dy (O.M.) = % digestibility of the organic matter

** % C.P. (O.M.) = % crude protein of the organic matter

Available pre-treatment herbage was normally young, leafy regrowth, whereas residual herbage was chiefly stubble and dead leaf bases. The differences in organic matter contents reflect soil contamination whilst differences in digestibility and crude protein point to the higher feeding value of pre-treatment herbage. Treatment effects were few, slight and largely confined to residual herbage in both experiments. Organic matter content was reduced by grazing compared with cutting and by low relative to high defoliation. On the other hand, the crude protein content was increased by grazing.

Discussion

In experiment S.24/N_0, herbage yields under cutting and grazing were similar. There is an apparent lack of yield response to excretal N since approximately 50-60% of the total N ingested is available for re-utilization by the sward (16). This may be attributed to the loss of symbiotic N by the suppression of clover observed under the grazing regimes. Trampling and selective grazing would further depress clover relative to cutting. The similarity in crude protein yield under both defoliation methods supports the inference that the input of excretal N was offset by the loss of symbiotic N. The apparent ineffectiveness of recirculated N in increasing yield on grazed grass/clover swards has been noted by Herriott et al. (7).

Even although the sheep grazed above and below the heights regularly achieved by cutting, the weighted annual utilization coefficients (i.e. amount of herbage removed as a percentage of the amount available) were around 50-60% for both cutting and grazing. The yields from grazing treatments would be slightly underestimated since growth during the grazing periods, totalling 9-12 days per year, was not included.

Similar results under cutting and grazing were obtained on a dry matter basis by Sears (12), Sears et al. (13), Taylor et al. (15) and Wolton (18).

In experiment S.23/N_{104}, grazing regimes gave only a slight increase in herbage yield over cutting regimes in the first year, but the increase was appreciable in the second year. The results (Fig. 1) indicate that recirculated N was cumulatively effective in increasing yield. The crude protein yields in Table 1 show that more N was available under grazing than under cutting. The yield responses may be linked to the suppression of clover and the concurrent development of grass dominance under grazing, changes which were accelerated by the N fertilizer. This infers that recirculated N is more effective on grass than on grass/clover swards (6). Further data (4) in support of this inference, are shown in Table 4.

Table 4 Annual herbage yields in experiments on grass swards (100 lb/ac)

	Organic matter			Crude protein		
Experiment	a	b	c	a	b	c
Method						
Cutting	40.2	55.1	55.3	8.8	10.5	12.6
Grazing	45.7	63.3	65.3	12.0	14.3	19.1
Sd	±0.5	±4.2	±4.2	±0.1	±1.0	±1.0
P	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001

Similar results on grass swards have been reported by others (12, 13, 18) but the reverse was obtained by Bryant and Blaser (1).

Herbage production was consistently increased by low defoliation compared with high; the difference between monthly and variable frequency defoliation was simply the reduction in yield with increasing number of defoliations. These results agree with work done elsewhere (1, 15).

Thus, the yield under comparable cutting and grazing is modified chiefly by the interactions between the 3 main sources of N, viz. symbiotic fixation, animal excreta and fertilizer.

Apart from their effect on yield through changing the botanical composition, trampling and selective grazing affect the yield relationship directly. Trampling can reduce herbage yield (3) directly by physical damage to growing plants and indirectly through compaction and puddling of the top layer of soil, especially in wet weather. The high stocking rates in the Auchincruive experiments would undoubtedly lead to depression of yields from trampling. Selective grazing, with its progressive, repeated and uneven inter- and intra-plant and area defoliation, results in patchy regrowth. Selective grazing was reduced by the high stocking rates, but not eliminated, and regrowths were typically uneven. Thus, a depressive effect on yield due to selective grazing cannot be ruled out, though its extent is difficult to determine.

The results show that the relationship between yields from cutting- and comparable grazing-regimes varies with different classes of sward. The relationship may also vary with different species and varieties (9, 14, 17). Hence the possibility of a simple general relationship for all swards and all treatments is unlikely. It may, however, be possible to establish relationships within certain classes of swards and treatments. Cutting per se cannot simulate grazing, yet the volume of grassland evaluation work makes it impossible to adopt grazing techniques widely in place of cutting techniques. Further work along the lines of the experiments reported is therefore warranted.

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