THE ROLE OF CLOVER IN GRASSLAND

With particular reference to the use of nitrogenous fertilizer on grass-clover swards.

by

David Reid

Synopsis

A review of the literature on the role of clover in grassland has shown that the greatest agronomic and practical interest at present centres on the problem of obtaining maximum benefit both from the clover in grass-clover swards, and from fertilizer nitrogen applied to such swards. Two experiments are described in which some of the managerial and botanical factors involved in this problem have been studied.

Managerial factors investigated in the first experiment were stage of growth at cutting, closeness of cutting, and dates and rates of fertilizer nitrogen application. The effects of these on yield and contribution of clover from an established sward in which perennial ryegrass predominated were measured. Closeness of cutting was shown to be an important factor controlling clover growth. Clover yields were greater when the herbage was cut 1 inch from ground level than when it was cut 2-2½ inches from ground level, but continued use of heavy fertilizer nitrogen dressings appeared to reduce this difference. Total herbage yields were also consistently greater under close than under lax-cutting. This effect is tentatively explained with reference to flower-shoot development in the grasses, but the need for further investigation is stressed.

The principal factor controlling clover suppression was shown to be the total amount of fertilizer nitrogen applied over the season, clover yields being on average inversely proportional to this. The date on which the first fertilizer nitrogen dressing was applied in the spring also had a controlling influence. Delaying the first dressing until after the first or second cut of the season slightly increased clover yields where a total of 8-12 cwt. 'Nitro-Chalk'/acre (= 139-208 lb. nitrogen) was applied, but had no effect on clover where the total applied was only 4 cwt. (= 69 lb. nitrogen). At all

nitrogen levels total herbage yields were reduced by this delay, but the seasonal distribution of these yields was more uniform than where the first dressing was applied early in the spring.

In the second experiment certain botanical factors were investigated. A study was made of the relative values of S184, S100 and Kersey white clover, their compatability with S23 or S24 ryegrass, S143 or S37 cocksfoot, S48 timothy or S53 meadow fescue and their reaction to increasing rate of fertilizer nitrogen application. Again the principal factor controlling clover suppression was the total amount of fertilizer nitrogen applied over the season. In the first harvest year, however, a total application of 4 cwt. 'Nitro-Chalk'/acre (= 69 lb. nitrogen) increased the clover yields from S24 ryegrass, S48 timothy and no sown grass mixtures, and only slightly depressed those from S143 and S37 cocksfoot mixtures. This treatment depressed clover yields from all seeds mixtures in the second year; so also did a total application of 10 cwt. 'Nitro-Chalk'/acre (= 174 lb. nitrogen) in both years.

Yields from all three clover strains were, on average, equally depressed under each of the fertilizer nitrogen treatments though in the second harvest year S100 was slightly less affected by the light treatment than were S184 or Kersey. In general S100 was superior to Kersey in all except the S143 and S37 cocksfoot mixtures in the first harvest year, but Kersey was equal or superior to S100 in all but the S24 and no sown grass mixtures in the second year; S184 was the poorest yielding strain throughout, but its greater stolon development suggests that it might be more persistent than the other two strains.

Clover growth under fertilizer nitrogen treatment varied to a greater extent with the strain of grass than with the strain of clover included in the seeds mixture. Throughout the experiment S53 meadow fescue was the best companion grass for clover, while S143 and S37 cocksfoot were the poorest.

It is concluded that under certain conditions maximum benefit can be obtained both from the clover in grass-clover swards and from fertilizer nitrogen applied to such swards. These conditions include the use of seeds mixtures in which meadow fescue predominates; close but not too frequent defoliation of the sward; and application of only moderate amounts of fertilizer nitrogen, or, alternatively, the delay of the first dressing of the season until after the first or second cut, if greater total amounts of nitrogen are applied.

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A thesis submitted to the University of Glasgow for the degree of Doctor of Philosophy in the Faculty of Science.

by

DAVID REID

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The Hannah Dairy Research Institute

Kirkhill,

Ayr.

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CONTENTS

PART 3 page

PART 4

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PART 1

INTRODUCTION AND REVIEW OF LITERATURE

Davis & Cooper (23) have stated that the advent of white clover (*Trifolium repens*) into grassland farming, the appreciation of strain differences and the development of improved vigorous types by selection and breeding were among the outstanding features of agriculture during the first half of the twentieth century. The value of red clover (*Trifolium pratense*) has, of course, been appreciated for at least three centuries, the introduction of cultivated forms of this clover having occurred about the year 1600 (see reference 77). Although wild white clover is probably indigenous, it does not seem to have come into general use in seeds mixtures until the present century. Davies (20), however, believes that there was some appreciation of its value as early as the seventeenth century. In support of this he quotes Lisle (55), who stated in 1715 that wild white clover was being sown in Hampshire. At the present time white clover is recognised (95) as the most important pasture legume in the temperate zones of the world. It has been called the basis of the British ley farming system (95), and has certainly been the prime factor in the remarkable increase in grassland output achieved in New Zealand over the past few decades (51). The work of Gilchrist (31) from 1889 onwards was the principal factor stimulating the widespread use of wild white clover and other white clovers in Britain. Findlay (29) and Cruickshank (18) in Scotland were also pioneers in this development.

The beneficial effects on yield and quality of herbage resulting from the inclusion of white clover in seeds mixtures have been demonstrated by many workers. For example, in 1937 Johnstone-Wallace (44, 45) reported on an experiment in which yields of 888 and 3072 lb./acre dry matter were obtained from Kentucky bluegrass and wild white clover respectively when grown separately, but yields of 2245 and 2742 lb./acre respectively when grown together. The total yield of the mixed sward greatly exceeded, therefore, the yield of either crop grown alone. Sears (72), working in New Zealand, noted an increase of over

500% in total herbage yield through including white clover in the seeds mixture, the increase in the grass component of the mixture being over 100%. Holmes & MacLusky (39) obtained greater yields of dry matter and of crude protein from ryegrass or meadow-fescue grown with white clover than the same grasses dressed with 139-174 lb. fertilizer nitrogen. per acre. Results reported by Brown & Munsell (9) indicate a smaller benefit, Kentucky bluegrass and Rhode Island bent grass giving only slightly greater yields when grown with Ladino white clover than when grown alone and dressed with 84 lb./acre fertilizer nitrogen.

Russell (69) holds that in many experiments the nitrogen content of the dry matter of a cereal or a grass was raised when grown in association with a legume, and that of the legume was lowered. However, the yield of the non-legume and the total amount of nitrogen it took up per acre were nearly always reduced. The greenhouse and field experiment of Aberg, Johnson & Wilsie (1) showed no significant gains or losses in herbage or root yields over a season from both members of an association of a grass and a legume. Similar results were reported by Roberts & Olson (65) and by Mann & Barnes (59). The findings of all these workers were based on small scale, short duration experiments, and most other work suggests that so far as grassland is concerned, the inclusion of a legume has a beneficial effect on yield and chemical composition of herbage.

A large part of this benefit derives directly from the clover itself with its relatively high nitrogen content resulting from the fixation of atmospheric nitrogen by Rhizobia in nodules on the clover roots. The mechanism of symbiotic nitrogen fixation in the legumes is now well understood, and all the pertinent literature has been reviewed by Wilson (101). Clover has also an indirect beneficial effect on the associated non-legume, as the work of Lipman (52) and Lyon & Bizzell (54) showed early in the present century. It has been conclusively demonstrated that this results from the transfer of fixed nitrogen from the root nodules on the legume to the non-legume (see eg. 17, 44, 45, 72, 95). There is still, however, considerable controversy as to the mechanism involved in this transfer.

Whyte, Nilsson-Leissner & Trumble (95) hold that the nitrogen fixed in the nodules of herbage legumes such as white clover, is gained by the associated grass largely following ingestion of the clover leaf by the animal and subsequent excretion of nitrogenous products in the urine. Evidence of nitrogen transfer has, however, been obtained in many experiments (eg. 17, 56) in which the herbage has been defoliated mechanically and to which no animals have had access. The two principal theories which have been put forward to explain the transfer under such conditions are, firstly, direct excretion of nitrogenous compounds by the nodules into the soil, and, secondly, sloughing-off and subsequent decay of entire nodules releasing nitrogenous compounds into the soil.

Virtanen and his co-workers (eg. 84, 85, 86, 87) in Finland consistently demonstrated in pot-culture experiments direct excretion of nitrogenous compounds by legume nodules and consequent increase in nitrogen intake by associated non-legumes. Wilson (101), Wilson & Burton (102), Trumble & Strong (81), Bond & Boyes (5) and many other workers were unable to confirm Virtanen's results, and it appears to be generally accepted nowadays that this phenomenon occurs rarely (see eg. reference 95). Wilson (101) conducted a series of experiments in which he studied the effect of temperature, light intensity, season and day-length, and concluded that excretion can take place only when the rate of photosynthesis is sufficient to ensure a fairly high rate of nitrogen fixation but no excess of carbohydrate which 'ties up' the nitrogen as it is fixed. This relationship between photosynthetic and nitrogen-fixation rates could occur only under certain climatic conditions, most probably long days with low maximum temperatures and cool nights. Such conditions prevail during the summer months in Finland, thus explaining the discrepancies between Virtanen's results and those of other workers. Roberts (67) has, in fact, demonstrated a marked improvement in the growth of several grasses grown in association with a legume under these conditions.

In a recent review Butler & Bathurst (13) have concluded that the major mechanism contributing to nitrogen transfer is the sloughing off and decay of nodules. Wilson (100) also held this view, and he demonstrated that the process could be brought about by a number of factors, including defoliation, shading, drying out of soil or maturity of the plant. More recent greenhouse studies reported by Butler (12) have confirmed that shading or defoliation stimulates nodule and root decay. These studies showed that regrowth of new roots was very slow under shading, but that leaf, root and nodule development was rapid after defoliation. Butler has suggested that white clover is a more suitable 'transmitter' of nitrogen to the associated grass than red clover, since periodic defoliation of the stoloniferous white clover in these experiments induced rapid turnover of root and nodule tissue. On the other hand he believes that less root decay will accompany defoliation or shading of red clover, because of the greater carbohydrate reserves in the tap root system. White clover nodules were, in addition, found to have a higher nitrogen content than red clover nodules.

Butler & Bathurst (13) have suggested two other mechanisms which might contribute in small measure to nitrogen transfer. These are the leaching of nitrogenous compounds from clover leaves by rain, and the decay of fallen leaves and decapitated petioles.

Results reported by Sears (72) appear to confirm the superiority of white clover as a nitrogen 'transmitter'. He estimated from one experiment that in one year 230 lb./acre of the nitrogen in total herbage had been fixed in white clover nodules by Rhizobia, and of this 55 lb./acre had been transferred to the grass. In a red clover sward, on the other hand, 220 lb./acre were fixed in the clover nodules by Rhizobia, but only 23 lb./acre transferred to the grass. In another experiment Sears estimated that nearly 500 lb./acre of the nitrogen in total herbage were fixed in the nodules of white clover, and 140 lb./acre transferred to the grass. The last appear to be the highest estimates of amounts of nitrogen fixation and transfer reported. More normal estimates compare favourably with those reported by Cowling & Green (17). They calculated that in a cocksfoot sward containing 30-40% white clover and receiving no fertilizer nitrogen, the clover supplied 120 lb. nitrogen per acre of which 45 lb. was transferred to the grass.

Although nitrogen-transferring power has been shown to vary with species of legume, no such differences appear to have been noted between strains within a particular species. Strains or types of white clover have long been known, however, to vary considerably in productivity and persistency. Early investigations reported by Stapledon, Williams & Jenkin (78) indicated that white clover consisted of a number of strains which could be grouped according to well marked growth habits ranging from short and dense to tall and lax. Seed lots from the same source or of the same nationality were, however, far from pure with respect to growth habit, but contained varying proportions of different strains. For example, wild white clover was shown to consist mainly of short, dense plants of great persistency in pasture, while English commercial seed lots contained only a few plants of this type and produced on average much less dense herbage. Later trials reported by Williams (96) showed that even in the first harvest year ordinary commercial or Dutch white clover was much less productive than English wild white clover and many New Zealand white clover types. Here again, however, individual samples from the same source varied considerably. In a further experiment Williams (97) showed that New Zealand wild white clover outyielded English wild white in the first and second harvest years, but the reverse occurred in the third year. Dutch white clover was again poorest. Davies & Levy (21) also demonstrated the importance of strain in white clover in relation to productivity and persistency under New Zealand conditions.

An experiment in which the performance of various white clover strains was compared under grazing conditions has been reported by Davis & Cooper (23, 24). They measured the production, in terms of liveweight increase of sheep, from S23 ryegrass swards containing one of four different white clover strains. Kent wild white clover was the most productive and persistent strain over a four-year period, but differences between it and S100 were not great and there were no consistent differences in their seasonal yield distributions. New Zealand Certified Mother white clover was only slightly inferior to Kent wild white and S100, but Dutch white was considerably poorer throughout. In contrast to these results, Troughton (80) obtained greater yields of total herbage and of clover from S23 ryegrass swards when they contained S100 rather than the wild white clover type S184.

No evidence can be found to suggest that the performande and persistency of the various white clover strains vary with the particular species of grass growing in association, but a number of workers have shown that performance and persistency of white clover in general is affected by grass species. For example, Davies (19) found that by the third year of a trial cocksfoot was much more aggressive towards white clover than either ryegrass or timothy. Holmes & MacLusky (59) have reported similar results. Over the three-year period of an experiment described by Hunt (40, 41) the clover content of herbage from perennial ryegrass and meadow-fescue mixtures was higher on average than that of herbage from cocksfoot and timothy mixtures, though the relationship varied considerably from year to year. In the third harvest year the mean clover contents of herbage from mixtures containing each of these four species of grass were almost the same, and clover content appeared to vary to a greater extent between strains within a grass species than between species. This was particularly so with timothy and cocksfoot strains. Nicol (62) has quoted Nilsson-Leissner's suggestion that some strains of cocksfoot are better suited than others to grow in association with wild white clover, and he believes that some non-legumes are better fitted to make use of fixed nitrogen transferred from legumes. Variations in the effects of different strains of particular grass species on the performance and persistency of white clover in general and also of different strains of clover, appear to require further investigation.

When the effect of pasture management techniques on the performance of white clover is considered, here again most of the experiments reported have dealt with a particular strain or even a mixture of strains and few attempts have been made to compare the responses of different strains. It appears obvious, however, that these responses will vary with the habit of growth of the strain, and Dodd (25) has shown that the wild white type is the most persistent under close grazing, while the large-leaved lax types, such as Ladino, are the most persistent under light-grazing or lax or infrequent cutting. Cooper & Davis (24) suggested that the large-leaved S100 and New Zealand strains might have outyielded Kent wild white clover under a less intensive grazing management than that applied in their experiment described above.

A series of experiments reported by M. Jones (47, 48, 49, 50) conclusively demonstrated that the balance of grass and clover in a sward can be altered by the grazing techniques applied, whatever the system of manuring adopted. These experiments showed that heavy grazing particularly in the spring months weakened the grass component by depleting its root reserves, thus allowing clover to dominate the sward, whereas light grazing in the spring and autumn had the opposite effect. Jones (46) also found that the density and yield of white clover in a mixed sward were greatest where the sward was subjected to hard grazing in the spring.

The effects appear to be similar where the sward is defoliated by a mower. Thus Robinson & Sprague (68) obtained uniformly higher clover percentages in herbage by cutting it to within ½ inch from ground level instead of to within 2 inches. They suggested, however, that clover is more tolerant of periodic close-clipping than grass only when allowed adequate time for recovery between clipping dates. This is confirmed by Brown (8) who reported that in a sward cut to within 1 inch from ground level clover yields were smaller when growth was allowed to reach only 2 inches before cutting as against 4-5 inches. Prolongation of the recovery period appears, however, to have an equally detrimental effect on white clover. Walker, Adams & Orchiston (88), for example, obtained much smaller clover yields by cutting herbage twice per season at the 'hay' stage than by cutting three times at the less mature 'silage' stage. Cutting four times per season at the leafy 'dried grass' stage, however, gave only slightly greater clover yields than cutting at the 'silage' stage. Sprague & Garbar (75) showed that the amount of clover in a sward decreased progressively with each delay in the removal of the first crop, and that as the grass component approached 'hay' stage clover was affected by competition to such an extent that closeness of cutting became of minor importance. When cut at 8 inches high, lowering the height of cut from 3 to 1 inches markedly increased clover yield, but at or approaching 'hay' stage little or no increase in clover occurred. Mott (61) showed that clover yield from a Kentucky blue-grass-Ladino clover sward cut to within ½ inch from ground level was four times as great when the herbage was allowed to grow to 4-6 inches high before cutting than when it was cut every week.

Although the particular management applied can bring about considerable changes in the botanical composition of a grass-clover sward, and in the relative yields from the grass and clover components, application of fertilizers may bring about equal or greater changes. Phosphate manuring, for example, has long been known to stimulate the clover content of mixed swards. The chief measure of the improvement of old permanent pasture by application of basic slag in the early work of Somerville (74), Middleton (60) and Gilchrist (32) at Cockle Park was, in fact, the spread of wild white clover. Increases in white clover content of mixed swards or in the yields of white clover following phosphate applications have been reported by Davies (19), Brown (8), Dodd (25), Sears (70, 71) and many others. Dodd has also shown that much the same effect can be obtained on certain soils by the addition of lime, which he contends increases the availability of phosphates in the soil. That this is probably an indirect effect is suggested by recent work reported by Walker, Adams & Orchiston (89). This showed that where lime was used to correct a molybdenum deficiency or to reduce the effect of a molybdenum-manganese antagonism, clover responses to phosphate were obtained which were not obtained in the absence of lime. Where the molybdenum deficiency was corrected by applications of molybdenum normal phosphate responses were obtained, suggesting that phosphate was equally available at the low pH.

In a series of experiments reported by Walker, Edwards, Cavell & Rose (91), phosphate applications had a pronounced effect on the legume content of herbage at only one centre where the soil was extremely phosphate-deficient. Holmes (37) and Holmes & MacLusky (38) obtained no benefit from phosphate applications in terms of either total herbage yield or clover content on soil with a low readily-available phosphate content. They suggested that the grasses were able to utilize part of the 'fixed' phosphate in the soil, which routine methods of soil analysis were unable to detect.

For various reasons, therefore, clover may not respond to phosphate applications on all soils. Phosphorous is, however, an important element in the nutrition of clover itself and of the nitrogen-fixing bacteria in its root nodules (95).

Responses of clover to potash applications occur more frequently and are normally of greater magnitude than responses to phosphate. Dodd (25) showed that potash, when applied in addition to phosphates and lime, gave a further increase in the white clover content of permanent pasture over that produced by lime and phosphate only, but phosphate plus potash had a smaller effect than phosphate alone. The beneficial effect of potash applications on the clover content of grass + clover swards has been noted by Holmes & MacLusky (38) and by Uverud (82). McNaught (57, 58) has observed that clover is more susceptible to potash deficiency than grass and he attributed this to the more efficient rooting system of grasses being able to obtain potash on deficient soils when clover is already showing deficiency symptoms. He recommends application of potash even if only isolated clover plants in a sward are showing such symptoms.

Application of potash fertilizer is particularly necessary for the maintenance of clover in a mixed sward receiving fertilizer nitrogen. Blaser & Brady (4) showed that increasing the rate of potash application from 0 to 100 lb./acre K_2O gave consistently increasing clover yields, but had no effect on grass yields, while spring applications of nitrogenous fertilizer increased grass and decreased clover yields in the first harvest but had no effect thereafter. Because of the higher potassium content of the grass herbage, they suggested that the depression of clover by nitrogen treatments was a result of competition for potash between the clover and nitrogen-stimulated grass. In a further experiment Blaser & Brady (4) showed that the reduction in clover yields by fertilizer nitrogen was smaller when the rate of potash application was high. Similar effects of nitrogen and potash applications on clover in a Dallisgrass-white clover sward were reported by Brown & Rouse (11). Like McNaught (57, 58) they concluded that grass has a greater ability to absorb potash from the soil than has clover. They, therefore, recommended application of potash in excess of the requirements of the grass to provide an adequate supply for the clover.

Suppression of clover in grass-clover swards by the application of nitrogenous fertilizers has been reported also by Dodd (25), Brown (8), Walker, Edwards, Cavell & Rose (91), Walker, Adams & Orchiston (88), Williams (97), Holmes & MacLusky (38) and many other workers. Wilson (101) has suggested that the combined nitrogen status of the soil is probably the most important single factor determining the relative abundance of different species in crop mixtures. He has summarized the various explanations which have been offered to account for clover suppression by applied nitrogen as follows:

1) Direct toxic action of the ammonium or nitrate ion on clover.
2) Differential intake of combined nitrogen by various species in the mixed sward.
3) Competition for plant nutrients, light and moisture.

Blackman (2) noted that application of nitrogen as sulphate of ammonium brought about a greater clover suppression than application of calcium nitrate. He concluded, however, that this was not due to a direct toxic effect on the clover of absorbed ammonium ions, but rather to a greater depressing effect of these ions on nodule formation, and to a more active growth of grass manured with ammonium sulphate. Walker, Adams & Orchiston (88) also noted greater clover suppression following application of sulphate of ammonia than with nitro-lime or urea, and attributed this to increased competition from the somewhat higher yields of grass obtained with sulphate of ammonia. They suggested that an alternative explanation might be the temporary reduction in soil pH following application of this fertilizer.

According to Wilson (101), Virtanen found that red clover grew better when fixing nitrogen or when supplied with organic nitrogen (eg. amino-acids) than when supplied with inorganic nitrogen. White clover, on the other hand, grew best on inorganic nitrogen. Vantsis & Bond (83) have shown more recently, however, that both utilize organic nitrogen more readily than inorganic. Using N15 - labelled potassium nitrate and ammonium sulphate, Walker, Adams & Orchiston (90) showed that white clover will utilize inorganic nitrogen, though not so efficiently as will the grasses, and will automatically fix correspondingly less nitrogen. In their experiment when white clover was grown in association with Italian ryegrass, the grass took up 95% of the mineral nitrogen utilized by the association. McAuliffe, Chamblee, Uribe-Arango & Woodhouse (55), using N15 - labelled ammonium sulphate, also demonstrated that Ladino white clover utilized applied inorganic nitrogen, and that the percentage nitrogen fixed by the clover was reduced in proportion to the amount of nitrogen applied.

Blackman (2) and Blackman & Templeman (3) concluded from a series of experiments that the balance between grass and clover in a mixed sward is dependent largely on competition for light. When the sward is infrequently defoliated the taller growing grasses shade the clover. Since density and height of grasses is correlated with nitrogen supply, additional fertilizer nitrogen may depress clover merely by increasing the degree of shading without having any direct effect on the clover. Robinson & Sprague (68) also believe that any changes in clover population resulting from nitrogen fertilization can be attributed to the indirect effects of nitrogen, i.e. increased competition with the grass for light and other factors. Results from their experiment suggest that one of these other factors might be moisture, since a high clover content was maintained even under heavy nitrogen fertilization when the swards were irrigated.

Although it seems to be fairly generally agreed, therefore, that the main factor in the suppression of clover by fertilizer nitrogen is competition for light between clover and companion grass, other factors may be involved. Thus the total effect is probably complex and requires further elucidation.

As mentioned above, relatively high herbage yields can be obtained where clover is used as the only source of nitrogen for growth. Distribution of yields over the season under such a system tends to be uneven, however, and to vary considerably from year to year. On the other hand, yields are usually much less variable where fertilizer nitrogen is used and no reliance is placed on clover. In addition, massive nitrogen dressings can be employed to give much higher yields than would be possible if clover was the only source of nitrogen. As Linehan (51) has pointed out, however, it is questionable whether the use of massive dressings is profitable except where the value of the animal product coming off the sward is high. There appears to be, therefore, a considerable case for investigating methods by which maximum benefit can be obtained from the clover fraction of a grass-clover sward while at the same time applying and efficiently utilizing fertilizer nitrogen. Consideration of factors which have been shown to modify the clover depressing action of fertilizer nitrogen provides some clues to the solution of this problem. The various factors involved can be classified into two categories - managerial and botanical.

Considering management first, a number of workers have shown that intensity of defoliation has a marked influence on the degree of suppression of clover by nitrogen. Robinson & Sprague (68) maintained a relatively high clover content in swards defoliated to within ½ inch from ground level under heavy nitrogen applications, whereas clover was practically eliminated by the same nitrogen treatment when the swards were defoliated to within 2 inches. Jones (48) showed that heavy and frequent grazing maintained the contribution of clover in swards receiving fertilizer nitrogen. Under a similar management in an experiment reported by Williams (98) clover was suppressed only by the heaviest of a series of nitrogen treatments. Williams suggested that this method of maintaining clover was of no practical value, since total herbage and clover yields were both lower under this heavy frequent grazing than under a less intense management. Robinson & Sprague (68) reported, however, that in their experiment yields were higher under closer than under lax-cutting, but they stressed the importance of allowing an adequate recovery period between cuts.

Another management factor which has been shown to influence the response of clover to fertilizer nitrogen, is the stage of growth at which the sward is defoliated. Walker, Adams & Orchiston (88) reported that fertilizer nitrogen had a considerably smaller effect on clover where the herbage was cut three times in the season at the 'silage' stage than when it was cut more frequently at the 'dried grass' stage, or less frequently at the 'hay' stage. Walker, Edwards, Cavell & Rose (91) suggested that legume suppression by fertilizer nitrogen could be minimized by earlier cutting.

Degree of clover suppression increases, of course, with the nitrogen application rate (see eg. 91) and this has led Raymond (63) to suggest that the use of medium levels of nitrogen would allow both an adequate clover contribution in the sward and efficient utilization of the applied nitrogen. Williams (98) believes that under grazing conditions valuable increases in productivity can be obtained from the use of nitrogen fertilizer on swards containing clover, and in his experiment the most economical application rate was 60-70 lb. nitrogen per acre in the season. Summarising this work elsewhere (99), he stressed that at this level white clover must be used along with fertilizer nitrogen to ensure best productivity. He found that clover was not seriously reduced by nitrogen applications of 60-70 lb./acre, but 70-140 lb./acre depleted clover to such an extent that the benefit of the applied nitrogen was lost. Dressings of over 140 lb./acre were required to balance the loss of clover. These results applied only under grazing with relatively long rest spells, and as mentioned previously, only the heaviest nitrogen application rate depressed clover under a more frequent grazing system. In one year of an experiment Watkin (94) obtained an increase in production under gang-mowing with 52 lb./acre applied nitrogen, followed by an extremely poor response up to 182 lb. and a good response at 312 lb. Throughout this experiment, however, response to nitrogen was linear under an intensive sheep grazing management.

Little attention seems to have been apid to the effect on clover yield of a heavy single dressing of fertilizer nitrogen compared with several small dressings totalling to the same amount. Walker, Edwards, Cavell & Rose (92) have reported greater clover depression resulting from a heavy single dressing than from split dressings, and attributed this to cutting too late. A similar effect was noted by Walker, Adams & Orchiston (88) but it was said to be less obvious on account of more frequent cutting. Some botanical composition data in a paper by Holmes (35) suggest, on the other hand, that the degree of clover depression depends mainly on the total rate of nitrogen application, and that it makes little difference whether a given rate is applied in one dressing or in several small dressings.

Turning now to botanical factors, Holmes & MacLusky (39) showed that the degree of suppression of clover by fertilizer nitrogen varies with the particular species or strain of grass growing in association. They attributed this to variations in relative vigour of spring and mid-season growth between different grasses. Most strains of cocksfoot included in their experiment were relatively slow in developing in the spring, and did not severely depress clover at this time, even when dressed with nitrogen. Their vigorous growth in mid-season, however, depressed clover more than any other grass. Strains of ryegrass, meadow-fescue, and Danish cocksfoot, in contrast, gave vigorous leafy growth in spring and caused greatest clover depression when nitrogen was applied for the first cut. The more erect and stemmy habit of growth of these grasses later in the season had a smaller effect on clover. Timothy strains with their erect habit of growth gave a rather open sward, and of all the grasses they exerted the least harmful effect on clover when receiving fertilizer nitrogen. From these results Holmes & MacLusky concluded that in a mixed sward receiving fertilizer nitrogen clover was depressed to the greatest extent when nitrogen applications coincided with the time when the growth of the companion grass was naturally dense and leafy.

Many problems connected with the role of clover in grassland have been indicated in this review. Of these, however, the one of greatest agronomic and practical interest at the present time appears to be that of obtaining maximum benefit from clover in a grass-clover sward while at the same time applying and efficiently utilizing fertilizer nitrogen. Accordingly two experiments were designed to investigate various aspects of this problem. These were begun in the spring of 1954, and the results obtained from them in the growing seasons of 1954-56 inclusive are described in Parts 2 and 3 of this thesis. The extent to which the results from these experiments aid in the solution of the above problem is considered in Part 4.

PART 2

Experiment 1. A study of the effect of stage of growth at cutting, closeness of cutting and dates and rates of fertilizer nitrogen application on the yield and contribution of clover from an established sward in which perennial ryegrass predominated.

INTRODUCTION

It has been shown in the preceding review of literature that the extent to which applications of fertilizer nitrogen will depress clover in a grass-clover sward depends on a number of factors. These can be roughly classified into two catagories - managerial factors (in which frequency and rate of fertilizer usage are included) and botanical factors (i.e. the composition of the seeds mixtures used). The experiment described in this section of the thesis deals with some of the factors in the first of these two catagories.

Much information is already available in the literature on the direct effects of the factors investigated in this experiment. Jones (47,48,49,50) and others (25,44,61,68) have demonstrated the profound effects on the grass-clover balance in a sward of varying frequency and severity of defoliation. Holmes & MacLusky (39) have studied the influence of fertilizer nitrogen on grass + clover swards as a subsidiary to an experiment in which they compared yields from pure grass swards receiving fertilizer nitrogen and from grass + clover swards unfertilized. Little or no information is available, however, on the interaction of these factors, though Walker, Edwards, Cavell & Rose (91) have suggested that an interaction does exist between stage of growth at which herbage is cut and the fertilizer nitrogen treatment.

In the present experiment it was hoped to explore these findings further and at the same time to investigate possible interactions between the various treatment factors.

TABLE 1. Seeds mixture sown in Paddock 4 at Kirkhill, April, 1950

	lb./acre
Italian ryegrass	10
Perennial ryegrass S23	6
Perennial ryegrass Ayrshire	6
White clover S100	2
Total	24

TABLE 2. Seeds mixture sown in part of Field E at Kirkhill, Spring, 1952

	lb./acre
Perennial ryegrass, Kent	9
Perennial ryegrass, Ayrshire	9
Italian ryegrass, Ayrshire	4
Timothy, Scots	6
Meadow fescue, Danish	6
Rough stalked meadow grass, Danish	1½
Cotswold late red clover	1
English broad leaved red clover	1
Canadian late red clover	1
English wild white clover	½
New Zealand white clover	½
S100 white clover	½
Total	40

EXPERIMENTAL

General

The experiment was begun in the spring of 1954 in Paddock 4 of the Institute farm at Kirkhill. The sward in this paddock was sown direct without a cover crop in the spring of 1950. Details of the general purpose ryegrass seeds mixture sown are given in Table 1. Before sowing, ground limestone was applied at the rate of 2 tons per acre and basic slag at 6 cwt./acre. Adequate dressings of phosphatic and potassic fertilizers, and occasional dressings of nitrogenous fertilizers were applied during the next 3 years. The herbage was seldom mown for conservation during this period, since the paddock served mainly as a temporary holding area for experimental animals. In the spring of 1954 the sward consisted predominantly of perennial ryegrass (Lolium perenne) with small amounts of cocksfoot (Dactylis glomerata) and timothy (Phleum pratense), and moderate amounts of dicotyledonous weeds (mainly Ranunculus repens), grass weeds (Poa trivialis, P. annua, Agrostis stolonifera, Holcus lanatus, etc.), and white clover (Trifolium repens). It became obvious later in the season that white clover was unevenly distributed in the sward. This made precise measurement of the effect of the various treatments on clover yield extremely difficult. The experiment was, therefore, conducted on this site for only one season.

In the spring of 1955 the experiment was transferred to part of Field E at Kirkhill. The sward here was sown down in 1952 with the seeds mixture detailed in Table 2. The entire area of Field E was used in 1952 to compare various methods of establishing grass-clover leys. Half of the site occupied by the present experiment had been sown down under oats harvested for grain, while the remainder had been sown down under oats cut for silage. By the spring of 1955, however, there was no visible botanical difference between the swards on the two sections, both sections having received the same management during 1953 and 1954. This consisted of intensive grazing with liberal applications of phosphatic and potassic fertilizers and heavy applications of nitrogenous fertilizers.

When the experiment began in Field E the amount of white clover in the sward was small on account of previous management, but it was uniformly distributed. The grass component of the sward was predominantly perennial ryegrass with small amounts of meadow-fescue (Festuca pratensis) and timothy, but no cocksfoot. Since rough-stalked meadow grass (Poa trivialis) was included in the seeds mixture sown, the Poa content of this sward was greater than that of the sward on Paddock 4. Weed grasses present included annual meadow grass (P. annua), bent, Yorkshire fog, and red fescue (Festuca rubra), all of which appeared in relatively small amounts. There were few dicotyledonous weeds present.

The experiment was continued on the site in Field B for two complete seasons - 1955 and 1956.

Treatments

The following treatments were included in this experiment:

A Height of cutting

1) close-cutting (to approx. 1 inch from ground level).
2) lax-cutting (to approx. 2-2½ inches from ground

1) close-cutting (to approx. 1 inch from ground level).
2) lax-cutting (to approx. 2-2½ inches from ground level).

B

1) cut at the 'grazing' stage (leafy: 6-8 inches tall).
2) cut at the 'silage' stage (long leafy to early flower: approx. 10 inches tall).

C Fertilizer nitrogen applications

N1) No applied nitrogen

N2) 2 cwt. 'Nitro-Chalk'/acre in early spring and again for the last cut of the season.

N3) 2 cwt. 'Nitro-Chalk'/acre after the first or second cut and again for the last cut of the season.

N4) 2 cwt. 'Nitro-Chalk'/acre in early spring and again after each cut but the last.

N5) 2 cwt. 'Nitro-Chalk'/acre after the first or second cut and again after each cut but the last.

N6) The first application of 'Nitro-Chalk' was delayed as in N5, but the same total amount was applied over the season as in N4.

Throughout the experiment the herbage was cut with an Allen Autoscythe fitted with a Universal foot. This device allows a certain amount of adjustment in closeness of cutting, and since the cutter bare is fitted on a central pivot a relatively even height of cut is obtained over its full width even on sloping or uneven ground.

TABLE 3. Dates of cutting - Experiment 1

Stage of cutting	Year	Cut No. 1	2	3	4	5	6
'Grazing'	1954	7/5	1/6	30/6	2/8	9/9	13/10
	1955	24/5	27/6	1/8	2/9	24/10	-
	1956	16/5	19/6	17/7	17/8	18/9	23/10
'Silage'	1954	27/5	9/7	24/8	13/10		
	1955	2/6	1/8	24/10	-		
	1956	30/5	17/7	29/8	23/10		

TABLE 4. Dates of application of 'Nitro-Chalk' for each cut - Experiment 1

Stage of cutting	Year	Cut No. 1	2	3	4	5	6
'Grazing'	1954	1/4	10/5	2/6	1/7	3/8	10/9
	1955	4/4	25/5	29/6	2/8	5/9	-
	1956	28/3	16/5	20/6	17/7	17/8	18/9
'Silage'	1954	1/4	27/5	10/7	25/8		
	1955	4/4	2/6	2/8	-		
	1956	28/3	31/5	17/7	29/8		

For the close cutting treatment the universal foot was set to cut as close to ground level as possible without the fingers of the cutter bar tearing into the ground. To give the required cutting height for the lax-cutting treatment the cutter bar of the mower was mounted on a removable roller device specially built for the purpose. Experience showed that with these arrangements defoliation at the prescribed heights could be achieved with only slight variation.

In the 'grazing' stage of cutting treatment herbage was cut when approximately 6 to 8 inches tall or at the 'leafy' stage. These two criteria generally coincided in practice. During the month of June, however, particularly under dry weather conditions, flowering in the grasses tended to begin when the average height of the sward was less than 6-8 inches. Under these conditions the height criterion was ignored and the herbage was mown as soon as stem elongation preparatory to flowering was noted. The last cut of the season was also often taken when the herbage was less than 6-8 inches tall because growth ceased before this height was reached. In 1954 and 1956 six cuts were obtained under the 'grazing' stage treatment, but, in 1955 on account of poor growth due to drought, only five cuts were obtained under this treatment.

The majority of cuts in all three years under the 'silage' stage of cutting treatment were taken when the herbage was approximately 10 inches tall and the grasses were in the early flower stage. Here again, however, the herbage tended to reach the appropriate stage of growth when shorter than 10 inches during June, and late in the season it reached the height limit with little evidence of flowering in the grasses. Herbage was cut four times during the 1954 and 1956 season under this treatment but only three times in 1955.

Dates of cutting under both 'stage of cutting' treatments are given in Table 3.

All fertilizer nitrogen applications in this experiment were made in the form of 'Nitro-Chalk' (15.5% N). The quantity for each plot was weighed separately in grams, and applied as uniformly as possible by hand. The first dressing of the season for nitrogen treatments N2 and N4 was applied in late March or early April, while that for treatments N3, N5 and N6 was applied after the second cut

TABLE 5. <u>Rates of application of 'Nitro-Chalk' (cwt./acre) for each cut - Experiment 1</u>

Stage of cutting	Nitrogen treatment	Cut. No. 1	2	3	4	5	6	Total
1954 and 1956								
'Grazing'	N1	-	-	-	-	-	-	-
	N2	2	-	-	-	-	2	4
	N3	-	-	2	-	-	2	4
	N4	2	2	2	2	2	2	12
	N5	-	-	2	2	2	2	8
	N6*	-	-	3	3	3	3	12
'Silage'	N1	-	-	-	-			-
	N2	2	-	-	2			4
	N3	-	2	-	2			4
	N4	2	2	2	2			8
	N5	-	2	2	2			6
	N6*	-	$2\frac{2}{3}$	$2\frac{2}{3}$	$2\frac{2}{3}$			8
1955								
'Grazing'	N1	-	-	-	-	-		-
	N2	2	-	-	-	2		4
	N3	-	-	2	-	2		4
	N4	2	2	2	2	2		10
	N5	-	-	2	2	2		6
	N6	-	-	3	4	3		10
'Silage'	N1	-	-	-				-
	N2	2	-	2				4
	N3	-	2	2				4
	N4	2	2	2				6
	N5	-	2	2				4
	N6	-	$2\frac{2}{3}$	$3\frac{1}{3}$				6

* not included in 1954

of the season under the 'grazing' stage of cutting treatment and after the first cut under the 'silage' treatment. Actual dates of fertilizer nitrogen applications under the various treatments are given in Table 4, and rates of application at each date in Table 5. Treatment N6 was not included in the experiment in 1954, but was added when the experimental site was changed in 1955. The addition was made because difficulty was experienced in deciding whether differences noted between treatments N4 and N5 in 1954 were due to variations in the date of the first application or to variations in the total rate of fertilizer nitrogen application over the season. It should be noted that because fewer cuts were obtained in 1955 than in 1954 and 1956, treatments N3 and N5 were identical under the 'silage' stage of cutting treatment in that year.

Observations on growth rate and colour of herbage throughout the experiment indicated that fertilizer nitrogen was uniformly applied, and that no sub-surface drift of nitrogen occurred between plots.

Experimental design

On both sites on which this experiment was conducted the experimental design used was of the split-plot type. In this design some precision in the estimation of certain main factors and interaction effects is sacrificed in order to obtained increased precision in the estimation of the effects of the remaining main factors and interactions. The design is also useful where certain treatment factors cannot be conveniently handled in small plots. Details of the layout and statistical analysis of split-plot deigns are given by Cochran & Cox (14) and by Federer (27).

When the experiment was first laid down in Paddock 4 in 1954 the two levels of the 'height of cutting' factor were arranged in main plots for convenience in cutting. Some precision was, therefore, lost in the estimation of the effects of this factor. Previous published work on the relative effects of different heights of cutting (e.g. 68), suggested that the difference between these treatments would be proportionately large and easily measured with this reduced precision. All possible combinations of the various levels of the other two factors (i.e. 'stage of cutting' and 'fertilizer nitrogen application') were arranged in sub-plots in the form of a randomized complete block within each main plot. Thus increased precision was obtained in the measurement of the effects of these two treatment factors and of all interactions of the three factors.

To facilitate the field work and at the same time improve the precision in measuring the height of cutting effect, the design was slightly altered when the experiment was laid down in Field N in 1955. Instead of arranging only the two levels of 'height of cutting' factor in main plots, giving two main plots per replicate block, the four possible combinations of this factor and the 'stage of cutting' factor were arranged in four main plots within each block. This, of course, reduced precision in the measurement of 'stage of cutting' effects, but the 1954 results had shown that the differences between two levels of this factor were relatively large. The six levels of the other factor - fertilizer nitrogen applications - were randomized in sub-plots within each main plot.

In both designs all possible treatment combinations were replicated three times. Sub-plot size throughout was 21 feet by 8 feet or 0.004 acre.

Experimental methods

a) Yield sampling procedure. Throughout the experiment the same sampling technique was followed whenever herbage on a particular set of plots reached the appropriate stage of growth for cutting. First of all the herbage on the pathways bordering the shorter sides of each plot was mown off close up to the marking pegs with the Allen Autoscythe set for close-cutting. This herbage was raked and carried off. Two sampling swaths each 38 inches wide by 21 feet long were then cut on each plot, leaving narrow discard strips between the swaths and along the margins of the plot, with the Allen Autoscythe set either for close or lax-cutting as the allotted treatment for the particular plot demanded. The herbage on the two sampling strips on each plot was raked together, placed on a hessian sheet and weighed to the nearest half pound on a spring balance in the field. Immediately after weighing a random sample of 700-1000 g. of the herbage from each plot was taken. In the first 2 years of the experiment this sample was rolled in greaseproof paper for transport to the laboratory, but a plastic bag was used for this purpose in 1956 in order to minimize losses.

The field work was completed by mowing the herbage on the discard strips of each plot with the cutter-bar of the Allen Autoscythe at the same setting as on the sampling swaths. The cut herbage was raked and carried off. Dressing of fertilizer nitrogen were then applied to the appropriate plots in the manner previously described.

In the laboratory the sample of herbage from each plot was thoroughly mixed and two 500 g. subsamples were drawn at random from it. One of the subsamples was oven-dried in a Blackburn Unitherm Drier (64) for approximately 12 hr. at 100°C. Its dry weight was then determined, and it was ground in a laboratory mill through a 0.7 m.m. mesh. The ground sample was stored in a glass bottle for chemical analysis. The clover content of the other subsample was determined as soon as possible by hand-separating the clover from it. Since this is an extremely time-consuming process the subsamples were normally stored in a refrigerator at slightly above 0°C. until required. In periods when pressure of field work in other experiments prevented hand-separation being carried out within 24-36 hr. of cutting, the subsamples were stored in an insulated box maintained at a lower temperature by means of 'Drikold' (solid carbon dioxide). After separation of the subsample the green weight of the two fractions was determined. The 'grass + weeds' fraction was then oven-dried, re-weighed and discarded. Since the clover fraction of each subsample was usually very small, these fractions of the subsamples from the three replicates of each treatment combination were bulked. The resulting sample was then oven-dried, weighed, ground in the laboratory mill and stored in a glass bottle for chemical anlysis.

b) <u>Determination of residual effects of treatments.</u> No fertilizer nitrogen treatments were applied to the plots of this experiment in the spring of 1957, nor were any mineral fertilizers applied. On May 2, when the herbage had reached a height of 6-8 inches and was at the leafy stage, all plots irrespective of previous 'stage' or 'height of cutting' treatment were cut to within 1 inch of ground level. Green and dry matter yields of herbage were determined in the same manner as in previous years, but no chemical or botanical analyses were made. The principal object of this first cut was to reduce all plots, whether close or lax-cut in previous years, to the same stubble height. The residual effects of the two height of cutting treatments could then be determined by measuring the regrowth after this cut. At the same time, of course, a measure of the residual effects of the 'stage of cutting' and 'nitrogen' treatments were obtained.

A second cut was taken on June 19, again to within 1 inch of ground level. Herbage at this date was only 4-6 inches high, but it was somewhat stemmy since most of the grass species in the sward were at the early flower stage. As at the first cut, only green and dry matter yields were determined.

Regrowth during the remainder of the 1957 season was poor and there were no visible differences between plots, so no further cuts were taken.

c) <u>Determination of sward botanical composition.</u> Shortly after the last cut of each season the botanical composition of the sward on each plot of the experiment was determined by a modification of the point-quadrat method (20). The apparatus used consisted of 10 pins, 6 in. long by 0.2 in. in diameter, inserted at 2 in. centres along the centre line of a wooden bar 22 in. long by 2 in. wide. This was dropped into the sward at 10 randomly selected positions on each plot and the species touching each of the 10 pins at ground level was identified and recorded. Where a pin did not contact a plant at ground level, 'bare ground' was recorded. The 100 'hits' so recorded give an estimate of the proportion of the total area of each plot covered by each plant species at ground level, and the results are presented in terms of 'percentage ground cover' for each species.

Brown (10) states that this modification of the point-quadrat method in which only the 'hit' at ground level on each pin is recorded instead of all 'hits', tends to bias the results in favour of the prostrate or creeping species. The advantage of the modification are, however, that the results appear to be little affected by the stage of growth of the sward, and that readings take less time. It is, therefore, possible to obtain comparable results from season to season with little fear of bias due to stage of growth of the sward, and it is also possible to take a greater number of readings per plot or to study a greater number of plots.

d) <u>Soil sampling</u>. In the autumn of each year a sample of soil was taken from every plot of the experiment. On each plot six auger borings were taken to a depth of 9 in. and the soil from these was mixed in a bag. Routine analyses of these samples were made by the Chemistry Department of the West of Scotland Agricultural College. The results of these analyses are not presented since the treatments studied had no differential effects on soil composition, probably because of the short term nature of the experiment. The data obtained on available phosphate and available potash content of the soil was, however, useful in determining the rate of application of mineral fertilizers each season.

<u>Mineral fertilization</u>

The rate of application of phosphate and potassic fertilizers was uniform over all plots of the experiment, though in order to ensure even application these fertilizers were weighed out and applied by hand on an individual sub-plot basis. Throughout the experiment the phosphate fertilizer used was superphosphate (18.8% P_2O_5) and the potassic fertilizer was muriate of potash (60% K_2O). Rates and dates of application of these were as follows:

1954	Fertilizer	cwt./acre
April 1	P_2O_5	2
	K_2O	2
July 12	P_2O_5	2
	K_2O	2
1955		
March 19	K_2O	3
March 30	P_2O_5	5
August 6	P_2O_5	2
	K_2O	1
1956		
March 26	P_2O_5	2
	K_2O	2
July 24	P_2O_5	2
	K_2O	1

These rates were determined from the analyses of soil samples taken the previous autumn, and were sufficient to satisfy requirements on the most deficient plots. Because of the recognised weaknesses in the analytical and sampling methods for soils this procedure was followed instead of attempting to balance the mineral deficiencies on the individual plots by applying varying amounts of fertilizer.

Statistical treatment of results

With all sets of data (i.e. mixed herbage dry matter yields, clover dry matter yields, etc.) collected in this experiment the significance of the differences between treatment means was tested by analysis of variance. Absolute yields were expressed in 100's of lb./acre before analysis, rounding to the first decimal place for dry matter yields and to the second place for crude protein yields. Percentage ground cover data, being counts out of 100, were transformed to angles (i.e. arc sin. $\sqrt{\%}$) before analysis, using tables given by Snedecor (75). This procedure corrects for the regular type of heterogenity of error variance which usually occurs in such data (50).

The standard error of the mean difference ($s_{\bar{d}}$) was calculated for all main factor effects whether significant or not, and for all significant interaction effects. In addition, the value $t_{\alpha}s_{\bar{d}}$ or least significant difference (L.S.D.) was calculated for all significant main factor and interaction effects. These values and a list of the significant effects are given below each table of means in this section. It should be noted that the values given for $s_{\bar{d}}$ and L.S.D. in the tables of percentage ground cover means refer to the mean angles in the lower part of the table and not to the mean percentages in the upper part. Accurate standard errors cannot be calculated for the latter.

Since the statistical methods employed in this study were the same throughout, only a few of the many analyses of variance calculated are presented as examples.

Presentation of results

In the following pages the results of this experiment are reported for each year separately and under the following sub-headings:

1) Mixed herbage dry matter yields - including total yields for the season, and distribution of yields over the season.
2) Clover dry matter yields - including total yields for the season, distribution of yields over the season, and weighted mean percentage clover in

TABLE 6. Mean total dry matter yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments					Means	Stage of cutting	
	N1	N2	N3	N4	N5		Grazing	Silage
Height of cutting								
Close	58.9	72.1	69.5	98.9	84.2	76.7	66.9	86.4
Lax	38.9	49.2	49.8	72.9	59.0	54.0	46.8	61.1
Stage of cutting								
Grazing	39.0	49.0	50.9	82.5	63.0	56.9		
Silage	58.8	72.4	68.1	89.3	80.2	73.8		
Nitrogen means	48.9	60.7	59.5	85.9	71.6			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	2.45	10.61	-
S means	1.40	2.84	3.81
N means	2.21	4.49	6.02
N means within a S (and vice versa)	3.15	6.35	8.51

Significant effects

H *
S ***
N *** (N1 v N2,3,4 & 5 ***; N2 & 3 v N4 & 5 ***; N4 v N5 ***)
N x S **

Coefficient of Variation: Main-plots = 14.6% Sub-plots = 8.3%

TABLE 7. Analysis of variance of total dry matter yields of mixed herbage - Experiment 1 (Paddock A) 1954

Source of variation	df	Sums of squares		Mean squares	Variance ratio (F)	
Height of cutting (H)	1	7740.70		7740.70	84.87	*
Replicates	2	828.44		414.22		
Error (a)	2	182.42		91.21		
Nitrogen treatments (N)	4	9437.24		2359.31	80.30	***
N1 v N2,3,4,5	1		4031.12	4031.12	137.21	***
N2 & 3 v N4 & 5	1		4173.87	4173.87	142.06	***
N2 v N3	1		8.17	8.17		
N4 v N5	1		1224.08	1224.08	41.66	***
Stage of cutting (S)	1	4272.33		4272.33	145.42	***
N x S	4	458.07		114.52	3.90	**
N x H	4	103.66		25.92		
S x H	1	104.28		104.28		
N x S x H	4	16.29		4.07		
Error (b)	36	1057.84		29.38		
Total	59	24201.27				

*** Significant at 0.1% level
** " " 1% "
* " " 5% "

the mixed herbage dry matter.

3) Mixed herbage crude protein yields - including total yields for the season, and weighted mean percentage crude protein in the mixed herbage dry matter.

4) Clover crude protein yields

5) Plant cover

All the results over the 5 years of the experiment are then considered together in the discussion at the end of the section.

RESULTS

1954 - Paddock 4 site

Mixed herbage dry matter yields

Mean total dry matter yields of mixed herbage (i.e. sown grass + clover + weeds) over the 1954 season are given in Table 6. The analysis of variance of these yields is presented in full in Table 7 as an example of the analyses carried out on each set of data collected for the experiment in 1954.

The difference between the means for the two height of cutting treatments was significant at the 5% level, close-cutting outyielding lax-cutting by 2,270 lb./acre or 42%.

On the average plots cut at the 'silage' stage of growth yielded 1,690 lb./acre more mixed herbage dry matter than those cut at the 'grazing' stage. This difference was highly significant.

Progressive increases in yield resulted from increasing rate of fertilizer nitrogen application (cf. N1, N2 and N4) and these increases were highly significant. Delaying the spring dressing of fertilizer nitrogen in treatment N5 caused a highly significant depression in yield in comparison with the companion treatment N4. A similar delay in the spring dressing where total seasonal dressings of nitrogen were light (cf. N2 and N3) had no significant effect on yield.

The highly significant interaction of 'nitrogen' with 'stage of cutting' treatments indicates that although plots cut at the 'silage' stage of growth consistently

TABLE 8. Mean dry matter yields of mixed herbage (in 100 lb./acre) at each cut in the season - Experiment 1 (Paddock 4) 1954

		'Grazing' Stage Cut No. 1	2	3	4	5	6	'Silage' Stage Cut No. 1	2	3	4
Height of cutting											
Close		18.8	14.9	9.4	10.3	10.7	2.8	41.8	18.6	16.5	9.6
Lax		11.6	10.2	8.4	7.3	8.4	0.9	26.1	19.7	10.6	4.7
$s_{\bar{d}}$	±	2.02	1.02	0.37	0.45	0.62	0.34	2.22	1.00	0.78	0.66
L.S.D.(5%	±	-	4.40	0.78	0.94	-	1.47	9.54	-	3.36	2.83
1%	±	-	-	-	1.29	-	-	-	-	-	-
F. Sig. at		NS	5%	5%	0.1%	NS	5%	5%	NS	5%	5%
Nitrogen treatments											
N1		13.5	11.1	4.7	3.5	5.6	0.6	31.4	13.9	10.2	3.4
N2		19.2	12.1	5.8	4.1	6.0	1.8	40.4	14.6	10.0	7.4
N3		13.4	10.6	10.6	7.6	6.9	1.8	28.2	22.6	10.0	7.4
N4		18.5	17.8	13.6	14.7	15.1	2.8	39.4	22.8	18.7	8.4
N5		11.5	11.2	9.8	13.9	14.3	2.4	30.5	21.8	18.8	9.0
$s_{\bar{d}}$	±	0.98	1.20	0.60	0.71	0.48	0.28	2.01	1.11	1.18	0.64
L.S.D.(5%	±	2.07	2.55	1.25	1.48	1.01	0.60	4.26	2.35	2.49	1.36
1%	±	2.86	3.52	1.71	2.03	1.39	0.83	5.86	3.24	3.44	1.88
F. Sig. at		0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

TABLE 9. Analysis of variance of dry matter yields of mixed herbage at first cut of season on 'grazing' plots

Experiment 1 (Paddock 4) 1954

Source of variation	df	Sums of squares	Mean squares	Variance ratio (F)
Height of cutting (H)	1	390.96	390.96	
Replicates	2	1.86	0.93	
Error (a)	2	60.88	30.44	
Nitrogen treatments (N)	4	280.44	70.11	24.43 ***
N1 v N2,3,4,5	1	21.34	21.34	7.44 *
N2 & 3 v N4 & 5	1	10.13	10.13	
N2 v N3	1	102.67	102.67	35.77 ***
N4 v N5	1	146.30	146.30	50.98 ***
N x H	4	14.42	3.60	
Error (b)	16	45.95	2.87	
Total	29	794.51		

*** Significant at 0.1% level

* " " 5% "

outyielded those cut at the 'grazing' stage the degree of difference between the two varied with the nitrogen treatment superimposed. The extent to which the former outyielded the latter was approximately the same within each of the treatments N1, N3 and N5, and was highly significant in all three cases. Within treatment N2 the difference was also highly significant but relatively greater than within treatments N1, N3 and N5, while within treatment N4 it was barely significant and considerably smaller.

The coefficients of variation calculated from these mixed herbage dry matter yields - 14.6% for main plots and 8.3% for sub-plots, were reasonably low for this type of data.

Mean yields of mixed herbage dry matter at each of the cuts on the 'grazing' and 'silage' stage of cutting plots for the two 'height of cutting' treatments and the five nitrogen treatments are shown in Table 8. This table also indicates the level of significance of the 'height of cutting' and 'nitrogen treatment' effects, and gives the $s_{\bar{d}}$'s and L.S.D.'s at each cut calculated from the analyses of variance of the type shown in Table 9.

Comparison of the seasonal distribution of yields under each of the 'stage of cutting' treatments is difficult since six cuts were taken over the season under the 'grazing' treatment but only four under the 'silage', and few of the cutting dates coincided. The data presented in Table 8 suggest, however, that a greater yield was obtained in the early part of the season where the herbage was cut at the 'silage' stage rather than at the less mature 'grazing' stage. The first two cuts at the 'grazing' stage gave a mean total yield of 2,780 lb./acre of mixed herbage dry matter, while the first cut at the 'silage' stage yielded 3,330 lb./acre over approximately the same total growth period.

Close-cutting outyielded lax-cutting at all cuts throughout the season under both 'stage of cutting' treatments, with the exception of the second 'silage' cut. At this cut lax-cutting yielded slightly more dry matter than close-cutting, though the difference between the two here, and at the first and fifth 'grazing' cuts was not significant.

The effect of the various nitrogen treatments on

FIGURE 1. Mean yields of mixed herbage at each cut in the season - Experiment 1 (Paddock 4) 1954

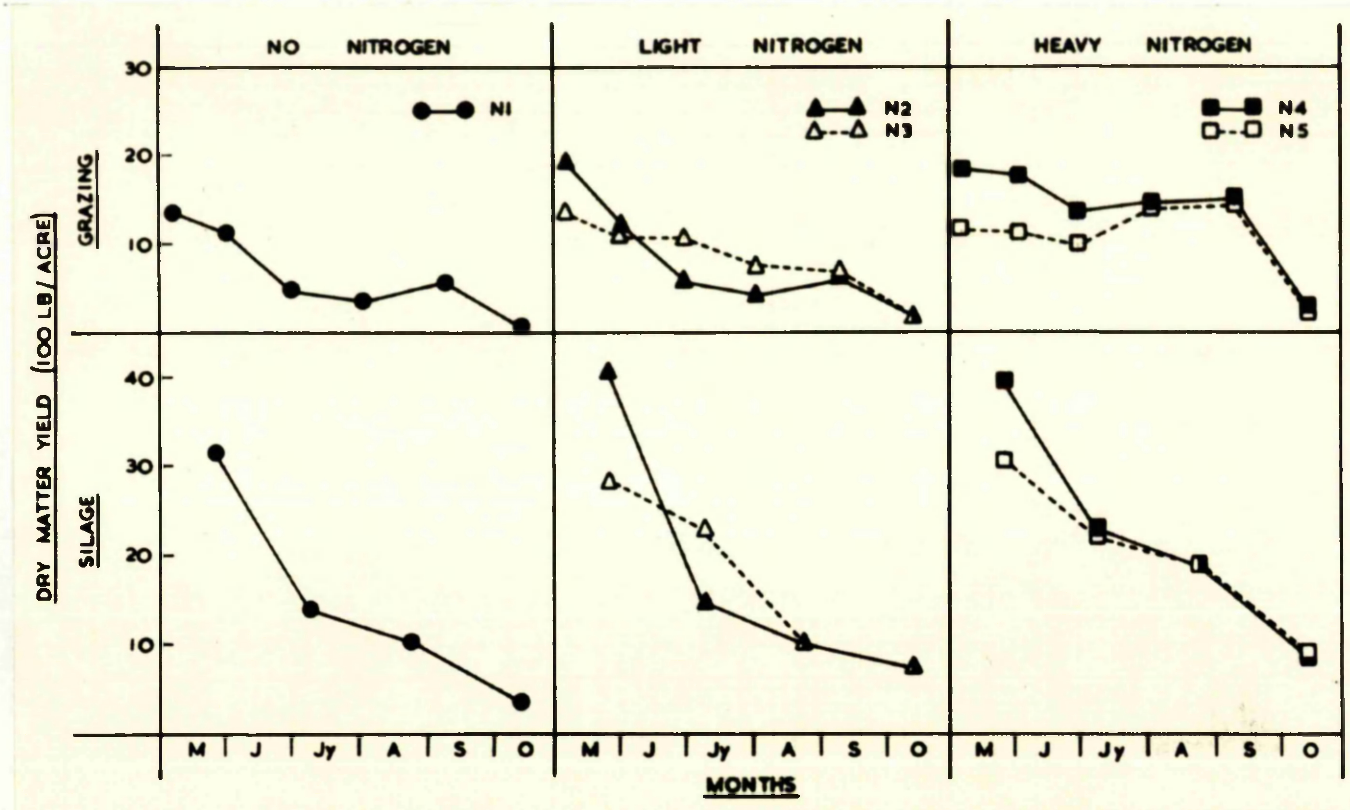


TABLE 10. **Mean total dry matter yields of clover (in 100 lb./acre) - Experiment 1 (Paddock 4) 1954**

	Nitrogen treatments						Stage of cutting	
	N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting								
Close	2.8	1.6	1.5	1.1	0.9	1.6	1.3	1.9
Lax	1.2	1.8	1.2	1.0	1.2	1.3	0.9	1.7
Stage of cutting								
Grazing	1.4	1.3	0.7	1.0	1.0	1.1		
Silage	2.7	2.1	2.0	1.2	1.1	1.8		
Nitrogen means	2.0	1.7	1.4	1.1	1.0			

	$s_{\bar{d}}$	
Between:	±	
H means	0.52	
S means	0.41	All effects NS
N means	0.65	

Coefficient of Variation: Main-plots = 140.1% Sub-plots = 110.1%

TABLE 11. Weighted mean percent clover in mixed herbage dry matter - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments						Stage of cutting	
	N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting								
Close	4.7	2.3	1.9	1.1	1.1	2.2	2.1	2.3
Lax	3.0	3.0	2.2	1.2	1.8	2.2	1.9	2.6
Stage of cutting								
Grazing	3.3	2.5	1.5	1.2	1.4	2.0		
Silage	4.4	2.8	2.6	1.2	1.4	2.5		
Nitrogen means	3.9	2.6	2.0	1.2	1.4			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±
H means	0.90	-
S means	0.59	-
N means	0.93	1.88

Significant effects:

N * (N1 v N2,3,4, & 5 **
(All other comparisons NS

Coefficient of variation: Main-plots = 156.7% Sub-plots = 102.1%

the seasonal distribution of herbage yields is illustrated graphically in Figure 1. Under treatment N1 in which no fertilizer nitrogen was applied, yields were relatively high in the spring and early summer, declined in mid-season and then increased slightly in the autumn, giving a sigmoidal growth curve. The shape of the curve was most typical under the 'grazing' stage of cutting treatment. Treatment N2, which received 2 cwt./acre 'Nitro-Chalk' for the first cut of the season and a further 2 cwt./acre for the last, merely exaggerated this curve by raising the yields at the early cuts and having little effect on those in mid-season. The same total application of fertilizer nitrogen over the season in treatment N3 but with the spring dressing delayed, resulted in a much more uniform distribution of growth over the season under both 'stage of cutting' treatments. With treatments N4 and N5 the general level of yield over the season was higher and it was more evenly distributed than with the no-nitrogen or light-nitrogen treatments. Treatment N5 gave a greater proportion of its total yield in mid-season than treatment N4, particularly under the 'grazing' stage of cutting treatment.

Clover dry matter yields

Mean total dry matter yields of clover over the season are given in Table 10. The coefficients of variation calculated for these yields were extremely large - 140% for main plots and 110% for sub-plots, reflecting the high error variance and very small mean yields. Thus none of the treatment effects were significant.

On average cutting at the 'silage' stage of growth resulted in a 70 lb. /acre increase in the yield of clover dry matter over cutting at the 'grazing' stage. Close-cutting gave a mean increase of 30 lb./acre in the clover dry matter yield in comparison with lax-cutting. Increasing the amount of fertilizer nitrogen applied caused increased depression of clover dry matter yields.

The effects of the various treatments on the weighted mean clover content of total mixed herbage dry matter (see Table 11) were similar to those on the absolute yields of clover. The difference between the means for the two 'height of cutting' treatments, and that between the means for the two 'stage of cutting' treatments was not significant. The mean clover content of herbage from plots receiving no fertilizer nitrogen (i.e. treatment N1) was, however,

TABLE 12. Mean total crude protein yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments						Stage of cutting	
	N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting								
Close	7.68	9.85	9.69	14.83	11.74	10.76	10.56	10.95
Lax	5.20	7.22	6.99	11.19	8.67	7.86	7.59	8.12
Stage of cutting								
Grazing	5.61	7.76	8.00	13.96	10.04	9.07		
Silage	7.26	9.31	8.67	12.06	10.38	9.54		
Nitrogen means	6.44	8.54	8.34	13.01	10.20			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.31	1.34	-
S means	0.23	-	-
N means	0.36	0.74	0.99
N means within a S (and vice versa)	0.52	1.05	1.40

Significant effects

H *

N *** { N1 v N2,3,4 & 5 ***; N2 & 3 v N4 & 5 ***; N 4 v N5 *** }

N x S **

Coefficient of Variation: Main-plots = 13.0% Sub-plots = 9.6%

TABLE 13. Weighted mean percent crude protein in mixed herbage dry matter - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments						Stage of cutting	
	N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting								
Close	13.2	14.0	14.2	15.1	14.1	14.1	15.6	12.6
Lax	13.6	14.8	14.2	15.4	14.8	14.6	15.9	13.2
Stage of cutting								
Grazing	14.3	15.9	15.6	17.0	16.0	15.8		
Silage	12.4	13.0	12.7	13.5	13.0	12.9		
Nitrogen means	13.4	14.4	14.2	15.2	14.5			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±	Significant effects			
H means	0.15	–	–	S	***		
S means	0.16	0.32	0.43				
N means	0.25	0.50	0.68	N	***	N1 v N2,3,4 & 5	***
						N2 & 3 v N4 & 5	**
						N4 v N5	**

Coefficient of Variation: Main-plots = 4.1% Sub-plots = 4.2%

significantly higher than that from plots receiving nitrogen (i.e. treatments N2-4). There were no significant differences in clover content between herbage from any of the latter.

Yields of clover at the individual cuts throughout the season were in most cases too small and variable to allow any conclusions to be drawn with regard to the effect of the treatments on seasonal distribution of clover yield.

Mixed herbage crude protein yields

Table 12 shows the mean total yields of crude protein in the mixed herbage over the season and Table 13 the weighted mean percentages of crude protein in the total mixed herbage dry matter.

On average close-cutting gave significantly greater crude protein yields than lax-cutting, the mean difference being 290 lb./acre. There was, however, no significant difference between the weighted mean percentages of crude protein in the total dry matter from the two 'height of cutting' treatments.

Cutting at the 'silage' stage yielded more crude protein than cutting at the 'grazing' stage though the difference was slight (41 lb./acre) and not significant. Herbage cut at the 'grazing' stage had, however, a weighted mean crude protein content of 15.8% against 12.9% for those cut at the 'silage' stage, and this difference was highly significant.

Yield and weighted mean percentage of crude protein increased progressively and significantly with increasing rate of fertilizer nitrogen application. At low levels of nitrogen application (i.e. treatments N2 and N3) delayed spring application did not significantly effect the total yield of crude protein for the season or the weighted mean percentage of crude protein in the total dry matter. At the high fertilizer nitrogen level, however, herbage from treatment N5 had a lower mean percentage of crude protein and gave a lower crude protein yield than that from treatment N4. This was probably due to the smaller total application of fertilizer nitrogen over the season under treatment N5 as compared with N4 rather than to the delay in spring application.

TABLE 14. Mean total crude protein yields of clover (in 100 lb./acre) - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments						Stage of cutting	
	N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting								
Close	0.74	0.42	0.40	0.27	0.22	0.41	0.33	0.49
Lax	0.33	0.46	0.31	0.25	0.29	0.33	0.24	0.42
Stage of cutting								
Grazing	0.37	0.34	0.20	0.26	0.25	0.28		
Silage	0.69	0.54	0.51	0.26	0.26	0.45		
Nitrogen means	0.53	0.44	0.35	0.26	0.25			
Between:	$s_{\bar{d}}$ ±							
H means	0.13		All effects NS					
S means	0.11							
N means	0.17							

Coefficient of Variation: Main-plots = 140.4% Sub-plots = 111.4%

TABLE 15. Botanical composition of sward (as percent ground cover) - Experiment 1 (Paddock 4) Autumn 1954

		Nitrogen treatments						Stage of cutting	
		N1	N2	N3	N4	N5	Means	Grazing	Silage
Height of cutting									
Close	Sown grass	32.2	33.2	37.0	37.5	40.7	36.1	36.9	35.3
	White clover	11.5	8.7	7.2	2.0	2.2	6.3	4.9	7.7
	Weed grass	40.7	40.1	37.2	48.8	40.3	41.4	42.5	40.3
	Dicot weeds	7.3	7.0	8.3	3.5	5.3	6.3	6.1	6.5
	Bare ground	8.3	11.0	10.3	8.2	11.5	9.9	9.6	10.2
Lax	Sown grass	42.3	36.8	41.5	48.8	45.0	42.9	44.4	41.4
	White clover	14.2	14.0	8.0	4.0	4.5	8.9	6.9	10.9
	Weed grass	25.8	31.8	29.5	33.0	30.8	30.2	31.9	28.5
	Dicot weeds	5.7	5.4	6.8	2.8	5.7	5.3	4.8	5.7
	Bare ground	12.0	12.0	14.2	11.4	14.0	12.7	12.0	13.5
Stage of cutting									
Grazing	Sown grass	39.2	35.3	41.8	43.2	43.8	40.7		
	White clover	11.5	10.3	3.8	1.8	2.2	5.9		
	Weed grass	33.3	36.8	35.8	42.7	37.5	37.2		
	Dicot weeds	6.7	7.7	5.8	2.5	4.7	5.5		
	Bare ground	9.3	9.9	12.8	9.8	11.8	10.7		
Silage	Sown grass	35.3	34.7	36.7	43.2	41.8	38.3		
	White clover	14.2	12.3	11.3	4.2	4.5	9.3		
	Weed grass	33.3	35.2	30.8	39.2	33.7	34.4		
	Dicot weeds	6.2	4.7	9.3	3.8	6.3	6.1		
	Bare ground	11.0	13.1	11.9	9.6	13.7	11.9		
Nitrogen means	Sown grass	37.2	35.0	39.2	43.2	42.8			
	White clover	12.8	11.3	7.6	3.0	3.3			
	Weed grass	33.3	36.0	33.3	40.9	35.6			
	Dicot weeds	6.5	6.2	7.6	3.2	5.5			
	Bare ground	10.2	11.5	12.3	9.7	12.8			

The interaction of 'stage of cutting' and 'nitrogen' treatments was highly significant in the crude protein yield data. Within nitrogen treatments N1, N2, N3 and N5 the mean yield of crude protein was greater under the 'silage' stage of cutting treatment than under the 'grazing' stage treatment, the difference being highly significant in N1 and N2, but small and not significant in N3 and N5. The reverse occurred within treatment N4, cutting at the 'grazing' stage yielding highly significantly more protein than cutting at the 'silage' stage. This interaction was not significant in the weighted mean crude protein percentage data.

Coefficients of variation calculated from the crude protein yield data - 13.0% for main plots and 9.6% for sub-plots, were much the same as those calculated for mixed herbage dry matter yields, while those for the weighted mean crude protein content data were much lower.

Clover crude protein yields

Mean yields of clover crude protein (Table 14) like those of clover dry matter, were small and extremely variable, and none of the treatment effects was significant. In general, however, the effects were similar in the two sets of data.

Close-cutting gave on average slightly higher clover crude protein yields than lax-cutting, while cutting at the 'silage' stage gave higher yields than cutting at the 'grazing' stage. Increasing rate of fertilizer nitrogen application caused progressive decline in the yield of crude protein from the clover fraction of the herbage.

Plant cover

The mean botanical composition of the sward in terms of 'percentage ground cover' under the various treatments in the autumn of 1954 is shown in Table 15. Since the percentage ground cover of many individual plant species showed quite obvious random variations unconnected with treatment, the data have been grouped into five fractions - 1) sown grass, 2) white clover, 3) weed grass, 4) dicotyledonous weeds, and 5) bare ground. Even after grouping, the effects of treatments on botanical composition of ground cover were to some extent obscured by random variation. The magnitude of error variance encountered in such data is

TABLE 16. Mean percentage ground cover of clover in sward - Experiment 1 (Paddock 4) 1954

	Nitrogen treatments					Means	Stage of cutting	
	N1	N2	N3	N4	N5		Grazing	Silage
Height of cutting	Mean percentages							
Close	11.5	8.7	7.2	2.0	2.2	6.3	4.9	7.7
Lax	14.2	14.0	8.0	4.0	4.5	8.9	6.9	10.9
Stage of cutting								
Grazing	11.5	10.3	3.8	1.8	2.2	5.9		
Silage	14.2	12.3	11.3	4.2	4.5	9.3		
Nitrogen means	12.8	11.3	7.6	3.0	3.3			
Height of cutting	Mean angular transformations							
Close	19.5	16.8	13.2	7.0	7.3	12.7	11.6	13.9
Lax	21.4	20.2	14.7	7.6	9.9	14.8	13.2	16.4
Stage of cutting								
Grazing	19.0	17.8	10.8	6.0	8.3	12.4		
Silage	21.9	19.2	17.1	8.6	8.8	15.1		
Nitrogen means	20.4	18.5	14.0	7.3	8.6			

	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%	Significant effects
Between:	±	±	±	
H means	2.79	-	-	N *** (N1 v N2,3,4 & 5 ***
S means	1.80	-	-	(N2 & 3 v N4 & 5 ***
N means	2.85	5.78	7.75	

Coefficient of variation: Main-plots = 78.5% Sub-plots = 50.7%

demonstrated in Table 16, which gives separately the mean ground cover percentage data for white clover. Because of the high coefficients of variation calculated for these data the data for other fractions of the sward were not analysed statistically.

Considering the clover data first, lax-cutting gave a slightly higher mean percentage clover cover than close-cutting but the difference was not significant. Percentage ground cover of clover was higher under the 'silage' stage of cutting treatment than under the 'grazing' stage treatment though here also the difference was not signficant. Difference in mean clover cover between treatment N1 and treatments N2-5 was highly significant, as was the difference between the two light nitrogen treatments (N2 and N3) and the two heavy nitrogen treatments (N4 and N5). Clover cover decreased on average as rate of fertilizer nitrogen application increased. Delaying the spring application of fertilizer nitrogen did not effect clover cover significantly either under light or heavy nitrogen treatments, though the mean for treatment N3 was somewhat lower than that for N2.

The effects of the various treatments on the percentage ground cover of any of the other constituents of the sward were not striking. On average cutting at the 'grazing' stage gave a greater percentage ground cover of both sown and weed grasses in the sward than cutting at the 'silage' stage, the difference being accounted for mainly in the greater percentage ground cover of clover under the latter treatment. Percentage ground cover of weed grasses was higher under close than under lax-cutting, while the percentage cover of sown grasses was lower.

Apart from their differential effect on clover cover, few of the other effects of the nitrogen treatments on ground cover were consistent. Sown grass cover in the sward, however, was generally slightly higher under the heavy than under the light or no nitrogen treatments. Weed grass cover was also higher under treatment N4 than under all the other treatments.

1955 - Field E site

Mixed herbage dry matter yields

Mean total dry matter yields of mixed herbage over the 1955 season are given in Table 17. A slightly

TABLE 17. **Mean total dry matter yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Field E) 1955**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	51.8	71.7	63.7	82.8	68.4	76.4	69.1	61.5	76.7
Lax	31.6	45.4	41.6	62.0	44.7	52.7	46.3	40.1	52.5
Stage of cutting									
Grazing	37.9	50.9	40.6	68.6	47.8	59.1	50.8		
Silage	45.5	66.2	64.6	76.2	65.2	70.0	64.6		
Nitrogen means	41.7	58.6	52.6	72.4	56.5	64.5			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	2.79	6.83	10.34
S means	2.79	6.83	10.34
N means	2.01	4.05	5.42
N means within a S	2.84	5.74	7.67
S means within a N	3.81	8.57	12.35

Significant effects

H ***

S **

N ***
- N1 v N2,3,4,5 & 6 ***
- N2 & 3 v N4,5 & 6 ***
- N2 v N3 **
- N4 v N5 & 6 ***
- N5 v N6 ***

N x S **

Coefficient of Variation: Main-plots = 20.5% Sub-plots = 8.5%

TABLE 18. Analysis of variance of total dry matter yields of mixed herbage - Experiment 1 (Field E) 1955

Source of variation	df	Sums of squares	Mean squares	Variance ratio (F)	
Height of cutting (H)	1	9368.52	9368.52	66.87	***
Stage of cutting (S)	1	3410.00	3410.00	24.34	**
H x S	1	35.99	35.99		
Replicates	2	114.63	57.32		
Error (a)	6	840.65	140.11		
Nitrogen treatments (N)	5	6548.62	1309.72	54.21	***
N1 v N2,3,4,5,6	1	3684.48	3684.48	152.50	***
N2 & 3 v N4,5,6	1	1139.20	1139.20	47.15	***
N2 v N3	1	211.23	211.23	8.74	**
N4 v N5 & 6	1	1129.71	1129.71	46.76	***
N5 v N6	1	384.00	384.00	15.89	***
N x H	5	74.97	14.09		
N x S	5	611.39	122.28	5.06	**
N x S x H	5	78.36	15.67		
Error (b)	40	966.33	24.16		
Total	71	22049.46			

*** Significant at 0.1% level
** " " 1% "

different design was used for the experiment on the new site in 1955, and this involved changes in the analysis of variance of the data. The analysis of the total dry matter yields of mixed herbage is, therefore, given in full in Table 18 as an example.

On average, yields were rather lower in 1955 than in 1954. Although this may have been due partly to treatments being applied on different sites in the two years, it was probably in the main a function of the weather. The summer of 1954 was an extremely wet one, while a prolonged drought was experienced in the summer of 1955 (see Appendix 1). On the whole, however, the relative effects of the various treatments on mixed herbage dry matter yields were very similar in the two seasons.

Close-cutting yielded on average 2,280lb./acre more dry matter than lax-cutting, or an increase of 49%. This difference, which was highly significant, was somewhat larger than that observed in 1954.

The mean yield from cutting at the 'silage' stage was 1,380 lb./acre greater than that from cutting at the 'grazing' stage, and this difference was highly significant.

Mean yield again increased progressively and highly significantly with increasing rate of fertilizer nitrogen application (cf. N1, N2 and N4). The effect of delaying the spring dressing of fertilizer nitrogen in treatment N3 as compared with treatment N2 was greater in 1955 than in 1954. In the second year treatment N3 yielded 600 lb./acre less mixed herbage dry matter than treatment N2, and this difference was highly significant. As in 1954 treatment N5 gave a highly significantly lower dry matter yield than treatment N4. The additional nitrogen treatment N6, in which the first dressing of the season was delayed, but the same total amount of fertilizer was applied over the season as in N4, also gave a highly significantly lower yield than N4. However, N6 outyielded N5 by a highly significant amount.

Although interaction of 'nitrogen' and 'stage of cutting' treatments was highly significant this was due solely to nitrogen treatments N3 and N5 being in fact identical, a summer drought making it possible to obtain only three cuts under the 'silage' stage of

TABLE 19. Mean dry matter yields of mixed herbage (in 100 lb./acre) at each cut in the season - Experiment 1 (Field E) 1955

		'Grazing' Stage Cut No.					'Silage' Stage Cut No.		
		1	2	3	4	5	1	2	3
Height of cutting									
Close		26.0	11.0	6.8	6.0	11.7	38.2	18.9	19.6
Lax		11.7	14.8	2.3	3.7	7.6	24.2	14.6	13.7
$s_{\bar{d}}$	±	1.64	0.61	0.54	0.65	1.20	1.26	0.67	1.88
L.S.D. (5%	±	7.05	2.62	2.34	-	-	2.61	2.87	-
L.S.D. (1%	±	-	-	-	-	-	3.55	-	-
F. Sig. at		5%	5%	5%	NS	NS	0.1%	5%	NS
Nitrogen treatments									
N1		15.5	12.1	2.3	3.4	4.5	23.5	11.2	10.8
N2		28.6	9.4	1.9	2.7	8.3	42.4	7.6	16.2
N3		13.7	12.2	4.4	2.9	7.5	27.6	19.9	17.0
N4		28.2	18.2	5.8	6.0	11.3	39.6	18.7	17.9
N5		14.2	12.8	4.6	5.6	10.6	27.5	19.6	18.1
N6		13.0	12.5	8.3	9.3	15.9	26.8	23.4	19.8
$s_{\bar{d}}$	±	1.27	0.80	0.55	0.49	0.83	2.18	0.90	1.81
L.S.D. (5%	±	2.66	1.67	1.16	1.02	1.73	4.52	1.87	3.78
L.S.D. (1%	±	3.62	2.28	1.58	1.39	2.36	6.15	2.56	5.16
F. Sig. at		0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	1%

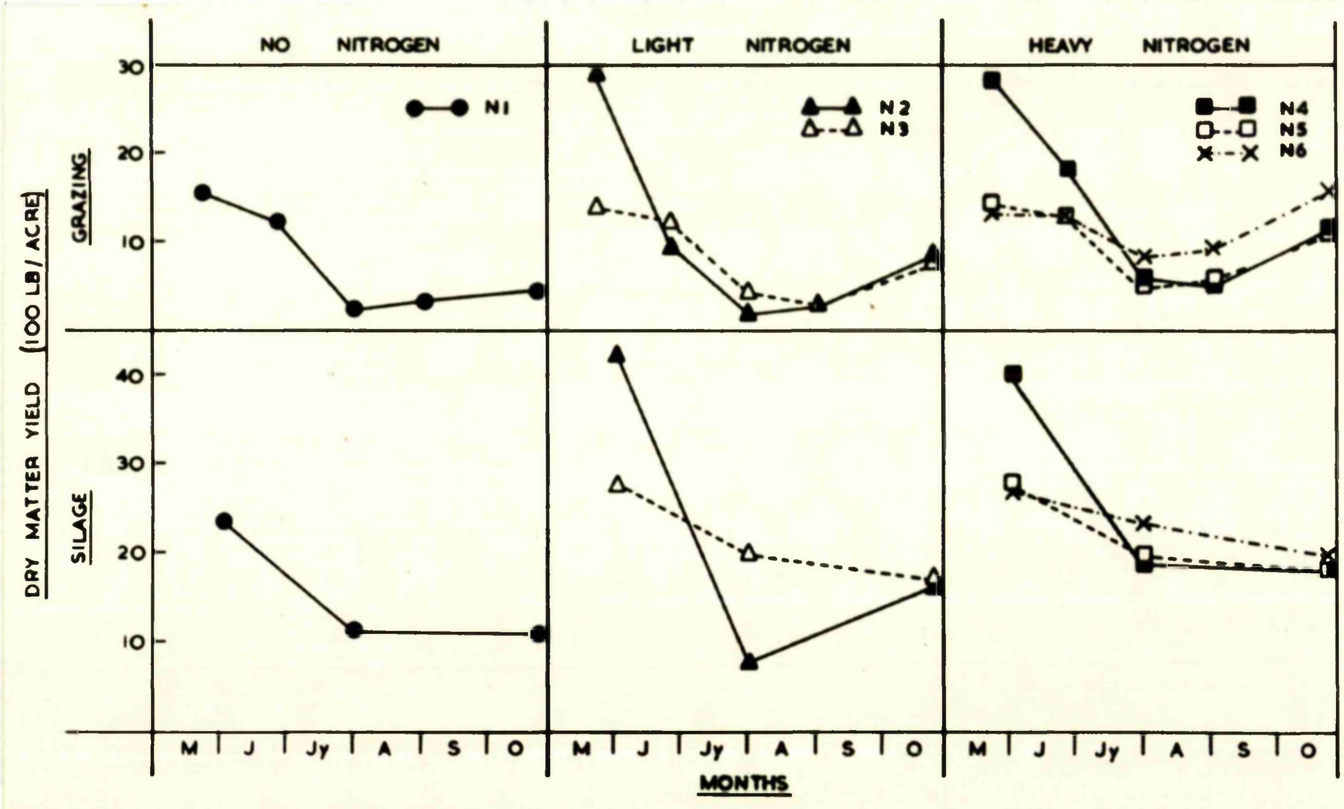
TABLE 20. Analysis of variance of dry matter yields of mixed herbage at first cut of season on 'Grazing' plots

Experiment 1 (Field E) 1955

Source of variation	df	Sums of squares	Mean squares	Variance ratio (F)
Height of cutting (H)	1	1850.44	1850.44	76.62 *
Replicates	2	118.70	59.35	
Error (a)	2	48.30	24.15	
Nitrogen treatments (N)	5	1655.03	331.01	67.97 ***
N1 v N2,3,4,5,6	1	80.67	80.67	16.56 ***
N2 & 3 v N4,5,6	1	52.27	52.27	10.73 **
N2 v N3	1	669.01	669.01	137.37 ***
N4 v N5 & 6	1	848.75	848.75	174.28 ***
N5 v N6	1	4.33	4.33	
N x H	5	37.45	7.49	
Error (b)	20	97.45	4.87	
Total	35	3807.37		

*** Significant at 0.1% level
** " " 1% "
* " " 5% "

FIGURE 2. Mean yields of mixed herbage at each cut in the season - Experiment 1 (Field E) 1955



cutting treatment in 1955. The difference in yield between N3 and N5 was not significant under the 'silage' stage of cutting treatment though it was under the 'grazing' treatment.

The coefficient of variation for main plots calculated from the 1955 mixed herbage dry matter yield data was somewhat higher than that calculated from the 1954 data, while the sub-plot coefficient was much the same.

Mean yields of mixed herbage dry matter for the various treatments at the individual cuts in 1955 are given in Table 19 and an example of the type of analysis of variance calculated for the individual cut data is given in Table 20.

As pointed out when dealing with the 1954 results, comparison of the seasonal distribution of yield under the two 'stage of cutting' treatments is difficult on account of the unequal number of cuts. As in 1954, however, the mean yield in the early part of the season was greater under the 'silage' stage treatment than under the 'grazing' stage treatment. The former treatment yielded on average 3120 lb./acre mixed herbage dry matter by the first cut on June 2, while the total yield of the first two cuts on the latter was only 3170 lb./acre, though the second cut was not taken until June 27.

Close-cutting gave greater yields of mixed herbage dry matter than lax-cutting at all but one cut under both 'stage of cutting' treatments. The exception was the second cut on the 'grazing' plots when the reverse occurred, the difference being significant. At all other cuts there was a relatively large difference in favour of close-cutting. This difference was highly significant at the first 'silage' cut, significant at the first, second and third 'grazing' cuts and the second 'silage cut, but not significant at the other cuts though it was still appreciable.

Yields at each cut over the season under each of the fertilizer nitrogen treatments are graphed in Figure 2. These 'growth curves' bear a general similarity to those constructed from the 1954 data, though the drought during the summer of 1955 caused a much greater mid-season depression in yield than occurred in 1954. In addition a secondary peak of growth occurred in the autumn of 1955 under many of the nitrogen treatments particularly within the 'grazing' stage of cutting treatment, whereas yields

TABLE 21. **Mean total dry matter yields of clover (in 100 lb./acre) - Experiment 1 (Field E) 1955**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	10.6	5.7	5.5	3.2	5.5	5.4	6.0	6.2	5.8
Lax	6.6	2.3	2.6	2.5	4.0	3.2	3.5	2.7	4.3
Stage of cutting									
Grazing	6.8	4.5	4.2	2.3	3.9	4.9	4.4		
Silage	10.4	3.5	3.9	3.4	5.7	3.6	5.1		
Nitrogen means	8.6	4.0	4.0	2.8	4.8	4.3			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	1.08	-	-
S means	1.08	-	-
N means	0.97	1.96	2.62

Significant effects

N *** (N1 v N2,3,4,5 & 6 ***
(N4 v N5 & 6 *

Coefficient of Variation: Main-plots = 96.7% Sub-plots = 49.9%

declined sharply during this period in 1954.

Comparison of the distribution of yield for the six nitrogen treatments under the 'silage' stage treatment is difficult since only three cuts were obtained over the season. For this reason the following remarks on the effect of nitrogen treatments on seasonal distribution of yields relate mainly to the 'grazing' stage treatment.

As in 1954 the sigmoidal pattern of yield under treatment N1 was exaggerated by treatment N2. The latter, in fact, gave lower yields at the second, third and fourth 'grazing' cuts than the former. On the other hand, treatment N3 gave a much more uniform distribution of yield over the season than treatment N2, though its total yield was lower. Comparison of the growth curves for treatments N4, N5 and N6 shows the same effect, distribution of yield over the season being particularly uniform with treatment N6.

<u>Clover dry matter yields</u>

The total dry matter yields from the clover fraction of the sward in 1955 are given in Table 21.

Clover yields were greater and showed less variation in 1955 than in 1954. Thus the coefficients of variation calculated from the 1955 data were considerably lower than those from the 1954 data. The coefficient of 96.7% for main plots was, however, still too large to allow precise measurement of the significance of the small differences encountered between treatments.

As in 1954, close-cutting gave higher mean clover dry matter yields than lax-cutting. Though the difference (250 lb./acre) between these treatments was considerably larger in 1955 than in 1954, it was not significant.

Cutting at the 'silage' stage of growth gave clover dry matter yields greater by 70 lb./acre on average than cutting at the 'grazing' stage. This difference was also not significant.

As in 1954 clover dry matter yields decreased with increasing rate of fertilizer nitrogen application. Though the difference between treatments N1 and N2 was significant, that between N2 and N4 was not. Where total applications of fertilizer nitrogen were light (treatments N2 and N3), delaying the spring dressing had no effect on clover yield, but at the higher rates

TABLE 22. Weighted mean percent clover in mixed herbage dry matter - Experiment 1 (Field E) 1955

	Nitrogen treatments						Means	Stage of cutting	
	N1	N2	N3	N4	N5	N6		Grazing	Silage
Height of cutting									
Close	20.4	8.1	9.1	3.8	8.1	7.0	9.4	10.5	8.3
Lax	19.4	5.2	6.3	3.8	8.0	6.3	8.2	7.2	9.1
Stage of cutting									
Grazing	16.9	8.3	9.2	3.3	7.2	8.3	8.9		
Silage	22.8	5.0	6.2	4.3	8.9	5.0	8.7		
Nitrogen means	19.9	6.6	7.7	3.8	8.0	6.6			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	1.62	-	-
S means	1.62	-	-
N means	1.60	3.23	4.32
N means within a S	2.26	4.57	-
S means within a N	2.62	5.73	-

Significant effects

N *** (N1 v N2,3,4,5 & 6 ***; N4 v N5 & 6 *)

N x S *

Coefficient of Variation: Main-plots = 78.3% Sub-plots = 44.5%

TABLE 23. Mean dry matter yields of clover (in 100 lb./acre) at each cut in the season - Experiment 1(Field E)1955

		'Grazing' Stage Cut No.					'Silage' Stage Cut No.		
		1	2	3	4	5	1	2	3
Height of cutting									
Close		0.3	1.0	1.4	1.6	1.8	0.3	2.1	3.3
Lax		0.1	0.6	0.5	0.8	0.8	0.2	1.8	2.4
$s_{\bar{d}}$	±	0.09	0.24	0.47	0.34	0.37	0.12	0.57	1.35
F. Sig. at		NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen treatments									
N1		0.2	1.2	1.2	2.1	2.2	0.5	4.4	5.5
N2		0.2	0.5	0.6	1.4	1.8	0.1	1.0	2.4
N3		0.1	0.6	1.0	1.1	1.3	0.2	1.5	2.2
N4		0.2	0.6	0.5	0.5	0.5	0.1	1.2	2.0
N5		0.1	0.8	0.9	1.0	1.0	0.3	1.7	3.6
N6		0.2	1.0	1.5	1.2	1.0	0.4	1.9	1.4
$s_{\bar{d}}$	±	0.08	0.29	0.25	0.35	0.37	0.13	0.72	0.95
L.S.D. (5%	±	-	-	0.52	0.73	0.77	-	1.50	1.99
L.S.D. (1%	±	-	-	0.72	1.00	1.05	-	2.05	2.71
F. Sig. at		NS	NS	1%	1%	1%	NS	1%	1%

of application (treatments N4, N5 and N6) a similar delay gave increased clover yields. The difference between treatments N5 and N4 was significant, but all other differences between the three heavy nitrogen treatments were not, though that between N4 and N6 was appreciable.

The effects of the various treatment factors on the weighted mean percentage of clover in the total mixed herbage dry matter are shown in Table 22.

The differences between the weighted mean clover percentages of herbage from the two 'height of cutting' and for the two 'stage of cutting' treatments were not significant. The effect of fertilizer nitrogen treatment on clover content was highly significant, the means for each of the six levels being generally in the same order as mean clover yields. The interaction of 'nitrogen' and 'stage of cutting' treatments had a significant effect on the percentage of clover in the herbage dry matter though not on the clover yields. The clover content of herbage cut at the 'grazing' stage was greater than that of herbage cut at the 'silage' stage under treatments N2, N3 and N6, while the reverse was observed under treatments N1, N4 and N5. The difference in clover content between herbage from the two 'stage of cutting' treatments was only significant under treatment N1.

Mean yields of clover dry matter at the individual cuts over the season for the various treatments are given in Table 23. Averaged over all treatments clover growth was slowest in the spring and early summer, increased slowly to a maximum at mid-season, and then remained steady into the autumn.

Under both the 'grazing' and the 'silage stage of cutting treatments, the yield of clover dry matter was higher from close-cutting than from lax-cutting at all cuts over the season, though none of the differences was significant.

Differences between the mean clover yields for the six nitrogen treatments at the first and second 'grazing' cuts and the first 'silage' cut were not significant. At all other cuts under both 'stage of cutting' treatments some differences were significant or highly significant. Clover yields at each cut over the season under each

FIGURE 3. Mean yields of white clover at each cut in the season - Experiment 1 (Field E) 1955

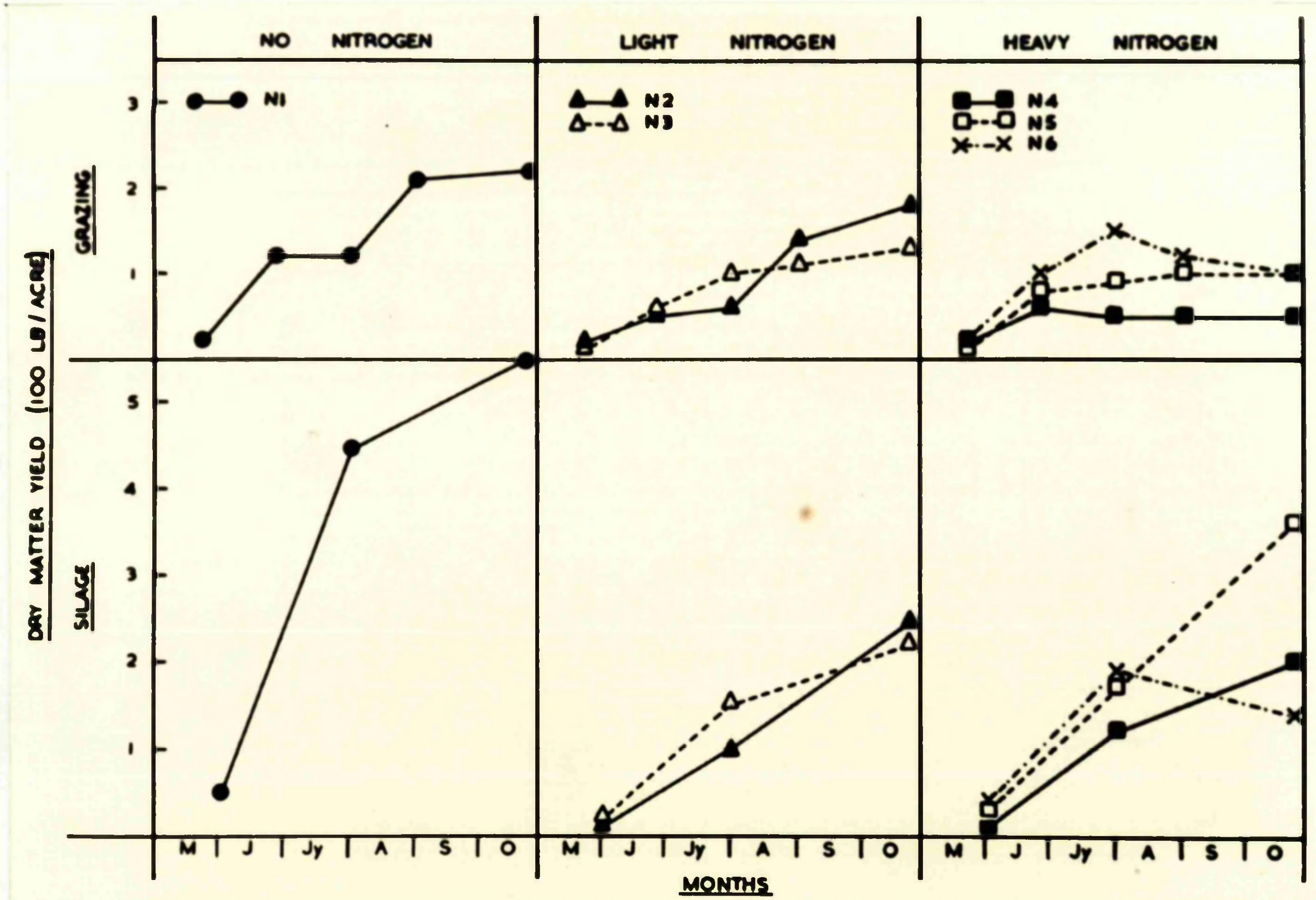


TABLE 24. **Mean total crude protein yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Field E) 1955**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	6.60	8.51	7.50	9.70	8.13	9.69	8.36	8.68	8.03
Lax	4.03	5.53	4.86	7.54	5.53	6.96	5.74	5.42	6.06
Stage of cutting									
Grazing	5.01	6.72	5.29	9.40	6.63	9.25	7.05		
Silage	5.63	7.32	7.07	7.84	7.03	7.40	7.05		
Nitrogen means	5.32	7.02	6.18	8.62	6.83	8.32			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.44	1.07	1.63
S means	0.44	-	-
N means	0.31	0.63	0.85
N means within a S	0.44	0.90	1.20
S means within a N	0.60	1.34	1.94

Significant effects

H ***

N ***
- N1 v N2,3,4,5 & 6 ***
- N2 & 3 v N4,5 & 6 ***
- N2 v N3 *
- N4 v N5 & 6 ***
- N5 v N6 ***

N x S ***

Coefficient of Variation: Main-plots = 26.4% Sub-plots = 10.9%

TABLE 25. Weighted mean percent crude protein in mixed herbage dry matter - Experiment 1 (Field E) 1955

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	12.8	12.0	12.1	11.8	12.2	12.9	12.3	14.0	10.5
Lax	12.6	12.3	11.7	12.2	12.3	13.4	12.4	13.2	11.6
Stage of cutting									
Grazing	12.9	13.2	12.7	13.7	13.6	15.7	13.6		
Silage	12.4	11.1	11.0	10.3	10.9	10.7	11.1		
Nitrogen means	12.7	12.2	11.9	12.0	12.2	13.2			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.21	-	-
S means	0.21	0.52	0.79
H means within a S (and vice versa)	0.30	0.73	1.11
N means	0.35	0.70	0.94
N means within a S	0.49	0.99	1.32
S means within a N	0.50	1.04	1.43

Significant effects

S ***

H x S **

N ** { N2 & 3 v N4,5 & 6 * ; N4 v N5 & 6 * ; N5 v N6 * }

N x S ***

Coefficient of Variation: Main-plots = 7.3% Sub-plots = 6.9%

nitrogen treatment are presented graphically for the two 'stage of cutting' treatments in Figure 5.

The growth curves for each of the six nitrogen treatments under the two 'stage of cutting' treatments do, in general, resemble one another, though the differences under the 'silage' treatment are less obvious on account of the infrequency of cutting. However, under the 'grazing' stage treatment, it is obvious that the early spring dressing of fertilizer nitrogen in treatment N2 depressed the clover yield at the first three cuts of the season in comparison with treatment N1. By the fourth and fifth cuts, however, this effect had diminished considerably, and though clover yields were still lower with treatment N2 than N1 the differences were not significant. In treatment N3 fertilizer nitrogen applied after the second cut had little effect on clover yield at the third cut. Yields were, however, considerably depressed at the fourth and fifth cuts of the season in comparison with treatments N1 and N2. Repeated application of fertilizer nitrogen throughout the season under treatment N4 gave small but relatively uniform clover yields at all cuts. In general the effect of treatment N5 was similar to that of N3, though the degree of depression of clover yields at the fourth and fifth cuts of the season was greater on account of the continued application of fertilizer nitrogen. With treatment N6 also the heavy dressing of fertilizer nitrogen applied after the second cut had no effect on clover yields at the third cut, although the continued use of such heavy dressings caused marked declines in these yields at the subsequent cuts.

Mixed herbage crude protein yields

Mean total yields of crude protein of the mixed herbage over the season are given in Table 24, and the weighted mean percentages of crude protein in the mixed herbage in Table 25.

The mean mixed herbage crude protein yield from close-cutting exceeded that from lax-cutting by proportionately the same amount as the dry matter yield from the former exceeded that from the latter, since the percentages of crude protein in the herbage from the two treatments were not significantly different over the season. The difference in absolute yield of crude protein (362 lb./acre) between the two treatments was highly significant. This is in direct agreement with the 1954 results.

On the other hand, there was no significant difference between the mean yields of crude protein from the two 'stage of cutting' treatments, although the weighted mean percentage of crude protein in the herbage under the 'grazing' treatment was higher than that in the herbage under the 'silage' treatment. This difference was highly significant. The effect was again similar to that noted in 1954.

Mean yield of crude protein increased significantly with increasing rate of fertiliser nitrogen application (cf. N1, N2 and N4). In the light nitrogen treatments delaying the spring dressing in treatment N3 as compared with treatment N2 caused a significant decrease in crude protein yield. In the heavy nitrogen treatments, however, a similar delay had no significant effect where the same total amount of fertiliser nitrogen was applied over the season (cf. treatments N4 and N6), but where a smaller amount was applied (treatment N5) crude protein yield was significantly lower.

The weighted mean percentage of crude protein in the herbage decreased slightly with increasing nitrogen application (cf. treatments N1, N2 and N4) though only the differqnce between treatments N1 and N4 was significant. The difference between the two light nitrogen treatments was not significant, but that in which the spring nitrogen dressing was delayed (N3) yielded herbage with a lower crude protein percentage than the other (N2) and differred significantly from treatment N1. With the heavy nitrogen treatments there was no significant differnece between the percentage of crude protein in the herbage from treatments N4 and N5. Treatment N6, however, gave herbage with a higher mean percentage of crude protein than treatments N4 and N5 and, in fact, the difference between this treatment and all others except treatment N1, was significant or highly significant.

The interaction of 'stage of cutting' with 'height of cutting' treatments was highly significant in the weighted mean crude protein percentage data, but not significant in the crude protein yield data. Under the 'grazing' stage of cutting treatment close-cutting yielded herbage with a significantly higher crude protein percentage than lax-cutting, while under the 'silage' stage treatment the reverse occurred.

The interaction of 'stage of cutting' with 'nitrogen'

TABLE 26. **Mean total crude protein yields of clover (in 100 lb./acre) - Experiment 1 (Field E) 1955**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	2.68	1.44	1.35	0.74	1.33	1.26	1.46	1.60	1.33
Lax	1.63	0.61	0.63	0.60	0.97	0.76	0.86	0.71	1.02
Stage of cutting									
Grazing	1.84	1.22	1.08	0.58	0.98	1.25	1.16		
Silage	2.47	0.83	0.91	0.76	1.32	0.77	1.17		
Nitrogen means	2.15	1.02	0.99	0.67	1.15	1.01			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.27	-	-
S means	0.27	-	-
N means	0.23	0.47	0.62

Significant effects

N *** (N1 v N2,3,4,5 & 6 ***
(N4 v N5 & 6 *

Coefficient of Variation: Main-plots = 99.8% Sub-plots = 48.8%

treatments had a highly significant effect on crude protein yields and on herbage crude protein percentages. Considering absolute yields first, under treatments N1, N2, N3 and N5 cutting at the 'silage' stage of growth gave a greater mean yield than cutting at the 'grazing' stage, though the difference was only significant with treatment N3. Under treatments N4 and N6 the 'grazing' treatment gave highly significantly greater yields of crude protein than the 'silage' treatment. In general, the relative effects of the various nitrogen treatments on crude protein yield were the same within each 'stage of cutting' treatment, though the degree of difference between some of the treatments did vary slightly.

Turning to the effect of this interaction on the percentage of crude protein, this was higher in herbage cut at the 'grazing' stage than in that cut at the 'silage' stage under all nitrogen treatments, but the degree of difference varied considerably. Within treatment N1 the difference was slight and not significant, while it was highly significant within all other nitrogen treatments, being rather larger with the heavy nitrogen treatments N4 and N5 than with the light treatments N2 and N3, but greatest with N6. There was no significant difference between the percentage of crude protein in the herbage from treatments N2 and N3 and that from treatment N1 within both 'stage of cutting' treatments. However, within the 'grazing' treatment treatments N4, N5 and N6 gave herbage with a significantly or almost significantly greater crude protein percentage than treatment N1, but within the 'silage' treatment the reverse occurred.

Clover crude protein yields

Mean yields of crude protein from the clover fraction of the sward (Table 26) were greater and showed less variation in 1955 than in 1954, though the relative effects of the various treatments were much the same in the two years.

The difference between the mean clover crude protein yields from the two 'height of cutting' treatments was not significant, though that from close-cutting was the greater as in 1954. The two 'stage of cutting' treatments gave virtually the same mean yield of clover crude protein. Though all of the differences between mean clover crude protein yields from the various nitrogen treatments were not significant in 1954, some were significant in 1955. Treatment N1 gave highly significantly greater yields than

TABLE 27. **Botanical composition of sward (as percent ground cover) - Experiment 1 (Field B) Autumn 1955**

		Nitrogen treatments							Stage of cutting	
		N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting										
Close	Sown grass	18.8	28.0	28.8	29.6	33.3	31.5	28.4	27.5	29.2
	White clover	39.3	17.2	16.5	9.2	10.7	10.3	17.2	14.9	19.5
	Weed grass	26.3	37.2	36.2	36.7	32.2	34.7	33.9	39.0	28.7
	Dicot weeds	1.0	0.6	1.2	1.6	0.3	0.8	0.9	1.4	0.4
	Bare ground	14.6	17.0	17.3	22.9	23.5	22.7	19.6	17.2	22.2
Lax	Sown grass	17.8	29.2	30.8	28.6	28.2	32.2	27.8	28.7	26.9
	White clover	39.8	15.3	14.0	8.3	16.3	14.0	18.0	13.4	22.5
	Weed grass	27.0	39.4	37.6	46.8	37.2	29.4	36.2	39.3	33.1
	Dicot weeds	1.6	0.3	0.6	0.4	1.6	0.3	0.8	1.5	0.2
	Bare ground	13.8	15.8	17.0	15.7	16.7	24.1	17.2	17.1	17.3
Stage of cutting										
Grazing	Sown grass	19.2	28.4	32.5	29.0	28.2	31.5	28.1		
	White clover	34.2	15.7	12.5	4.3	9.3	9.0	14.2		
	Weed grass	31.3	42.3	37.7	48.8	39.4	35.4	39.2		
	Dicot weeds	2.0	0.8	1.6	1.3	1.8	1.0	1.4		
	Bare ground	13.3	12.8	15.7	16.6	21.3	23.1	17.1		
Silage	Sown grass	17.6	28.8	27.2	29.5	33.3	32.2	28.1		
	White clover	45.0	16.8	18.0	13.2	17.7	15.4	21.0		
	Weed grass	22.0	34.2	36.0	34.6	30.0	28.7	30.9		
	Dicot weeds	0.4	0.2	0.2	0.7	0.1	0.1	0.3		
	Bare ground	15.0	20.0	18.6	22.0	18.9	23.6	19.7		
Nitrogen means	Sown grass	18.3	28.6	29.8	29.2	30.8	31.8			
	White clover	39.6	16.2	15.2	8.8	13.5	12.2			
	Weed grass	26.7	38.2	36.8	41.8	34.7	32.0			
	Dicot weeds	1.2	0.5	1.0	1.0	1.0	0.6			
	Bare ground	14.2	16.5	17.2	19.2	20.0	23.4			

TABLE 28. **Mean percentage ground cover of clover in sward - Experiment 1 (Field E) 1955**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
	Mean percentages								
Height of cutting									
Close	39.3	17.2	16.5	9.2	10.7	10.3	17.2	14.9	19.5
Lax	39.8	15.3	14.0	8.3	16.3	14.0	18.0	13.4	22.5
Stage of cutting									
Grazing	34.2	15.7	12.5	4.3	9.3	9.0	14.2		
Silage	45.0	16.8	18.0	13.2	17.7	15.3	21.0		
Nitrogen means	39.6	16.2	15.2	8.8	13.5	12.2			
	Mean angular transformations								
Height of cutting									
Close	38.8	23.6	22.4	17.2	17.9	18.1	23.0	21.1	24.9
Lax	39.0	23.0	21.0	15.9	21.7	21.7	23.7	19.8	27.6
Stage of cutting									
Grazing	35.7	22.8	19.6	11.8	16.0	16.8	20.4		
Silage	42.1	23.8	23.8	21.2	23.6	23.0	26.2		
Nitrogen means	38.9	23.3	21.7	16.5	19.8	19.9			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	1.81	-	-
S means	1.81	4.42	-
N means	2.62	5.29	7.07

Significant effects

S *

N ***(N1 v N2,3,4,5 & 6 ***
N2 & 3 v N4,5 & 6 *)

Coefficient of Variation: Main-plots = 32.8% Sub-plots = 27.4%

all the other nitrogen treatments. In addition, treatment N5 gave a significantly greater yield of clover crude protein than treatment N4.

Plant cover

The effects of the various treatments on the botanical composition of the sward in terms of 'percentage ground cover' are shown in Table 27. As with the 1954 results detailed statistical analysis was carried out on the clover ground cover data only and the means for these are given in Table 28.

Clover ground cover varied with treatment in a similar manner in both 1954 and 1955, though it constituted a greater proportion of total cover on average in the second year. There was no significant difference between the mean percent ground cover of clover under the two 'height of cutting' treatments. However, cutting at the 'silage' stage of growth gave a significantly greater clover ground cover in the sward than cutting at the 'grazing' stage. Increasing rate of fertilizer nitrogen application progressively decreased clover ground cover in the sward (cf. treatments N1, N2 and N4), the differences between means being significant or highly significant. Delaying the spring application of fertilizer nitrogen in the light nitrogen treatments depressed clover cover slightly, but not significantly (cf. treatments N2 and N3), while in the heavy nitrogen treatments (N4, N5 and N6) the same delay increased it, though again the difference was not significant.

The more uniform distribution of clover on the Field E site in 1955 in comparison with that on the Paddock 4 site in 1954 is indicated by the considerably smaller coefficients of variation calculated from the 1955 data compared with those calculated from the previous year's data.

The mean percentage ground cover of weed grasses under the 'grazing' stage of cutting treatment was greater than that under the 'silage' stage of cutting treatment, but there was no difference in sown grass cover. Weed grass cover in lax-cut swards was, on average, slightly higher than in close-cut swards, but there was no difference in the sown grass cover. The effects of the various nitrogen treatments on ground cover were more clear-cut in 1955 than in the previous year. The amount of bare ground in the sward and also the ground cover contributed by weed grasses increased slightly as rate of fertilizer nitrogen application increased. The sown grass cover in

TABLE 29. **Mean total dry matter yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Field E) 1956**

	Nitrogen treatments						Means	Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	57.8	61.6	60.0	83.8	69.4	78.3	68.5	61.6	75.3
Lax	38.9	44.7	40.3	62.5	49.2	60.6	49.4	42.1	56.7
Stage of cutting									
Grazing	40.3	45.9	41.8	66.8	52.3	63.8	51.8		
Silage	56.4	60.4	58.6	79.4	66.3	75.0	66.0		
Nitrogen means	48.3	53.1	50.2	73.2	59.3	69.4			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	2.48	6.08	9.20
S means	2.48	6.08	9.20
N means	1.38	2.80	3.74

Significant effects

H	***		
S	**		
N	***	N1 v N2,3,4,5 & 6	***
		N2 & 3 v N4,5 & 6	***
		N2 v N3	*
		N4 v N5 & 6	***
		N5 v N6	***

Coefficient of Variation: Main-plots = 17.9% Sub-plots = 5.8%

swards under treatment N1 was somewhat lower than in those under the other nitrogen treatments, but there were no distinct differences between the latter treatments.

Field E site - 1956

Mixed herbage dry matter yields

Total dry matter yields of mixed herbage over the 1956 season (see table 29) were on a similar level to those over the 1955 season. The effect of the more abundant rainfall of the 1956 season appears to have been counteracted by generally lower temperatures and fewer hours of sunshine (see Appendix 1).

The difference between mean yields from the two 'height of cutting' treatments was once again highly significant. In 1956 close-cutting yielded on average 1,910 lb./acre or 39% more mixed herbage dry matter than lax-cutting, a somewhat smaller increase than in 1955. Although the mean yield for close-cutting was much the same in the two seasons, that for lax-cutting was greater in 1956 than in 1955.

As in 1955, cutting at the 'silage' stage of growth gave a greater mean yield of mixed herbage dry matter than cutting at the 'grazing' stage. The difference between the two 'stage of cutting' treatments in 1956 (1,420 lb./acre) was highly significant.

The effects of the nitrogen treatments on the mean total dry matter yield of mixed herbage were highly significant and very similar to those observed in 1955, though the degree of difference between the means varied slightly in certain cases. Increasing rate of fertilizer nitrogen application caused progressive increase in mean total mixed herbage dry matter yield (cf. treatments N2, N1 and N4). Mean yield from treatment N1 was, however, considerably higher in 1956 than in 1955, while that from N2 was lower, and that from N4 slightly higher. All differences between these three treatments were highly significant. Treatment N2 again outyielded N3, but the difference in mean yield between them though significant, was smaller than in 1955. This was due to a reduction in the mean yield from treatment N2 and a slight increase in that from N3. As in 1955 treatment N4 outyielded treatments N5 and N6, while N6 outyielded

TABLE 30. Weighted mean percent dry matter in mixed herbage - Experiment 1 (Field E) 1956

	Nitrogen treatments N1	N2	N3	N4	N5	N6	Means	Stage of cutting Grazing	Silage
Height of cutting									
Close	17.8	18.2	19.6	19.0	18.5	17.9	18.5	17.1	19.9
Lax	20.0	20.2	21.4	19.9	19.3	18.7	19.9	18.7	21.2
Stage of cutting									
Grazing	17.9	17.7	19.2	18.1	17.7	16.7	17.9		
Silage	19.9	20.7	21.8	20.8	20.1	19.9	20.5		
Nitrogen means	18.9	19.2	20.5	19.4	18.9	18.3			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.24	0.58	0.87
S means	0.24	0.58	0.87
N means	0.26	0.53	0.72
N means within a H	0.37	0.76	-
H means within a N	0.42	0.90	-

Significant effects

Effect		Comparison	
H	***		
S	***		
N	***	N2 & 3 v N4,5 & 6	***
		N2 v N3	***
		N4 v N5 & 6	***
		N5 v N6	*
N x H	*		

Coefficient of Variation: Main-plots = 5.2% Sub-plots = 3.4%

N5. Mean yields from treatments N5 and N6 were considerably higher in this second year, but that from N4 was only slightly higher. The differences between these three treatments, though highly significant, were smaller than in 1955.

None of the interactions between treatment factors was significant in the total mixed herbage dry matter yield data for 1956.

The coefficients of variations for main and sub-plots (17.9% and 5.8% respectively) calculated from these data were considerably lower than those from the 1955 data.

The weighted mean percentage of dry matter in the herbage was not calculated from the 1954 and 1955 results, since in these two seasons samples were transported from field to laboratory wrapped only in greaseproof paper. The use of plastic bags for this purpose in 1956 ensured smaller moisture losses. The weighted mean percentages of dry matter in the herbage over the 1956 season were, therefore, calculated and are presented in Table 30.

Herbage had a significantly lower mean percentage dry matter under close than under lax-cutting. This is in agreement with the fact that over the greater part of the season herbage was more leafy under the former than under the latter treatment.

Cutting at the 'silage' stage of growth gave herbage with a significantly higher mean percentage dry matter than cutting at the 'grazing' stage. This was to be expected since herbage from the former treatment was more mature and stemmy when cut.

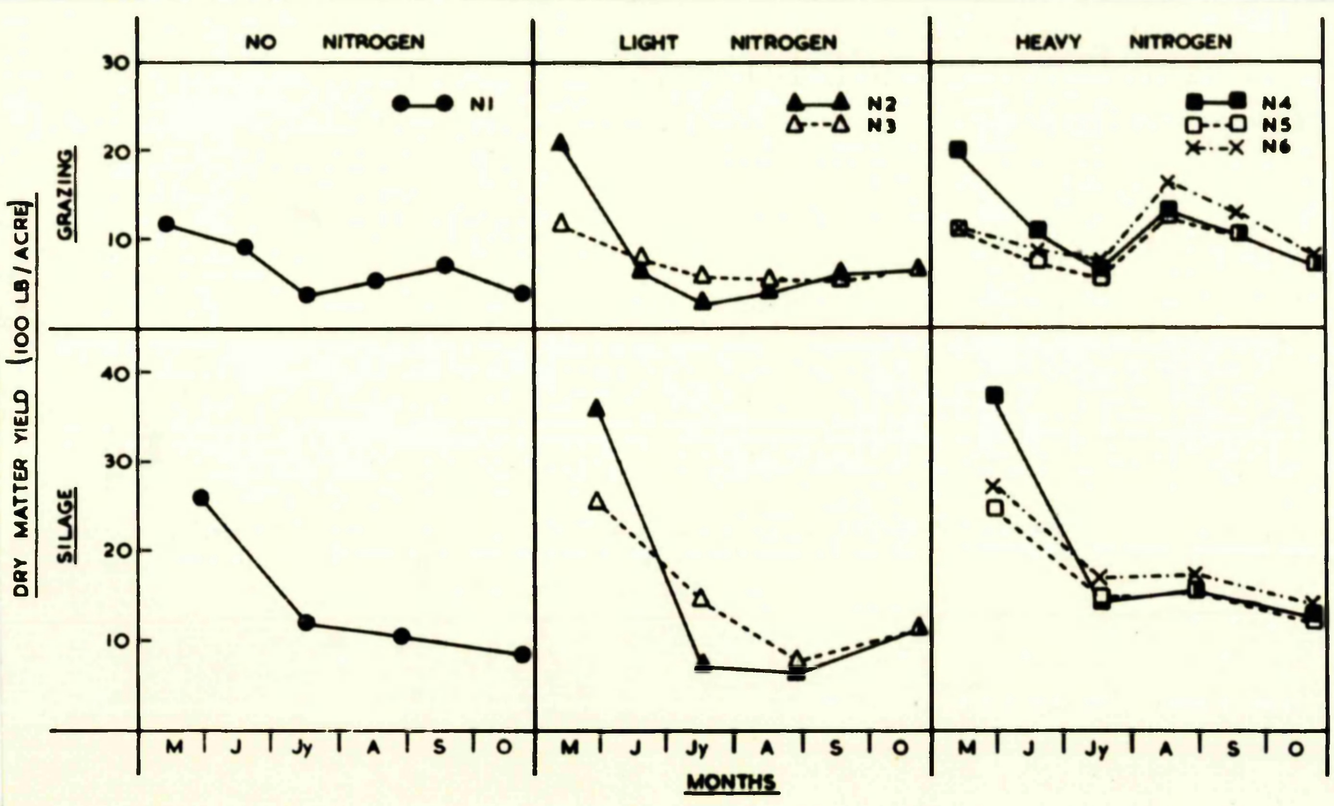
Increasing rate of fertilizer nitrogen application (cf. treatments N1, N2 and N4) caused slight increases in the mean percentage of dry matter in the herbage. The increase was proportionately larger between N1 and N2 than between treatments N2 and N4, but the only significant difference was that between N1 and N4. With the light nitrogen treatments (cf. N2 and N3) delaying the spring application of fertilizer nitrogen caused a significant increase in herbage dry matter content, while with the heavy nitrogen treatments (cf. N4, N5 and N6) it caused a significant decrease.

The relationship between the mean dry matter percentages of herbage from the six nitrogen treatments was the same under close-cutting as the average relationship mentioned above. Under lax-cutting, however, dry matter

TABLE 31. Mean dry matter yields of mixed herbage (in 100 lb./acre) at each cut in the season - Experiment 1 (Field E) 1956

		'Grazing' Stage Cut No.						'Silage' Stage Cut No.			
		1	2	3	4	5	6	1	2	3	4
Height of cutting											
Close		18.5	8.2	7.3	10.5	9.8	7.2	33.6	15.7	12.7	13.3
Lax		9.9	8.0	5.0	8.2	7.4	5.6	25.0	10.6	11.4	9.8
$s_{\bar{d}}$	±	0.54	0.42	0.44	0.34	0.39	0.42	0.79	1.93	1.49	1.21
L.S.D. (5%	±	2.32	-	1.88	0.71	1.67	-	3.40	-	-	-
1%	±	5.35	-	-	0.96	-	-	7.84	-	-	-
F. Sig. at		1%	NS	5%	0.1%	5%	NS	1%	NS	NS	NS
Nitrogen treatments											
N1		11.6	9.0	3.6	5.2	7.0	3.8	25.8	11.8	10.4	8.4
N2		20.7	6.2	2.7	3.9	6.0	6.4	35.8	7.0	6.3	11.2
N3		11.4	7.6	5.7	5.4	5.2	6.4	25.2	14.3	7.7	11.4
N4		19.6	10.6	6.4	13.1	10.4	6.9	37.1	14.2	15.5	12.6
N5		10.8	6.9	5.4	12.1	10.2	6.9	24.5	14.6	15.2	12.0
N6		11.1	8.5	7.0	16.3	12.9	8.0	27.1	16.9	17.2	13.9
$s_{\bar{d}}$	±	0.51	0.66	0.56	0.59	0.63	0.27	1.03	0.97	1.00	0.63
L.S.D. (5%	±	1.06	1.37	1.17	1.23	1.31	0.56	2.14	2.03	2.10	1.31
1%	±	1.45	1.87	1.60	1.67	1.78	0.77	2.92	2.77	2.86	1.78
F. Sig. at		0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

FIGURE 4. Mean yields of mixed herbage at each cut in the season - Experiment 1 (Field E) 1956



percentage was little affected by increasing rate of fertilizer nitrogen application (cf. treatments N1, N2 and N4), but the response to delaying the spring application was the same as described above. Within all nitrogen treatments close-cut herbage had a significantly lower dry matter percentage than lax-cut herbage, but the difference was greater under the no nitrogen and light nitrogen treatments (i.e. N1, N2 and N3) than under the heavy (i.e. N4, N5 and N6).

Mean yields of mixed herbage dry matter for the various treatments at the individual cuts through the 1956 season are given in Table 31.

As in 1955, the rate of growth in the spring was considerably greater under the 'silage' stage of cutting treatment than under the 'grazing' treatment. On average, the first cut of the season under the former yielded 2,930 lb./acre mixed herbage dry matter, while the first two cuts under the latter gave a total yield of only 2,230 lb./acre, though the second of these cuts was not taken until 20 days after the first 'silage' cut.

Under both 'stage of cutting' treatments close-cutting gave greater yields of mixed herbage dry matter than lax-cutting at all cuts over the season. The difference between the means for these two treatments was highly significant at the first and fourth 'grazing' cuts and the first 'silage' cut; significant at the third and fifth 'grazing' cuts; and not significant at all the other cuts.

Yields at each cut over the season under each of the six nitrogen treatments are graphed in Figure 4. Allowing for differences in weather conditions the effect of the various nitrogen treatments on the seasonal pattern of growth was similar to that in 1955. This was particularly so during the first 3 months of growth when dry weather conditions prevailed in both seasons. The prolonged heavy rain during the remainder of the 1956 season resulted, however, in higher growth rates than in the corresponding period of 1955. This effect was particularly marked with nitrogen treatments N4, N5 and N6.

As in previous years treatment N2 merely exaggerated the typical sigmoidal pattern of growth shown by treatment N1. The former gave smaller mean mixed herbage dry matter

TABLE 32. **Mean total dry matter yields of clover (in 100 lb./acre) - Experiment 1 (Field E) 1956**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	18.6	10.0	10.0	4.6	7.6	7.4	9.7	9.2	10.1
Lax	9.9	4.4	5.8	2.7	4.2	3.1	5.0	3.4	6.6
Stage of cutting									
Grazing	12.4	7.6	7.4	1.9	4.6	4.2	6.3		
Silage	16.1	6.9	8.5	5.4	7.2	6.3	8.4		
Nitrogen means	14.2	7.2	7.9	3.6	5.9	5.2			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	1.44	3.52	-
S means	1.44	-	-
N means	1.05	2.12	2.84
N means within a H	1.49	3.00	-
H means within a N	1.98	4.44	-

Significant effects

H *

N *** { N1 v N2,3,4,5 & 6 *** ; N2 & 3 v N4,5 & 6 *** ; N4 v N5 & 6 * }

N x H *

Coefficient of Variation: Main-plots = 83.0% Sub-plots = 35.0%

yields than the latter at all 'grazing' stage cuts except the first and last, and at all 'silage' stage cuts except the first. Treatment N5 again gave a more uniform distribution of yield over the season than treatment N2, and actually outyielded N2 at the second, third and fourth cuts under both 'grazing' and 'silage' treatments. Treatment N5 also gave more uniform distribution of yield over the season than treatment N4, while treatment N6 gave lower yields than N4 in the first half of the season but higher yields thereafter.

Clover dry matter yields

Mean total dry matter yields of clover over the 1956 season are given in Table 52. On the average, these yields were greater and showed less variation than in 1955.

Close-cutting again gave greater clover yields than lax-cutting; the difference between the means for the two treatments was larger than in previous years - 470 lb. per acre and proved significant.

The difference between the means for the two 'stage of cutting' treatments was also larger than in 1954 and 1955, cutting at the 'silage' stage yielding on average 210 lb./acre more clover dry matter than cutting at the 'grazing' stage. This difference, however, was not significant.

Mean clover dry matter yields for the six nitrogen treatments were all greater in 1956 than in 1955, though the relative effects were the same. Increasing rate of fertilizer nitrogen application caused progressive decline in clover yields (cf. treatments N1, N2 and N4), all differences being highly significant. With light total applications of fertilizer nitrogen (treatments N2 and N3) delaying the spring dressing had little effect on clover yield, whereas with heavy and equal applications (treatments N4 and N6) it resulted in considerable, though not significant, increase. Where the delay involved reduction in the total fertilizer nitrogen application over the season (treatment N5) the resulting increase in clover yield was significant.

The interaction of 'nitrogen' with 'height of cutting' treatments was significant in the clover yield data for the 1956 season, though not in the data

TABLE 33. Weighted mean percent clover in mixed herbage dry matter - Experiment 1 (Field E) 1956

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	32.5	16.4	16.8	5.1	10.6	9.3	15.1	16.3	14.0
Lax	25.2	10.0	13.2	4.1	7.8	4.9	10.8	9.6	12.1
Stage of cutting									
Grazing	29.6	15.6	15.6	2.8	7.9	6.1	12.9		
Silage	28.1	10.8	14.4	6.5	10.5	8.0	13.0		
Nitrogen means	28.8	13.2	15.0	4.6	9.2	7.1			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	1.72	4.21	-
S means	1.72	-	-
N means	1.80	3.63	4.86

Significant effects

H *

N *** { N1 v N2,3,4,5 & 6 ***; N2 & 3 v N4,5 & 6 ***; N4 v N5 & 6 * }

Coefficient of Variation: Main-plots = 56.1% Sub-plots = 33.9%

TABLE 34. Mean dry matter yields of clover (in 100 lb./acre) at each cut in the season - Experiment 1(Field E) 1956

		'Grazing' Stage Cut No.						'Silage' Stage Cut No.			
		1	2	3	4	5	6	1	2	3	4
Height of cutting											
Close		1.2	1.3	1.8	2.2	2.1	0.6	3.6	2.9	2.4	1.2
Lax		0.3	0.4	0.4	0.9	1.2	0.2	1.5	2.4	2.0	0.7
$s_{\bar{d}}$	±	0.22	0.23	0.49	0.28	0.18	0.07	0.91	1.22	0.52	0.37
L.S.D. (5%	±	-	-	-	1.19	0.37	0.28	-	-	-	-
L.S.D. (1%	±	-	-	-	-	0.51	-	-	-	-	-
F. Sig. at		NS	NS	NS	5%	0.1%	5%	NS	NS	NS	NS
Nitrogen treatments											
N1		1.6	2.0	1.8	2.7	3.4	0.8	4.6	5.2	4.3	2.0
N2		0.9	0.7	0.9	1.6	2.6	0.8	1.9	1.4	2.4	1.2
N3		0.9	1.0	1.5	1.5	1.9	0.6	2.6	2.8	2.2	1.1
N4		0.1	0.2	0.3	0.8	0.4	0.1	1.7	2.1	1.2	0.4
N5		0.6	0.6	0.9	1.4	1.0	0.2	2.3	2.4	1.9	0.6
N6		0.4	0.8	1.2	1.2	0.5	0.1	2.3	2.0	1.4	0.6
$s_{\bar{d}}$	±	0.18	0.24	0.46	0.34	0.31	0.08	0.91	0.70	0.43	0.18
L.S.D. (5%	±	0.38	0.51	-	0.71	0.64	0.17	-	1.47	0.90	0.38
L.S.D. (1%	±	0.52	0.70	-	0.97	0.88	0.23	-	2.00	1.23	0.52
F. Sig. at		0.1%	0.1%	NS	0.1%	0.1%	0.1%	NS	0.1%	0.1%	0.1%

for previous years. In general the relationships between the means for the six 'nitrogen' treatments were not affected by 'height of cutting' treatment. The relative effects of 'height of cutting' treatments varied slightly, however, with 'nitrogen' treatment. Clover yields were higher under close than under lax-cutting with all nitrogen treatments, but the difference between the means for the two 'height of cutting' treatments was significantly only under treatments N1 and N2, and approached significance under N5.

Weighted mean percentages of clover in total mixed herbage dry matter are given in Table 33. Herbage had a significantly higher percentage of clover under close than under lax-cutting. The relative effects of the two 'stage of cutting' treatments and the six nitrogen treatments on weighted mean percentage of clover in the herbage were similar to those on absolute clover yields, but the 'nitrogen' x 'height of cutting' interaction was not significant here.

Mean yields of clover dry matter at the individual cuts over the season for the various treatments are given in Table 34. The distribution of clover growth over the 1956 season differed slightly from that in 1955. Under the 'grazing' stage of cutting treatment yields were generally greater at the first two cuts in 1956 than at the same cuts in 1955, particularly with 'nitrogen' treatments N1, N2 and N3. In addition, clover yields dropped sharply at the last cut of the 1956 season with all nitrogen treatments, whereas they remained high at this cut in 1955. Under the 'silage' treatment clover yields at the first cut were relatively larger with all 'nitrogen' treatments in 1956 than in 1955. During the remainder of the second season clover yields remained steady or declined to varying extents, while in the previous year there was a general increase from cut to cut.

Clover yields from close-cutting exceeded those from lax-cutting at all cuts in 1956, though the difference was significant only at the fourth, fifth and sixth cuts under the 'grazing' stage of cutting treatment. The distribution of clover yield with close-cutting varied slightly from that with lax-cutting under the 'grazing' treatment, but not under the 'silage' treatment. On close-cut 'grazing' plots the greatest clover yield per

FIGURE 5. Mean yields of white clover at each cut in the season - Experiment 1 (Field E) 1956

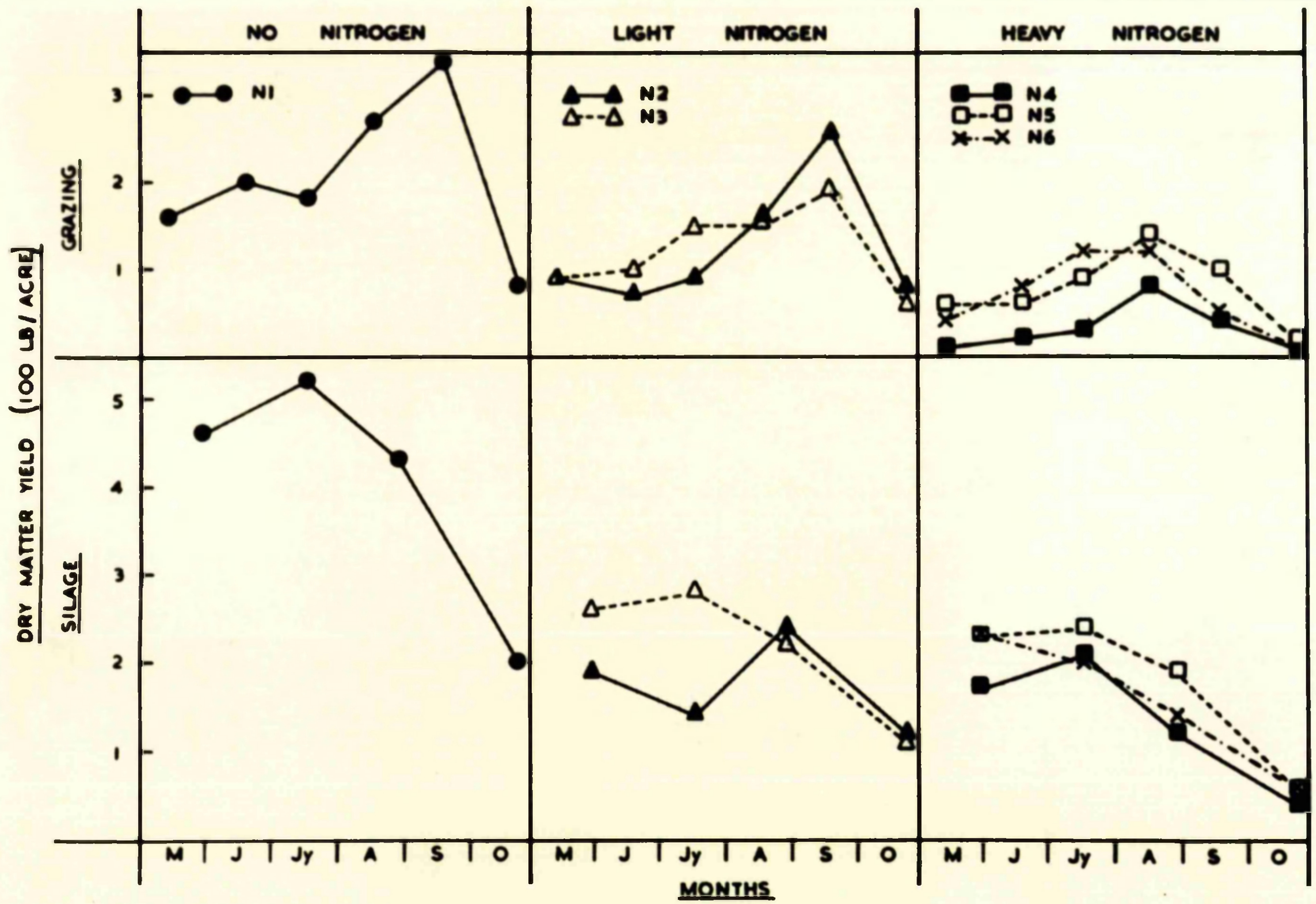


TABLE 35. Mean total crude protein yields of mixed herbage (in 100 lb./acre) - Experiment 1 (Field E) 1956

	Nitrogen treatments						Means	Stage of cutting	
	N1	N2	N3	N4	N5	N6		Grazing	Silage
Height of cutting									
Close	9.86	9.43	9.01	11.86	10.12	11.88	10.36	11.15	9.57
Lax	6.55	6.91	6.08	9.80	7.92	9.78	7.84	7.75	7.93
Stage of cutting									
Grazing	7.81	8.36	7.43	11.60	9.40	12.12	9.45		
Silage	8.60	7.98	7.66	10.07	8.64	9.54	8.75		
Nitrogen means	8.21	8.17	7.54	10.83	9.02	10.82			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.49	1.21	1.83
S means	0.49	-	-
N means	0.30	0.61	0.81
N means within a S	0.42	0.86	1.15
S means within a N	0.63	1.44	2.09

Significant effects

H **

N ***
- N1 v N2,3,4,5 & 6 ***
- N2 & 3 v N4,5 & 6 ***
- N2 v N3 *
- N4 v N5 & 6 **
- N5 v N6 ***

N x S ***

Coefficient of Variation: Main-plots = 23.0% Sub-plots = 8.1%

TABLE 36. Weighted mean percent crude protein in mixed herbage dry matter - Experiment 1 (Field E) 1956

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	17.4	15.6	15.3	14.4	14.7	15.4	15.4	18.1	12.7
Lax	17.2	15.7	15.4	15.9	16.4	16.4	16.2	18.3	14.0
Stage of cutting									
Grazing	19.2	18.1	17.6	17.4	18.0	19.0	18.2		
Silage	15.3	13.2	13.2	12.8	13.1	12.8	13.4		
Nitrogen means	17.2	15.6	15.4	15.1	15.6	15.9			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.35	-	-
S means	0.35	0.86	1.31
N means	0.27	0.54	0.72
N means within a H	0.38	0.76	1.02
H means within a N	0.49	1.10	1.59
N means within a S	0.38	0.76	1.02
S means within a N	0.49	1.10	1.59

Significant effects

S ***

N *** (N1 v N2,3,4,5 & 6 ***; N4 v N5 & 6 *)

N x H **

N x S **

Coefficient of Variation: Main-plots = 9.5% Sub-plots = 4.2%

cut was obtained at the fourth cut of the season, whereas it was not reached until the fifth cut on lax-cut 'grazing' plots.

At all cuts, with the exception of the third 'grazing' cut and the first 'silage' cut, nitrogen treatment had a significant effect on mean clover yield. Figure 5 shows that the effects of the various nitrogen treatments on distribution of clover yield over the 1956 season were similar to those in 1955. Although differences between the growth curves for the six nitrogen treatments under the 'silage' stage of cutting treatment were small, the trends were similar to those under the 'grazing' treatment. Under this treatment nitrogen treatment N2 severely depressed clover growth for the first three cuts of the season in comparison with treatment N1, but the rate of clover growth increased thereafter, though it did not reach the same level as with N1. With the delayed spring application of fertiliser nitrogen in treatment N3 clover yields were greater at the first three cuts of the season than with N2, though the previous year's treatment appears to have depressed these yields in comparison with treatment N1. Clover yield from treatment N3 was lower than that from treatment N2 at the fifth cut of the season, but almost equal at the last. As in 1955 clover yields from treatment N4 were low throughout the season. Apart from a decline in the autumn, the distributions of clover yields over the season with treatments N5 and N6 were similar in 1956 to those in 1955, and clover yields were greater with both than with treatment N4 at all cuts except the last.

Mixed herbage crude protein yields

Mean total yields of mixed herbage crude protein in 1956 are given in Table 55 and weighted mean percentages of crude protein in mixed herbage dry matter in Table 56. On average both yields of crude protein and percentages of crude protein in the herbage were greater in 1956 than in 1955. Mean yield of mixed herbage crude protein under close-cutting exceeded that under lax-cutting by 252 lb./acre, and this difference was highly significant. However, the weighted mean percentages of crude protein in the herbage from the two treatments did not differ significantly, though the percentage was slightly higher under lax than under close-cutting. Similar results were obtained in 1954 and 1955.

Cutting at the 'grazing' stage of growth gave a slightly, but not significantly, greater yield of mixed herbage crude protein than cutting at the 'silage' stage. The herbage from the former, however, had a highly significantly greater crude protein percentage than had the herbage from the latter. This again confirms the results from previous years.

The relative effects of the six nitrogen treatments on crude protein yields varied somewhat from those in 1955. Although treatment N4 gave a greater mean yield of mixed herbage crude protein than treatments N1 and N2, and these differences were highly significant, there was no significant difference between the means for treatments N1 and N2. In 1955 the mean yield of crude protein from treatment N4 exceeded that from N2, which exceeded that from N1, and all differences were significant. Apart from this the 1956 results were similar to those of previous years. With light total applications of fertilizer nitrogen (cf. treatments N2 and N3) delaying the spring dressing caused a significant decrease in crude protein, while with heavy total applications (cf. N4 and N6) it had no significant effect. In treatment N5, where the delay in the spring dressing was coupled with a reduction in the total application of fertilizer over the season, the crude protein yield was significantly lower than with treatments N4 and N6.

When the relative effects of the six nitrogen treatments on the weighted mean percentages of crude protein in the herbage are considered, it is obvious that many of the differences in absolute crude protein yields noted above were the result of the nitrogen treatments affecting total dry matter yields and not the quality of the herbage. Although treatment N4 gave a significantly greater yield of crude protein than treatment N1, the percentage of crude protein in the herbage from the former was significantly lower. The percentage of crude protein in the herbage from treatment N2 was also significantly lower than that of herbage from N1, and almost significantly greater than that in the herbage from N4. Delaying the spring dressing of fertilizer nitrogen in the light nitrogen treatments had no significant effect on the percentage of crude protein in the herbage (cf. N2 and N3), but in the heavy nitrogen treatments it caused a slight increase (cf. N4, N5 and N6), this difference being significant between treatments N4 and N6 and almost significant between N4 and N5.

As in 1955, the interaction of 'stage of cutting' with 'nitrogen' treatments was highly significant both in the crude protein yield and crude protein percentage data. The actual effects of this interaction on crude protein yields were not, however, the same in 1956 as in the previous year. Cutting at the 'silage' stage of growth resulted in slightly but not significantly greater yields of crude protein than cutting at the 'grazing' stage when treatments N1 and N5 were applied. With all other nitrogen treatments the reverse was observed, though the difference between the mean crude protein yields from the two 'stage of cutting' treatments was significant only with treatments N4 and N6. The relationships between the mean crude protein yields for the nitrogen treatments were approximately the same within each 'stage of cutting' treatment except that the yields from N2 and N6 were slightly greater than from N1 and N4 respectively within the 'grazing' treatment, while the reverse occurred within the 'silage' treatment. The differences were not, however, significant. Within all nitrogen treatments herbage from the 'grazing' treatment had a significantly higher percentage of crude protein than herbage from the 'silage' treatment. The relationships between the mean percentages of crude protein in the herbage from the nitrogen treatments were much the same within each 'stage of cutting' treatment. Within the 'grazing' treatment, however, herbage from treatment N6 had a highly significantly greater crude protein percentage than herbage from treatments N4 and N5, while within the 'silage' treatment there were no significant differences between the crude protein percentages of the herbage from these three treatments. Herbage from treatment N6 had, in fact, almost the same percentage of crude protein as herbage from treatment N1 under the 'grazing' treatment, but a significantly lower crude protein percentage under the 'silage' treatment.

The interaction of 'higher of cutting' with 'nitrogen' treatments was also highly significant in the 1956 weighted mean percentage crude protein data, but not significant in crude protein yield data. Though the difference between the mean percentages of crude protein in the herbage from

TABLE 37. **Mean total crude protein yields of clover (in 100 lb./acre) - Experiment 1 (Field E) 1956**

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	4.46	2.57	2.47	1.01	1.80	1.66	2.33	2.39	2.27
Lax	2.46	1.17	1.35	0.60	0.96	0.69	1.20	0.93	1.48
Stage of cutting									
Grazing	3.34	2.08	1.88	0.48	1.20	0.99	1.66		
Silage	3.58	1.66	1.94	1.14	1.56	1.37	1.88		
Nitrogen means	3.46	1.87	1.91	0.81	1.38	1.18			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.32	0.78	-
S means	0.32	-	-
N means	0.24	0.50	0.66

Significant effects

H *

N *** { N1 v N2,3,4,5 & 6 ***; N2 & 3 v N4,5 & 6 ***; N4 v N5 & 6 * }

Coefficient of Variation: Main-plots = 76.2% Sub-plots = 33.9%

the two 'height of cutting' treatments under nitrogen treatments N1, N2 and N3 was not significant, lax-cutting gave herbage with a higher crude protein percentage than close-cutting under treatments N4, N5 and N6, the difference being highly significant under treatments N4 and N5, and significant under treatment N6. In general, the relative effects of the six nitrogen treatments were the same within each 'height of cutting' treatment.

Clover crude protein yields

Total crude protein yields of clover (Table 37) were on average considerably higher in 1956 than in 1955, but the effects of the various treatments were similar in the 2 years.

The difference between the mean clover crude protein yields form the two 'height of cutting' treatments was larger in 1956 than in previous years, and proved significant. As before, however, close-cutting gave a greater mean yield of clover crude protein than lax-cutting. The two 'stage of cutting' treatments once again gave almost equal mean yields of clover crude protein. The differences between the mean yields of clover crude protein from the six nitrogen treatments were on average greater than in previous years. Increasing rate of application of fertilizer nitrogen caused progressive and significant decreases in these yields (cf. treatments N1, N2 and N4). Delaying the spring application of fertilizer nitrogen in the light-nitrogen treatments (cf. N2 and N3) had no significant effect on yield of clover crude protein, while in the heavy nitrogen treatments (cf. N4, N5 and N6) a similar delay caused a slight increase. This increase was greatest and significant where the delay involved a reduction in the total amount of fertilizer nitrogen applied over the season (i.e. treatment N5).

Plant cover

The percentage ground cover data given in Table 38 show the effects of treatment on botanical composition of the sward by the autumn of 1956. Clover ground cover means are given separately in Table 39.

Averaged over all treatments, a smaller proportion of the toal area of the sward was covered by clover in the autumn of 1956 than in the previous autumn. With close-cutting the reduction in clover ground cover between the two autumns was slight, while with lax-cutting it was

TABLE 38. Botanical composition of sward (as percent ground cover) - Experiment 1 (Field E) Autumn 1956

		Nitrogen treatments							Stage of cutting	
		N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting										
Close	Sown grass	20.5	29.8	29.2	36.8	33.4	36.4	31.0	27.7	34.3
	White clover	33.5	23.7	17.0	5.5	10.3	8.0	16.3	15.8	16.9
	Weed grass	25.5	24.6	31.7	31.2	32.8	25.0	28.5	33.7	23.3
	Dicot weeds	2.4	1.9	3.6	1.4	2.0	0.8	2.0	2.7	1.3
	Bare ground	18.1	20.0	18.5	25.1	21.5	29.8	22.2	20.1	24.2
Lax	Sown grass	23.0	32.8	29.7	35.8	32.8	39.5	32.3	33.5	31.0
	White clover	29.8	20.0	12.5	3.5	9.0	6.2	13.5	9.4	17.6
	Weed grass	24.8	25.5	35.6	32.5	34.8	26.2	29.9	31.9	28.0
	Dicot weeds	1.7	0.5	0.8	-	0.2	-	0.5	0.9	0.1
	Bare ground	20.7	21.2	21.4	28.2	23.2	28.3	23.8	24.3	23.3
Stage of cutting										
Grazing	Sown grass	19.2	29.6	28.5	35.7	32.6	38.2	30.6		
	White clover	27.3	21.7	12.7	2.5	7.3	4.2	12.6		
	Weed grass	30.2	28.6	37.8	34.4	37.5	27.8	32.8		
	Dicot weeds	3.0	2.3	2.6	1.0	1.2	0.6	1.8		
	Bare ground	20.3	17.8	18.4	26.4	21.4	29.2	22.2		
Silage	Sown grass	24.3	33.1	30.4	37.0	33.5	37.6	32.7		
	White clover	36.0	22.0	16.8	6.5	12.0	10.0	17.2		
	Weed grass	20.2	21.5	29.5	29.2	30.2	23.4	25.6		
	Dicot weeds	1.0	-	1.8	0.3	1.0	0.2	0.7		
	Bare ground	18.5	23.4	21.5	27.0	23.3	28.8	23.8		
Nitrogen means	Sown grass	21.8	31.3	28.4	36.3	33.1	37.9			
	White clover	31.7	21.8	14.8	4.5	9.7	7.1			
	Weed grass	25.2	25.1	33.7	31.8	33.8	25.6			
	Dicot weeds	2.0	1.2	2.2	0.7	1.1	0.4			
	Bare ground	19.3	20.6	19.9	26.7	22.3	29.0			

TABLE 39. Mean percentage ground cover of clover in sward - Experiment 1 (Field E) 1956

	Nitrogen treatments N1	N2	N3	N4	N5	N6	Means	Stage of cutting Grazing	Silage
Height of cutting	**Mean percentages**								
Close	33.5	23.7	17.0	5.5	10.3	8.0	16.3	15.8	16.9
Lax	29.8	20.0	12.5	3.5	9.0	6.2	13.5	9.4	17.6
Stage of cutting									
Grazing	27.3	21.7	12.7	2.5	7.3	4.2	12.6		
Silage	36.0	22.0	16.8	6.5	12.0	10.0	17.2		
Nitrogen means	31.7	21.8	14.8	4.5	9.7	7.1			
Height of cutting	**Mean angular transformations**								
Close	35.4	29.0	23.4	12.4	17.0	14.2	21.9	21.2	22.6
Lax	33.0	26.0	20.0	9.3	15.0	13.9	19.5	15.5	23.6
Stage of cutting									
Grazing	31.4	27.3	20.2	7.6	13.8	9.9	18.4		
Silage	36.9	27.7	23.2	14.2	18.2	18.2	23.1		
Nitrogen means	34.2	27.5	21.7	10.9	16.0	14.0			

Between:	s_d ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	2.08	-	-
S means	2.08	-	-
N means	2.33	4.70	6.29

Significant effects

N *** { N1 v N2,3,4,5 & 6 ***; N2 & 3 v N4,5 & 6 ***; N2 v N3 *; N4 v N5 & 6 * }

Coefficient of Variation: Main-plots = 42.5% Sub-plots = 27.5%

considerable. As a result the mean clover ground cover was greater under close than under lax-cutting in 1956, while the reverse occurred in 1955. In both years, however, the difference between the means for the two treatments was not significant.

The difference between clover ground cover means in swards subjected to the two stage of cutting treatments was not significant in 1956, though it was in 1955. Once again, however, cutting at the 'silage' stage gave a greater mean clover ground cover than cutting at the 'grazing' stage.

Though the effects were in general the same, the differences between the mean clover ground cover percentages for the six nitrogen treatments were larger in 1956 than in 1955, and were in many cases significant. The mean clover ground cover percentage for treatment N1 was slightly lower and that for treatment N2 slightly higher in 1956 than in 1955. However, in both years the proportion of total area covered by clover decreased significantly with increasing rate of fertilizer nitrogen application (cf. N1, N2 and N4). In light nitrogen treatments (cf. N2 and N3) a delay in the spring nitrogen application caused a significant decrease in clover ground cover percentage, while in the heavy nitrogen treatments it caused a significant or almost significant increase.

The other ground cover data in Table 38 show that on average the sward was less dense in 1956 than in the previous year, the proportion of bare ground being higher under all treatments. Apart from clover, the relative proportions of the various species in the sward were similar under the two 'height of cutting' treatments. Swards cut at the 'grazing' stage of growth had on average a greater percentage ground cover of weed grass than those cut at the 'silage' stage. Under close-cutting, swards cut at the 'grazing' stage had a lower percentage ground cover of sown grasses than those cut at the 'silage' stage, but under lax-cutting the reverse was observed.

Increasing rate of fertilizer nitrogen application caused a progressive decrease in the density of the sward, i.e. an increase in the percentage of bare ground (cf. N1, N2 and N4), while percentage ground cover contributed by sown grasses tended to increase. The heavy nitrogen treatment N4 gave swards with a higher mean weed grass cover than treatment N2, but there was no difference in

TABLE 40. Mean dry matter yield of mixed herbage (in 100 lb./acre) at first 'residual fertility' cut - Experiment 1 (Field E) 1957

	Nitrogen treatments						Means	Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	22.2	23.6	21.1	19.7	21.5	19.4	21.2	21.9	20.6
Lax	27.5	28.0	26.3	27.3	27.1	28.0	27.4	28.0	26.7
Stage of cutting									
Grazing	25.1	27.4	24.1	24.4	25.0	23.8	25.0		
Silage	24.6	24.2	23.2	22.6	23.6	23.7	23.6		
Nitrogen means	24.8	25.8	23.7	23.5	24.3	23.7			

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
H means	0.86	2.12	3.21
S means	0.86	-	-
N means	0.92	-	-

Significant effects

H ***

Coefficient of Variation: Main-plots = 15.1% Sub-plots = 9.2%

TABLE 41. Mean dry matter yields of mixed herbage (in 100 lb./acre) at second 'residual fertility' cut – Experiment 1 (Field E) 1957

	Nitrogen treatments							Stage of cutting	
	N1	N2	N3	N4	N5	N6	Means	Grazing	Silage
Height of cutting									
Close	18.6	18.2	16.9	16.4	16.5	17.4	17.3	16.7	18.0
Lax	16.9	15.3	15.8	15.0	15.2	15.7	15.6	15.5	15.8
Stage of cutting									
Grazing	17.1	15.9	16.1	15.7	15.6	16.1	16.1		
Silage	18.4	17.7	16.6	15.8	16.0	17.0	16.9		
Nitrogen means	17.7	16.8	16.3	15.7	15.8	16.6			

	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%	
Between:	±	±	±	
H means	0.76	–	–	All effects N.S.
S means	0.76	–	–	
N means	0.72	–	–	

Coefficient of Variation: Main-plots = 19.5% Sub-plots = 10.7%

this respect between swards under treatment N2 and those under treatment N1. Under the light nitrogen treatments (cf. N2 and N3) delaying the spring dressing of fertilizer nitrogen had little effect on the sown grass cover but increased the weed grass cover, while under the heavy nitrogen treatments receiving equal total dressings over the season a similar delay slightly increased the ground cover of sown grasses and substantially reduced that of weed grasses. Where the delay in the spring dressing was coupled with a reduction in the total fertilizer application over the season (treatment N5) the ground cover of sown grasses was slightly reduced and that of weed grasses slightly increased. These effects of nitrogen treatments on ground cover contribution varied somewhat, however, with 'height of cutting' and 'stage of cutting' treatments.

1957 - Field N site

Residual effects of the 1955-56 treatments on yields

Mean dry matter yields of mixed herbage at the two cuts in 1957 from plots subjected to the various treatments in the previous 2 years are given in Tables 40 and 41.

On account of the longer stubble on the previously lax-cut swards before growth began in the spring, these lax-cut sward significantly outyielded close-cut swards at the first cut in 1957. At the second cut the reverse occurred, though the difference between the mean yields was not significant.

At both cuts in 1957 the mean dry matter yields of herbage from swards cut at the 'grazing' stage of growth in 1955 and 1956 were not significantly different from the yields from swards previously cut at the 'silage' stage, though at the first cut yields from the former swards were slightly greater than those from the latter. There were no significant differences at either cut between the mean yields from swards which had previously received each of the six fertilizer nitrogen treatments.

DISCUSSION

Effect of closeness of cutting

Throughout the experiment the treatment factor which had the most striking effect on herbage yields was closeness of cutting. Herbage dry matter yields from swards cut to within 1 inch of ground level exceeded those from swards cut to within 2-2½ inches of ground level by 42%, 49% and 39% in 1954, 1955 and 1956 respectively. This increase was actually greater than that obtained by applying 'Nitro-Chalk' at the rate of 4 cwt. per acre over the season. Lax-cutting gave a significantly greater yield than close-cutting only at the second 'grazing' stage cut in 1955. However, herbage from lax-cut swards at this cut consisted mainly of infloresence and stem, whereas that from close-cut swards was predominantly leaf. At the third cut in 1954 and the second cut in 1956, dates of which coincided most closely with the second cut in 1955, mean differences in yield between the two 'height of cutting' treatments were much smaller than at other cuts in the same seasons, and herbage from the lax-cut swards was more stemmy than that from the close-cut swards.

In contrast to these results, a number of workers have shown that herbage yields decrease with increasing intensity of defoliation. Stapledon (70), for example, obtained greater yields from cocksfoot by cutting to 2 inches instead of to ground level, and total leaf production was greater with the more lenient defoliation, though the leaf to stem ratio was lower. Roberts & Hunt (66) obtained similar results with ryegrass and timothy cut to 1 inch, ½ inch or ground level. Brougham (6) in New Zealand compared the effect of three intensities of defoliation, 1, 3 and 5 inches above ground level, on the regrowth of a short rotation ryegrass pasture. Over a 32-day regrowth period in the spring, herbage yields were greatest with the most lenient treatment and least with the most severe. With the latter, leaf efficiency (i.e. average daily herbage dry matter increment/area of leaf) was lower in the early stage of regrowth than with the other treatments. However, a higher maximum leaf efficiency was eventually obtained with the more severe treatment, though it was reached after a longer regrowth period than with the others. In contrast to these results an experiment on a Kentucky bluegrass sward reported by Robinson & Sprague (68) showed that, averaged over a number of nitrogen fertilization and irrigation treatments, cutting to within ½ inch of ground level gave greater herbage dry matter yields than cutting to 2 inches.

Among the factors which could explain the discrepancies between the results of many of the above studies and those of the present experiment are species differences and variations in dates and intensities of cutting. In addition, the experiment reported by Brougham (6) was of very short duration, and the reactions of the sward over an entire season cannot be inferred from it. A more recent New Zealand experiment reported by the same author (7) in which swards were defoliated by animals over a full year has, however, given similar results to his cutting experiment. The closely-defoliated swards in the later experiment had a greater and more uniformly distributed population of ryegrass tillers than the lax-defoliated swards, and Brougham suggests that the thinning out of tillers on the latter may reduce future yields.

The results of the present experiment may be partly explained with reference to the morphology of stem and leaf formation in the grasses. As mentioned above, at the second cuts in 1955 and 1956 and the third cut in 1954, all of which were taken in the latter half of June, herbage from lax-cut swards was predominantly leafy. This suggests that at the preceding cuts (approximately 30 days earlier in each season) the stage of development of the differentiated flowering shoot apices in the grasses was such that cutting to 1 inch from ground level removed most of them, while cutting to 2-2½ inches had little effect. Studies made at the Grassland Research Institute, Berkshire (53), the results from which have been reviewed by Taylor (79), show that the shoot apex in a number of grass species reached a height of 2 inches above ground level in the first fortnight in May. Taking into account differences in latitude and climate, it seems reasonable to assume that the shoot apex in the grasses will not reach a height of 2 inches above ground level until late May at Kirkhill. This would, therefore, confirm the above suggestion regarding the different effects of close and lax-cutting on shoot production. Now Cooper & Saeed (16) have shown that the differentiation of the flowering shoot with its accompanying low number of leaves limits the number of axillary buds from which tillers can arise, and consequently reduces the rate of tiller production and leaf growth. Thus the regrowth on swards cut to 2-2½ inches in late May will have a low leaf-stem ratio, while that on swards cut to 1 inch will be predominantly leafy.

During the remainder of the season close-cut swards will give higher yields per cut than lax-cut swards, since the grass plants in the former have a greater number of vegetative tillers, and their reserves have not been drained to the same extent by the process of shoot formation. The former swards will, therefore, give greater total yields over the season. Unfortunately no quantitative information is available with regard to the effects of the treatments on tiller populations in this experiment, although qualitative observations suggested that close-cut swards were, in fact, more dense than lax-cut swards. As mentioned above, however, Brougham (7) working in New Zealand has demonstrated a greater and more uniformly distributed population of ryegrass tillers under close than under lax-cutting.

The lower mean percentage of dry matter in the herbage from close-cut swards in 1956 confirms that this was less mature on average than herbage from lax-cut swards. In all 3 years of the experiment, however, closeness of cutting had little effect on the mean percentage of crude protein in the herbage, though the actual yields of crude protein were greater from close than from lax-cut swards because of the greater total dry matter yields from the former. Of swards cut at the 'grazing' stage of growth in 1955 those which were close-cut gave herbage with a higher percentage of crude protein than those which were lax-cut, while the reverse occurred with swards cut at the 'silage' stage of growth. This interaction was not reflected in crude protein yields in 1955, nor was it noted in the other 2 years of the experiment.

When all the plots of the experiment were cut to within 1 inch of ground level at the beginning of May, 1956, swards previously cut to 2-2½ inches outyielded those cut to 1 inch throughout, on account of the longer stubble which was present on the former swards before growth began in the spring. Regrowth over the next 6 weeks was, however, more rapid on the previously close-cut swards and these gave the higher yields at a second cut in mid-June. This suggests that continued close-cutting over a 2 year period did not drain the swards reserves as much as lax-cutting over the same period.

The clover fraction of the sward consistently gave greater dry matter and crude protein yields under close-cutting than under lax-cutting. In terms of total yields over the season, however, the difference between the means for the two cutting systems was significant only in 1956 when the treatments had been applied on the same site for two seasons. Further, on an individual cut basis, the difference was significant only at the last three cuts under the 'grazing' stage of cutting treatment in 1956. The proportion of the total ground area covered by clover was slightly smaller under close than under lax-cutting in the autumns of 1954 and 1955 but the reverse was observed in the autumn of 1956, though the difference was again slight. It appears, therefore, that close-cutting over a short period at least, stimulated clover yield by increasing the size or number of leaves per unit length of stolon without affecting stolon-length. Herbage from close-cut swards had, in fact, almost the same mean percentage clover content as herbage from lax-cut swards where the treatments had been applied for only one season (i.e. in Paddock 4, 1954, and Field E in 1955). In other words close-cutting increased the yields of all constituents of the herbage equally. By the second season of the treatments on the same site (i.e. Field E in 1956), however, the herbage contained almost 50% more clover under close than under lax-cutting.

Apart from the slight difference in clover ground cover mentioned above there were no consistent differences in botanical composition between swards under the two 'height of cutting' treatments.

Effect of stage of growth at cutting

In all three seasons of this experiment swards cut at the 'silage' stage of growth gave significantly greater yields of herbage than those cut at the 'grazing' stage. Although the mean percentage of crude protein in the herbage from the former swards was lower, their mean absolute yield of crude protein was not significantly different because of their greater total dry matter yield.

Stage of growth at which herbage was cut had little effect on dry matter or crude protein yields from the clover fraction of the sward. On average these yields were slightly greater when the herbage was cut at the 'silage' stage but this was again a result of the greater mean total dry matter yield from this treatment, mean percentages of clover in the herbage being the same under the two treatments. Since clover covered a proportionately greater area of the sward under the 'silage' treatment than under the 'grazing' treatment, the more frequent cutting under the latter obviously stimulated the production of more leaves per unit length of stolon, thus producing almost the same clover yield as the former.

Although the proportion of the total area covered by clover was smaller in swards cut at the 'grazing' stage than in those cut at the 'silage' stage, the former were somewhat more dense on average. This, however, was due mainly to the presence of a greater amount of weed grass, particularly Poa spp.

These results are on the whole in agreement with the findings of Walker, Adams & Orchiston (88) in New Zealand. They obtained greater total herbage yields by cutting at the 'silage' stage three times per season than at the 'dried grass' stage (comparable with 'grazing' stage in the present experiment) five times per season. It was found also that clover yields varied little between these two treatments in this New Zealand experiment, but that cutting only twice per season at the 'hay' stage severely depressed clover yields, and also gave lower total herbage yields than cutting three times per season at the 'silage' stage.

Effect of fertilizer nitrogen applications

Throughout the experiment dry matter and crude protein yields of total herbage increased with increasing rate of fertilizer nitrogen application, while those of the white clover fraction of the sward decreased. On the whole, these effects were in close agreement with those noted in many similar studies (e.g. 59, 88, 91, 92). The mean percentage of white clover in the herbage also decreased with increasing fertilizer rate in all three seasons. In 1954 the mean percentage of crude protein in the herbage increased with increasing fertilizer rate, but in 1955 and 1956 it decreased. This was not reflected in absolute yields of crude protein, because of the proportionately greater increases in total herbage dry matter yields in 1955 and 1956.

In treatments in which two dressings of 'Nitro-Chalk', each of 2 cwt./acre, were applied over the season, delaying the first dressings until after the first or second cut reduced dry matter and crude protein yields of total herbage, but had no consistent or significant effect on dry matter and crude protein yields of white clover. A similar delay in treatments in which more frequent and heavier total dressings of fertilizer nitrogen (10-12 cwt. 'Nitro-Chalk'/acre in the season) were applied, gave reduced dry matter yields of total herbage and slightly increased dry matter and crude protein yields of clover. Where the delay did not involve a reduction in the total amount of fertilizer nitrogen applied over the season the percentage of crude protein in the herbage was increased, but the crude protein yield was unaffected. In contrast, where the delay was coupled with a reduction in the total amount of fertilizer nitrogen applied, the percentage of crude protein in the herbage was slightly increased but the crude protein yield was reduced.

In addition to their effects on total yields the various nitrogen treatments had marked effects also on the seasonal distribution of dry matter yields of mixed herbage and of white clover. Although slight variations attributable to weather occurred, the pattern of yield distribution under each of the nitrogen treatments was remarkably similar in each year of the experiment.

In general dry matter yields of herbage from swards receiving no fertilizer nitrogen were greatest in spring and early summer, declined in midsummer and then increased slightly in the autumn by amounts which depended on weather conditions. Of the treatments receiving two 2 cwt./acre dressings of 'Nitro-Chalk' in the season, that in which the first dressing was applied early merely exaggerated the growth pattern shown by swards receiving no fertilizer nitrogen, giving a higher peak of growth in spring and early summer, poorer yields midseason, and only slightly greater autumn yields. On the other hand, herbage yield was much more evenly distributed over the season on swards receiving the treatment in which the first of the two dressings was delayed until after the first or second cut. Yields from swards receiving 2 cwt. 'Nitro-Chalk' per acre for every cut were much greater throughout but fluctuated over the season in a similar manner to those from swards receiving no fertilizer nitrogen. In the other heavy-nitrogen treatments, delaying the first application of the season resulted in a much more uniform distribution of yield, particularly where the same total amount of fertilizer nitrogen was applied.

The pattern of distribution of clover dry matter yields over the season under each of the nitrogen treatments was obscured in 1954 by the extreme variability of these yields. However, the effects were much more obvious in 1955 and 1956, particularly under the 'grazing' stage of cutting treatment. With a total application of 4 cwt. 'Nitro-Chalk'/acre split into two dressings over the season, swards on which the first dressing was applied before the first cuts gave lower clover yields at the first three 'grazing' stage cuts than swards receiving no fertilizer nitrogen. During the remainder of the season clover yields from these swards increased considerably, though they were still slightly smaller at each cut than those from 'no nitrogen' swards. Other swards receiving 4 cwt. 'Nitro-Chalk'/acre over the season on which the first dressing of fertilizer nitrogen was delayed until after the second 'grazing' stage cut, gave greater clover yields at the first three cuts and smaller thereafter than those on which the first dressing was applied before the first cut. Only in the 1955 season, however, did the clover yields at the first three cuts on these swards approach those at the same cuts on the no nitrogen swards. The carry-over effect of the fertilizer nitrogen applications in 1955 depressed clover yields at these cuts in 1956. Total seasonal applications of 10-12 cwt. 'Nitro-Chalk' per acre split into 5 or 6 dressings over the season under the 'grazing' stage of cutting treatment gave small but quite uniformly distributed clover yields in both years where the first dressing was given before the first cut. In comparison, delaying this dressing until after the second cut increased clover yields at all cuts in both years, particularly where the delay involved a reduction in total seasonal application.

The most consistent effect of nitrogen treatments on the botanical composition of the sward in terms of ground cover was a progressive decrease in the clover fraction with increasing rate of fertilizer nitrogen application. Under the light nitrogen treatments delaying the first application in the spring tended, on average, to depress clover cover slightly, while under the heavy nitrogen treatments it caused a slight increase. The proportion of bare ground also tended to increase slightly with increasing nitrogen application. Percentage ground cover of sown grass was on average higher under heavy nitrogen treatment than under zero or light nitrogen treatments, but the differences were neither proportional to nitrogen application rate nor were they consistent.

Apart from the straight effects of the nitrogen treatments on total yields, distribution of yield over the season, and on the chemical and botanical composition of herbage, these treatments had in many cases a modifying influence on the effects of other treatment factors. In 1954, for instance, swards cut at the 'silage' stage of growth gave greater yields of total herbage dry matter than those cut at the 'grazing' stage whichever nitrogen treatment was applied. The difference due to stage of growth was, however, much larger under zero and light nitrogen treatments than under the heavy nitrogen treatment. Since the total amount of fertilizer applied over the season under the latter was determined by the number of cuts taken, swards cut at the 'grazing' stage received a total of 12 cwt. 'Nitro-Chalk'/acre, whereas those cut at the 'silage' stage received only 8 cwt./acre, thus modifying the difference due to stage of growth. Although the interaction was not significant in 1955 and 1956, this effect can be seen also in the total herbage dry matter yield data for those years.

A similar modifying effect of nitrogen treatment on the response of total herbage crude protein yields to the 'stage of growth' factor was noted in all three seasons of the experiment. Under zero and light nitrogen treatments cutting at 'silage' stage of growth gave greater total herbage crude protein yields than cutting at the 'grazing' stage in 1954 and 1955, and almost the same yields in 1956. Under heavy nitrogen treatment, however, cutting at the 'grazing' stage gave the greater crude protein yields in all three seasons. This is again attributable to the greater total applications under the heavy nitrogen treatments on swards cut at the 'grazing' stage. Nitrogen treatments had a much less marked effect on the response to 'stage of growth' of the mean percentage of crude protein in the herbage. In all three seasons herbage cut at the 'grazing' stage had a higher percentage of crude protein than herbage cut at the 'silage' stage, irrespective of nitrogen treatment. In 1955 and 1956 the difference between the percentages of crude protein in the herbage cut at each of the two growth stages was greatest under the treatment in which 8-12 cwt. 'Nitro-Chalk'/acre were applied over the season but the first dressing was delayed until after the first or second cut.

Nitrogen treatment had a modifying effect on the response of the clover fraction of the herbage to stage of growth at cutting in 1955 only. In that season the mean percentage of clover in the herbage was lower on swards cut at the 'grazing' stage than on those cut at the 'silage' stage under the no nitrogen treatment. Under all other nitrogen treatments the percentage of clover in the herbage did not vary significantly with the stage of growth at cutting.

Only in the clover dry matter yield and in the herbage crude protein percentage data for 1956, when the treatments had been applied on the same site for two seasons, did nitrogen treatment modify the effect of closeness of cutting. Throughout the experiment, and irrespective of nitrogen treatment, clover dry matter yields were greater from close than from lax-cut swards. The difference in 1956 was, however, proportionately greater under the zero and light nitrogen treatments than under the heavy. Presumably heavy dressings of fertilizer nitrogen had a relatively greater depressing effect on clover than had lax-cutting, and thereby masked the beneficial effects of close-cutting.

In 1956 herbage from close-cut swards had almost the same crude protein percentage as herbage from lax-cut swards when the zero and light nitrogen treatments were applied. Under the heavy nitrogen treatments herbage from lax-cut swards had a higher crude protein percentage than herbage from close-cut swards. Although the interaction was not significant, a similar effect was noted in the crude protein percentage data for 1955. This suggests that the efficiency of utilization of fertilizer nitrogen was lower under close than under lax-cutting. Where no fertilizer nitrogen or only light dressings were applied, it is possible that herbage from close-cut swards had almost the same percentage of crude protein as herbage from lax-cut swards, because it had a greater clover content. Under heavy nitrogen treatments, however, the difference in clover content was not sufficient to make good the difference.

Throughout the experiment variations in neither closeness of cutting nor stage of growth at cutting had any significant modifying influence on the response of the sward to nitrogen treatment.

<u>Fixation and transfer of nitrogen by clover</u>

A comparison of the various nitrogen treatments on clover-free swards was not included in this experiment. It was, therefore, not possible to determine directly how much of the total nitrogen in the 'grass' fraction of the herbage was derived from the clover by transfer of fixed nitrogen and how much from fertilizer nitrogen and other sources. In addition, because of lack of facilities and the recognised deficiences in sampling and analytical methods, the average nitrogen content of soil under the various treatments was not determined, so that the amount of nitrogen obtained from this source was not known. An indication of the relative importance of various sources of nitrogen available to the 'grass' fraction of the herbage can, however, be obtained mathematically as described below.

In a grass-clover sward from which the herbage is cut and removed and on which no animals are grazed the grass obtains its nitrogen from three main sources - transfer from the clover, available nitrogen in the soil, and applied fertilizer nitrogen (if any). Walker, Orchiston & Adams (93) have shown that if it is assumed that over a certain limited range the clover contributes nitrogen to the grass in proportion to the yield of nitrogen in the clover (C_N) over a given period of time, and that the grass recovers nitrogen from the available soil and fertilizer nitrogen at rates proportional to the percentage nitrogen in the soil (S_N) and in the fertilizer (F_N), then the yield of nitrogen in the grass (G_N) over the period is given by the equation:

$$G_N = aS_N + bC_N + cF_N$$

where a, b and c are constants. Over a given period of time variations in F_N will affect the yield of G_N and C_N, but aS_N should be constant for the various treatments. The above equation can, therefore, be reduced to:

$$G_N = bC_N + cF_N + K$$

where K is a constant. Using the data from a New Zealand experiment Walker <u>et al</u>. obtained, by multiple regression, an equation of identical form to this, namely:

$$G_N = 0.65C_N + 0.69F_N + 36$$

which gave estimated values of G_N in reasonable agreement with the experimental values. They showed that over the range of fertilizer nitrogen rates (0 - 270 lb./acre) used in this New Zealand experiment, G_N was linearly related to

TABLE 42. Estimation of yield of nitrogen in the grass fraction of herbage by the multiple regression equation $G_N = 0.66C_N + 0.64F_N + 34$ using data from Experiment 1 (Field E), 1956

Cutting treatment	Nitrogen treatment	Clover nitrogen (C_N) lb./acre	Fertilizer nitrogen (F_N) lb./acre	Grass nitrogen (G_N) Actual lb./acre	Grass nitrogen (G_N) Estimated lb./acre	Error of estimate
'Grazing' stage Close-cut	N1	73	-	88	82	6
	N2	45	70	110	108	2
	N3	48	70	106	110	-4
	N4	9	209	195	174	21
	N5	30	139	150	143	7
	N6	24	209	192	184	8
'Grazing' stage Lax-cut	N1	33	-	55	56	-1
	N2	21	70	91	93	-2
	N3	13	70	71	87	-16
	N4	6	209	161	172	-11
	N5	8	139	112	128	-16
	N6	7	209	164	172	-8
'Silage' stage Close-cut	N1	69	-	85	80	5
	N2	37	70	110	103	7
	N3	31	70	103	99	4
	N4	23	139	153	138	15
	N5	28	104	116	119	-3
	N6	29	139	134	142	-8
'Silage' stage Lax-cut	N1	45	-	76	64	12
	N2	16	70	93	89	4
	N3	30	70	80	99	-19
	N4	13	139	133	132	1
	N5	22	104	110	115	-5
	N6	15	139	127	133	-6

$G_N + F_N$. At higher rates, however, the response curve flattens out and the equation does not hold.

Using data from seven experiments conducted in England by Walker, Edwards, Cavell & Rose (91, 92), Walker, Orchiston & Adams (93) showed that the relationship between G_N, C_N and F_N conformed always to a general equation:

$$G_N = 0.67(C_N + F_N) + K$$

where K was a variable constant either positive or negative, but fixed for a particular sward over a given period of time.

The experiments from which data were obtained to develop this relationship covered a variety of grass + clover mixtures on different soils and under different climatic conditions. It seems likely, therefore, that this relationship is of quite general application. Accordingly an equation of this type has been derived from some of the data obtained in the present experiment.

Yields of nitrogen in the grass and in the clover and amounts of fertilizer nitrogen applied were calculated for all 72 plots of the experiment on the Field B site in 1956. Assuming that the relationships were, in fact, linear, the following correlation coefficients were calculated using total sums of squares and sums of products:

$$C_N \text{ and } F_N = -0.6580$$

$$C_N \text{ and } G_N = -0.3560$$

$$G_N \text{ and } F_N = +0.8075$$

The F-test showed that the first and last of these coefficients were significant at the 0.1% level, while the second was significant at the 1% level. The following equation was then obtained by multiple regression:

$$G_N = 0.66C_N + 0.64F_N + 34$$

This bears a striking similarity to the full equation derived by Walker <u>et al.</u>, and the F-test showed that it was significant at the 0.1% level. Calculated and mean experimental values of G_N are given in Table 43 and are in reasonable agreement.

Since the calculation of the above equation was based on total sums of squares and sums of products, the true relationship is obscured by block differences and by differences due to cutting treatments. The correct

TABLE 43. Estimation of yield of nitrogen in the grass fraction of herbage by the multiple regression equation $G_N = 0.24C_N + 0.54F_N + 55$ using data from Experiment 1 (Field E) 1956

Nitrogen treatment	Clover nitrogen (C_N) lb./acre	Fertilizer nitrogen (F_N) lb./acre	Grass nitrogen (G_N)		Error of estimate
			Actual lb./acre	Estimated lb./acre	
N1	55	-	76	68	8
N2	30	70	101	100	1
N3	30	70	90	100	-10
N4	13	174	160	152	8
N5	22	122	122	126	-4
N6	19	174	154	153	1

basis of the calculation is, of course, error sums of squares and sums of products, but since F_N was, in fact, an applied treatment, no error term exists for this or for any products including it. However, all the data was subjected to multiple covariance analysis, and the multiple regression was re-calculated on the basis of 'nitrogen' or 'nitrogen + sub-plot error' sums of squares and sums of products. This gave the following somewhat different set of correlation coefficients:

C_N and F_N = -0.8384

C_N and G_N = -0.7697

G_N and F_N = +0.9596

all of which were significant at the 0.1% level. The resulting multiple regression equation was:

$$G_N = 0.24C_N + 0.54F_N + 55$$

The F-test indicated that this also was significant at the 0.1% level, and Table 43 shows that there was reasonable agreement between the calculated and mean experimental values of G_N.

This equation shows that in the present experiment, when the effects of cutting treatments have been removed, the mean yield of nitrogen in the grass increased by 0.24 lb. for each 1 lb. of nitrogen in the clover and by 0.54 lb. for each 1 lb. of fertilizer nitrogen applied. Further interpretation of this equation is perhaps unjustified, but it might be inferred from the foregoing statement that the mean efficiency of utilization of applied nitrogen by the grass was 54% in the present experiment. This figure comes within the range calculated from another experiment by Holmes (56). A second inference which might be made from the above equation is that the clover transferred fixed nitrogen to the grass at a mean rate equivalent to 0.24 lb. for every 1 lb. nitrogen in the clover, if account is taken of the above ground portions of the plants only. If this inference is accepted the mean amount of nitrogen transferred from clover to grass in the present experiment would be 28 multiplied by 0.24, or approximately 7 lb. An estimate of the total amount of fixed nitrogen appearing in the herbage can then be obtained by adding this to the mean yield of nitrogen in the clover. This total was 35 lb., which is equivalent to 4.7 lb. for every 100 lb. of clover dry matter harvested.

Cowling & Green (17) estimated the amount of nitrogen fixed in white clover by a more direct method. They grew swards of either cocksfoot alone or cocksfoot, + white clover, and ascribed the difference in nitrogen yield between the two to fixation in the clover. The resulting estimate was 4.5 lb./100 lb. of clover harvested, which agrees closely with that from the above indirect method, suggesting that the inferences made might be justified.

SUMMARY and CONCLUSIONS

SUMMARY and CONCLUSIONS

1) In an experiment conducted over three seasons (1954-1956 inclusive) a sward in which perennial ryegrass predominated was cut to within either 1 inch or 2-2½ inches of ground level, when the herbage had reached either the 'grazing' or the 'silage' stage of growth. Superimposed on these cutting treatments in a split-plot design were several fertilizer treatments, which involved varying amounts of nitrogen applied at different dates over the season. Yields and chemical and botanical composition of the herbage under the various treatments were determined.

2) Throughout the experiment cutting to within 1 inch of ground level gave greater dry matter and crude protein yields of total herbage and of white clover than cutting to within 2-2½ inches of ground level. The effect of close versus lax-cutting has been explained by means of a theory based on certain published information on the morphology of stem and leaf formation in the grasses. Over a 2 year period close-cutting appeared to increase clover yields by stimulating the production of more leaves per unit length of stolon or by increasing the size of the leaves rather than by encouraging stolon growth.

3) Though greater dry matter yields of total herbage were obtained when cutting was carried out at the 'silage' than at the 'grazing' stage of growth, crude protein yields of total herbage, and dry matter and crude protein yields of clover were little affected.

4) Dry matter and crude protein yields of total herbage increased and those of white clover decreased with increasing rate of fertilizer nitrogen application.

5) The effect of delaying the first fertilizer nitrogen

dressing of the season varied with the total amount applied over the season. Where the total amount applied was small (4 cwt. 'Nitro-Chalk'/acre) dry matter and crude protein yields of total herbage were reduced, while those of white clover were little affected. Dry matter yields of total herbage were also reduced where greater total amounts of fertilizer nitrogen (8-12 cwt. 'Nitro-Chalk'/acre) were used, but here dry matter and crude protein yields of clover were slightly increased. Under these heavy nitrogen treatments crude protein yields of herbage decreased where the delay involved a reduction in the total amount of fertilizer nitrogen applied over the season, but were unaffected where the same total amount was applied.

6) Delaying the first fertilizer nitrogen dressing of the season decreased herbage yields in the spring, but increased them in mid-season, and thus resulted in a more uniform distribution of growth over the season.

7) In the final year of the experiment close-cutting appeared to stimulate clover growth to a much greater extent in swards receiving no fertilizer nitrogen or only light dressings than in those receiving heavy dressings.

8) An equation has been derived from the 1956 data relating yield of nitrogen in the grass fraction of the herbage to that in the clover fraction and to the amount of fertilizer nitrogen applied. It has been suggested that an estimate of the total amount of fixed nitrogen appearing in the herbage might be obtained by inference from this equation. The resulting estimate calculated from the 1956 data was 4.5 lb. of fixed nitrogen per 100 lb. of clover dry matter harvested.

PART 3

Experiment 2. A study of the relative values of various strains of white clover, their compatability with different species and strains of grass and their reaction to different dressings of fertilizer nitrogen.

INTRODUCTION

In the introduction to the preceding section it was pointed out that the extent to which applications of fertilizer nitrogen will depress clover in a grass-clover sward depends on a number of factors, which can be roughly classified into two catagories - managerial and botanical. The experiment described in this section deals with certain factors in the second catagory.

Existing literature provides a considerable amount of information on the direct effects of these botanical factors, and this is reviewed in detail on pages 1-14 of this thesis. Stapledon, Williams & Jenkin (78) and other workers (26, 24, 80, 96, 97) have shown that white clover strains vary in their yielding ability and persistency; Davies (19) and Holmes & MacLusky (39) have demonstrated variations in the compatability of white clover with different species and strains of grasses; and the fact that white clover in a grass-clover sward is generally depressed by fertilizer nitrogen applications has been proved by many workers (8, 25, 38, 39, 88, 91, 92, 97).

Little information is available, however, to show whether or not interactions exist between the various factors involved. Subsidiary comparisons in an experiment reported by Holmes & MacLusky (39) suggested that the compatability of clover with various species and strains of grasses (i.e. the relative capacity of clover to grow in association with the different grasses) varied with the level of fertilizer nitrogen application. Further information on this point, and on possible variations in the relative value of various white clover strains with fertilizer nitrogen treatment is required.

The objects of the present experiment were, therefore, firstly to obtain further information on the relative values of various strains of white clover, their compatability with different species and strains of grasses, and their reaction to different levels of fertilizer nitrogen application, and secondly, to investigate possible interactions between these factors.

EXPERIMENTAL

General

The plots of this experiment were sown in the spring of 1954 in part of field F on the Institute farm at Kirkhill. From 1947 to 1952 the area occupied by the experiment was in grass which was intensively managed. This was followed in 1953 by a crop of barley, which on account of the high residual fertility from the preceding ley and heavy rainfall during July and August, lodged badly. As a result a considerable amount of straw and shed-grain was turned in when the area was ploughed in March 1954.

Treatments

The treatments included in this experiment were as follows:

A) Fertilizer nitrogen applications
  1) No nitrogen (N0)
  2) 1 cwt. 'Nitro-Chalk'/acre per grazing (N1)
  3) 2 cwt. 'Nitro-Chalk'/acre per grazing (N2)

B) Clover strains
  1) Wild white type - S184
  2) Medium-leaved type - S100
  3) Large-leaved type - Kersey

C) Grass species and strains
  1) No sown grass
  2) Perennial ryegrass - S23
  3) Perennial ryegrass - S24
  4) Cocksfoot - S143
  5) Cocksfoot - S37
  6) Timothy - S48
  7) Meadow-fescue - S53

All fertilizer nitrogen dressings were applied in the form of 'Nitro-Chalk' (15.5% N), the required amount for each plot being weighed out in grams and applied by

TABLE 44. Dates of application of 'Nitro-Chalk' for each cut - Experiment 2

Nitrogen treatment	Year	Cut No.	Date
N1	1955	1	April 14
		2	May 30
		3	July 8
		4	Aug. 20
	1956	1	March 29
		2	May 24
		3	July 3
		4	Aug. 14
N2	1955	1	April 14
		2	May 25
		3	June 27
		4	July 28
		5	Sept. 12
	1956	1	March 29
		2	May 21
		3	June 25
		4	July 28
		5	Sept. 6

hand. Plots of treatment N1 received four dressings each of 1 cwt./acre (≡46.6 g./sub-plot) over the season, and those of treatment N2 five dressings each of 2 cwt./acre (≡93.2 g./sub-plot). In both treatments the first dressing of the season was applied in late March or early April, and the other dressings were applied after each grazing except the last. Actual dates of applications of 'Nitro-Chalk' under treatments N1 and N2 in 1955 and 1956 are given in Table 44.

Each of the three clover strains was sown alone (i.e. no sown grass treatment) and also in association with one of the six grass strains. Pedigree strains of grasses and clovers were used to ensure the greatest possible uniformity of plant type within each strain. Details of origin, morphological characteristics and agronomic behaviour of the various strains may be found elsewhere (15, 42, 43), but the following brief notes will be of value in the consideration of the results of this experiment.

S184 and S100 strains of white clover were bred at the Welsh Plant Breeding Station, Aberystwyth. The first resembles commercial types of wild white clover, but the leaves are slightly larger and darker green; it has a denser habit of growth, and the individual plants are more uniform in performance. S100 has considerably larger leaflets carried on long stems arising from relatively stout stolons. These root fairly readily at the nodes, and have quite short internodes. The sward from S100 strain is, therefore, dense and leafy. Growth begins earlier in the spring and continues later into the autumn with S100 than with S184. Kersey (26) was raised from a single plant found in a crop of lucerne in Suffolk. It is vigorous, roots freely and recovers rapidly after defoliation. In habit of growth it is more upright than S100, and it starts growth earlier in the season but has poorer production later.

All six grass strains included in the experiment originated at the Welsh Plant Breeding Station. Of the two ryegrass strains S23 is a late 'grazing' type and S24 an early 'hay' type. The former has a prostrate spreading growth and late flowering habit, and is high tillering, dense, leafy and persistent. Although growth from S23 is poor in the spring, it gives high yields in mid-season, and continues to grow late into the autumn. S24, on the

TABLE 45. <u>Purity and germination capacity of seed lots sown in May, 1954 - Experiment 2</u>

Species	Strain	Purity %	Germination %
Perennial ryegrass	S23	99.1	87
" "	S24	98.6	82
Cocksfoot	S143	96.0	89
"	S37	95.1	89
Timothy	S48	99.3	89
Meadow fescue	S53	98.0	62
White clover	S184	98.8	61 (+ 19 H.S.*)
" "	S100	99.4	78 (+ 18 H.S.)
" "	Kersey	98.8	55 (+ 13 H.S.)

*H.S. = hard seed

other hand, has a more upright, open and stemmy habit of growth, and is not so persistent. It produces a bulky hay crop, and the aftermath recovery is better than that of the commercial types of ryegrass. Late summer growth is very leafy, since few flowering stems are produced in the aftermath.

The S143 strain of cocksfoot is an extreme pasture type, having a spreading habit of growth, dense tillers and broad leaves. In contrast, S37 is relatively erect in growth, though well-leaved, and may, therefore, be considered a 'hay' type. S37 is less persistent than S143 on average.

Plants of S48 timothy are broad based, tiller more profusely than commercial types and form a dense, leafy herbage. It performs well as a hay strain, but is very persistent even under heavy grazing.

S53 meadow-fescue is primarily a pasture type, tillering more profusely, and forming, therefore, a denser and more persistent sward than the commercial types.

Details of germination and purity of the seed lots of the various grass and clover strains used in the experiment are given in Table 45. The purity of all lots was satisfactory. The seed of S53 meadow-fescue had, however, a much lower germination percentage than that of the other grass strains. Similarly the seed of Kersey white clover had a lower germination percentage than that of the other clovers. Perennial ryegrass, cocksfoot and meadow-fescue strains were sown at the rate of 20 lb./acre (≡8.33 g./sub-plot), and timothy at 15 lb./acre (≡6.25 g./sub-plot). In mixtures with a companion grass, clover seed was sown at the rate of 3 lb./acre (≡1.25 g./sub-plot), and alone, at 6 lb./acre (≡2.50 g./sub-plot).

<u>Experimental design</u>

In designing this experiment, account was taken of the fact that the direct effects of nitrogen treatments on grass-clover leys had been well established by previous studies (eg. 59, 91), and that the differences between these treatments were likely to be large and easily measured. The principal interest centred, therefore, on the interactions of these treatments with the strains of grass and clover included in the seeds mixtures. Thus a split-plot design (14, 27) was used, arranging each of the three nitrogen treatments in a main-plot within the replicate block. All possible combinations of one clover strain with one grass strain (or no sown grass) were then laid down in sub-plots within each main plot, giving 21 sub-plots per main plot. Some precision was, therefore, lost in the estimation of the effects of the nitrogen treatments, but increased precision was obtained in the estimation of the effects of the other main factors (i.e. clover strains and grass strains), and of all interactions.

Sub-plot treatments were independently randomized within each main plot, and the main plot treatments were randomised within each replicate block. All possible treatment combinations were replicated three times. Sub-plot size was 8 ft. by 5 ft. or 0.001 acre.

In the field, pathways 6 ft. wide separated the main plots from one another, and from the margins of the experimental area. S23 perennial ryegrass was sown on these at a heavy seed rate, and for the duration of the experiment the herbage from this was kept short and no fertilizer of any kind was applied. These pathways had two functions: 1) to act as barriers to any fertility drift which might occur, and 2) to facilitate access to the plots. In addition, unsown borders 12 in. wide separated the sub-plots from one another and also separated the entire main plot from the surrounding pathways. These borders were kept free from weeds as far as possible by frequent cultivation. Their function was to prevent the spread of clover between sub-plots, and they were efficient in this respect, but the labour involved in cultivating at frequent intervals during the growing season was considerable. Narrower borders (say 4-6 in.) would probably have been equally effective, and more readily cultivated mechanically. A further drawback with 12 in. wide borders was the slightly greater growth shown by plants round the margins of the sub-plots. This was no doubt due to the greater root range available to these plants, and would be reduced by using narrower borders. Even with 12 in. borders this effect extended at most 2-3 in. into the sub-plot, and was most pronounced in dry weather. In sampling plots for yield these marginal areas were ignored.

Establishment of seeds mixtures

The experimental area was ploughed on March 13 to 15, 1954. Late harvest and bad weather conditions prevented the ploughing being done in the previous autumn which would have been preferable. On April 10 a dressing of muriate of potash (60% K_2O) at the rate of 1.2 cwt./acre and superphosphate (18.3% P_2O_5) at the rate of 3.2 cwt./acre was applied. The area was thoroughly cultivated with disc and chain harrows on April 13, and ring-rolled on April 15. The seed-bed at this date was sufficiently fine and firm for sowing grass and clover seeds, but the soil was very dry on account of the low spring rainfall (see Appendix 1) and low humidity conditions. An additional fertilizer dressing was applied on the rolled seed bed on April 22. This consisted of 4 cwt. ground mineral phosphate, 4 cwt. ground limestone and 0.8 cwt. 'Nitro-Chalk'/acre.

The seed bed was reasonably moist on May 11, when the grass and clover seeds were sown on the sub-plots of two replicate blocks under favourable weather conditions. Seeds were sown on the sub-plots of the remaining block on May 12. Grass and clover seeds were sown separately by hand in the quantities given previously. Because of the small amounts involved, the timothy and white clover seeds were mixed with small quantities of fine dry top soil before sowing. Seeds were covered immediately after sowing by raking lightly. The entire area was rolled twice with a heavy garden roller on May 13.

The pathways surrounding the main-plots of the experiment were sown with S23 perennial ryegrass in the same way on June 28-29.

Establishment of the grass and clover seeds was slow at first on account of dry weather in the 3-4 weeks following sowing, and many of the plots became weed infested. Weeds were controlled, however, by periodic cutting during the season, and by hand-pulling in June and July. Barley plants, from grain shed by the 1953 crop, docks (Rumex obtusifolius) and thistles (Cirsium arvense) were the most prevalent weeds, but these were quickly eradicated by spudding or pulling. Couch grass (Agropyron repens) was also a problem on the unsown borders in 1954, and large quantities of rhizomes of this grass were dug up.

The herbage on all plots was mown closely and removed on July 16, August 10 and November 5, 1954. This helped to control weed growth, and at the same time encouraged tillering in the sown grasses. The frequency of cutting was such that the grasses did not grow tall enough to shade the clover and thus by the autumn of the seeding year clover establishment was good on all plots. In addition, plants of the sown grasses were well-tillered, and the weed content of the sward was moderate.

Grazing management

Previous investigations along similar lines at the Institute (59) were conducted on plots defoliated with the mowing machine, and under such conditions highest yields were invariably obtained using fertilizer nitrogen. It was of interest to investigate whether this applied under grazing conditions or if clover was of greater value there. Accordingly from the first harvest year of the experiment onwards, the plots were defoliated by sheep under a modified grazing management.

Walker, Edwards, Cavell & Rose (91) have shown that the suppression of clover by fertilizer nitrogen application is often accentuated in experiments by defoliating the fertilized plots at the same time interval as the control (or no nitrogen) plots. Under this procedure the grasses on the former plots are at a more advanced stage of growth than those on the latter at any particular cutting date, and consequently exert a greater shading action on the clover fraction of the sward. In this experiment, therefore, it was decided to graze the plots when the grasses were at as nearly as possible the same stage of growth. Thus all plots were grazed at the 'leafy' stage or when 6-8 in. tall. Some difficulty was experienced in adhering rigidly to this scheme. The smallest unit which it was possible to fence off for grazing was the main plot. These contained sub-plots sown with grass strains of varying maturity types, and, therefore, at any particular grazing date all strains were not at exactly the same growth stage but ranged slightly about the above-mentioned stage.

In practice the management scheme worked in the following way. At the beginning of each growing season plots receiving the heavy nitrogen treatment N2 reached

TABLE 46. Details of grazing periods - Experiment 2

Nitrogen treatment	Year and Grazing No.	Grazing began	Duration (hr.)	Sheep/ main plot
N0	1955			
	1	May 31	40	7
	2	July 15	28	7
	3	Sept. 28	48	4
	1956			
	1	May 25	41	10
	2	July 11	43	10
	3	Sept. 24	43	9
N1	1955			
	1	May 26	44	7
	2	July 6	41	7
	3	Aug. 17	39	7
	4	Oct. 5	50	4
	1956			
	1	May 22	39	10
	2	June 28	40	10
	3	Aug. 8	48	9
	4	Oct. 4	28	9
N2	1955			
	1	May 20	47	7
	2	June 23	43	7
	3	July 26	24	7
	4	Sept. 6	50	5
	5	Oct. 18	49	4
	1956			
	1	May 19	46	10
	2	June 22	39	10
	3	July 25	54	9
	4	Sept. 3	48	9
	5	Oct. 9	48	9

the appropriate stage of growth first, followed a few days later by those receiving the light nitrogen treatment N1, and soon after by those receiving the no nitrogen treatment N0. Thereafter treatment N2 plots had the shortest recovery interval after grazing, and treatment N0 plots the longest. Thus in 1955 and 1956 treatment N2 plots were grazed five times per season, treatment N1 plots four times and treatment N0 three times.

When the herbage on plots of any given nitrogen treatment was judged to be at the 'grazing' stage, it was first sampled for yield, botanical and chemical composition as described below. All sub-plots within each main plot were then defoliated with an Allen Autoscythe down to a uniform stubble length of 2-3 in. and the cut herbage was removed. The remaining stubble was grazed to ground level by sheep, stocking rate being sufficiently heavy to complete the defoliation in 36 to 48 hr. at most grazing periods. To ensure rapid defoliation the sheep were starved for 4-6 hr. before each grazing period.

This modified grazing scheme was adopted in preference to complete grazing for several reasons. Firstly, with the limited sheep stock available the scheme allowed close and uniform defoliation within a short period, thus allowing little or no regrowth after sampling. Secondly, the uniform height of herbage and the relatively heavy stocking rate appeared to offset any differences in palatability which might exist between the various grass species and strains within main plots, and the intensity of grazing was remarkably uniform over all. Thirdly, the effects of treading, dunging and urinating on the sward were kept to a minimum.

Date, duration and stocking rate for each grazing period on the plots of the three nitrogen treatments in 1955 and 1956 are given in Table 46.

Experimental methods

a) Yield sampling procedure. Before every grazing the herbage on a sample area 6 ft. long by 1 ft. wide on each sub-plot was cut to as near ground level as possible with a Tarpen Trimmer fitted with a special grass-cutting blade. This trimmer is electrically driven, and has an effective cutting width of 1 ft. Since the long-term effect of cutting with this machine would undoubtedly differ from that of grazing, sample cuts were taken from a different area of the plot at each grazing. For this purpose the plot was divided by eye into three sections, and samples were cut at random within each of these sections in turn at successive grazings. Thus no area of any plot was cut more than twice in any season.

Immediately after being cut, all herbage from the sample area was collected and taken to the laboratory either wrapped in greaseproof paper as in 1955 or in a plastic bag as in 1956. In the laboratory the entire sample from each plot was weighed to the nearest gram on a Towers' rotating-weight balance, and after mixing the herbage thoroughly a subsample of 300 g. green weight was drawn at random from it. This subsample was oven-dried for approximately 12 hr. at 100°C. in a Blackburn Unitherm Drier (64). Its dry weight was then determined, and it was ground in a laboratory mill through a 0.7 mm. sieve. The ground sample was stored in a glass bottle for chemical analysis.

The remainder of the herbage sample from each plot was placed in a refrigerator or cold-storage box until required. The clover content of herbage on the plot was determined by hand-separating clover from a 200-300 g. subsample of the cold-stored material. Green weights of the 'clover' and 'grass + weeds' fractions of the subsample were determined in grams after separation. The latter fraction was then oven-dried, re-weighed and discarded. Since the clover fractions of many subsamples were extremely small, those fractions from the three replicates of each treatment combination were bulked. The resulting sample was then oven-dried, reweighed, and ground for chemical analysis.

b) Determination of sward botanical composition. Throughout the experiment detailed analyses were made of the botanical composition of the sward on every plot in spring soon after growth began and again in autumn shortly after the last grazing of the season. The methods used gave estimates of the proportion of the total area of each plot covered by the various plant species at ground level, and the results have been presented here in terms of 'percentage ground cover' for each species.

The method of analysis used in the autumn of 1954 was similar to that described for Experiment 1 (page 22). The same ten-pin apparatus used there was placed at ten randomly selected positions along one diagonal of each plot, and the species touching each of the ten points at ground level was identified and recorded. Where a pin did not contact a plant at ground level 'bare ground' was recorded.

Although statistical analyses of the data obtained by this method showed that it was satisfactorily precise, it was thought that a more representative sampling of the vegetation on each plot would be obtained if the 'points' or sampling units were distributed more evenly over the total area. An apparatus designed and constructed specially for this experiment was, therefore, used for the analyses from the spring of 1955 onwards. The main part of this apparatus was a rectangular frame of external dimensions 8 ft. by 5 ft. (i.e. the exact dimensions of a sub-plot), built of 2 in. square section timber. Across this frame lay a movable wooden bar 5 ft. x 2 in. x $\frac{3}{4}$ in., with legs 5 in. long recessed to grip the long sides of the rectangular frame. Ten pins 6 in. long by 0.2 in. in diameter were inserted at intervals along the centre line of this bar, the outside pins being at $7\frac{1}{2}$ in. centres from the end of the bar and the remainder evenly spaced between at 5 in. centres. On the upper surface of the long sides of the rectangular frame, wooden blocks were fitted so that the cross bar could be placed successively at ten accurately located positions. The first blocks at either end of the frame were positioned to hold the cross bar with the line of points at 12 in. centres from the ends of the plot. Between these extremes blocks were placed to hold the line of points at 8 in. intervals. In the field the frame was placed so that its outside edges coincided with the margins of a sub-plot. The cross bar was then placed at each of the ten positions in turn and the plant species or 'bare ground' touching each of the ten pins at ground level was recorded.

c) <u>Soil sampling</u>. Because of the small size of the sub-plots of this experiment and the large number of plots involved, it was decided not to take individual soil samples from every plot. Instead one composite sample was taken in the autumn of 1955 and again in 1956 from each of five groups of sub-plots within each main plot. The groups were: 1) all six sub-plots sown with S23 and S24 mixtures (1 auger/sub-plot), 2) all six sub-plots sown with S143 and S37 mixtures (1 auger/sub-plot), 3) all three sub-plots sown with S48 mixtures (2 augers/sub-plot), 4) all three sub-plots sown with S53 mixtures

(2 augers/sub-plot), and 5) all three sub-plots sown with mixtures containing no sown grass (2 augers/sub-plot). Auger borings were taken to a depth of 9 in. and bulked according to the above groupings. Routine analyses of the resulting samples were made by the Chemistry Department of the West of Scotland Agricultural College.

The results of these analyses are not presented since the method of sampling probably introduced considerable error. However, the data obtained were useful in deciding at what rates mineral fertilizers should be applied each season.

Mineral fertilization

As in Experiment 1 the rate of application of phosphatic and potassic fertilizers were uniform over all plots of the experiment. The rates of application were determined from the results of analysis of soil samples taken from the plots the previous autumn, and were sufficient to satisfy requirements on the most deficient plots. Because of the small size of the sub-plots mineral fertilizers were weighed and applied by hand on a main-plot basis in this experiment, half the required amount being applied in spring and the remainder in mid-summer. Superphosphate (18.5% P_2O_5) and muriate of potash (60% K_2O) were used as the phosphatic and potassic fertilizers throughout the experiment. The rates and dates of application were as follows:

1955	Fertilizer	cwt./acre
April 7	P_2O_5	2
	K_2O	2
August 5	P_2O_5	2
	K_2O	1
1956		
March 27	P_2O_5	2
	K_2O	2
July 24	P_2O_5	2
	K_2O	1

In both years, therefore, a total of 4 cwt. superphosphate and 5 cwt. muriate of potash/acre were applied to all plots.

Statistical treatment of results

The methods of statistical analyses used in this experiment were basically similar to those used in Experiment 1 (see page 24). Sward botanical composition data from this

TABLE 47. **Mean total dry matter yields of mixed herbage (in 100 lb./acre) - Experiment 2, 1955**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	99.3	105.5	87.8	93.3	97.2	99.4	94.0	96.6	70.0	103.3	116.6
S100	98.1	111.4	85.6	92.8	98.4	98.2	91.1	96.5	72.2	100.0	117.4
Kersey	103.5	103.0	86.7	88.4	90.3	96.4	90.9	94.2	66.2	101.8	114.5
Nitrogen treatments											
NO	70.2	77.9	59.5	64.0	67.6	76.7	70.3	69.5			
N1	106.8	113.4	92.8	99.0	102.3	101.3	96.1	101.7			
N2	123.9	128.7	107.8	111.5	115.9	115.9	109.5	116.2			
Grass means	100.3	106.6	86.7	91.5	95.3	98.0	92.0				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	4.68	12.99	21.55
C means	1.30	-	-
G means	1.98	3.92	5.18

Significant effects

N **

G ***
- No grass v. rest **
- S23+S24 v. S143+S37 ***
- S23 v. S24 **
- S143 v. S37 *

Coefficient of Variation: Main-plots = 27.4% Sub-plots = 7.6%

TABLE 48. Analysis of variance of total dry matter yields of mixed herbage - Experiment 2, 1955

Source of variation	df	Sums of squares	Mean square	Variance ratio (F)
Nitrogen (N)	2	72045.99	36023.00	52.19 **
Replicates	2	194.87	97.44	
Error (a)	4	2760.77	690.19	
Clover (C)	2	244.18	122.09	
Grasses (G)	6	6982.55	1163.76	22.04 ***
No grass v rest	1	448.04	448.04	8.48 **
S23+S24+S143+S37 v S48+S53	1	4.92	4.92	
S23+S24 v S143+S37	1	5577.14	5577.14	105.63 ***
S23 v S24	1	546.58	546.58	10.35 **
S143 v S37	1	309.60	309.60	5.86 *
S48 v S53	1	96.27	96.27	
C x G	12	824.40	68.70	
C x N	4	348.22	87.06	
N x G	12	1032.51	86.04	
N x G x C	24	1852.95	77.21	
Error (b)	120	6336.38	52.80	
Total	188	92622.82		

*Significant at the 5% level; **Significant at the 1% level; ***Significant at the 0.1% level experiment were, however, analysed in greater detail.

Presentation of results

In the following pages the results relating to herbage yields and quality are considered first, those from 1955 and 1956 being dealt with separately under the following sub-headings:

1) Mixed herbage dry matter yields - including total yields for the season, and distribution of yields over the season.
2) Clover dry matter yields - including total yields for the season, distribution of yields over the season, and weighted mean percentage clover in the mixed herbage dry matter.
3) Mixed herbage crude protein yields - including total yields for the season, and weighted mean percentage crude protein in the mixed herbage dry matter.
4) Clover crude protein yields

Results of the analyses of sward botanical composition made during 1954, 1955 and 1956 are then considered together. The section ends with a discussion of all the results obtained from the experiment.

RESULTS

Yields - 1955

Mixed herbage dry matter yields

Mean total dry matter yields of mixed herbage in the 1955 season are shown in Table 47. The analysis of variance of these yields is given in Table 48 as an example of the type of analysis employed on all data from this experiment.

Total dry matter yields of mixed herbage increased with increasing rate of fertilizer nitrogen application. Treatment N1 outyielded treatment N0 by 3,220 lb./acre (10,170 lb. compared with 6,950 lb.) or 46.3%, and this difference was highly significant. The additional nitrogen applied under treatment N2 gave a proportionately smaller return, the mean total yield for this treatment exceeding that for treatment N1 by only 1,450 lb./acre or 14.2%. This difference was significant only at the 5% level.

The effect of strain of white clover included in the seeds mixture on total dry matter yields of mixed herbage was not on average significant. Mixtures

TABLE 49. Mean dry matter yields of mixed herbage (in 100 lb./acre) at each crop in the season - Experiment 2, 1955

		N0 Crop No.			N1 Crop No.				N2 Crop No.				
		1	2	3	1	2	3	4	1	2	3	4	5
Clover													
S184		25.9	21.6	22.5	31.3	27.9	20.0	24.1	31.6	27.4	19.7	18.9	19.0
S100		26.9	22.6	22.7	30.4	26.8	19.8	23.0	31.1	28.0	21.0	18.4	18.8
Kersey		25.2	20.1	20.9	30.4	27.3	21.0	23.1	30.5	27.3	19.7	18.0	19.0
$s_{\bar{d}}$	±	1.28	0.97	1.16	1.04	0.89	0.99	1.08	1.03	1.21	0.95	0.67	1.08
L.S.D. 5%	±	-	1.96	-	-	-	-	-	-	-	-	-	-
F. Sig. at		NS	5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grasses													
S23		22.6	23.9	23.6	31.9	30.7	21.2	22.8	30.1	31.1	20.6	19.6	22.5
S24		37.9	19.8	20.1	46.5	23.2	19.5	24.1	44.6	23.7	19.1	20.2	21.1
S143		21.9	18.5	19.1	27.0	28.6	17.5	19.8	26.5	25.3	21.2	19.6	15.1
S37		22.5	18.8	22.7	26.9	28.0	19.6	24.5	28.0	27.3	21.6	19.5	15.1
S48		24.7	22.7	20.3	29.0	28.0	19.9	25.4	30.6	30.4	18.6	16.7	19.6
S53		26.8	23.7	26.2	29.1	28.0	21.4	22.8	29.2	28.8	20.8	17.2	19.9
No sown grass		25.7	22.7	22.0	24.6	24.8	22.5	24.2	28.7	26.2	19.2	16.2	19.3
$s_{\bar{d}}$	±	1.95	1.48	1.78	1.58	1.35	1.51	1.65	1.57	1.86	1.45	1.02	1.66
L.S.D. 5%	±	3.94	3.60	3.59	3.20	2.74	3.04	3.33	3.18	3.75	-	2.06	3.35
L.S.D. 1%	±	5.26	4.01	4.80	4.28	3.66	-	-	4.25	5.02	-	2.75	4.48
F. Sig. at		0.1%	0.1%	1%	0.1%	0.1%	5%	5%	0.1%	1%	NS	0.1%	0.1%

TABLE 50. Analysis of variance of dry matter yields of mixed herbage at first crop of season under treatment NO. Experiment 2, 1955

Source of variation	df.	Sums of squares	Mean square	Variance ratio (F)
Clover (C)	2	30.98	15.49	
Grasses (G)	6	1660.30	276.71	16.21 ***
No grass v. rest	1	1.27	1.27	
S23+S24+S143+S37 v. S48+S53	1	2.80	2.80	
S23+S24 v. S143+S37	1	585.64	585.64	34.31 ***
S23 v. S24	1	1048.82	1048.82	61.44 ***
S143 v. S37	1	1.50	1.50	
S48 v. S53	1	20.27	20.27	
C x G	12	93.51	7.79	
Replicates	2	670.72	335.36	19.65 ***
Error	40	682.89	17.07	
Total	62	3138.40		

*** Significant at the 0.1% level

containing S184 and S100 gave approximately equal mean yields, while those containing Kersey gave slightly less.

Strain of grass in the seeds mixture had a highly significant effect on total dry matter yields of mixed herbage. Mixtures containing S24 gave a significantly greater, and those containing S143 a significantly smaller, mean yield than all the other mixtures. The S23 mixtures significantly outyielded all the remaining mixtures with the exception of those containing S53, while the S48, no sown grass and S37 mixtures gave smaller yields than the S53 mixtures. The difference between the mean yields for mixtures containing S48 and S53 was not significant.

None of the interactions of treatment factors had a significant effect on total dry matter yields of mixed herbage in 1955.

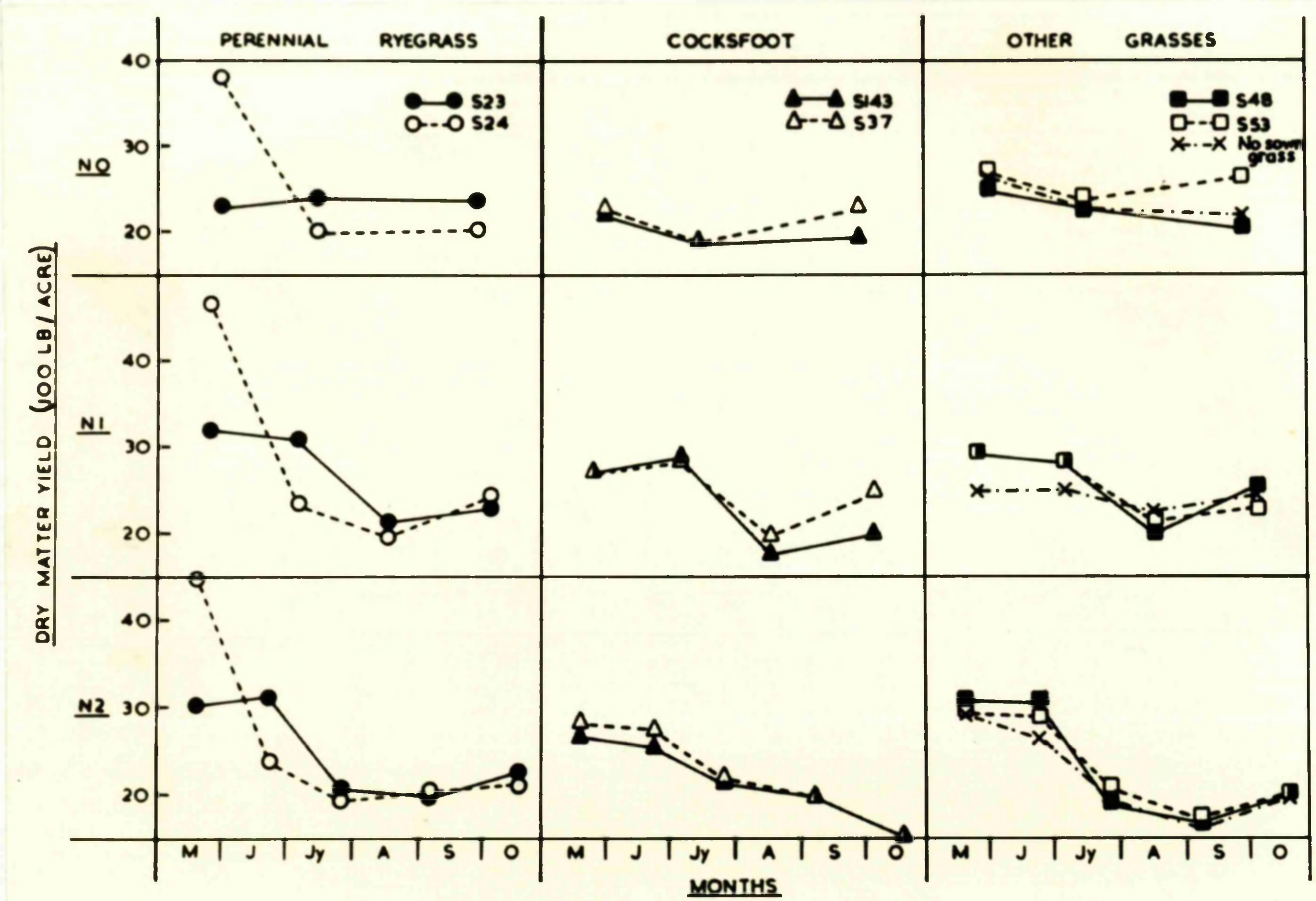
The main plot coefficient of variation calculated from these yields was somewhat higher than expected, probably because of the confounding of nitrogen treatments with sampling dates, and the comparatively large area of the main plots. The sub-plot coefficient was closer to expectation.

Dry matter yields of mixed herbage at the individual crops in 1955 are shown in Table 49, as means for mixtures containing each of the clover strains and also as means for mixtures containing each of the grass strains. Levels of significance and other statistics in this table were calculated from an analysis of variance of the type shown in Table 50. The effect of the 'grass strain' x 'clover strain' interaction was not significant in the yield data for any crop in 1955.

Distribution of herbage dry matter yields over the season under all three nitrogen treatments was little affected by the strain of white clover included in the seeds mixture. Mean yields for mixtures containing each clover strain were greatest at the first crop, declined over mid-season and then increased slightly in the autumn. At all crops differences between the mixtures were very slight, and only reached significance at the second crop under treatment NO, when the S100 mixtures significantly outyielded the Kersey mixtures.

The effect of the grass strain included in the seeds mixture on the seasonal distribution of mixed herbage dry

FIGURE 6. Mean yields of mixed herbage at each cut in the season - Experiment 2. 1955



matter yields is shown both by the means in Table 49 and by the graphs in Figure 6.

Under each of the nitrogen treatments the pattern of yield distribution of mixtures containing each grass strain, except S24, was very similar, though the general level of yield varied. Mixtures containing S24 gave a large proportion of their total yield at the first crop of the season under all nitrogen treatments, significantly outyielding all other mixtures, but comparatively low yields over the rest of the season, apart from a slight increase in the autumn.

Under treatment NO the yields from all other mixtures were quite uniformly distributed over the season, the greatest deviation between crops for any one mixture being about 300 lb./acre. The S23 mixtures had a particularly uniform yield distribution under this treatment giving a considerably lower mean yield than the S24 mixtures at the first crop but significantly greater mean yields at the other crops. The general level of yield from mixtures containing S143 or S37 was lower than that of the S23 mixtures. Yields from these mixtures dropped slightly from the first to the second crop, at neither of which were differences between them significant. They then increased at the third crop. This increase was somewhat greater with the S37 than the S143 mixtures, so the former gave a significantly greater mean yield at the third crop. Throughout the season the S48, S53 and no sown grass mixtures gave generally higher yields than the S143 or S37 mixtures. They also outyielded the S23 mixtures at the first crop, and almost equalled them in mid-season yield. Mixtures containing S53 again slightly outyielded those containing S23 at the third crop but those containing S48 and no sown grass gave lower yields. The pattern of yield distribution over the season for the S48 mixtures was very similar to that for the no sown grass mixtures, yields falling steadily but slightly from spring to autumn. None of the differences between the yields recorded for these mixtures was significant. Mean yield from the S53 mixtures did not differ significantly from those from the S48 and no sown grass mixtures at the first two crops, but was significantly higher at the third crop.

Apart from S24 the various grass strains had no striking influence on the general pattern of yield distribution of the seeds mixtures over the season under treatment N1. Yields were generally about the same at the second crop as at the first, declined at the third crop, and increased by varying amounts at the fourth crop. The S23 mixtures again gave a considerably lower mean yield than the S24 mixtures at the first crop of the season, and a significantly higher mean yield at the second crop, but almost the same yield at the remaining crops. Mixtures containing S143 and S37 gave lower mean yields than those containing S23 at most crops apart from the fourth when the S37 mixtures outyielded the S23 mixtures. At this crop the S37 mixtures also outyielded the S143 mixtures, though their yields did not differ significantly at any other crop. The S48 and S53 mixtures gave very similar yields to the S143 and S37 mixtures at the first two crops of the season but somewhat higher yields thereafter. Differences between these mixtures at the four crops in the season were not significant. Under treatment N1 the no sown grass mixtures gave significantly lower yields than the S48 and S53 mixtures at the first and second crops of the season but similar yields at the remaining two crops.

Mixtures containing S23, S48, S53 and no sown grass had similar yield distribution patterns under treatment N2 as under N1, though there were somewhat larger differences between yields at the early crops and those at the latter crops under N2. The S23 mixtures once again gave significantly lower yields than the S24 mixtures at the first crop, significantly higher yields at the second crop, and almost the same yields thereafter. Under treatment N2 the growth curves for mixtures containing S143 and S37 were roughly similar to those under treatment N1 in early and mid-season, but the yields from these mixtures dropped to a very low level in the autumn under treatment N2 whereas they increased slightly at this time under treatment N1. There were no significant differences between the yields from the S143 and S37 mixtures at any crop. Mixtures containing S48 and S53 had similar yield distribution patterns to those containing S23 and gave about the same yields at the first two crops of the season. The decline in yield after the second crop was, however, much greater with the S48 and S53 mixtures, and their yields were lower at the last three crops. The no sown grass mixtures again gave slightly lower yields than the S48 and S53 mixtures at the first two crops, though the difference was significant or almost significant at the

TABLE 51. **Mean total dry matter yields of clover (in 100 lb./acre) - Experiment 2, 1955**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	N0	N1	N2
Clover strains											
S184	10.0	8.8	4.4	9.3	21.0	20.9	45.0	17.1	20.6	19.4	11.2
S100	18.9	16.9	4.6	4.8	27.2	27.6	46.0	20.9	24.2	22.3	16.1
Kersey	17.1	9.0	5.7	8.2	23.7	21.4	44.4	18.5	19.2	23.1	13.2
Nitrogen treatments											
N0	21.7	13.1	6.6	9.4	26.4	30.8	41.3	21.3			
N1	13.7	16.7	6.3	8.1	29.2	24.7	52.4	21.6			
N2	10.5	4.8	1.9	4.8	16.3	14.3	41.8	13.5			
Grass means	15.3	11.6	4.9	7.4	24.0	23.3	45.2				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	1.98	5.51	-
C means	1.28	2.52	-
G means	1.94	3.85	5.09
G means within a N	3.37	6.67	8.82
N means within a G	3.48	7.19	9.86

Significant effects

N *

C *

G *** { No grass v. rest ***; S23+S24+S143+S37 v. S48+S53 ***; S23+S24 v. S143+S37 *** }

N x G **

Coefficient of Variation: Main-plots = 59.2% Sub-plots = 38.0%

second crop only and almost the same yields over the rest of the season.

One interesting point about the individual crop yields under treatment N2 was that mean yield at the third crop was not significantly affected by the strain of grass included in the seeds mixture. All the variation occurred in the earlier and later parts of the season.

Clover dry matter yields

Mean total dry matter yields of clover are shown in Table 51. Coefficients of variation calculated for clover yield data from this experiment were considerably smaller than those calculated for similar data from Experiment 1. This is probably due in part at least to the fact that the small area of the individual sub-plots in Experiment 2 allowed determination of clover content to be made on a proportionately larger sample of the total herbage yield from each sub-plot than in Experiment 1.

Mean clover dry matter yields from treatment N0 were almost equal to those from treatment N1 in 1955. Treatment N2, however, markedly depressed clover yield. Differences between the mean for this treatment and those for treatment N0 and N1 were significant.

Clover yields from mixtures containing S100 were on average greater, and those from mixtures containing S184 smaller, than those from mixtures containing Kersey. The only significant difference, however, was that between the means for the S100 and S184 mixtures.

Yield of clover dry matter varied significantly with the particular strain of grass included in the seeds mixture. Those containing no sown grass gave significantly greater mean clover yields than all the other mixtures. Of the grass + clover mixtures, those containing S48 or S53 yielded most clover, and those containing S143 or S37 least, the S23 and S24 mixtures being intermediate. Differences in mean clover yield between these three groups of mixtures were significant, but differences within the groups were not. The highest yields of clover from grass + clover mixtures (i.e. from S48 and S53 mixtures) were just over half of those from the no sown grass mixtures.

The only significant interaction of treatment factors in the clover yield data was that between nitrogen treatments and grass strains. In general, the response of clover yield to the particular strain of grass contained in the mixture

TABLE 52. Weighted mean percent clover in mixed herbage dry matter - Experiment 2, 1955

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	N0	N1	N2
Clover strains											
S184	11.6	9.1	6.3	10.5	23.6	23.5	49.6	19.2	28.8	18.8	9.9
S100	21.0	16.9	5.6	5.7	29.9	30.0	52.1	23.0	33.1	22.3	13.7
Kersey	19.2	9.0	7.3	10.7	27.2	23.3	48.6	20.8	27.6	22.7	11.9
Nitrogen treatments											
N0	30.6	16.7	10.6	14.5	38.4	40.0	58.2	29.8			
N1	12.6	14.7	6.8	7.9	28.5	24.6	53.7	21.3			
N2	8.5	3.7	1.8	4.5	13.9	12.2	38.3	11.8			
Grass means	17.2	11.7	6.4	9.0	26.9	25.6	50.1				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	2.25	6.25	10.36
C means	1.18	2.33	3.08
G means	1.80	3.56	4.70
G means within a C (& vice versa)	3.11	6.16	-
G means within a N	3.11	6.16	8.14
N means within a G	3.30	6.95	9.66

Significant effects

N **

C **

G *** { No grass v. rest ***; S23+S24+S143+S37 v. S48+S53 ***; S23+S24 v. S143+S37 ***; S23 v. S24 ** }

C x G *

N x G ***

Coefficient of Variation: Main-plots = 60.2% Sub-plots = 31.5%

was similar within each nitrogen treatment. The only exception to this was the relative response of clover yield to S23 and S24. Within treatments N0 and N2, the S23 mixtures gave greater yields of clover dry matter than the S24 mixtures. The difference was significant within treatment N0 and almost significant in N2. On the other hand the S24 mixtures yielded slightly but not significantly more clover dry matter than the S23 mixtures within treatment N1. The relative effects of the three nitrogen treatments on clover yield varied considerably with the strain of grass included in the seeds mixture. With the no sown grass mixtures treatment N1 gave a highly significant increase in clover yield over treatment N0 while treatment N2 gave almost the same clover yield as treatment N0. Treatment N1 also caused slight, but in this case not significant, increases in clover yield over treatment N0 with mixtures containing S24 or S48. Clover yields from these mixtures, were, however, depressed to a highly significant degree by treatment N2 in comparison with treatments N0 and N1. In the S23 and S53 mixtures clover yields declined steadily with increasing rate of fertilizer nitrogen application, all differences being significant except that between treatments N1 and N2 with the S23 mixtures. The already low clover yields from the S143 and S37 mixtures under treatment N0 were slightly depressed by N1, and further reduced by N2, but none of the differences were significant.

Weighted mean clover percentages in mixed herbage dry matter are given in Table 52. The percentage of clover in the herbage decreased with increasing rate of fertilizer nitrogen application, and all differences between the means were significant or highly significant. Since the mean absolute clover yields from treatment N0 and N1 were the same, treatment N1 must, therefore, have stimulated the growth of the 'grass' fraction of the herbage and had no direct effect on the clover fraction.

The relative clover contents of herbage from mixtures containing each of the three white clover strains were on average in the same order as their absolute clover yields. Thus the S100 mixtures gave herbage with the highest clover percentage and the S184 mixtures gave herbage with the lowest. The differnnce in mean clover percentage of herbage between the S184 and S100 mixtures was highly significant, that between the S100 and Kersey mixtures significant, and that between the S184 and Kersey mixtures not significant.

Herbage from the no sown grass mixtures had a highly significantly greater clover content than herbage from all the other mixtures. The S48 and S53 mixtures yielded herbage of the next highest clover content, followed by the S23 and S24 mixtures, with the S143 and S37 mixtures lowest. Differences in mean clover percentage of herbage between these three groups were highly significant, but differences within the first and last groups were not significant. However, the percentage of clover in the herbage from the S23 mixtures was highly significantly greater than that from S24 mixtures.

The 'clover strain' X 'grass strain' interaction had a significant effect on herbage clover content, the relative effects of grass strains being similar whichever clover strain was included in the seeds mixture, but those of clover strains varying with grass strains. Inclusion of S100 gave herbage with the highest percentage of clover from the S23, S24, S48 and S53 mixtures. S184 gave herbage of lower clover percentage from the S23 and S48 mixtures than did Kersey, but of almost the same clover percentage from the S24 and S53 mixtures. The clover content of herbage from the no sown grass mixtures did not vary significantly with the strain of clover in the mixture, though those containing S100 gave herbage of a slightly higher clover content than the others. The S143 and S37 mixtures yielded their lowest clover content herbage where they contained S100. S184 and Kersey gave about the same percentage of clover in the herbage from the S37 mixtures, but Kersey was slightly better than S184 in this respect in the S143 mixtures.

The interaction between nitrogen treatments and grass strains had a highly significant effect on the mean percentage of clover in the herbage. The variation in the relative effects of grass strains on herbage clover content within nitrogen treatments was slight. Within treatment N1 the clover percentage in the herbage from the S24 mixtures was slightly, but not significantly, higher than that in the herbage from the S23 mixtures, while within treatments N0 and N2 the reverse was observed and the differences were significant. Whichever grass strain was included in the mixture the percentage of clover in the herbage increased with increasing nitrogen level, but the degree of difference varied somewhat with strain. Clover percentages of herbage from the S24 and no sown grass

TABLE 53. <u>Mean dry matter yields of clover (in 100 lb./acre) at each crop in the season - Experiment 2, 1955</u>

		N0 Crop No.			N1 Crop No.				N2 Crop No.				
		1	2	3	1	2	3	4	1	2	3	4	5
Clover													
S184		5.0	6.7	8.8	3.9	4.6	5.4	5.4	1.9	3.0	2.4	1.7	2.1
S100		5.9	8.0	10.3	4.2	5.7	5.8	6.6	3.2	4.2	3.6	2.4	2.8
Kersey		4.3	6.3	8.5	3.6	4.9	6.8	7.8	2.0	3.4	2.7	2.6	2.6
$s_{\bar{d}}$		0.78	0.67	1.04	0.49	0.59	1.02	1.00	0.44	0.59	0.75	0.51	0.61
L.S.D. (5%	±	-	1.35	-	-	-	-	-	0.89	-	-	-	-
1%	±	-	-	-	-	-	-	-	1.19	-	-	-	-
F. Sig. at		NS	5%	NS	NS	NS	NS	NS	1%	NS	NS	NS	NS
Grasses													
S23		3.7	7.6	10.4	1.7	3.3	4.0	4.7	2.0	3.2	2.4	1.5	1.4
S24		1.8	4.7	6.5	1.7	4.2	4.4	6.3	0.5	1.2	1.4	1.0	0.7
S143		1.7	2.1	2.7	2.1	2.2	1.0	0.8	0.6	0.8	0.3	0.1	0.1
S37		2.4	4.0	2.9	2.6	2.2	2.0	1.3	1.4	1.9	0.9	0.3	0.3
S48		6.1	9.7	10.6	5.2	6.3	9.1	8.6	2.9	4.3	3.9	2.6	2.6
S53		7.0	8.8	14.9	4.6	5.8	6.2	8.1	3.1	3.4	3.2	2.1	2.4
No sown grass		12.8	12.0	16.5	9.4	11.2	15.2	16.6	6.0	9.9	8.1	7.8	10.0
$s_{\bar{d}}$	±	1.19	1.02	1.58	0.76	0.90	1.56	1.53	0.67	0.91	1.15	0.78	0.93
L.S.D. (5%	±	2.40	2.06	3.20	1.53	1.83	3.15	3.09	1.36	1.83	2.32	1.58	1.88
1%	±	3.21	2.76	4.29	2.04	2.45	4.21	4.13	1.82	2.45	3.10	2.12	2.52
F. Sig. at		0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

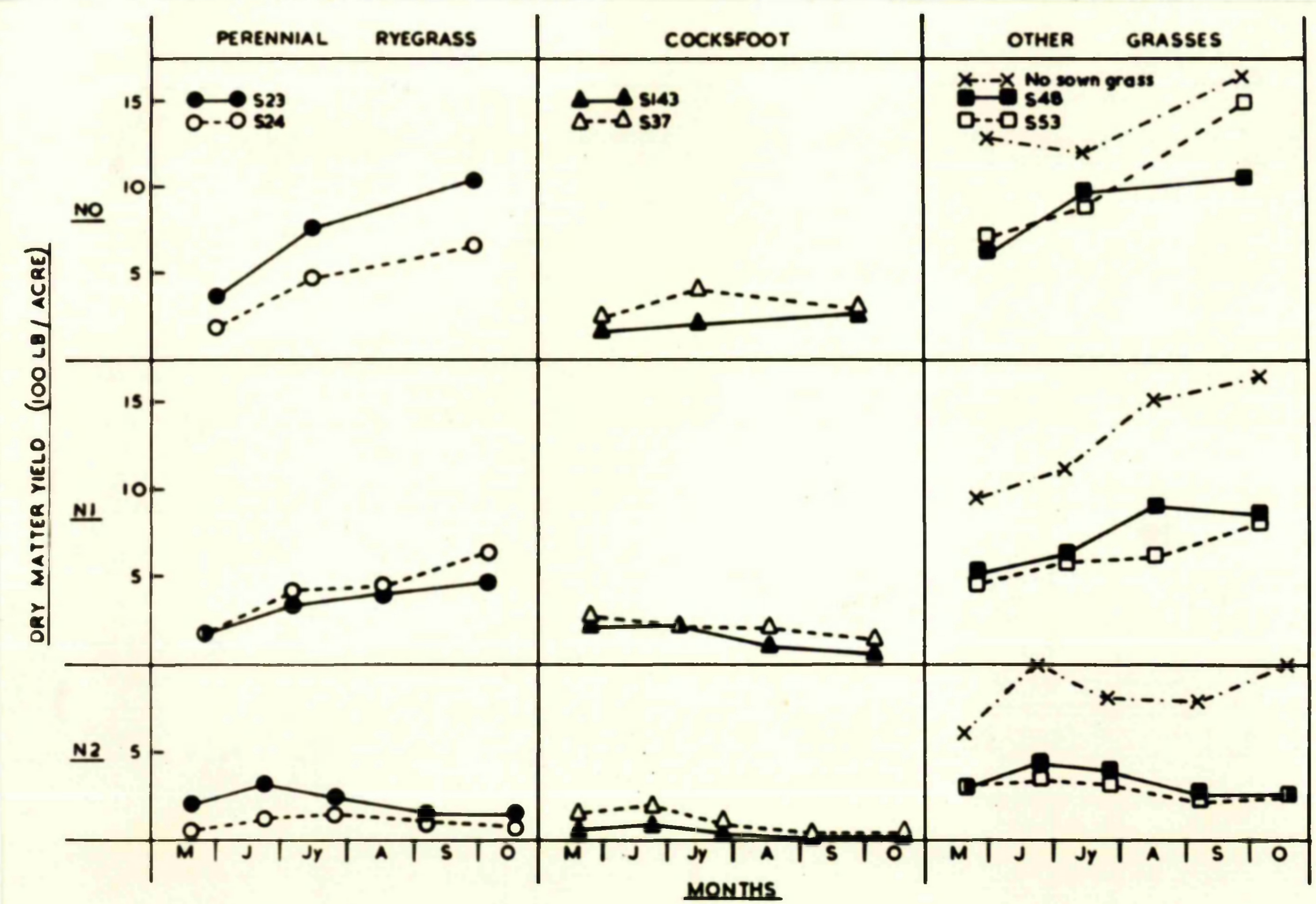
mixtures did not differ significantly between treatments N0 and N1, but did between N1 and N2, while the reverse was true with the S23 and S37 mixtures. All differences were significant in the S48 and S55 mixtures, but in the S143 mixtures only the difference between treatments N0 and N2 was significant. In general, therefore, the decrease in the percentage of clover in the herbage was greater between treatments N0 and N1 than between N1 and N2 with the S23, S37 and S53 mixtures, but smaller with all the other mixtures.

Dry matter yields of clover at the individual crops in 1955 are given in Table 53, meaned in the same way as dry matter yields of mixed herbage in Table 49. Analyses of variance were carried out on the individual crop data in the same way as is shown in Table 50. The effect of the 'grass strain' X 'clover strain' interaction was significant only at the second crop of the season under treatment N0 as mentioned below.

On average the seasonal distribution of clover yield was little affected by the strain of white clover included in the seeds mixture. Yields of all three strains increased over the season under treatments N0 and N1, though not to the same extent under the latter, and here S184 showed no increase after the third crop. Under treatment N2 yields from all three strains increased from the first to the second crop and then decreased to the fourth crop. Yield of S184 and S100 increased again slightly at the fifth crop, but that of Kersey remained steady.

At all crops under treatment N0, S100 gave the highest clover yields and Kersey the lowest, but differences between the means were only significant at the second crop. On average S100 gave a significantly greater yield than S184 and Kersey at this crop, but the difference in yield between S184 and Kersey was not significant. There was here a significant variation in the relationship between the three strains depending on the grass strain included in the mixture. In mixtures containing S48 and S55, S100 gave a significantly greater, and Kersey a significantly or almost significantly smaller mean yield than S184. The relationship was similar in the S24 mixtures though only the difference between the mean yields from S184 and Kersey was significant. In the S23 mixtures Kersey gave a slightly greater yield than S100 and both significantly outyielded S184. The differences between the mean yields of the three clover strains in

FIGURE 7. Mean yields of white clover at each cut in the season - Experiment 2, 1955



mixtures with the remaining grasses were not significant, though S100 tended to give the lowest yields in mixtures with S143 or S37 and Kersey the lowest when sown alone. None of the differences between the mean yields of the three clover strains was significant at the four crops under treatment N1. S100, however, gave slightly higher yields than the other two strains at the first and second crops but was slightly outyielded by Kersey at the remaining crops. Under treatment N3, S100 gave the greatest mean yields at all crops except the fourth, when it was very slightly outyielded by Kersey, but the mean yield of S100 was significantly greater than that of Kersey or S184 at the first crop only.

Mean dry matter yields of white clover from mixtures containing each of the grass strains at the various crops are presented graphically in Figure 7.

Under treatment NO clover yields from the S23 and S24 mixtures increased from crop to crop over the season, though those from the former were significantly greater throughout. Changes in clover yields over the season from the S143 and S37 mixtures were slight. The S37 mixtures gave slightly higher yields than the S143 mixtures at all crops, but the differences were not significant. Mixtures containing S37 did not differ significantly in clover yield from those containing S24 at the first two crops of the season. At the third crop, however, the S37 mixtures yielded significantly less clover than the S24 mixtures. The pattern of clover yield distribution from the S48 mixtures was similar to that from the S23 mixtures, though yields from the former were significantly greater at the first two crops. The S53 mixtures gave much the same clover yields as the S48 mixtures at the first two crops of the season, but a significantly greater yield at the third crop. Mixtures containing no sown grass gave a slightly smaller mean clover yield at the first than at the second crop under treatment NO, though they yielded significantly more clover than all the other mixtures at both these crops. Clover yields from the no sown grass mixtures increased at the third crop, and again yielded more clover than all the other mixtures. The difference between the mean clover yields for the no sown grass and S53 mixtures was not, however, significant at this crop.

Clover yields from the S23 and S24 mixtures increased over the season under treatment N1 also, but not to the same extent as under treatment N0. The S24 mixtures gave the same mean clover yield as the S53 mixtures at the first crop, but slightly, though not significantly, greater yields thereafter. Under this treatment the S143 and S37 mixtures gave slightly but not significantly greater clover yields at the first crop than the S23 and S24 mixtures. Over the rest of the season, however, clover yields from the S143 and S37 mixtures declined steadily to reach a very low level by the fourth crop. The difference in clover yield between the S143 and S37 mixtures was not significant at any crop, though the latter tended to give very slightly greater clover yields. Yields of clover from the S48 and S53 mixtures increased fairly steadily over the season, and were greater throughout than those from all the other grass + clover mixtures. Differences between clover yields from mixtures containing these two grasses were not significant at the first, second and fourth crops, but the mean clover yield from the S48 mixtures was almost significantly greater than that from the S53 mixtures at the third crop. Clover yields from the no sown grass mixtures increased steadily over the season to reach a very high level (actually the same yield as at the last crop under treatment N0) by the fourth crop, and were significantly greater than those from the other mixtures at all crops.

Under treatment N2, clover yields from the S23 mixtures, though small throughout the season, increased slightly from the first to the second crop and then decreased at the third crop. The S24 mixtures gave lower clover yields than the S23 mixtures at all crops, but the difference was only significant at the first crop. Clover yields from the S37 mixtures were slightly greater than those from the S24 mixtures at the first two crops and slightly smaller during the rest of the season. None of the differences was significant. Mixtures containing S143 gave lower yields of clover than those containing S37 at all crops. Yields from both were so low throughout, however, that none of the differences was significant. Patterns of clover yield distribution for the S48 and S53 mixtures were similar to that for the S23 mixtures, but the yields at all crops were greater though not significantly so. As under treatments N0 and N1 the no sown grass mixtures yielded significantly more clover than the other mixtures at all crops. Mean clover yields from the no sown grass mixtures increased greatly from the first to the second

TABLE 54. **Mean total crude protein yields of mixed herbage (in 100 lb./acre) - Experiment 2, 1955**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	N0	N1	N2
Clover strains											
S184	11.88	11.75	11.34	12.20	15.13	14.58	18.42	13.62	9.32	14.00	17.53
S100	13.02	14.15	10.53	11.65	16.18	15.82	18.18	14.22	10.00	14.05	18.60
Kersey	12.94	11.30	11.28	11.48	13.96	14.12	17.02	13.16	8.48	13.75	17.24
Nitrogen treatments											
N0	8.48	7.62	6.36	7.03	10.28	11.18	13.92	9.27			
N1	12.13	13.02	10.86	11.80	15.78	14.65	19.27	13.95			
N2	17.22	16.56	15.94	16.50	19.21	18.69	20.42	17.79			
Grass means	12.62	12.40	11.05	11.78	15.09	14.84	17.87				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.71	1.98	3.29
C means	0.31	0.61	0.80
G means	0.47	0.93	1.23
G means within a C (& vice versa)	0.81	1.61	-
G means within a N	0.81	1.61	-
N means within a G	0.90	1.92	-

Significant effects

Effect	Significance	Contrast	Contrast significance
N	***		
C	**		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	**
C x G	*		
N x G	*		

Coefficient of Variation: Main-plots = 29.4% Sub-plots = 12.6%

TABLE 55. Weighted mean percent crude protein in mixed herbage dry matter - Experiment 2, 1955

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	11.8	11.0	12.4	12.7	15.4	14.7	19.8	14.0	13.3	13.6	15.1
S100	13.0	12.5	12.0	12.3	16.3	16.0	20.0	14.6	13.8	14.1	15.8
Kersey	12.4	10.6	12.6	12.6	15.3	14.4	18.6	13.8	12.6	13.5	15.2
Nitrogen treatments											
NO	12.0	9.8	10.6	10.9	15.1	14.5	19.8	13.2			
N1	11.4	11.4	11.7	11.8	15.4	14.5	19.9	13.7			
N2	13.8	12.8	14.8	14.8	16.5	16.1	18.7	15.4			
Grass means	12.4	11.3	12.4	12.5	15.7	15.0	19.5				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.29	0.82	1.36
C means	0.19	0.37	0.49
G means	0.29	0.57	0.75
G means within a C (& vice versa)	0.50	0.98	1.30
G means within a N	0.50	0.98	1.30
N means within a G	0.36	0.75	1.03

Significant effects

Effect		Comparison	
N	**		
C	***		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	**
		S23 v. S24	***
		S48 v S53	*
C x G	**		
N x G	***		

Coefficient of Variation: Main-plots = 11.7% Sub-plots = 7.4%

crop, decreased at the fourth crop, and increased again at the last crop of the season to the same level as at the second crop.

Mixed herbage crude protein yields

Mean total yields of mixed herbage crude protein and the weighted mean percentages of crude protein in the mixed herbage are given in Tables 54 and 55.

On average crude protein yields, like dry matter yields, increased by highly significant amounts with increasing rate of fertilizer nitrogen application. The mean crude protein percentages of herbage from treatments N0 and N1 did not differ significantly from one another, with the result that the increase in mean crude protein yield between these two treatments was proportionately the same as the increase in dry matter yield. Herbage from treatment N2 had, however, a significantly higher crude protein percentage than herbage from the other two treatments. Thus the increase in mean crude protein yield between treatments N0 and N1 and treatment N2 was proportionately greater than the increase in dry matter yield.

Mixtures containing S100 white clover gave a significantly greater mean crude protein yield and herbage with a significantly higher percentage of crude protein than mixtures containing either of the other two strains. The S184 and Kersey mixtures did not differ significantly from one another in terms of absolute crude protein yield or herbage crude protein percentage.

Mean crude protein yield and weighted mean percentage of crude protein in total herbage were both significantly affected by the strain of grass included in the seeds mixtures. Mixtures containing no sown grass gave the greatest crude protein yields and yielded herbage with the highest crude protein percentage, differing significantly in both respects from all the other mixtures. The S48 and S53 mixtures gave significantly greater crude protein yields and herbage with a higher crude protein percentage than any other grass + clover mixture. Though the S53 mixtures gave slightly poorer in both respects than the S48 mixtures, the differences between them were not significant. Of the remaining mixtures those containing S143 and S37 gave significantly lower crude protein yields than those containing S23 and S24. Within these two groups differences were not significant though the S23 and S37 mixtures gave slightly greater crude protein yields than the S24 and S143 mixtures respectively. Crude protein percentages of herbage from the S23, S143 and S37 mixtures were approximately equal, while that of herbage from the S24 mixtures was significantly lower.

The 'clover strain' X 'grass strain' interaction had a significant effect on mean crude protein yield, and a highly significant effect on the weighted mean crude protein percentage of herbage. The relative effects of the grass strains on crude protein yield varied little with the strain of clover included in the seeds mixture, but the relative effects of the clover strains varied somewhat with the grass strains. In mixtures containing S23, S24, S48 and S53 crude protein yields were greatest where S100 was included. Differences were significant, however, only with the S24 and S48 mixtures. The S24 mixtures gave significantly greater yields of crude protein when they contained S100 instead of S184 or Kersey, while the S48 mixtures gave greater crude protein yields when they contained S100 instead of Kersey. Other differences were not significant. The S143 and S37 mixtures gave their greatest crude protein yields when they contained S184, but none of the differences were significant here. The no sown grass mixtures gave their greatest crude protein yields with S184, and their smallest with Kersey, though again none of the differences was significant.

The relative effects of grass strains on the percentage of crude protein in the herbage were also little affected by the strain of clover included in the seeds mixture, although again the relative effects of clover strains varied with grass strains. Herbage from the S143 and S37 mixtures had much the same crude protein percentage whichever clover strain was included. The S23, S24, S48, S53 and no sown grass mixtures yielded herbage with a higher crude protein percentage when they contained S100 than when they contained S184 or Kersey. Differences in this respect between S100 and Kersey were significant in all these mixtures except those containing S23, while differences between S100 and S184 were significant only in the S23, S24 and S53 mixtures. S184 and Kersey did not have significantly different effects on the percentage of crude protein in the herbage from any of these seeds mixtures.

The 'nitrogen treatment' X 'grass strain' interaction had a significant effect on mean mixed herbage crude protein yield, and a highly significant effect on the weighted mean crude protein percentage of the herbage. Grass strains had much the same relative effects on crude protein yield whichever nitrogen treatment was applied, but the relative effects of nitrogen treatments varied slightly with the grass strain included in the seeds mixture. In all the mixtures except those containing no sown grass crude protein yield increased significantly with each increase in nitrogen level. Although treatment N1 produced a significantly greater yield of crude protein than treatment N0 in the no sown grass mixtures, treatment N2 gave only a very slight additional increase in these mixtures.

Under each of the nitrogen treatments the no sown grass mixtures gave herbage with the highest crude protein percentage followed by the S48 and then the S53 mixtures. The relative effects of the other grass strains on herbage crude protein percentage varied with the nitrogen treatment applied. Under treatment N0 the S23 and S24 mixtures gave herbage with significantly higher and lower crude protein percentages respectively than the S143 and S37 mixtures, and there was no significant difference between herbage from mixtures containing S143 and S37. There were no significant differences between the percentages of crude protein in the herbage from mixtures containing S23, S24, S143 and S37 under treatment N1, but under treatment N2 the herbage from both the S23 and S24 mixtures had a significantly lower crude protein percentage than the herbage from the S143 and S37 mixtures. As under treatment N0, however, the herbage from the S23 mixtures had a significantly higher crude protein percentage than that from the S24 mixtures. The relative effects of nitrogen treatments on the percentage of crude protein in the herbage varied considerably with the grass strain included in the seeds mixture. There was no significant difference between the crude protein percentage of herbage under treatment N0 and that under treatment N1 in mixtures containing S23, S48 and S53, though treatment N2 gave herbage with a significantly higher percentage of crude protein than treatment N1 in all. Herbage from the S24, S143 and S37 mixtures, however, showed significant increases in the percentage of crude protein with each increase in nitrogen level. With the no sown grass mixtures there was again no significant difference in crude protein percentage between herbage under treatments N0 and N1, while herbage under treatment N2 had a significantly lower percentage of crude protein.

TABLE 56. **Mean total crude protein yields of clover (in 100 lb./acre) - Experiment 2, 1955**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	N0	N1	N2
Clover strains											
S184	2.34	2.02	1.00	2.15	5.12	5.06	11.77	4.21	4.99	4.73	2.91
S100	4.46	3.99	1.07	1.13	6.90	6.80	11.87	5.18	5.81	5.54	4.18
Kersey	3.74	1.99	1.27	1.82	5.64	5.10	10.75	4.32	4.36	5.34	3.28
Nitrogen treatments											
N0	4.88	3.04	1.42	2.06	6.32	7.31	10.35	5.05			
N1	3.08	3.84	1.46	1.84	7.10	6.00	13.11	5.20			
N2	2.58	1.19	0.46	1.20	4.24	3.66	10.94	3.46			
Grass means	3.51	2.67	1.12	1.70	5.89	5.66	11.46				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.46	1.27	-
C means	0.31	0.62	0.82
G means	0.48	0.94	1.25
G means within a N	0.83	1.64	2.16
N means within a G	0.85	1.74	2.38

Significant effects

N	*		
C	**		
G	***	No grass v. rest	***
		S23+S24+S143+S36 v. S48+S53	***
		S23+S24 v. S143+S37	***
N x G	**		

Coefficient of Variation: Main-plots = 56.0% Sub-plots = 38.3%

Clover crude protein yields

Mean total crude protein yields of clover are shown in Table 56.

As with clover dry matter yield, there was no significant difference between the mean clover crude protein yield under treatment N1 and that under treatment N0, while treatment N2 gave a significantly lower mean yield.

Clover crude protein yield varied also in much the same way as clover dry matter yield with the particular strain of white clover included in the seeds mixture, mixtures containing S100 giving the greatest yields, and those containing S184 the smallest. The difference between the S184 and Kersey mixtures here was not significant, however, though the difference between these and the S100 mixtures was highly significant.

The various grass strains had similar relative effects on crude protein yields of clover as on dry matter yields of clover. Clover crude protein yields from the nosown grass mixtures were highly significantly greater than those from all the other mixtures. Among the other mixtures those containing S48 and S53 gave the greatest clover crude protein yields, and those containing S143 and S37 the smallest, with the S23 and S24 mixtures intermediate. All the differences between these three groups, but none of the differences within the groups, were significant.

The 'nitrogen treatment' X 'grass strain' interaction had a highly significant effect on mean clover crude protein yield as it had also on mean clover dry matter yield. Variations in the relative effects of grass strains within nitrogen treatments were slight. Clover crude protein yield from the S23 mixtures was significantly or almost significantly greater than that from the S24 mixtures under treatments N0 and N2, but slightly smaller under treatment N1. In addition the S24 mixtures outyielded mixtures containing S143 and S37 in clover crude protein under treatments N0 and N1, but only outyielded those containing S143 under treatment N2. Relative effects of nitrogen treatments varied considerably with the grass strain included in the seeds mixture. Mean clover crude protein yield decreased steadily with increasing rate of fertilizer nitrogen application in the S23, S37 and S53 mixtures, though many of the differences were not significant. In the S24, S143 and S48 mixtures, mean clover cnude protein

TABLE 57. **Mean total dry matter yields of mixed herbage (in 100 lb./acre) - Experiment 2, 1956**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	87.4	104.9	84.7	86.4	83.8	84.4	72.1	86.2	70.9	84.5	103.3
S100	97.0	105.8	87.8	86.8	83.9	80.5	72.6	87.8	72.7	87.0	103.6
Kersey	95.1	103.5	87.5	81.6	88.7	84.6	79.3	88.6	71.6	85.4	108.7
Nitrogen treatments											
NO	69.8	82.7	71.8	68.5	73.2	72.2	64.0	71.8			
N1	91.2	100.6	87.6	87.5	85.4	77.8	69.3	85.6			
N2	118.6	130.8	100.5	98.8	97.8	99.5	90.6	105.2			
Grass means	93.2	104.7	86.6	84.9	85.5	83.2	74.6				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	4.67	12.96	21.49
C means	1.86	–	–
G means	2.84	5.62	7.43
G means within a N	4.92	9.74	12.87
N means within a G	5.50	11.95	17.02

Significant effects

N	**		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	***
		S23 v. S24	***
N x G	**		

Coefficient of Variation: Main-plots = 29.9% Sub-plots = 11.9%

yield was slightly but not significantly greater under treatment N1 than under treatment N0. Treatment N2, however, caused considerable depression in these yields. The no sown grass mixtures gave a significantly greater mean yield of clover crude protein under treatment N1 than under N0 and a significantly smaller mean yield under treatment N2 than under N1. The mean for these mixtures under treatment N2 was still slightly greater, however, than that under treatment N0.

Yields - 1956

Mixed herbage dry matter yields

Mean total dry matter yields of mixed herbage in the 1956 season are given in Table 57.

Treatment N0 gave much the same mean yield in 1956 as in 1955, but treatment N1 and N2 gave considerably smaller mean yields, the reduction being most pronounced with treatment N1. Once again, however, the mean dry matter yield of mixed herbage increased significantly with each increase in rate of fertilizer nitrogen application, though differences were smaller than in the previous year. Treatment N1 outyielded treatment N0 by 1,380 lb./acre or 19.2%, while treatment N2 outyielded treatment N1 by 1,960 lb./acre or 22.9%.

The mean effect of clover strain on herbage dry matter yields was not significant. Mixtures containing Kersey gave the greatest mean yield, however, and those containing S184 the smallest, but the differences were slight.

The relative effects of grass strains on dry matter yield of mixed herbage varied somewhat from the effects in the previous year, and mean yields were smaller for all mixtures except those containing S24 and S143. The no sown grass mixtures showed the most marked decline in yield between the two years, and were, in fact, the poorest yielding mixtures in 1956, differing by highly significant amounts from all the others. Mixtures containing S24 again gave the greatest mean yield followed by those containing S23. The difference between these two was highly significant. The S143,

TABLE 58. **Mean dry matter yields of mixed herbage (in 100 lb./acre) at each crop in the season - Experiment 2, 1956**

		NO Crop No.			N1 Crop No.				N2 Crop No.				
		1	2	3	1	2	3	4	1	2	3	4	5
Clover													
S184		30.1	18.0	22.9	21.7	19.1	19.4	24.2	23.3	19.2	17.2	24.9	18.6
S100		29.8	19.0	23.9	22.7	18.8	20.9	24.6	24.5	20.0	17.4	22.5	19.3
Kersey		31.2	18.2	22.2	23.2	20.0	20.0	22.2	25.1	19.1	18.4	26.2	19.9
$s_{\bar{d}}$	±	1.14	1.14	1.65	1.25	1.12	1.26	1.36	0.98	0.96	1.70	2.05	0.90
F. Sig. at	±	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grasses													
S23		27.4	19.7	22.8	18.6	25.0	20.7	26.8	23.0	23.1	22.4	29.0	21.1
S24		44.3	15.9	22.5	39.4	15.9	20.4	24.9	35.7	18.2	22.4	32.6	22.1
S143		30.2	20.2	21.5	24.3	19.5	21.6	22.2	26.0	19.6	19.2	20.3	15.4
S37		27.2	18.7	22.6	22.2	20.4	19.4	25.4	23.4	20.4	17.5	21.3	16.1
S48		29.8	20.1	23.2	20.1	21.4	21.2	22.8	22.8	22.8	14.2	20.1	18.0
S53		29.3	17.5	25.5	17.8	18.8	19.9	21.3	19.6	16.8	13.2	27.0	23.0
No sown grass		24.4	16.6	23.1	15.2	14.2	17.6	22.1	19.6	15.4	14.8	21.6	19.2
$s_{\bar{d}}$	±	1.75	1.75	2.52	1.90	1.71	1.92	2.07	1.49	1.46	2.59	3.13	1.38
L.S.D. (5%	±	3.54	-	-	3.85	3.45	-	-	3.02	2.96	5.21	6.32	2.78
1%	±	4.73	-	-	5.15	4.62	-	-	4.04	3.96	7.00	8.46	3.72
F. Sig. at		0.1%	NS	NS	0.1%	0.1%	NS	NS	0.1%	0.1%	1%	0.1%	0.1%

S37, S48 and S53 mixtures were significantly lower yielding than the S23 mixtures, but did not differ significantly from one another.

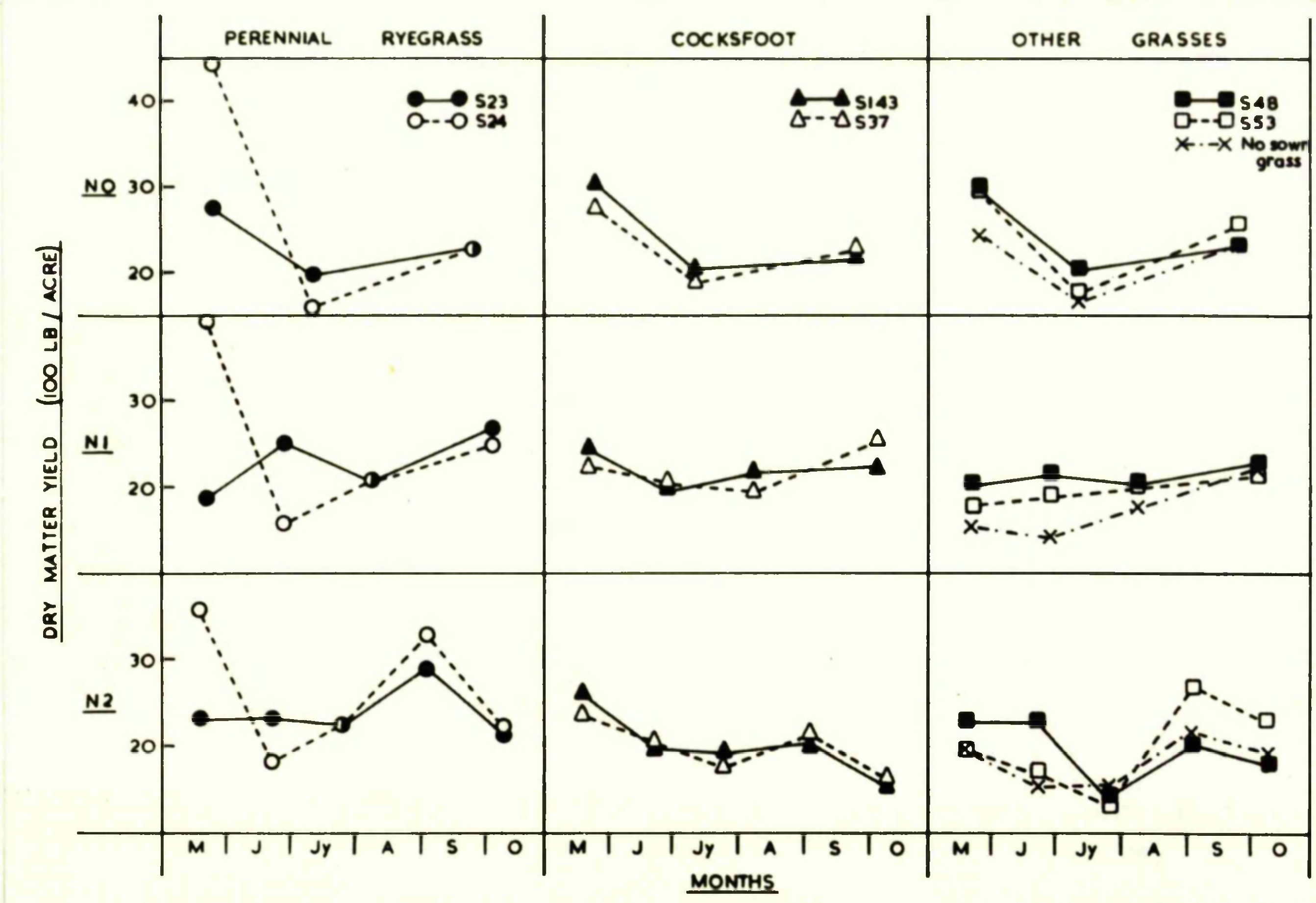
The only interaction which had a significant effect on mean dry matter yield of mixed herbage was that between nitrogen treatments and grass strains. The relative effects of grass strains on mean yield varied considerably with the nitrogen treatment applied. Under treatment NO the S24 mixtures gave a significantly greater mean yield than all other mixtures, which did not differ significantly from one another, though those containing S48 gave the greatest yield and those containing no sown grass the smallest. The S24 mixtures also gave the greatest mean yield under treatment N1, but the S23 mixtures were the second highest yielders here, followed by the S143 and S37 mixtures and then the S48 mixtures. The S53 and no sown grass mixtures gave the lowest mean yields under this treatment, their yields differing significantly from those of the S23 mixtures but not from one another. Mean yields for the various mixtures were in much the same order under treatment N2 as under treatment N1, except that the S53 mixtures slightly outyielded the S143. The relative effect of nitrogen treatments on mixed herbage yield did not vary much with the grass strain included in the seeds mixture. With most mixtures mean yield increased by almost equal amounts with each increase in nitrogen level and the differences were significant or highly significant in all cases. Mixtures containing S53 and no sown grass deviated slightly from this pattern in that the increase in yield between treatment NO and N1 was small and not significant, while that between treatments N1 and N2 was much larger and highly significant.

Coefficients of variation for the 1956 mixed herbage dry matter yield data were slightly greater than those for the 1956 data. This was probably due in part to the greater range of yields in the second year.

Mean dry matter yields of mixed herbage at the individual crops in 1956 are given in Table 58. As in 1955 the effect of the 'grass strain' X 'clover strain' interaction was not significant at any crop.

The strain of white clover included in the seeds mixture had little effect on the seasonal distribution

FIGURE 8. Mean yields of mixed herbage at each cut in the season - Experiment 2, 1956



of herbage yields under each of the nitrogen treatments in 1956 as in 1955. Under treatments N0 and N1 yields were high at the first crop, decreased in mid-season and then increased again at the last crop. As a result of this increase yields were actually higher on average at the last crop than at the first crop under treatment N1, but not under treatment N0. The pattern of yield distribution was similar under treatment N2, though the autumn increase here came at the fourth crop, and there was a marked decrease in yield at the last crop of the season. At all crops under all nitrogen treatments differences between the mean yields for mixtures containing each of the three clover strains were slight and never significant.

Figure 8 shows that the relative effects of the various grass strains on the seasonal distribution of herbage yield in 1956 were similar to those in 1955. Again only the inclusion of S24 in the seeds mixture caused any gross deviation from mean distribution, these mixtures giving a much larger proportion of their total yield in the early part of the season than any of the other mixtures, and a comparatively low yield in mid-season.

Under treatment N0 the pattern of yield distribution for all seeds mixtures was less uniform than in 1955. All gave their greatest yield at the first crop, declined at the second crop and then increased slightly at the last crop. As before, however, the S24 mixtures significantly outyielded all the other mixtures at the first crop. Few of the differences between mean yields for the other mixtures were significant at this crop, though the no sown grass mixtures gave the lowest mean yield. At the second and third crops under treatment N0 mean yields for the various mixtures did not differ significantly, though the S24 mixtures gave the lowest mean yield at the second crop.

The pattern of yield distribution under treatment N1 in 1956 varied considerably from that in 1955 with all mixtures apart from those containing S24. The S23 mixtures gave their lowest mean yield of the 1956 season at the first crop. Mean yield then increased at the second crop, decreased at the third, and increased again to its highest level in the season at the fourth crop. At the first crop of the season the S23 mixtures yielded 50% less herbage than the S24 mixtures, while at the second crop the position was reversed, and at the remaining crops these mixtures gave almost the same mean yields. The S143 and S37 mixtures gave comparatively uniform yields over the season, significantly outyielding the S23 mixtures at the first crop but giving significantly lower yields at the second, and very similar yields thereafter. Differences between the mean yields from mixtures containing S143 and those containing S37 were not significant at any crop, though the S37 mixtures gave a slightly greater yield at the fourth crop as in 1955. Mean yields from the S48 and S53 mixtures increased steadily but slightly over the season, and were lower than those from the S143 and S37 mixtures at the first crop, but did not differ significantly thereafter. Throughout the season the S53 mixtures gave smaller yields than the S48 mixtures, but the difference was not significant at any crop. Following a slight decrease between the first and second crops, mean yield from the no sown grass mixtures increased over the rest of the season. These mixtures gave lower mean yields than all the others at all crops but the last.

Under treatment N2 only the S23 and S24 mixtures showed patterns of yield distribution in 1956 which varied much from those in 1955. The S23 mixtures gave much the same mean yield at the first as at the second, third and fifth crops, but a considerably higher yield at the fourth crop. A similar sharp increase at the fourth crop was shown by the S24 mixtures. As under treatments N0 and N1 the S23 mixtures gave a significantly lower mean yield at the first crop than the S24 mixtures, a significantly higher mean yield at the second crop, and almost equal yields thereafter. The S143 and S37 mixtures started the season with slightly higher mean yields than the S23 mixtures, but their yields decreased steadily over the rest of the season as in 1955. Throughout, differences in mean yield between the S143 and S37 mixtures were not significant. Patterns of yield distribution for the S48, S53 and no sown grass mixtures were fairly similar to one another, mean yield decreasing from the first to the third crop, increasing at the fourth crop and decreasing slightly again at the fifth crop. The S48 mixtures gave almost the same yields as the S23 mixtures at the first two crops, but lower yields thereafter. The S53 and no sown grass mixtures were significantly outyielded by the S48 mixtures at the first two crops, but did not differ significantly from one another. At the third crop the S48, S53 and no sown grass mixtures gave

TABLE 59. **Mean total dry matter yields of clover (in 100 lb./acre) - Experiment 2, 1956**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	11.9	9.3	2.6	3.8	9.0	13.4	14.3	9.2	17.5	6.8	3.2
S100	13.9	16.8	1.6	2.6	9.4	22.6	19.1	12.3	19.0	12.5	5.4
Kersey	17.0	15.0	4.0	6.0	15.2	24.4	20.3	14.7	25.1	13.2	5.8
Nitrogen treatments											
NO	28.0	24.4	6.3	8.5	20.7	29.1	26.8	20.6			
N1	10.7	14.3	1.7	3.3	10.2	20.2	15.4	10.8			
N2	4.2	2.4	0.1	0.6	2.6	11.0	12.4	4.8			
Grass means	14.3	13.7	2.7	4.1	11.2	20.1	18.2				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	2.31	6.41	10.64
C means	0.94	1.87	2.47
G means	1.44	2.86	3.77
G means within a N	2.50	4.94	6.54
N means within a G	2.78	6.01	8.54
N means within a C	1.82	3.94	-
C means within a N	1.64	3.24	-

Significant effects

N	**		
C	***		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	***
		S48 v. S53	***
C x N	*		
N x G	***		

Coefficient of Variation: Main-plots = 107.6% Sub-plots = 44.0%

almost the same mean yield, which was lower than that of any other mixture. The increase in yield at the fourth crop was greatest with the S53 mixtures, and they significantly outyielded the S48 and no sown grass mixtures at this and the following crop. Differences in mean yield between the S48 and no sown grass mixtures were not significant at these crops.

Clover dry matter yields

Mean total dry matter yields of clover in 1956 are shown in Table 59. The main-plot coefficient of variation for these data was very much larger than that for the 1955 data, but the sub-plot coefficient was only slightly larger. The increase in the main-plot coefficient was no doubt due partly to the greater range in clover yields between the three nitrogen levels in 1956.

Mean yield of clover from N1 was highly significantly smaller than that from treatment N0 in 1956, though equal to it in 1955. Treatment N2 produced a further significant depression of mean clover yield over treatment N1. Only treatment N0 gave a comparable mean yield of clover in both years, mean yields under treatments N1 and N2 being smaller in 1956 than in 1955.

Mean clover yields for mixtures containing each of the three clover strains were all lower in the second than in the first harvest year, and the relationships between them were different. In both years the S184 mixtures gave the smallest mean yield of clover dry matter, while the S100 mixtures gave the greatest yield in 1955, and the Kersey mixtures in 1956. All differences between means were significant in the second year. In 1956 only, the relative effects of clover strains on clover dry matter yield varied with nitrogen treatment (i.e. 'clover strain' X 'nitrogen treatment' interaction was significant). Under treatment N0 the Kersey mixtures gave the greatest mean yield of clover and the S184 the smallest, all differences being significant or almost significant. Under treatment N1 the Kersey mixtures gave only a slightly greater clover yield than the S100 mixtures, while the S184 mixtures yielded significantly less than both. None of the differences between the means was significant under treatment N2, but the relationships between the three clover strains were similar to those under treatment N1. Whichever strain was included in the seeds mixture, clover yield decreased with increasing

TABLE 60. Weighted mean percent clover in mixed herbage dry matter - Experiment 2, 1956

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	16.7	10.9	4.1	4.7	11.9	16.7	20.9	12.2	24.9	8.4	3.4
S100	16.5	17.2	2.0	3.2	12.2	30.0	28.2	15.6	26.6	15.0	5.2
Kersey	21.7	16.4	5.3	8.8	18.4	30.9	27.9	18.5	34.2	15.6	5.6
Nitrogen treatments											
NO	39.9	28.6	9.3	12.4	28.2	40.3	41.3	28.6			
N1	11.6	14.0	1.9	3.6	11.5	26.2	22.3	13.0			
N2	3.4	1.9	0.1	0.6	2.7	11.1	13.4	4.8			
Grass means	18.3	14.8	3.8	5.6	14.2	25.9	25.7				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	2.11	5.85	9.70
C means	1.04	2.06	2.73
G means	1.59	3.15	4.17
G means within a C (& vice versa)	2.76	5.46	7.22
G means within a N	2.76	5.46	7.22
N means within a G	2.96	6.25	8.73
N means within a C	1.94	4.09	5.71
C means within a N	1.81	3.58	4.73

Significant effects

Effect		Contrast	
N	***		
C	***		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	***
		S23 v. S24	*
		S48 v. S53	***
C x G	**		
C x N	**		
N x G	***		

Coefficient of Variation: Main-plots = 76.5% Sub-plots = 37.9%

nitrogen level. The difference between the means for treatments N0 and N1 was greater than that between the means for treatments N1 and N2 in the Kersey and S184 mixtures, but the two differences were almost equal in the S100 mixtures.

Though the no sown grass mixtures gave considerably smaller clover yields in 1956 than in 1955, they still outyielded all the grass + clover mixtures, except those containing S53, in this respect by highly significant amounts. The S53 mixtures gave a slightly, but not significantly greater mean clover yield than the no sown grass mixtures. Among the other grass-clover mixtures the S23, S24 and S48 mixtures gave the greatest mean clover yields in that order, the only significant difference here being between the S23 and S48 mixtures. The S143 and S37 mixtures gave significantly smaller mean clover yields than all the other mixtures. The S37 mixtures slightly outyielded the S143 mixtures in this respect, but the difference was not significant.

As in 1955 the 'nitrogen treatment' X 'grass strain' interaction had a highly significant effect on mean clover yield. The relative effects of the grass strains varied with the particular nitrogen treatment applied. Under treatment N0 the mean yield of clover from the S23 mixtures exceeded that from the no sown grass mixtures, and was only slightly smaller than that from the S53 mixtures. However none of these differences was significant. Under treatments N1 and N2 mean clover yield from the S23 mixtures was significantly smaller than those from the S53 and no sown grass mixtures. As in 1955 the S23 mixtures gave a greater mean yield of clover than the S24 mixtures under treatments N0 and N2, but a smaller mean yield under treatment N1. The relative effects of nitrogen treatments on clover yield varied little with the particular grass strain included in the seeds mixture, mean clover yield decreasing with increasing nitrogen level in all seeds mixtures. The decrease between treatments N1 and N2 was proportionately smaller than that between treatments N0 and N1 in most mixtures, but in those containing S24 and S53 the two differences were almost equal.

Weighted mean percentages of clover in the mixed herbage dry matter are given in Table 60. The mean percentage of clover in the herbage decrease with increasing rate of fertilizer nitrogen application in much the same way as absolute clover yield, and all differences between the means were highly significant.

All differences between mean clover percentages of herbage from mixtures containing each of the three clover strains were highly significant. Mixtures containing Kersey gave herbage with the highest mean clover percentage, and those containing S184 gave herbage with the lowest clover percentage. Here again, however, the 'clover strain' X 'nitrogen treatment' interaction was significant, this time at the 1% level. The relative effects of clover strain varied little with nitrogen treatment, herbage from the Kersey mixtures having the highest and that from S184 mixtures the lowest percentages of clover throughout. The relative effects of nitrogen treatments varied, however, with the clover strain included in the seeds mixture. With all three strains the clover content of herbage decreased with each increase in nitrogen level. As with clover yields, however, the difference between the means for treatments N0 and N1 was greater than that between the means for treatments N1 and N2 in the Kersey and S184 mixtures, but the two differences were almost equal in the S100 mixtures.

The relative effects of grass strains on the percentage of clover in the herbage were similar to those on absolute clover yields. Thus herbage from the S53 and no sown grass mixtures had highly significantly greater mean clover percentages than herbage from all the other mixtures. Herbage from S23 mixtures had the next highest clover percentage, followed by herbage from the S24 and S48 mixtures, which had significantly lower clover percentages. Mixtures containing S143 and S37 yielded herbage with highly significantly lower clover percentages than all the other mixtures. Though the mean for the S37 mixtures was slightly higher than that for the S143 mixtures, the differencewas not signifcant.

The 'clover strain' X 'grass strain' interaction had a highly significant effect on the mean percentage of clover in the herbage. The relative effects of the grass strains varied with the particular clover strain included in the seeds mixture. Where S184 was included the S53 mixtures yielded herbage with a lower clover percentage than the no sown grass mixtures, but with the same clover percentage as the herbage from the S23 mixtures. Where S100 or Kersey were included, however, the percentage of clover in the herbage from the S53 mixtures was slightly

TABLE 61. **Mean dry matter yields of clover (in 100 lb./acre) at each crop in the season - Experiment 2, 1956**

	N0 Crop No. 1	N0 2	N0 3	N1 Crop No. 1	N1 2	N1 3	N1 4	N2 Crop No. 1	N2 2	N2 3	N2 4	N2 5
Clover												
S184	8.8	4.7	4.0	2.1	1.6	1.6	1.5	1.3	0.9	0.3	0.3	0.3
S100	9.5	4.6	4.9	5.2	2.9	1.4	2.8	1.8	1.6	0.4	0.6	0.8
Kersey	11.7	6.4	7.0	4.0	3.0	2.3	3.8	2.0	1.4	0.9	0.8	0.6
$s_{\bar{d}}$ ±	0.98	0.80	0.77	0.66	0.41	0.45	0.58	0.53	0.45	0.29	0.26	0.30
L.S.D. (5% ±	1.98	-	1.55	1.33	0.83	-	1.18	-	-	-	-	-
L.S.D. (1% ±	-	-	2.08	1.78	1.11	-	1.57	-	-	-	-	-
F. Sig. at	5%	NS	1%	0.1%	1%	NS	1%	NS	NS	NS	NS	NS
Grasses												
S23	12.8	7.0	8.1	3.0	2.6	2.1	3.0	1.5	1.4	0.5	0.4	0.3
S24	10.0	5.5	8.8	5.8	2.8	2.0	3.6	1.1	0.6	0.3	0.2	0.1
S143	3.4	1.3	1.7	1.0	0.4	0.1	0.1	0.1	-	-	-	-
S37	5.4	2.0	1.0	1.6	0.6	0.9	0.1	0.3	0.2	0.1	-	-
S48	10.6	6.0	4.1	3.5	2.6	1.4	2.7	1.2	0.8	0.2	0.1	0.3
S53	14.7	7.6	6.8	6.7	5.3	2.9	5.3	2.8	2.8	1.0	2.1	2.2
No sown grass	13.1	6.9	6.8	4.9	3.1	3.2	4.1	4.8	3.4	1.8	1.2	1.3
$s_{\bar{d}}$ ±	1.50	1.22	1.17	1.00	0.63	0.69	0.89	0.82	0.69	0.45	0.39	0.45
L.S.D. (5% ±	3.02	2.47	2.37	2.03	1.27	1.40	1.80	1.65	1.40	0.91	0.80	0.91
L.S.D. (1% ±	4.04	3.30	3.17	2.71	1.70	1.88	2.40	2.21	1.87	1.22	1.07	1.22
F. Sig. at	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	1%	0.1%	0.1%

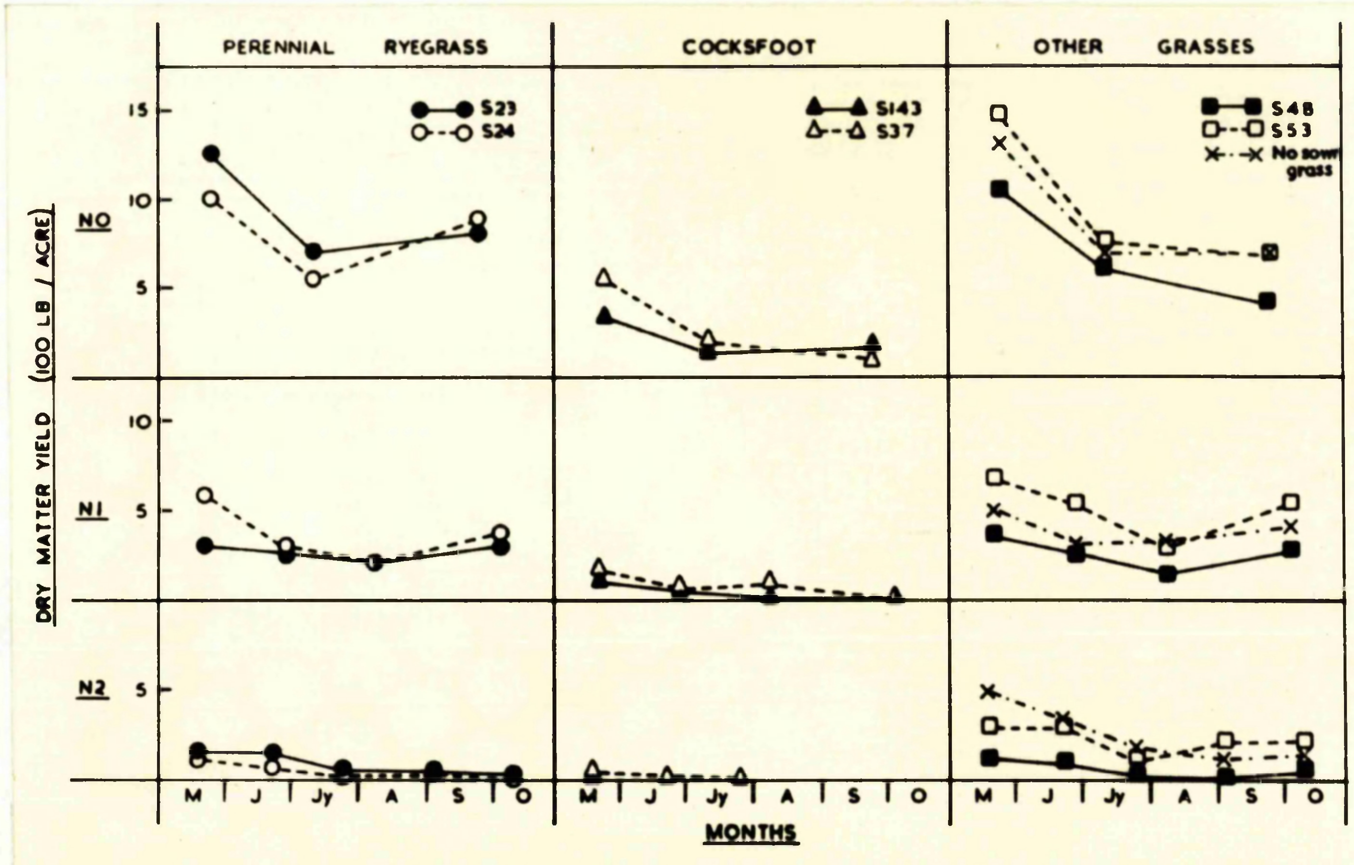
higher than that in the herbage from the no sown grass mixtures and significantly higher than that in the herbage from the S23 mixtures. In addition where S184 or Kersey was included the S23 mixtures gave herbage with a higher clover percentage than the S24 mixtures, but with S100 the reverse occured. The relative effects of the clover strain on herbage clover content varied also with the grass strain included in the seeds mixture. The percentages of clover in the herbage from the S48 and S53 mixtures were highest with Kersey and lowest with S184, while those of herbage from the S24 and no sown grass mixtures were highest with S100 and lowest with S184. Not all the differences here were significant. With herbage from the S143 and S37 mixtures the clover percentages were highest with Kersey and lowest with S100. The mean percentages of clover in the herbage from the S23 mixtures were almost the same whether they contained S184 or S100, but were higher when they contained Kersey.

The 'nitrogen treatment' X 'grass strain' interaction also had a highly significant effect on herbage clover content, and there were two main variations in the relationships between grass strains within the individual nitrogen levels. Firstly, the percentage of clover in the herbage from the S23 mixtures was almost equal to that in the herbage from the S53 mixtures under treatment NO, but significantly greater under treatments N1 and N2. Secondly, the S23 mixtures gave herbage with a higher clover percentage than the S24 mixtures under treatments NO and N2 but lower under treatment N1. The variation in the relative effects of nitrogen treatment with strain of grass included in the seeds mixtures was slight, the percentage of clover in the herbage from all seeds mixtures decreasing with increasing nitrogen level. In the S24 and S53 mixtures the decrease between treatments NO and N1 was almost equal to that between treatments N1 and N2, whereas in all the other mixtures the former decrease was proportionately greater than the latter.

Clover dry matter yields at the individual crops under each nitrogen treatment in 1956 are given in Table 61.

The general pattern of clover yield distribution over the season within each nitrogen treatment was not greatly affected by the strain of clover included in the seeds mixture. Under all nitrogen treatments mixtures containing each of the clover strains gave their highest

FIGURE 9. Mean yields of white clover at each cut in the season - Experiment 2. 1956



mean clover yields at the first crop of the season, and yield decreased thereafter. Slight increases occurred at the last crop of the season under treatments N0 and N1 with both the S100 and Kersey mixtures, and under treatment N2 with the S100 mixtures only. Under treatment N0 the Kersey mixtures gave a greater mean clover yield than the S184 and S100 mixtures at all crops though the difference was significant only at the first and third crops. The S100 mixtures yielded slightly but not significantly more clover than the S184 mixtures at the first and third crops under this treatment, and gave almost the same yield at the second crop. Mean clover yields from the S184 mixtures were significantly lower than those from the S100 and Kersey mixtures at all crops except the third under treatment N1. At the third crop the S184 mixtures gave almost the same mean clover yield as the S100 mixtures. The difference between the S100 and Kersey mixtures was not significant at any crop under this treatment, though the mean for the former was greater at the first crop and smaller at all other crops. The effect of the 'clover strain' X 'grass strain' interaction was significant at the first crop under treatment N1. Here S100 gave greater yields than Kersey in the S53 and no sown grass mixtures, slightly greater yields in the S24 mixtures, but smaller yields in the S143 and S37 mixtures. Not all of these differences were significant. In the S23 and S48 mixtures the clover yield was the same whether S100 or Kersey was included. All seeds mixtures, except those containing S37 gave lower clover yields with S184 than with S100 or Kersey. In the S37 mixtures S184 gave a slightly, but not significantly, greater mean yield of clover than S100. Under treatment N2 none of the differences between mean clover yields for mixtures containing each of the three clover strains was significant. The S184 mixtures gave the lowest mean clover yields throughout, however, while those containing Kersey gave the greatest at the first, third and fourth crops, and those containing S100 gave the greatest at the second and fifth crops.

Figure 9 shows that mean clover yields over the season for mixtures containing each of the grasses under all nitrogen treatments generally decreased from spring to autumn in 1956, though those from certain mixtures increased slightly at the last crop of the season. This is in contrast to the 1955 season when under treatments N0 and N1 clover yields generally increased from crop to crop.

Under treatment N0 clover yields from the S23 and S24 mixtures were greatest at the first crop, decreased at the second crop and increased slightly at the last crop. Mean clover yield from the S23 mixtures was greater than that from the S24 mixtures at the first and second crops, though the differences were not significant. The increase at the last crop of the season was greatest with the S24 mixtures, which, therefore, gave a slightly, but not significantly greater mean yield than the S23 mixtures at this crop. The S143 and S37 mixtures yielded significantly less clover than the S23 and S24 mixtures at all crops under this treatment. The mean clover yield for the S37 mixtures was slightly greater than that for the S143 mixtures at the first crop, but differences were negligible at the other two crops. The S48, S53 and no sown grass mixtures had fairly similar clover yield distribution patterns to one another, mean yield decreasing sharply from the first to the second crop and then less steeply to the third crop. First crop clover yields from the S53 and no sown grass mixtures were greater than those from the S23 and S24 mixtures, while second crop yields were slightly greater and third crop yields slightly lower. The S48 mixtures, on the other hand, yielded less clover than the S23 and S24 mixtures, and also less than the S53 and no sown grass mixtures at all crops.

The S23 mixtures gave a significantly smaller mean clover yield than the S24 mixtures at the first crop under treatment N1, but thereafter differences between these mixtures were very slight. The general trend here was a gradual decrease from the first to the third crops followed by a slight increase at the last crop. The S143 and S37 mixtures gave very low clover yields throughout the season, decreasing to almost zero by the fourth crop. The patterns of distribution of clover yield from the S48, S53 and no sown grass mixtures were similar to that from the S24 mixtures. The no sown grass mixtures gave about the same clover yields as the S24 mixtures at all crops, while the S53 and S48 mixtures gave generally higher and lower yields respectively. Differences in clover yield between the S53 and no sown grass mixtures were significannt at the second crop only. The S48 mixtures differed significantly in clover yield from the S53 mixtures at the first, second and fourth crops of the season, and from both the S53 and no sown grass mixtures at the third crop.

TABLE 62. **Mean total crude protein yields of mixed herbage (in 100 lb./acre) - Experiment 2, 1956**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	12.45	14.02	11.30	11.79	13.21	14.22	12.94	12.85	10.26	11.76	16.52
S100	14.97	15.10	11.47	11.62	13.50	14.09	13.59	13.48	10.62	12.81	17.00
Kersey	14.48	13.46	12.39	11.48	14.18	15.03	14.43	13.64	10.73	12.29	17.89
Nitrogen treatments											
NO	11.13	11.10	8.16	8.00	11.42	12.34	11.62	10.54			
N1	12.76	13.13	10.96	10.91	13.06	13.17	12.01	12.29			
N2	18.03	18.34	16.03	15.98	16.42	17.82	17.32	17.14			
Grass means	13.97	14.19	11.72	11.63	13.63	14.46	13.65				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.69	1.93	3.19
C means	0.34	–	–
G means	0.52	1.03	1.37

Significant effects

N **

G *** (S23+S24+S143+S37 v. S48+S53 ***
S23+S24 v. S143+S37 ***

Coefficient of Variation: Main-plots = 29.2% Sub-plots = 14.4%

TABLE 63. **Weighted mean percent crude protein in mixed herbage dry matter - Experiment 2, 1956**

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	NO	N1	N2
Clover strains											
S184	14.4	13.2	13.1	13.4	15.6	16.8	18.0	14.9	14.5	14.1	16.2
S100	15.4	14.2	12.9	13.1	16.0	17.4	18.7	15.4	14.8	14.9	16.5
Kersey	15.3	12.9	13.8	13.7	16.0	17.7	18.0	15.4	15.0	14.5	16.6
Nitrogen treatments											
NO	15.9	13.3	11.4	11.7	15.6	17.1	18.2	14.7			
N1	13.9	13.0	12.5	12.4	15.3	17.0	17.4	14.5			
N2	15.2	14.0	16.0	16.2	16.8	17.9	19.0	16.4			
Grass means	15.0	13.4	13.3	13.4	15.9	17.3	18.2				

Between:	s_d ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.21	0.59	0.98
C means	0.19	0.38	0.50
G means	0.29	0.58	0.76
G means within a N	0.50	1.00	1.40
N means within a G	0.51	1.03	1.38

Significant effects

N	**		
C	*		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	***
		S23 v. S24	***
		S48 v. S53	***
N x G	***		

Coefficient of Variation: Main-plots = 7.8% Sub-plots = 7.0%

Under treatment N2 mean clover yields were extremely small from all seeds mixtures except those containing S53 and no sown grass. The S23, S24 and S48 mixtures gave measurable yields at the first two crops under this treatment, but they yielded less than 50 lb. clover dry matter per acre at each of the other crops. The S37 mixtures yielded a trace of clover at the first three crops but none thereafter, while the S143 mixtures yielded a trace at the first crop only. Mean clover yield from the no sown grass mixtures decreased gradually from the first to the fourth crops of the season. Those from the S53 mixtures reamined steady at the first two crops, decreased at the third and then increased again at the fourth crop to remain steady to the fifth crop. The no sown grass mixtures gave greater mean clover yields than the S53 mixtures at the first three crops of the season, and smaller yields at the remaining two crops. Differences were significant or almost significant at all crops except the second.

Mixed herbage crude protein yields

Mean total yields of mixed herbage crude protein and weighted mean percentages of crude protein in mixed herbage dry matter are given in Tables 62 and 63.

Mean crude protein yield increased with each increase in the rate of fertilizer nitrogen application, all differences being significant or highly significant. As in 1955, the weighted percentage of crude protein in the herbage did not differ significantly between treatments N0 and N1 but was highly significantly greater under treatment N2.

Mixtures containing Kersey white clover gave the greatest mean crude protein yield, and those containing S184 the smallest, but differences were small and not significant. However, the S184 mixturem yielded herbage with a significantly lower crude protein percentage than the S100 and Kersey mixtures, which did not differ significantly from one another in this respect.

The no sown grass mixtures yielded herbage with a significantly higher percentage of crude protein than all the other mixtures, but their actual mean yield of crude protein was not significantly different from those of the S23, S24, S48 and S53 mixtures. The S143 and S37 mixtures gave significantly lower crude protein yields than the other grass + clover mixtures. Herbage from the S53 mixtures had a significantly higher crude protein percentage than

TABLE 64. Mean total crude protein yields of clover (in 100 lb./acre) - Experiment 2, 1956

	Grass species and strains								Nitrogen treatments		
	S23	S24	S143	S37	S48	S53	No sown grass	Means	N0	N1	N2
Clover strains											
S184	2.89	2.16	0.54	0.86	2.19	3.30	3.64	2.22	4.20	1.66	0.82
S100	3.26	3.96	0.34	0.58	2.27	5.67	4.90	3.00	4.52	3.08	1.39
Kersey	3.82	3.30	0.87	1.28	3.60	5.84	4.98	3.38	5.64	3.08	1.43
Nitrogen treatments											
N0	6.51	5.52	1.36	1.83	4.92	6.96	6.40	4.79			
N1	2.46	3.34	0.38	0.73	2.47	4.99	3.87	2.60			
N2	0.99	0.56	0.02	0.16	0.66	2.86	3.25	1.22			
Grass means	3.32	3.14	0.58	0.91	2.68	4.93	4.51				

Between:	$s_{\bar{d}}$ ±	L.S.D. 5% ±	L.S.D. 1% ±
N means	0.52	1.45	2.40
C means	0.23	0.45	0.60
G means	0.35	0.69	0.91
G means within a C (& vice versa)	0.60	1.19	-
G means within a N	0.60	1.19	1.58
N means within a G	0.66	1.42	2.00

Significant effects

N	**		
C	***		
G	***	No grass v. rest	***
		S23+S24+S143+S37 v. S48+S53	***
		S23+S24 v. S143+S37	***
		S48 v. S53	***
C x G	*		
N x G	***		

Coefficient of Variation: Main-plots = 102.0% Sub-plots = 44.4%

that from any other grass + clover mixture. The S48 mixtures came next, yielding herbage with a significantly higher crude protein percentage than the S23 mixtures. Herbage from the S24, S143 and S37 mixtures had the lowest crude protein percentages, and the values were significantly different from the corresponding values for all the other mixtures, but not from one another.

None of the interactions of treatment factors had a significant effect on mean crude protein yields of mixed herbage in 1956. The 'nitrogen treatment' X 'grass strain' interaction, however, had a highly significantly effect on the mean crude protein percentage of the herbage as in 1955. There was only a slight variation in the relative effects of grass strains within each of the three nitrogen levels. Herbage from the S23 and S24 mixtures had a higher mean crude protein percentage than herbage from the S143 and S37 mixtures under treatments N0 and N1, but a lower crude protein percentage under treatment N2. The relative effects of nitrogen treatments varied considerably with the grass strain included in the seeds mixture. With the S24, S48, S53 and no sown grass mixtures the percentage of crude protein in the herbage was lower under treatment N1 than under treatment N0, and higher under treatment N2 than under the other two treatments, though many of the differences were not significant. The percentage of crude protein in the herbage from the S143 and S37 mixtures increased with increasing nitrogen level, and here all differences were significant except that between the means for the S37 mixtures under treatments N0 and N1. The S23 mixtures yielded herbage with a slightly lower crude protein percentage under treatment N2 than under treatment N0, but with a significantly lower crude protein percentage under treatment N1 than under treatments N0 and N2.

Clover crude protein yields

Mean total crude protein yields of clover are given in Table 64.

These yields decreased on average with each increase in the rate of fertilizer nitrogen application. The difference between the means for treatments N0 and N1 was highly significant, and that between the means for treatments N1 and N2 almost significant.

Mixtures containing Kersey white clover gave the greatest yield of clover crude protein and those containing

S184 the smallest. The mean for the S184 mixtures differed significantly from those for mixtures containing the other two strains, but the difference between the means for the S100 and Kersey mixtures was not quite significant.

Mixtures containing S53 gave a slightly but not significantly greater mean yield of clover crude protein than those containing no sown grass and both significantly outyielded all the other mixtures. Of the remaining mixtures those containing S23 yielded slightly, but not significantly more than those containing S48. Once again the S143 and S37 mixtures gave significantly smaller mean yields of clover crude protein than all the other mixtures.

The 'grass strain' X 'clover strain' interaction had a significant effect on mean yield of clover crude protein in 1956, though not in 1955. The relative effects of grass strains varied little with the particular strain of white clover included in the seeds mixture, but the relative effects of clover strains varied somewhat with grass strains. S100 gave smaller mean yields of crude protein than S184 in the S143 and S37 mixtures, but greater mean yields in all the other mixtures, though the difference was significant with the S24, S53 and no sown grass mixtures only. Kersey gave slightly greater crude protein yields than S100, and considerably greater crude protein yields than S184 in all seeds mixtures except those containing S24, but again many of the differences were not significant. In the S24 mixtures crude protein yield from Kersey was slightly but not significantly smaller than that from S100.

The 'nitrogen treatment' X 'grass strain' interaction had a highly significant effect on mean clover crude protein yield in 1956 as in 1955. There were few variations in the relative effects of the various grass strains within each nitrogen level. As in 1955, the S23 mixtures gave a greater mean yield of clover crude protein than the S24 mixtures under treatments N0 and N2, but a smaller mean yield under treatment N1. Although clover crude protein yields decreased with each increase in nitrogen level whichever grass strain was included in the seeds mixture, the extent of the decreases varied somewhat. In the S24 and S53 mixtures the difference between the means for treatments N0 and N1 was almost equal to that between means for treatments N1 and N2, whereas in all the other seeds mixtures the former difference was considerably larger than the latter. Many of the differences here were not significant.

TABLE 65. **Effect of nitrogen treatments on sward botanical composition - Experiment 2, 1954-1956**

Nitrogen treatment	AUTUMN 1954					AUTUMN 1955					AUTUMN 1956				
	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground
	Mean ground cover percentages														
N0	35.6	13.8	19.7	14.9	21.0	32.7	38.6	4.1	5.7	23.6	38.6	24.1	11.2	8.3	23.2
N1	33.1	12.9	21.2	14.4	23.1	40.3	28.0	6.8	5.7	24.9	41.0	10.0	20.2	7.4	27.2
N2	37.0	10.2	21.4	14.6	22.2	44.6	14.9	11.9	4.9	29.9	40.7	3.0	29.2	3.8	29.0
	Mean angular transformations														
N0	36.4	20.3	25.6	22.2	26.6	34.3	37.8	10.4	13.2	28.7	38.1	28.2	17.3	16.0	28.6
N1	34.9	19.5	26.6	21.5	28.3	39.1	30.4	14.3	12.7	29.8	39.6	16.9	25.2	15.0	31.3
N2	37.2	17.2	26.5	21.8	27.8	41.9	19.8	19.2	12.0	33.0	39.2	7.7	31.6	10.2	32.4
$s\bar{d}$ ±	1.69	1.02	1.19	1.73	2.68	1.38	2.28	1.22	0.90	1.26	1.10	1.48	0.60	1.55	0.94
L.S.D. (5% ±	-	-	-	-	-	3.84	6.38	3.39	-	-	-	4.12	1.65	4.31	2.61
L.S.D. (1% ±	-	-	-	-	-	-	10.49	5.62	-	-	-	6.84	2.74	-	-
F. Sig. at	NS	NS	NS	NS	NS	5%	1%	1%	NS	NS	NS	0.1%	0.1%	5%	5%

N.B. Three of the 21 seeds mixtures contained clover only, so the ground cover percentages for 'sown grass' given above are the means of only 54 values, whereas those for the other components of the sward are the means of 63 values. Thus the total of the mean percentages for the five components of the sward exceeds 100.

Sward Botanical Composition
1954 - 1956

Detailed sward botanical analyses were made every spring and autumn throughout the experiment. Only the results of the autumn analyses are presented here, however, since the results of the spring analyses were in general very similar to those of analyses conducted in the preceding autumn. Results throughout are given in terms of 'percentage ground cover' at ground level. In order to facilitate presentation the data have been grouped, as in Experiment 1, into five fractions: 1) sown grass, 2) white clover, 3) weed grasses, 4) dicotyledonous weeds, and 5) bare ground. The direct effects of nitrogen treatments, clover strains and grass strains on these fractions are considered first, and then the interactions of treatment factors which had significant effects on any of the fractions are considered separately.

Nitrogen treatments

The mean effect of the various nitrogen treatments on the ground cover percentages of the five fractions of the sward are shown in Table 65. These treatments were not applied in 1954, but the means for the plots to which they were later applied are given as an indication of the initial uniformity of the sward.

In the autumn of 1955, after the nitrogen treatments had been applied for one complete season, percentage ground cover of both sown grass and white clover were greater under treatments N1 and N2 than in autumn 1954 but only that of clover was greater under treatment N0. Percentage ground cover of weed species was smaller under all nitrogen treatments. At this time mean white clover cover was greatest under treatment N0 and smallest under treatment N2, and all differences between nitrogen levels were significant or highly significant. Mean sown grass cover, on the other hand, was smallest under treatment N0 and greatest under treatment N2 though the difference between treatments N1 and N2 was not significant. Mean weed grass cover varied with nitrogen treatment in the same way as sown grass cover, but all differences were significant. Mean dicotyledonous weed cover and mean percentage bare ground were not significantly affected by nitrogen treatment.

During the 1956 season clover cover decreased on average, while weed grass and dicotyledonous weed cover

TABLE 66. **Effect of clover strains on sward botanical composition - Experiment 2, 1954-1956**

Clover strain	AUTUMN 1954					AUTUMN 1955					AUTUMN 1956				
	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground
	Mean ground cover percentages														
S184	36.3	13.5	20.1	14.4	20.8	39.5	31.4	7.0	4.4	23.4	40.3	13.0	20.5	6.2	25.7
S100	33.8	13.7	21.8	13.7	21.8	38.0	28.0	7.3	5.5	26.7	41.1	11.0	19.9	6.7	27.1
Kersey	35.6	9.7	20.3	15;8	23.7	40.2	22.1	8.6	6.4	28.3	39.0	13.1	20.2	6.7	26.6
	Mean angular transformations														
S184	36.8	20.1	25.8	21.7	26.5	38.6	32.2	14.1	11.4	28.6	39.1	18.2	24.7	13.4	30.2
S100	35.3	20.2	26.9	21.2	27.4	37.6	29.6	14.1	12.8	30.9	39.4	16.4	24.6	13.9	31.2
Kersey	36.4	16.7	25.9	22.6	28.8	39.1	26.2	15.6	13.7	32.0	38.4	18;2	24.9	13.9	30.8
$s\bar{d}$	0.68	0.86	1.05	0.85	0.66	0.70	0.96	0.82	0.85	0.55	0.72	0.80	0.77	0.77	0.64
L.S.D. (5%	-	1.70	-	-	1.30	-	1.91	-	1.68	1.09	-	1.58	-	-	-
1%	-	2.25	-	-	1.72	-	2.52	-	-	1.44	-	-	-	-	-
F. Sig. at	NS	0.1%	NS	NS	1%	NS	0.1%	NS	5%	0.1%	NS	5%	NS	NS	NS

N.B. See note under Table 65.

increased. By that autumn, however, mean clover and weed grass cover varied in the same way with nitrogen treatment as in the autumn of 1955. Mean sown grass cover was slightly lower under treatment N0 than under treatments N1 or N2 in the autumn of 1956, but none of the differences was significant. At this time dicotyledonous weed cover was lowest under treatment N2, while mean percentage bare ground was lowest under treatment N0.

Clover strains

The percentage ground cover data in Table 66 show the relative effects of each of the three clover strains on the botanical composition of the sward.

Throughout the experiment the mean ground cover percentages of sown and weed grass in the sward were not significantly affected by the strain of white clover indluded in the seeds mixture. In the autumn of 1954, however, swards of the Kersey mixtures had a significantly lower mean clover cover than swards of the S184 or S100 mixtures. Clover cover increased by varying amounts in the different swards over the following year, and in the autumn of 1955 it was greatest in S184 swards and smallest in Kersey swards, all differences being significant. By the autumn of 1956 clover cover had decreased on average, and did not differ significantly between swards of the S184 and Kersey mixtures but was significantly lower in S100 swards.

In the autumn of 1954 and 1955 Kersey swards had the greatest mean percentage bare ground, and S184 swards had the smallest, all differences being significant or almost significant. However, in the autumn of 1956 mean percentage bare ground in the swards did not vary with the clover strain included.

The only other fraction of the sward significantly affected at any time by the strain of clover included in the seeds mixture was the dicotyledonous weed cover, which in the autumn of 1955 was smallest in S184 swards and greatest in Kersey swards, but only the difference between S184 and Kersey swards was significant.

Grass strains

Mean ground cover percentages for the various fractions of swards sown with mixtures containing each grass strain are given in Table 67. The effects of grass strains included in the seeds mixture on each of the five fractions of the sward were highly significant in all three years.

TABLE 67. **Effect of grass strains on sward botanical composition - Experiment 2, 1954-1956**

Grass strain	AUTUMN 1954					AUTUMN 1955					AUTUMN 1956				
	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground	Sown grass	White clover	Weed grass	Dicot weeds	Bare ground
						Mean ground cover percentages									
S23	45.2	6.9	12.0	11.2	24.7	44.7	24.0	5.5	3.8	22.0	49.8	14.2	8.0	4.6	23.4
S24	42.9	5.7	12.0	8.1	31.3	39.0	21.6	7.0	6.0	25.5	38.0	15.0	14.6	6.5	25.8
S143	39.2	6.3	15.8	11.7	26.1	53.1	7.4	3.7	5.2	30.6	55.2	3.0	6.1	3.4	32.2
S37	33.1	6.4	21.9	15.8	22.8	49.0	11.0	3.8	5.2	30.9	46.9	3.6	10.5	6.5	32.5
S48	25.2	15.3	24.8	16.2	18.4	25.4	38.4	7.8	4.6	23.8	34.2	12.8	20.0	6.3	26.6
S53	25.8	13.9	25.5	16.0	16.8	24.0	34.9	9.2	5.5	26.2	16.4	19.7	31.7	7.3	24.9
No sown grass	-	31.6	32.2	23.3	12.8	-	52.9	16.2	7.8	23.0	-	18.5	50.7	11.0	19.8
						Mean angular transformations									
S23	42.2	6.4	19.7	19.4	29.6	41.9	28.0	12.7	10.2	27.8	45.1	20.1	15.6	11.5	28.7
S24	40.9	4.9	19.7	16.2	33.8	38.5	25.8	14.5	13.0	30.8	38.0	20.0	21.8	13.3	30.4
S143	38.6	5.7	23.7	19.7	30.4	46.8	14.0	10.4	12.6	33.5	48.1	7.0	13.4	9.8	34.5
S37	35.0	5.9	27.3	22.9	28.1	44.4	17.6	10.2	12.5	33.7	43.4	8.3	17.2	14.0	34.6
S48	30.0	14.7	29.3	23.2	25.2	29.9	37.8	15.9	11.5	29.0	35.7	18.6	26.1	14.0	30.9
S53	30.2	13.2	29.6	23.1	25.4	29.1	35.4	16.4	13.0	30.6	23.7	25.0	33.5	14.8	29.8
No sown grass	-	31.1	34.2	28.3	20.3	-	46.7	22.2	15.6	28.4	-	24.2	45.4	18.7	26.2
$s_{\bar{d}}$ ±	0.97	1.32	1.60	1.29	1.00	0.99	1.47	1.25	1.29	0.84	1.02	1.22	1.19	1.17	0.98
L.S.D. (5% ±	1.92	2.60	3.17	2.56	1.98	1.97	2.92	2.47	2.56	1.67	2.02	2.41	2.36	2.32	1.94
L.S.D. (1% ±	2.55	3.44	4.18	3.38	2.62	2.61	3.86	3.26	3.39	2.21	2.67	3.19	3.12	3.07	2.57
F. Sig. at	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

In the autumn of 1954 mean sown grass ground cover was significantly greater in S23 and S24 swards, and significantly smaller in S48 and S53 swards than in S143 and S37 swards. S23 and S48 swards did not differ significantly from S24 and S53 swards respectively, but S143 swards had a significantly greater mean sown grass cover than S37 swards. Mean sown grass cover decreased slightly in S24 swards and increased in S143 and S37 swards during 1955 so that in the autumn of that year S143 and S37 swards had a significantly greater mean sown grass cover than S23 and S24 swards, while S48 and S53 swards were still lowest in this respect. Mean sown grass cover was again significantly greater in S143 than in S37 swards, and also significantly greater in S23 than in S24 swards. In the autumn of 1956, S143 swards had the greatest sown grass cover, and S48 and S53 the smallest. Sown grass cover had increased in S23, S143 and S48 swards and decreased in S53 swards over the preceding year, and was thus slightly, but not significantly, higher in S23 than in S37 swards, and significantly higher in S48 than in S53 swards.

Although the percentage ground cover of clover increased in all swards between the autumn of 1954 and the autumn of 1955, it was significantly greater in no sown grass swards than in swards of all the other mixtures in both years. Similarly S48 and S53 swards had significantly greater clover cover percentages than swards of the remaining mixtures in both years. S23, S24, S143 and S37 swards had comparatively low mean clover cover in 1954, and did not vary significantly from one another. Clover spread more rapidly during 1955 in S23 and S24 swards than in S143 and S37 swards, so mean clover cover was significantly higher in the former than in the latter by that autumn. At this time clover cover was greater in S23 and S37 swards than in S24 and S143 swards respectively, but only S37 and S143 swards differed significantly from one another. During 1956 clover cover decreased in all swards, but the decrease was greatest in swards sown with the S143, S37, S48 and no sown grass mixtures. By the autumn of that year clover cover was slightly, but not significantly, lower in no sown grass than in S53 swards. As before, however, clover cover was significantly higher in no sown grass and S53 swards than in S23 and S24 swards, but it was lower in S48 swards. S143 and S37 swards had the lowest clover cover percentages as in 1955.

Throughout the experiment no sown grass swards had a significantly greater mean ground cover of weed grass than swards of most other mixtures. In all swards weed grass cover decreased during the 1955 season but increased again in 1956. S53 and no sown grass swards actually contained considerably more weed grass in the autumn of 1956 than in the autumn of 1954. Apart from no sown grass swards, S48 and S53 swards had the greatest weed grass cover in all three years, and only differed significantly from one another in this respect in 1956 when the weed grass cover in S53 swards was the greater. Weed grass cover was significantly greater in S143 and S37 swards than in S23 and S24 swards in 1954 but significantly smaller in 1955. In 1956 it was significantly greater in S24 swards than in S23, S143 and S37 swards.

Percentage ground cover of dicotyledonous weeds varied with the grass strain included in the seeds mixture in much the same way as weed grass cover, but was on average somewhat lower throughout, particularly in 1956.

Swards of the no sown grass mixtures had a significantly smaller mean percentage of bare ground than all the other swards in the autumn of 1954. Among the others, S48 and S53 swards had the smallest and S24 swards the highest percentages of bare ground, while S143 swards had a slightly higher and S37 swards a slightly lower percentage of bare ground than S23 swards. Over the following year the percentage of bare ground increased in all except S23 and S24 swards, and in the autumn of 1955, S23 and no sown grass swards had the lowest, whereas S143 and S37 swards had the highest mean percentages of bare ground with S24, S48 and S53 swards intermediate. Differences between these three groups were significant or almost significant, but none of the differences within the groups was significant. Further changes in the percentage of bare ground were slight, and it was still highest on average in S143 and S37 swards in the autumn of 1956, but it was now significantly lower in no sown grass swards than in S23 swards. As in 1955, S23 swards had a lower mean percentage of bare ground than swards of all the other mixtures, but they were not significantly different in this respect from S53 and S24 swards.

TABLE 68. Effect of 'clover strain' x 'grass strain' interaction on percentage ground cover of dicotyledonous weeds. Autumn, 1954

Experiment 2

Clover strain	Grass strain						
	S23	S24	S143	S37	S48	S53	No sown grass
	Mean ground cover percentages						
S184	9.9	8.3	12.9	14.4	15.3	14.1	25.9
S100	11.0	8.9	12.7	15.4	15.3	16.2	16.3
Kersey	12.8	7.2	9.4	17.4	18.1	17.6	27.8
	Mean angular transformations						
S184	18.2	16.4	20.9	21.7	22.6	21.6	30.4
S100	19.2	17.0	20.7	22.7	22.2	23.3	23.1
Kersey	20.8	15.2	17.4	24.3	24.9	24.4	31.4

F. Sig. at 5% level

Between:	$s_{\bar{d}}$	L.S.D. 5%
C means within a G (& vice versa)	±2.24	±4.43

TABLE 69. Effect of 'clover strain' x 'grass strain' interaction on percentage ground cover of white clover. Autumn, 1955

Experiment 2

Clover strain	Grass strain S23	S24	S143	S37	S48	S53	No sown grass
	Mean ground cover percentages						
S184	24.1	23.6	8.7	15.7	44.1	39.2	64.3
S100	27.4	26.7	6.4	7.4	39.7	35.9	52.2
Kersey	20.3	14.4	7.1	10.0	31.4	29.7	42.1
	Mean angular transformations						
S184	28.3	27.0	15.9	21.4	41.3	38.1	53.5
S100	30.3	30.2	11.3	13.9	38.6	36.3	46.2
Kersey	25.3	20.3	14.7	17.4	33.5	31.8	40.3

F. Sig. at 1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
C means within a G (& vice versa)	±2.55	±5.05	±6.68

TABLE 70. Effect of 'clover strain' x 'grass strain' interaction on percentage of bare ground Autumn, 1955. Experiment 2

Clover strain	S23	S24	S143	S37	S48	S53	No sown grass
				Mean percentages			
S184	19.7	26.1	27.9	31.6	18.8	22.6	17.4
S100	21.8	26.2	32.6	31.0	24.6	28.3	22.6
Kersey	24.7	27.2	31.2	30.1	28.0	27.9	29.0
				Mean angular transformations			
S184	26.1	30.5	31.8	34.0	25.4	27.8	24.6
S100	27.5	30.6	34.7	33.8	29.6	32.0	28.2
Kersey	29.7	31.4	33.9	33.2	31.8	31.8	32.5

F. Sig. at 1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
C means within s G (& vice versa)	±1.46	±2.89	±3.82

'Clover strain' X 'grass strain' interaction

This interaction had a significant effect on mean dicotyledonous weed cover in 1954, and a highly significant effect on both mean clover cover and mean percentage of bare ground in 1955.

The effect of the 'clover strain' X 'grass strain' interaction on dicotyledonous weed cover in 1954 is shown in Table 68. Dicotyledonous weed cover varied significantly with clover strain only in no sown grass swards, being significantly smaller in those containing S100 than in those containing S184 or Kersey. The relative effects of grass strains on dicotyledonous weed cover was the same in S184 as in Kersey swards but varied in S100 swards. With this clover strain the mean dicotyledonous weed cover of no sown grass swards was not significantly different from that of S53, S48 or S37 swards, though with S184 or Kersey, no sown grass swards had a significantly higher mean.

In Table 69 are given the mean ground cover percentages of white clover for the 'clover strain' X 'grass strain' interaction in 1955. The mean clover cover of S48, S53 and no sown grass swards was greatest where S184 was sown and smallest where Kersey was sown, though some of the differences were not significant. In S23 and S24 swards, however, S100 gave the greatest mean clover cover and Kersey the smallest, while in S143 and S37 swards S184 gave the greatest and S100 the smallest. Here again some of the differences were not significant. The relative effects of grass strains on clover cover varied little with the particular strain of clover included in the seeds mixture.

As shown in Table 70 the mean percentages of bare ground in S23, S48 and no sown grass swards were greatest in the autumn of 1955 where Kersey was included, and smallest with S184. However, in S143 and S53 swards the percentages of bare ground were slightly higher with S100 than with Kersey, and smallest with S184. In S24 and S37 swards the percentage of bare ground varied little with the strain of white clover included. Grass strains had much the same relative effects on the percentage of bare ground in the sward whichever clover strain was included in the seeds mixture.

TABLE 71. Effect of 'clover strain' x 'nitrogen treatment' interaction on percentage of bare ground. Autumn, 1955

Experiment 2

Nitrogen treatment	Clover strain		
	S184	S100	Kersey
		Mean percentages	
N0	18.3	25.4	27.1
N1	22.6	24.5	27.7
N2	29.4	30.2	30.1
		Mean angular transformations	
N0	24.9	30.1	31.3
N1	28.2	29.5	31.6
N2	32.7	33.2	33.2

F. Sig. at 0.1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
C means within a N	±0.96	±1.89	±2.50
N means within a C	±1.39	±2.97	±4.20

TABLE 72. Effect of 'clover strain' x 'nitrogen treatment' interaction on percentage ground cover of white clover. Autumn, 1956

Experiment 2

Nitrogen treatment	Clover strain		
	S184	S100	Kersey
	Mean ground cover percentages		
N0	27.1	20.0	25.3
N1	8.7	10.1	11.3
N2	3.3	3.0	2.8
	Mean angular transformations		
N0	30.2	24.8	29.4
N1	15.9	16.7	18.2
N2	8.4	7.8	6.9

F. Sig. at 1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
C means within a N	±1.38	±2.74	±3.62
N means within a C	±1.46	±3.06	±4.25

TABLE 73. Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage ground cover of sown grass. Autumn, 1955. Experiment 2

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53
	Mean ground cover percentages					
N0	37.1	31.8	47.4	44.9	17.0	17.9
N1	45.1	38.4	56.8	53.2	26.0	22.4
N2	51.9	46.8	55.2	49.0	33.2	31.8
	Mean angular transformations					
N0	37.4	34.0	43.5	42.0	24.0	24.9
N1	42.1	38.2	48.9	46.8	30.5	28.1
N2	46.1	43.3	48.0	44.4	35.2	34.2

F. Sig. at 1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
G means within a N	±1.72	±3.41	±4.52
N means within a G	±1.85	±3.95	±5.55

'Clover strain' X 'nitrogen treatment' interaction

Tables 71 and 72 show that the 'clover strain' X 'nitrogen treatment' interaction had a highly significant effect on the percentage of bare ground in the sward in 1955, and on the percentage ground cover of clover in 1956.

The percentage bare ground was greatest under treatment N2, and smallest under treatment N0 in S184 swards and all differences were significant. In S100 and Kersey swards, however, the percentage of bare ground did not differ significantly between treatments N0 and N1, but it was significantly higher under treatment N2. Clover strains included in the seeds mixture had the same relative effects on the percentage of bare ground under treatment N0 as under treatment N1, means for S184 swards being significantly smaller, and those for Kersey swards significantly greater, than those for S100 swards. Under treatment N2 differences in the mean percentage of bare ground between swards containing each of the clover strains were not significant.

Although the mean clover cover in swards of all mixtures decreased with increasing fertilizer nitrogen application rate in autumn 1956, the extent of the decrease varied with the clover strain included in the seeds mixture. Thus in S184 and Kersey swards the decrease between treatments N0 and N1 was considerably greater than that between treatments N1 and N2, while in S100 swards it was only slightly greater. The relative effects of the clover strains varied slightly with the particular nitrogen treatment applied. Under treatment N0 S100 swards had a significantly lower mean percentage clover cover than S184 and Kersey swards, while under treatments N1 and N2 there was no significant difference between them.

'Nitrogen treatment' X 'grass strain' interaction

This interaction had a highly significant effect on the mean percentage ground cover of sown grass and on the mean percentage of bare ground in the sward in 1955, and a significant or highly significant effect on the mean percentage ground cover of sown grass, white clover, and weed grass and on the mean percentage of bare ground in the sward in 1956.

As Table 73 shows, sown grass ground cover in autumn 1955 increased with increasing rate of fertilizer nitrogen application in all but S143 and S37 swards, in which it was significantly higher under treatments N1 than N0, but slightly

TABLE 74. **Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage of bare ground**
Autumn, 1955. Experiment 2

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53	No sown grass
				Mean percentages			
N0	16.3	23.9	29.2	29.1	21.9	20.9	23.9
N1	23.3	24.2	29.8	27.7	21.2	25.7	22.4
N2	26.4	31.4	32.7	35.9	28.2	32.2	22.7
				Mean angular transformations			
N0	23.6	29.1	32.7	32.6	27.6	26.7	28.8
N1	28.8	29.3	32.9	31.7	27.3	30.4	28.1
N2	30.8	34.1	34.8	36.8	32.0	34.6	28.3

F. Sig. at 1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
G means within a N	±0.96	±1.89	±2.50
N means within a G	±1.39	±2.97	±4.20

TABLE 75. Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage ground cover of sown grass. Autumn, 1956

Experiment 2

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53
	Mean ground cover percentages					
N0	42.7	35.3	56.6	50.0	28.7	17.6
N1	51.7	35.1	57.4	50.0	33.8	18.0
N2	55.1	43.7	51.7	40.0	40.3	13.7
	Mean angular transformations					
N0	40.8	36.4	48.8	46.0	32.2	24.7
N1	46.6	36.3	49.4	45.0	35.4	24.9
N2	47.9	41.4	46.0	39.1	39.4	21.5

F. Sig. at 0.1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
G means within a N	±1.76	±3.50	±4.63
N means within a G	±1.83	±3.80	±5.24

TABLE 76. <u>Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage ground cover of white clover. Autumn, 1956. Experiment 2</u>

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53	No sown grass
	Mean ground cover percentages						
N0	28.6	29.7	7.3	8.6	26.9	34.2	33.7
N1	12.0	13.4	1.6	1.9	10.0	15.9	15.6
N2	2.1	1.9	0.1	0.4	1.6	9.0	6.2
	Mean angular transformations						
N0	32.2	32.7	14.5	15.7	31.0	35.7	35.4
N1	20.0	21.2	6.0	7.2	18.1	23.0	23.0
N2	8.0	6.0	0.6	2.2	6.6	16.4	14.1

F. Sig. at 0.1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
G means within a N	±2.11	±4.18	±5.53
N means within a G	±2.23	±4.68	±6.50

lower under treatment N2 than N1. The only variation in the relative effects of grass strains with nitrogen treatment was that the mean sown grass cover was lower in S23 and S24 swards than in S143 and S37 swards under treatments N0 and N1, but not significantly different under treatment N2.

Table 74 shows that in the autumn of 1955 the mean percentage of bare ground in no sown grass swards was not significantly affected by nitrogen treatment, but in S23 and S53 swards it increased significantly with each increase in nitrogen application rate. In S24, S143, S37 and S48 swards the mean percentage of bare ground did not differ significantly between treatments N0 and N1, but it was significantly higher under treatment N2. The relative effects of the grass strains varied only slightly with the particular nitrogen treatment applied, the mean percentage of bare ground being significantly greater in S53 than in S48 swards under treatments N1 and N2, but slightly, though not significantly, smaller under treatment N0.

In the autumn of 1956, as shown in Table 75, the mean sown grass cover in S23 and S48 swards increased with increasing nitrogen application rate, though in S23 swards the increase between treatments N0 and N1 was proportionately greater than that between treatments N1 and N2, while in S48 swards it was smaller. In all other swards there were no significant differences between the mean sown grass cover percentages under treatment N0 and those under treatment N1, but in S24 swards the percentage ground cover of sown grass was significantly greater under treatment N2 than under treatments N0 and N1, while in S143, S37 and S53 swards it was significantly or almost significantly smaller. The only variation in the relative effects of grass strains with nitrogen level was that the sown grass cover was smaller in S23 and S24 than in S143 and S37 swards under treatments N0 and N1, but slightly greater under treatment N2.

Though the mean percentage ground cover of clover in all swards decreased significantly with each increase in nitrogen application rate in autumn 1956, the pattern of the decrease varied with the grass strain included in the seeds mixture as shown in Table 76. In S23, S24 and S48 swards the decrease between treatments N0 and N1 was slightly greater than that between treatments N1 and N2 but in S143 and S37 swards the first decrease was in proportion considerably greater than the second. This occurred also

TABLE 77. Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage ground cover of weed grass. Autumn, 1956. Experiment 2

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53	No sown grass
	Mean ground cover percentages						
N0	3.7	7.0	2.8	2.7	13.0	14.6	34.9
N1	8.9	16.7	5.1	8.4	21.2	30.8	50.4
N2	11.3	20.1	10.4	20.3	25.8	49.7	66.8
	Mean angular transformations						
N0	9.9	15.1	8.8	8.6	20.9	22.2	36.0
N1	17.2	23.9	12.9	16.4	27.2	33.5	45.2
N2	19.6	26.5	18.5	26.6	30.3	44.8	54.9

F. Sig. at 0.1% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	L.S.D. 1%
G means within a N	±2.03	±4.01	±5.30
N means within a G	±2.01	±4.02	±5.37

TABLE 78. Effect of 'nitrogen treatment' x 'grass strain' interaction on percentage of bare ground
Autumn, 1956. Experiment 2

Nitrogen treatment	Grass strain S23	S24	S143	S37	S48	S53	No sown grass
				Mean percentages			
N0	19.2	19.2	28.4	28.8	22.8	26.3	17.8
N1	22.0	26.7	32.9	33.8	28.2	25.1	21.6
N2	28.9	31.7	35.4	34.9	28.9	23.2	20.0
				Mean angular transformations			
N0	25.9	25.9	32.2	32.3	28.2	30.8	24.8
N1	27.9	31.0	34.9	35.4	32.0	29.9	27.6
N2	32.4	34.2	36.5	36.1	32.5	28.7	26.4

F. Sig. at 5% level

Between:	$s_{\bar{d}}$	L.S.D. 5%	1%
G means within a N	±1.70	±3.37	-
N means within a G	±1.23	±2.54	-

in S53 and no sown grass swards though the general level of clover cover was considerably higher in these swards. The relative effects of grass strains on clover cover varied little with the particular nitrogen treatment applied.

Table 77 shows that in autumn 1956, the mean percentage ground cover of weed grass in all swards increased with increasing fertilizer nitrogen application rate. In S23, S24 and S48 swards the increase between treatments N0 and N1 was greater than that between treatments N1 and N2, while in S143 and S37 swards it was smaller. In S53 and no sown grass swards the increases between N0 and N1 and between N1 and N2 were almost equal. Grass strains had much the same relative effects on weed grass cover whichever nitrogen treatment was applied.

In the autumn of 1956 the mean percentage of bare ground in all but the S53 and no sown grass swards increased with each increase in nitrogen application rate, though several of the differences were not significant (see Table 78). In S53 swards this trend was reversed, but the differences were slight and not significant, while in no sown grass swards the percentage of bare ground was significantly higher under treatment N1 than under treatment N0, but slightly, though not significantly, lower under treatment N2. Mean percentage of bare ground was highest in S143 and S37 swards and lowest in no sown grass swards under all nitrogen treatments, but the inter-relationships of the other swards varied somewhat with nitrogen treatment. Both S48 and S53 swards had significantly higher percentages of bare ground than S23 and S24 swards under treatment N0, but the differences in this respect between S48 and S53 swards, and between S23 and S24 swards were not significant. Under treatment N1 S48 swards had a significantly higher percentage of bare ground than S23 swards, and all other differences between the percentages of bare ground in S23, S24, S48 and S53 swards were not significant. Under treatment N2 also most of these differences were not significant, though S53 swards had a significantly lower percentage of bare ground than S24 swards.

DISCUSSION

Effect of nitrogen treatments

The average effects of the nitrogen treatments on herbage in this experiment were similar to those noted in many other experiments (eg. 39, 91, 97), total herbage yields from all mixtures increasing almost linearly with nitrogen application rate in the second harvest year. In the first year, however, total herbage yields from all mixtures showed a greater average increase per 1 cwt. 'Nitro-Chalk' applied under the light than under the heavy nitrogen treatment, and clover yields were unaffected by the light treatment but were depressed by the heavy. It is likely, therefore, that the greater apparent efficiency of nitrogen utilization under the light nitrogen treatment resulted directly from the presence of clover and indirectly from the transfer of fixed nitrogen from the clover to the grass in the sward. In an experiment reported by Williams (97) light rates of nitrogen application stimulated clover yields from an Italian ryegrass/white clover sward in the early part of the first harvest year, but depressed them later, resulting in only a slight depression over the season as a whole. Individual crop clover yield data suggest that the effect of the light nitrogen treatment was similar in the present experiment.

The effect of the light nitrogen treatment on clover yield varied in the first harvest year with the strain of grass growing in association, and the variations can be attributed to the different growth habits of the grasses. Thus clover yields from the S24 and S48 mixtures increased under the light nitrogen treatment, since these grasses had an upright stemmy habit of growth during most of the season. On the other hand, the relatively dense and leafy habit of growth of S23 and S53 throughout the season under the light nitrogen treatment caused considerable depression of the associated white clover. Between these two extremes S143 and S37, although competing severely with clover under the no nitrogen treatment, had only a slight additional depressing effect under the light nitrogen treatment. Under the light treatment S143 and S37 had a lax growth habit early in the season but became denser later. The heavy nitrogen treatment stimulated leaf growth which resulted in severe depression of clover by all the grasses. Where clover was grown without a companion grass its yield was stimulated by the light but unaffected by the heavy nitrogen treatment. Presumably the beneficial effect of nitrogen on clover was cancelled out by the increasing competition from weed grass under the heavy treatment.

In the second harvest year clover yields from all mixtures were depressed by both nitrogen treatments, possibly because of the increasing density of the sward. S100 was apparently better able than the other clover strains to withstand the increased competition, since it was not depressed to the same extent under the light nitrogen treatment as were S184 or Kersey.

The percentages of clover in the herbage from all the seeds mixtures decreased with increasing nitrogen application rate in both years of the experiment. Since clover yields from the S24, S48 and no sown grass mixtures actually increased under the light nitrogen treatment in the first harvest year, the decrease in the percentage of clover in the herbage from these mixtures shows that the yield from the grass fraction of the herbage was increased by a proportionately greater amount than that from the clover fraction. This was true to some extent with the S143 and S37 mixtures also, clover yields from these being only slightly depressed by the light nitrogen treatment. In the second harvest year the percentages of clover in the herbage from mixtures containing the S100 strain of clover were not reduced to the same extent by the light nitrogen treatment as were those in the herbage from mixtures containing S184 or Kersey.

Crude protein yields of total herbage responded to nitrogen treatments in much the same way as dry matter yields. On average, however, crude protein increased by almost the same proportion as dry matter yields under the light nitrogen treatment, but by a greater proportion under the heavy. This resulted from the fact that, on average, the crude protein percentage of herbage was the same under the light as under the no nitrogen treatment, but was higher under the heavy nitrogen treatment. In both 1955 and 1956 these effects varied with the strain of grass present. The seeds mixtures fell roughly into three groups in this respect in the first year. In the first group, which included the S48, S53 and no sown grass mixtures, the light nitrogen treatment increased crude protein yields by almost the same proportion as dry matter yields, since the herbage from these mixtures had almost the same crude protein percentages under the light as under the no nitrogen treatment. On the other hand crude protein yields from the S24, S143 and S37 mixtures were increased by a much greater proportion than dry matter yields, because these mixtures yielded herbage with higher crude protein percentages under the light than under the no nitrogen treatment. Only the S23 mixtures gave herbage with a lower crude protein percentage under the light than under the no nitrogen treatment, giving, therefore, a smaller proportional increase in crude protein than in dry matter yield with the light nitrogen application. In the same year the heavy nitrogen treatment had a proportionately greater effect on crude protein than on dry matter yield from all but the no sown grass mixtures, since it increased the percentages of crude protein in the herbage. The reverse occurred with the no sown grass mixtures.

Variations in the crude protein percentages of herbage from the S48, S53, S143 and S37 mixtures with nitrogen treatment in the second year were similar to those noted in the first year. However, in the second year the percentage of crude protein in the herbage from the S24 mixtures varied with nitrogen treatment in the same way as that in the herbage from the S48 and S53 mixtures. The crude protein percentage of the herbage from the S23 and no sown grass mixtures, on the other hand, decreased considerably under the light nitrogen treatment. The herbage from the no sown grass mixtures had a slightly higher percentage of crude protein under the heavy than under the no nitrogen treatment, but the reverse occurred with the S23 mixtures.

In an experiment reported by Holmes & MacLusky (39) the percentage of crude protein in the herbage from a number of seeds mixtures decreased over a range of fertilizer nitrogen treatments similar to that in the present experiment. However, when a total of 4 cwt. 'Nitro-Chalk'/acre was applied over the season the percentages of crude protein in the herbage from mixtures containing S48 timothy and S53 meadow-fescue were little affected, while those in the herbage from mixtures containing H1 ryegrass, Scotia cocksfoot and Scots timothy were increased. On the other hand, the percentages of crude protein in the herbage from almost all of the seeds mixtures decreased when a total of 10 cwt. 'Nitro-Chalk'/acre was applied over the season. Holmes & MacLusky demonstrated that a close relationship existed between the compatability of the grass strains with clover and the percentage of crude protein in the herbage in this experiment. No obvious relationship of this kind was found in the present experiment. The effects of nitrogen treatment on the percentages of both crude protein and clover in the herbage varied with the strain of grass included in the seeds mixture, but the variations in the two sets of percentages bore little similarity to one another. The percentage of crude protein in the herbage may have been related in part to the compatability of the grass strain with the clover in the seeds mixture, but other factors such as leaf:stem ratio and seasonality of production were probably involved also.

The crude protein yields of clover from the various seeds mixtures were affected by the nitrogen treatments in much the same way as were the dry matter yields of clover. Thus the clover crude protein yields from the S24, S48 and no sown grass mixtures increased under the light nitrogen treatment in the first year while those from all others decreased. Clover crude protein yields from all the mixtures decreased under the heavy nitrogen treatment in the first year, and under both the light and heavy treatments in the second.

Changes brought about by the nitrogen treatments in the botanical composition of the sward were complex and showed some variations with the particular strain of grass or clover included in the seeds mixture. Although these changes are of ecological interest, few of them appeared to be directly related to the yielding ability of the sward. In the first harvest year increasing the rate of fertilizer nitrogen application increased the contribution of sown and weed grasses in the sward and also the proportion of bare ground, but decreased the contribution of clover and had little effect on that of dicotyledonous weeds. Sown grass cover in S143 and S37 swards was considerably greater under the light than under the no nitrogen treatment, but slightly smaller under the heavy than under the light. The proportion of bare ground in no sown grass swards did not vary with nitrogen treatment.

Similarities in the overall botanical response of certain swards to the nitrogen treatments by the autumn of the second harvest year allow them to be classified into three groups as follows. In S23, S24 and S48 swards clover contribution decreased with increasing nitrogen level, while that of sown and weed grasses increased. The increase in the latter, however, was not sufficient to compensate for the decrease in the former, so that the proportion of bare ground in these swards increased. The contribution of both clover and sown grass decreased with increasing nitrogen level in S143 and S37 swards, and only that of weed grass increased. The reductions in clover and sown grass contribution were not great, however, and were largely compensated by the increase in weed grass, so that the proportion of bare ground increased to a smaller extent in these swards than in the first group. In S53 and no sown grass swards the contribtuion of clover, and also to a slight extent that of sown grass in S53 swards, decreased with increasing nitrogen level. This was compensated by a large increase in weed grass, however, and the proportion of bare ground in these swards decreased slightly.

In agreement with the clover yield and herbage clover content results discussed above, the decrease in clover ground cover was proportionately greater under the light than under the heavy nitrogen treatment in S184 and Kersey swards in the second year, and almost the same under both in S100 swards.

Effect of clover strains

The relationships between the dry matter yields from the three clover strains and their effects on total herbage yields from seeds mixtures in this experiment were in general agreement with the findings of Troughton (80) and Davies (22). Averaged over all seeds mixtures and nitrogen treatments the poorest yields of clover dry matter came, in both years, from S184, and the best from S100 in the first year but from Kersey in the second. Total herbage yields showed little variation with clover strain though the mixtures which contained Kersey gave the smallest yields in the first year and the greatest in the second.

The yields of the three clover strains varied to some extent with the strain of grass included in the seeds mixture but the variations were not significant. However, on the basis of the percentages of clover in the herbage S100 was the most valuable clover strain in the first harvest year, except when it was grown in association with S143 or S37 cocksfoot. In the cocksfoot mixtures Kersey was the best strain in that year. Kersey generally improved in performance by the second harvest year, when it proved to be equal or superior in value to S100 in all but the S24 and no sown grass mixtures. S184 was a uniformly poor strain throughout.

No striking differences were noted in the seasonality of production from the three clover strains, nor had they any marked influence on the seasonal distribution of total herbage yields from the mixtures in which they were included.

The crude protein yields and the percentages of crude protein in the herbage from the S23, S24, S48 and S53 mixtures were roughly related to the percentages of clover in the herbage in the first year, both being greatest when the mixtures contained S100. Clover strains had little effect on the crude protein yields or on the percentages of crude protein in the herbage from the S143, S37 and no sown grass mixtures in the first harvest year, or on the crude protein yields from any of the mixtures in the second year. In the second year the percentage of crude protein in the herbage was generally lowest when the seeds mixture contained the clover strain giving the lowest percentage of clover, but there was little difference in the effect of the other two strains.

Clover crude protein yields varied with clover strain in much the same way as clover dry matter yields.

Considering sward botanical composition, only the clover fraction of the sward was affected to any extent by the strain of clover included in the seeds mixture sown. S184 and S100 gave the greatest ground cover of clover in swards of all seeds mixtures in the autumn of the seeding year. In swards of the S48, S53 and no sown grass mixtures S184 gave the highest and Kersey the lowest clover cover in the first harvest year. In S23 and S24 swards S100 gave a greater clover cover than S184, while in S143 and S37 swards it gave a smaller clover cover than Kersey. Swards of all seeds mixtures had a higher clover cover when they contained S184 or Kersey rather than S100 in the second harvest year under the no nitrogen treatment, but there were no significant differences between mean clover cover percentages for each of the strains under the other two nitrogen treatments.

The high average ground cover of clover in swards sown with mixtures containing S184 was in marked contrast to the somewhat poor yield performance of this clover strain. The ground cover data suggested that S184 produced more stolons than either S100 or Kersey. This should render it the most persistent of the strains, and on a long-term basis offset its lower yielding ability. Ground cover contributed by the other two strains was closely related to their relative yields, S100 giving on average a greater ground cover and greater yield than Kersey in the first year, but a smaller ground cover and smaller yield in the second year.

Effect of grass strains

The performance of the seeds mixtures studied in this experiment was governed to a greater extent by the strain of grass than by the strain of clover which they contained. Mean herbage yields in the first harvest year ranged from 10,700 lb./acre for mixtures containing S24 down to 8,700 lb./acre for mixtures containing S143. In the second year the highest mean yield, 10,500 lb./acre, was again given by the S24 mixtures, while the no sown grass mixtures gave the lowest, 7,500 lb./acre. The interrelationships between total herbage yields of mixtures containing the different grasses varied to some extent in the second year with the nitrogen treatment applied, though the S24 and no sown grass mixtures were the highest and lowest yielders respectively throughout. The S23 mixtures gave a slightly smaller yield than the S143, S48 and S53 mixtures under the no nitrogen treatment, but a considerably greater yield under the light and heavy nitrogen treatments. The S53 mixtures gave smaller yields than the S143, S37 and S48 mixtures under the light nitrogen treatment but equal or greater yields under the other two treatments.

In the first harvest year clover grew best in the no sown grass mixtures because of the absence of competitors, but it was considerably depressed in the second year by a rapid increase in the weed grass content of the herbage from these mixtures. Despite this, in the second year the no sown grass mixtures gave greater clover yields and herbage with higher percentages of clover than all other mixtures except those containing S53 meadow fescue. The clover yields and the percentages of clover in the herbage from the other mixtures clearly demonstrated the compatability of the various grass strains with clover. Thus S48 timothy and S53 meadow fescue were shown to be the best companion grasses for clover in the first harvest year. However, S48 tillered rapidly in the second year, and depressed clover grown in association with it. On the other hand, S53 tended to thin out in that year, and mixtures containing it gave greater clover yields and herbage with higher percentages of clover than all other grass + clover mixtures in the second as in the first harvest year. S143 and S37 cocksfoot were the most severe competitors of clover in both years, while S23 and S24 ryegrass were intermediate in this respect between the cocksfoots and S53 fescue. The S23 and S24 mixtures gave slightly greater clover yields than the S48 mixtures in the second year. Although different strains were used, the relationships between the compatability of the various grass species with clover in the present experiment were similar to those reported for other experiments by Davies (19) and by Holmes & MacLusky (39).

S23 and S24 ryegrass were the only grass strains whose relative compatability with clover varied much with either the nitrogen treatment applied or with the clover strain growing in association. The S23 mixtures gave greater clover yields and herbage with a higher percentage of clover than the S24 mixtures under the no nitrogen and heavy nitrogen treatments, but the reverse occurred under the light treatment in both the first and second harvest years. In the second year the S23 mixtures gave herbage with a higher percentage of clover than the S24 mixtures when both contained either S184 or Kersey white clover, but with a lower percentage when they contained S100. This was not observed in the first year.

The effects of grass strains on the seasonal distribution of herbage yields varied with the nitrogen treatment applied, but detailed comparisons could not be made between nitrogen treatments because of the varying cutting frequencies. Under each nitrogen treatment the pattern of yield distribution was fairly similar for most of the seeds mixtures, though their general level of yield varied. The most striking exception to this was with the S24 mixtures, which gave a large proportion of their total yield at the first crop of the season, when they outyielded all the other mixtures. This extremely high peak of yield was the sole factor enabling the S24 mixtures to exceed all the others in total yield over the season, since they gave smaller yields than the S23 mixtures at the second crop, and almost equal yields thereafter. In contrast to the markedly different seasonal production patterns obtained for mixtures containing each of the ryegrass strains, those obtained for mixtures containing each of the cocksfoot strains followed one another closely. In the first year the S143 and S37 mixtures gave smaller yields than the S23 mixtures early in the season, and similar yields later, while in the second year they gave slightly greater yields early and smaller yields later. Under the heavy nitrogen treatment, the S143 and S37 mixtures gave much smaller autumn yields than all the other mixtures. Yields from the S48, S53 and no sown grass mixtures were distributed over the season in a similar fashion to those from the S23 mixtures, apart from a marked mid-season decline in the second year.

In the first harvest year clover yields from all except the S143 and S37 mixtures increased from crop to crop over the season under the no nitrogen and light nitrogen treatments. Under the heavy nitrogen treatment they increased only from the first to the second crop and then decreased over the rest of the season, except for a slight increase from the no sown grass mixtures at the last crop. In the second year clover yields from all the mixtures decreased from crop to crop under all nitrogen treatments. The relationships between the clover yields from the various mixtures at any one crop were generally similar to the relationships between total clover yields over the season.

In the first harvest year mixtures which yielded herbage with the highest percentages of clover, i.e. the no sown grass, S48 and S53 mixtures, gave the highest crude protein yields, while those yielding herbage with the lowest percentages of clover, i.e. the S143 and S37 mixtures, gave the lowest crude protein yields. The no sown grass, S48 and S53 mixtures also yielded herbage with the highest percentages of crude protein under all nitrogen treatments. In the case of the remaining seeds mixtures, however, there appeared to be no relationship between the percentages of clover and that of crude protein in the herbage. In fact, the effects of the grass strain included in the seeds mixture on the percentages of crude protein in the herbage varied with the nitrogen treatment applied, though this did not occur with the percentage of clover. Thus under the no nitrogen treatment herbage from the S23 mixtures had a higher, and that from the S24 mixtures a lower, percentage of crude protein than herbage from the S143 and S37 mixtures, while under the light nitrogen treatment there was no difference between the mixtures in this respect. Under the heavy nitrogen treatment both the S23 and S24 mixtures gave herbage with lower percentages of crude protein than the S143 and S37 mixtures.

In the second harvest year neither the crude protein yields nor the percentages of crude protein in the herbage from mixtures containing the different grass strains appeared to bear much relationship to the percentages of clover in the herbage. The S23 , S24, S48 and S53 mixtures all gave about the same yield of crude protein, and outyielded the S143 and S37 mixtures in this respect. The no sown grass and S53 mixtures again gave herbage with the highest percentages of crude protein and of clover. Under all nitrogen treatments the S23 mixtures gave herbage with a higher percentage of crude protein than the S24 mixtures. The percentages of crude protein in the herbage from the S143 and S37 mixtures were lower than those in the herbage from both the S23 and S24 mixtures under the no nitrogen and light nitrogen treatments, but higher under the heavy nitrogen treatment.

Effects of strain of companion grass on clover crude protein yields were similar to those on clover dry matter yields, and varied in much the same way with nitrogen treatment in both years.

The sward botanical analyses results showed that the strain of grass included in the seeds mixture sown had a much greater effect on sward composition than had the strain of clover. Thus the percentage ground cover of all fractions of the sward were affected by the grass strain, whereas only that of the clover fraction was affected by the clover strain. In addition the effects of the grass strains varied in many instances with the strain of clover included in the seeds mixture and with the nitrogen treatment applied.

Swards of the no sown grass mixtures had the highest ground cover percentages of clover and of weed grass in the autumn of the seeding year. Sown grass cover was lower and clover and weed grass cover higher in S48 and S53 swards than in S23, S143 and S37 swards. S23 and S24 swards had almost the same clover cover as S143 and S37 swards, but a greater sown grass cover and smaller weed grass cover.

The balance of the various components in no sown grass, S48 and S53 swards had altered little by the autumn of the first harvest year. At this time, however, sown grass cover was higher, and white clover and weed grass cover lower, in S143 and S37 swards than in S23 and S24 swards under the no nitrogen and light nitrogen treatments, though all had approximately the same sown grass cover under the heavy nitrogen treatment. Under all nitrogen treatments both sown grass and clover cover were higher in S23 than in S24 swards, while sown grass cover was lower and clover cover higher in S37 than in S143 swards.

In the autumn of the second harvest year clover cover was slightly lower in no sown grass than in S53 swards.

As in the previous year clover and weed grass cover was higher and sown grass cover lower in S53 than in S23, S24, S143 and S37 swards. S48 swards, however, had a higher sown grass and lower clover cover than S53 swards. In the remaining swards sown grass cover was lowest in those containing S24, and highest in those containing S143, while the reverse occurred with weed grass. The relationships between sown grass cover in the S23, S24, S143 and S37 swards varied with nitrogen treatment as in the previous year.

Fixation and transfer of nitrogen by clover

As in Experiment 1 it was not possible to determine directly the amount of nitrogen fixed in the clover or the proportion of this transferred to the grass component of the sward, since the various nitrogen treatments were not compared on clover-free swards. An attempt was made, however, to estimate it mathematically by the method previously described on pages 58-62, but this proved impossible on account of an additional unknown factor, namely the amount of nitrogen returned to the sward in the urine of the grazing animal. Calculations suggest that this factor was of considerable magnitude, for in many cases the apparent efficiency of fertilizer nitrogen utilization exceeded 100% while that of clover as a nitrogen donor appeared to be a negative quantity.

SUMMARY and CONCLUSIONS

1) In an experiment begun in the spring of 1954 a study was made of the relative values of three white clover strains, their compatability with certain grass strains, and their reaction to increasing rate of fertilizer nitrogen application. The results obtained in the seeding year and in the first and second harvest years of this experiment have been presented.

2) The three clover strains studied were S184, S100 and Kersey. These were each grown in association with one of the following grasses: S23 or S24 perennial ryegrass, S143 or S37 cocksfoot, S48 timothy, S53 meadow fescue or no sown grass. The resulting 21 seeds mixtures were compared under three fertilizer nitrogen treatments - 0, 4 or 10 cwt. 'Nitro-Chalk'/acre over the season.

3) On average the dry matter and crude protein yields of mixed herbage increased, and those of clover decreased with

increasing rate of fertilizer nitrogen application.

4) Mixed herbage dry matter yields were almost linearly related to fertilizer nitrogen application rates in the second harvest year of the experiment. In the first year, however, the 4 cwt. 'Nitro-Chalk'/acre treatment had a proportionately greater effect on mixed herbage dry matter yields than the heavier treatment. The light nitrogen treatment actually increased the clover yields from certain mixtures, and only slightly depressed those from others. It has been suggested, therefore, that the greater apparent efficiency of nitrogen utilization under the light treatment resulted directly and indirectly from the presence of clover.

5) Throughout the experiment the percentage of crude protein in the mixed herbage was on average unaffected by the light, but increased by the heavy nitrogen treatment. This effect varied somewhat between the different seeds mixtures, and also from year to year with certain of the seeds mixtures. None of these variations appeared to be directly related to variations in the percentage of clover in the herbage, which can be taken as a measure of the compatability of the grass strain with the clover in the seeds mixture. Other factors which might play a part have been suggested.

6) Few of the changes in the botanical composition of the sward resulting from increasing rate of fertilizer nitrogen application were directly related to the yielding ability of the sward.

7) In terms of the yields of mixed herbage and those of clover from the seeds mixtures, the S100 strain of white clover was superior to the Kersey strain in the first harvest year, except in the S143 and S37 cocksfoot mixtures. However, in the second year Kersey was equal or superior to S100 in all but the S24 ryegrass and no sown grass mixtures. S184 was the poorest yielding clover strain throughout, but trends in the botanical composition of the sward suggested that it might be the most persistent.

8) On average increasing rate of fertilizer nitrogen application depressed all three white clover strains to the same extent, but S100 appeared somewhat better able to withstand competition from the grass under the light nitrogen treatment in the second harvest year than were S184 or Kersey.

9) The general performance of a seeds mixtures in this experiment was influenced to a greater extent by the grass strain which it contained than by the clover strain.

10) In the first and second harvest years seeds mixtures containing S24 ryegrass gave greater total yields of mixed herbage than any of the other mixtures. However, a large proportion of the total yield from the S24 mixtures came in the early part of the season and yields thereafter were comparatively low. On the other hand, the S23 ryegrass mixtures, which gave the next greatest total yields of mixed herbage, had a much more uniform seasonal yield distribution pattern, as was shown with most of the other mixtures.

11) The S143 cocksfoot and no sown grass mixtures gave the smallest total yields of mixed herbage in the first and second harvest years respectively.

12) Under all fertilizer nitrogen treatments throughout the experiment S53 meadow fescue was the best and S143 and S37 cocksfoot the poorest companion grasses for white clover. Cocksfoot, in fact, severely depressed clover even under the no nitrogen treatment. Perennial ryegrass was a slightly better companion grass for clover than cocksfoot. The relative values of the two ryegrass strains varied in this respect with the nitrogen treatment applied, S23 being the better of the two under the no nitrogen and heavy nitrogen treatments, but the poorer to a slight extent under the light treatment. S48 timothy equalled S53 fescue in compatability with clover in the first harvest year, but competed more severely with clover than did the ryegrasses in the second year.

13) In the first harvest year variations in crude protein yields were directly related to variations in the percentages of clover in the herbage, and so to the compatability of the grass strains with clover. This relationship did not apply in the second harvest year, nor could any relationship be observed in either year between the percentages of crude protein and those of clover in the herbage.

14) The strain of grass included in the seeds mixture was shown to have a much greater effect on the botanical composition of the sward than the strain of clover.

PART 4

GENERAL DISCUSSION and CONCLUSIONS

In the preceding pages detailed descriptions have been given of two experiments which were designed to investigate certain aspects of the problem of obtaining maximum benefit from clover in a grass-clover sward while at the same time applying and efficiently utilizing fertilizer nitrogen. It remains to consider the extent to which the results of these experiments aid in the solution of the problem. Accordingly in this section the more important results are summarized and their implications examined.

Intensity of defoliation of herbage was shown in Experiment 1 to be an important factor controlling the contribution of clover from a grass-clover sward, confirming the findings of Jones (47, 48, 49, 50), Robinson & Sprague (68) and others. Clover yields were consistently greater under close than under lax-cutting, but there was some evidence that the continued use of heavy fertilizer nitrogen applications reduced this difference.

The contention of Williams (98) that close defoliation reduces total herbage yields is not confirmed by this experiment, close-cutting consistently giving greater yields of total herbage than lax-cutting. Under the conditions of this experiment, reducing stubble height by 1-1½ inches through cutting more closely, gave greater increases in herbage dry matter yields than did application of 'Nitro-Chalk' at the rate of 4 cwt./acre over the season.

The average height of stubble left by a farm mower approximates fairly closely to that left under the lax-cutting treatment in this experiment. Mechanical difficulties may arise in close-cutting herbage on a farm-scale, at least where a mower of the reciprocating-blade type is used. If, however, these difficulties could be overcome, it would appear that considerable increases in herbage production and quality would be achieved without additional expenditure on fertilizers. Certain reservations should, however, be made here. Firstly, in this experiment the treatments were compared on a relatively dense and well established sward, and the results from it might not apply, therefore, to a more open sward in its first harvest year.

Continued close-cutting on such a sward might have a detrimental effect, though no such effect was noted over the admittedly short period of the present experiment. Secondly, it is possible that swards containing a dominant grass with a different growth habit from perennial ryegrass might react differently. Further investigations are being made to compare close and lax-cutting on ryegrass and timothy swards from their first harvest year onwards, and preliminary results (54) agree closely with those of the present experiment. Thirdly, Robinson & Sprague (68) and Mott (61) have suggested that close-cutting will only benefit clover and total herbage yields when the sward is allowed adequate time for recovery between cutting dates. Close-cutting at more frequent intervals than those used in the present experiment, although increasing the clover content of herbage from a grass-clover sward, might reduce the actual yield of clover and will almost certainly reduce total herbage yields.

Both experiments have shown that the factor which has the greatest control over the degree of clover suppression is the total amount of fertilizer nitrogen applied over the season - large amounts have the greatest effect and small amounts the least. The only exceptions to this occurred in the first harvest year of Experiment 2, when light dressings of fertilizer nitrogen actually increased clover yields from swards sown with the S24 ryegrass, S48 timothy and pure clover mixtures, and only slightly depressed those from swards of the S143 and S37 cocksfoot mixtures.

It was shown in Experiment 1 that the degree of clover suppression varied to some extent with the date on which fertilizer nitrogen application began in the spring. With relatively large amounts of fertilizer nitrogen applied in split dressings over the season total yields of clover and of crude protein were somewhat greater where the first application was delayed until after the first or second cut of the season. However, clover yields were unaffected and crude protein yields were reduced by this delay, where the total seasonal application was small and was given in two dressings, one in spring and the other in autumn. With both the light and heavy nitrogen treatments total dry matter yields of mixed herbage over the season were reduced by delaying the first nitrogen application, but most of this reduction occurred in the early part of the season, and midseason yields were increased. The seasonal distribution of herbage yields was, therefore, more uniform than under a system in which the first dressing was applied early in the spring. This may be of some practical value where a steady supply of high quality herbage is required throughout the season for conserving or grazing, since it will help to fill the so-called 'summer gap'. The problem, however, is to decide whether the loss in total production over the season is outbalanced by the higher quality of the herbage and by the convenience of a more uniformly distributed production. Further investigation of this problem on a larger scale is necessary.

The clover strains compared in Experiment 2 showed little variation in their average ability to withstand suppression by the companion grass when the swards in which they were growing received dressings of fertilizer nitrogen. In the second harvest year S100 was depressed to a smaller extent by 'Nitro-Chalk' applied in four dressings each of 1 cwt./acre over the season than were S184 or Kersey, but all were similarly depressed by a total dressing of 10 cwt. /acre over the season. No such variation in the response to the light nitrogen treatment occurred in the first harvest year. In general S100 was superior to Kersey in all except the S143 and S37 mixtures in the first harvest year, but the improved performance of Kersey made it equal or superior to S100 in all but the S24 and pure-clover mixtures in the second harvest year. S184 was the poorest yielding strain throughout, but it appeared to produce more stolons than the other two strains and it might, therefore, be the most persistent.

Results from Experiment 2 suggest that the degree of depression of clover under fertilizer nitrogen treatment is governed to a greater extent by the strain of grass than by the strain of clover in the seeds mixture. S53 meadow fescue was on average the best companion grass for clover. However, in the first harvest year it had, in company with S23, a proportionately greater depressing effect on clover than all other grasses under the light nitrogen treatment, but even here clover yields were greater from the S53 mixtures than from most of the others. The S53 mixtures would appear, therefore, to provide the best opportunity for the combined use of clover and fertilizer nitrogen. Cocksfoot, on the other hand, was extremely aggressive towards clover. Clover yields from mixtures containing S143 and S37 cocksfoot were small when no fertilizer nitrogen was applied, and almost negligible with even small dressings. On the basis of total herbage yields the cocksfoot strains performed badly in the first harvest year of this experiment and only moderately well in the second harvest year compared with the ryegrass strains. The cocksfoot strains compared by Holmes & MacLusky (39) were also relatively poor yielders when grown with clover and given no fertilizer nitrogen, or when dressed with only moderate amounts of nitrogen. They gave higher yields than all other grasses, however, under fertilizer nitrogen dressings totalling 20 cwt. 'Nitro-Chalk'/acre over the season. The heaviest fertilizer nitrogen application rate of the present experiment (10 cwt. 'Nitro-Chalk'/acre) would appear, therefore, to be insufficient to stimulate the highest potential yield from cocksfoot. The ryegrasses, particularly S24, gave the greatest yields and largest responses to fertilizer nitrogen in this experiment, and were, in addition, rather better companion grasses for clover than were the cocksfoot strains. This was particular so where no fertilizer nitrogen was applied.

To summarize, it can be concluded from the results of the experiments described in this thesis that maximum benefit should be obtained from the clover in a grass clover sward, and at the same time applied fertilizer nitrogen should be efficiently utilized where:

1) The seeds mixture used is predominated by meadow fescue, and contains a vigorous strain of white clover such as S100.

2) The sward is closely defoliated (to within 1 inch from ground level) and an adequate recovery period (4-5 weeks) is allowed between defoliations.

3) Only moderate amounts of fertilizer nitrogen (4-8 cwt. 'Nitro-Chalk'/acre over the season) are applied, or alternatively,

4) The first dressing of the season is delayed until after the first or second crop, if greater total amounts of fertilizer nitrogen are applied.

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APPENDIX 1

Note on the weather in 1954-56

Month	Rainfall (in./month) Mean 1931-53	1954	1955	1956	Sunshine (hr./month) Mean 1935-53	1954	1955	1956
January	3.68	3.49	6.05	2.55	40.5	50.3	37.1	44.4
February	2.43	2.85	1.49	0.95	64.7	46.0	93.5	67.6
March	2.14	2.11	1.42	1.42	102.7	116.9	137.7	128.8
April	2.08	1.54	2.60	0.84	141.1	180.3	163.6	183.7
May	2.08	1.79	2.96	1.76	200.0	144.5	239.9	183.0
June	2.49	3.70	2.43	2.19	174.3	131.3	130.0	182.5
July	3.36	5.18	1.59	5.12	147.3	106.1	274.9	134.8
August	3.08	4.03	2.04	6.35	143.4	96.0	184.5	126.1
September	3.59	5.02	3.46	3.44	104.3	95.7	128.0	77.3
October	4.01	8.02	1.99	3.32	80.3	54.5	78.8	99.3
November	3.70	4.96	0.65	1.19	49.2	42.5	61.3	54.0
December	3.70	5.25	4.49	4.23	35.9	16.0	31.0	20.1
Total	36.34	47.94	31.17	33.36	1283.7	1080.1	1560.3	1301.6

The above data were recorded at a weather station approximately 800 yards from the site of the experiments described in the thesis. This station is maintained by the Plant Pathology Department of the West of Scotland Agricultural College.

Although the hours of sunshine recorded in April of 1954 were above average, and rainfall was below average in that and the following month, the weather was extremely poor during most of the growing season of that year. Rainfall was high and hours of sunshine low from June to October.

Weather conditions in the 1955 growing season were in marked contrast to those in 1954. Sunshine was above average in every month except June; while slightly above average rainfall in April, May and part of June was followed by relatively dry weather late into the autumn.

In 1956 rainfall was low during the spring and early summer, but above average from July onwards. Approximately average sunshine was recorded during most of the growing season of that year.