HILL PASTURE IMPROVEMENT

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HILL PASTURE IMPROVEMENT

with special reference to

the USE of HERBICIDES

by

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Dissertation presented for the Degree of Master of Science
in the Faculty of Science (Department of Agriculture).

October 1964.

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INTRODUCTION

The production of hill pastures in this country has been decreasing steadily for many years and is considerably below its full potential. (27) This reduction is due, in part, to the continual removal from the hill areas of sheep and cattle as store animals, and to the non-replacement of the minerals so removed. (27,66) Further contributory causes are the repeated burning-off of the herbage and the lack of mixed grazing. (27) Dunlop (27) writing in 1948 suggested that the production per acre could be raised by 50 lb. of beef and 10 lb. of mutton in addition to the 4 lb. per acre of mutton being produced at that time. This is no less a possibility today.

The production potential of hill areas, the proper crop for which is grass, is not much less that that of low ground. A yield of 3-4 tons/acre dry matter can be obtained from the hill and this compares favourably with the 4-5 tons/acre which can be obtained from lowland areas, (13) the hill yields being obtained at an elevation of more than 1,000 feet. The reason for the apparently high hill yield is the increased rainfall which helps to offset the much shorter growing season. Unfortunately there is an increase in leaching coupled with this higher rainfall and leaching is further encouraged by a reduction in evaporation, thus causing the formation of an acid soil. (15) This soil has its own peculiar flora of low nutritional value. Many of these poor quality grasses e.g. Moor Mat Grass are unpalatable to sheep and are thus encouraged to spread by selective grazing. (37)

The purpose of any hill pasture improvement scheme, thus, is to increase herbage production and complementary to this is the improvement of the soil and its maintenance in a fertile state by good management. The criterion of having reached a sufficiently high standard of improvement can be taken as the invasion of the pasture by earthworms. (14)

ANIMAL INFLUENCE

As already mentioned, the selective grazing of sheep on hill land for many years, has resulted in the encouragement of poor quality vegetation such as Moor Mat Grass. In fact the carrying capacity of a hirsel is directly related to the amount of bent/fescue type sward which occurs therein. (57) In bygone days the demand for wether mutton meant that there were plenty of these animals, along with the cattle which used to be kept on the hill, to control the coarser vegetation. (79)

It is therefore obvious that hill cattle must be kept in far greater numbers than they are at present. (92) If the grazing of these animals can be controlled by adequate fencing this in itself will cause a great improvement and over a period of time volunteer plants of greater palatability and feeding value will appear in the sward. (21) The proportion of cattle to sheep should always be maintained at the optimum ratio (65,101). In one particular instance the introduction of 20 cattle on 300 acres of hill caused the existing sheep flock to thrive considerably better than before and greatly reduced the need for burning which is itself a wasteful process (101,27). Areas of Moor Mat Grass dominant land can gradually be changed to Bent dominance by the tearing action of the grazing cattle as Moor Mat Grass is slow to recover from defoliation. (101)

USE OF FERTILISERS

The improving action of the grazing animal can be greatly assisted by the correct application of fertilisers, a significant increase in the yield of the native herbage being obtained by applying lime, phosphate and general fertilisers (20), phosphate and lime are the most important. Farmyard manure can also be used to great advantage (101). Lime, nitrogen and potash have little beneficial effect in the absence of phosphate.

A high rate of lime application improves the soil condition but is not of great agronomic advantage (84) and it has been suggested that between 1 and 4 cwts. per acre of lime may be sufficient for improvement purposes. (89)

The application of fertilisers alone or combined with grazing can radically alter the composition of a hill sward. A Flying Bent dominant sward can be changed to a Bent/Fescue dominant one within three years by grazing and manuring (96) and in Norway a Bent/Moor Mat Grass mixture has over fifteen years been changed to:- 10% Common Bent, 20% Tufted Hair Grass, 10% Clover, 10% Alpine Cat's Tail/Fescue/Meadow Grass, 20% Lady's Mantle by the application of superphosphate, fertilisers and nitrate of lime. (71) The change in sward content is brought about partly by the encouragement of volunteer plants of useful species (20) and partly by the suppressive effect of the fertilisers on certain less useful species. Heather, bent and particularly Moor Mat Grass tend to be suppressed in this way, (84) and thus to leave room for more nutritious plants. Even when a sward is already of a Bent/Fescue type it will pay to fertilise it as volunteer establishment will occur (20) and furthermore under general fertiliser treatment this class of sward can double its yield whereas any Moor Mat Grass present will tend to be suppressed as mentioned above. (80)

FLUSHING

The areas of ground watered by hill springs are invariably greener and more closely grazed than the surrounding hill. This is because of the beneficial effect which the passage of water between pH 6.5 and 7.5 has on these areas. On studying such portions of the hill it has been found that the herbage contains Meadow Grasses, Fescues, Bents, and Yorkshire Fog, all these being considerably more useful grasses than the Moor Mat Grass and Wary Hair Grass which make up the surrounding Moor. (87)

The deliberate flushing of sections of hill by diverting spring water has been successfully carried out. (53) The first result was an improvement in the existing sward and this was followed by a change in composition towards broad-leaved grasses coupled with the disappearance of Moor Mat Grass.

Under suitable conditions flushing can be more effective than manuring and though of limited application it can have much to commend it in the way of cheapness. (87,53)

BURNING

Burning of hill pastures is an age-old practice and if not carried out properly can cause steady degeneration of the grazing, especially in the case of Heather moors. (69) The Burning-off of grassland moor is also wasteful as any herbage thus destroyed can never be converted into productive material by the animal.(27) However, as a pre-treatment to surface-seeding burning can be most advantageous as establishment can occur a year sooner than would be the case if burning were not carried out. (10) When heather is burned on peat this decreases the acidity and renders more nitrogen and phosphate available. (83)

SURFACE-SEEDING

This process can be carried out quite readily on an open type of sward such as a heather moor provided sufficient lime and phosphate is present. (44,46,45,23) If seed is sown thus, without cultivation, some form of consolidation is a great asset. This can be achieved by turning stock onto the area to allow the trampling action of their hooves to cover the seed and press it into the ground. (46,43)

If sufficient calcium and phosphate is available, white clover can be established on its own in a rough sward without mechanical aid.(95)

But the sowing of a seedsmixture as such, requires either the open heather type of conditions mentioned above or some form of cultivation. Moisture is a critical factor in surface seeding therefore these operations should be carried out in July which has, on average, a high rainfall. (46,45)

Heavy Harrowing or ripping of the sward is necessary when a seedsmixture containing grasses is to be sown into a grassy sward. (45,46,44,55) Disc or pitchpole harrows can be used alone or in combination with burning, (55) the degree of toughness of the surface mat determining the number of passes which will have to be made before some form of seedbed is achieved. The presence of lime for some time before cultivations start will accelerate the breakdown of the mat as will the sowing of White Clover by itself. (97)

CULTIVATIONS and MACHINERY.

More drastic forms of surface treatment than heavy harrowing, e.g. ploughing or rotovation can be used to give satisfactory seed establishment. Much depends on the environmental and climatic conditions as to whether ploughing or surface cultivation will be more successful. One experiment (85) gives both methods as being equally satisfactory, but in another case (52) harrowing has practically no success and ploughing is advocated wherever possible.

Rotovation is particularly useful on peat land where it should be followed by heavy rolling to prevent the formation of a puffy seed-bed. (83) Rotovation can also be of use when a mixing of strata is desirable and has been used for this purpose, in conjunction with subsoiling in Holland. (102)

The breaking up of the mat in a mineral type soil can leave large chunks of this mat on the surface of the soil and these will greatly hinder the proper and easy formation of a seedbed.

This problem can be overcome in a dry season by collecting this debris with a machine such as a tractor mounted road sweeper and burning it. (49) Burning can also be used advantageously as a precursor to any form of cultivation as it reduces the amount of vegetation to be disposed of. (49) It should, if possible, be done twice.

Ploughing and direct reseeding or seeding after a pioneer crop has been used successfully as an improvement technique on much of the more amenable hill land. In shallow peat it can mix the sandy subsoil with the surface layer to give a much improved soil. (88) Alternatively a stratum of well decomposed peat can be turned up which may prove easier to work. (75) A great improvement in soil structure and texture is obtained if the ground is ploughed in early autumn and left to weather over the winter. (6)

On certain soils, however, the passage of the plough sole can seal off the innumerable cracks which allow of good drainage. This causes water-logging and is the reason why ploughed hill or marginal land quite often reverts to a rushy and poorly drained state, no better, in fact than it was originally. (13)

Reseeding after ploughing can be done after a pioneer crop of Rape/ Italian Ryegrass or something similar. (32) Whether or not the pioneer crop is used depends on the type of land. If it is in very poor heart the pioneer crop can be grazed off and this gives an extra season in which to build up fertility. The pioneer crop can also act as a nurse for the seedsmixture in which case the consolidation effect of the grazing animal is invaluable.

SOD SEEDING

Seed can be introduced to a pasture by sod-seeding. This technique was developed in New Zealand and consists of drilling seed at 8-9 inch intervals into slits cut in the ground by coulters of some form, (33,36)

This may work alright in New Zealand but on the tougher British Soil it is not of much use (54) as any gap made in the soil soon grows over and the young seedlings are smothered.

Welsh trials with a 10 inch spacing and a combined skim and disc coulter leaving a furrow 2-4 in. wide have been somewhat more successful, (99) the combined coulter being better at cutting the mat. In Scotland a Cuthbertson machine has been developed with 2 discs which cut out furrows 4 inches wide by 2 inches deep some 3 feet apart, (51) this greater distance apart being necessary to allow the displaced furrow to fall well clear. Good clover establishment is obtained by this method but the plants show a reluctance to spread from the furrow due to its depth.

FORAGE HARVESTER

A flail type forage harvester can make a useful pasture improvement implement. If rough pastures are regularly mowed with one a change in botanical composition and habit of growth will occur. (8) Tall rough plants are eliminated and a close-knit sward with a higher percentage of White Clover is encouraged. When used in combination with fertilisers and surface seeding a great improvement can be brought about. The debris from the machine serves as a cover for the germinating seeds. If the harvester is set low enough a certain amount of bare ground will result, on which seedlings can usually establish well. (8) In fact seeds sown on an area treated by a harvester and covered in debris established as well as those on a rotary cultivated area. (34) The use of the harvester does not mean that animals need be kept off the area - on the contrary, controlled grazing can again be an important contributory factor to the improvement. (8)

SEED VARIETIES AND SOWING TIME.

Many types of seedsmixture have been used in hill pastures improvement and they can be roughly divided as follows:-

1) Pure Clover

2) Seed cleanings at high rates

3) Seedsmixtures of non-ley type

4) Cockle Park type mixtures frequently containing bred strains.

1) Clovers only It is usually quite easy to establish clover alone in a hill sward without mechanical aids provided there is sufficient phosphate present. (51, 95). This is due to the heavier clover seed penetrating the vegetation on the surface and coming to rest in a moist situation which is not too prone to dry out. It is interesting to note that under some conditions (94) it has been found easier to establish Alsike Clover and it was suggested that the less persistant Alsike be sown first to provide the necessary bacteria for the White Clover.

2) Seed Cleanings The use of seed cleanings - primarily from Ryegrass - has proved a cheap and effective method of establishing an improved sward. The cleanings are applied at a high rate of up to 100 lbs/acre (43) and animals are allowed access from the time of sowing. Slag is essential and on skinned heather ground a tenfold increase in productivity has been achieved by this method. (43)

3) Seedsmixtures of Non-ley type This means mixtures of seeds which are not normal constituents of a low ground ley, or if they are, they are not usually sown at the rates used on the hill. Yorkshire Fog, Crested Dogstail and Rough Stalked Meadow Grass are all used. (93, 9) Yorkshire Fog is easy to establish and though of low palatability it is still a great improvement/

on most natural hill swards, Red Fescue is much the same. (9) Rough Stalked Meadow Grass does well especially on moist areas and is quite a palatable and nutritious grass. (9) The addition of various herbs such as Ribgrass, Daisy, Dandelion, Hawkweed, and Buttercup has been suggested (93) but in any improvement scheme such plants would appear in any case as volunteer colonisers.

Cockle Park type mixtures and bred strains. There is little real division between this and the previous section as mixtures containing both types of seed are often sown. Bred strains of grass are much more expensive, therefore it can be difficult to justify their inclusion in a mixture for hill land on grounds of economics. Some authorities, however, maintain that only the best of grasses should be used (46) but with certain grasses e.g. Rye-grass this would mean the maintenance of a very high standard of fertility. Many of the better strains of grasses do well on the hill notably S 50 Timothy, Cocksfoot, Meadow Fescue and in some areas, Italian and Perennial Rye-grass. (9,11,86,58) When good quality seeds are used the standard of the pasture must be maintained by the regular use of fertilisers and this envisages the upgrading of hill land to ley standard.

Time of Sowing.

Clover on its own can be sown at any time of year with very little difference in establishment between dates. (51) When grass seeds are sown as well, however, certain times are more suitable. Sowing at the end of June is recommended by some as July is almost always a wet month, (45,51) but successful establishment has also been achieved with mid-May to mid-September sowings. (9) When sowing seed cleanings in open ground 1 month before normal sowing time has been proved the most successful. This is because the seedlings have a chance to establish before competition from the native herbage starts.

BRACKEN

Much of the better class hill land is rendered virtually unavailable for grazing due to its dense cover of Bracken which favours good well-drained soil.

On ploughable land adequate control can be had by deep ploughing followed by heavy discing. A pioneer crop of Rape/Italian Ryegrass or similar mixture can then be sown in conjunction with a good fertiliser dressing and followed by rolling. The land can then be re-seeded the following year to a pasture mixture.(70) If the land is unploughable reasonable control is also achieved by cutting, slashing or bruising the fronds just before full frond development. This treatment must be carried out twice a year as new fronds grow after the earlier treatment and it must be continued for at least three years. Heavy stocking by Cattle also helps eradiction - due to the trampling action of their hooves. This can be used alone for several years on an intensive scale or in conjunction with some form of mechanical frond destruction.(70)

Herbicidal controls of Bracken are being developed with a certain degree of success. For maximum kill, spraying should take place just after full frond unrolling.

Aminotriazole and 4 - CPA both give successful control under some conditions but under others they can be a complete failure. (100,60) A new chemical called Tordon has shown itself to be successful but is, as yet, under trial and further results are awaited.

WHINS.

Whins can be controlled on the hill by grubbing out and burning followed by cultivations and oversowing. Deep ploughing is also successful and the area should be stocked heavily to prevent regrowth. (16,1)

Chemical control can be achieved by spraying with 2,4,5 - T in summer with a second spray some 2 months later if necessary to ensure a complete kill.(1,78)

HERBICIDES

Within the last 15 years or so herbicides have been introduced as a tool in hill pasture improvement. The following points have been proposed as advantages. (68)

1) Quick kill of old sward

2) Nutrients are available from dead litter

3) The seedbed is well consolidated

4) Seedlings are protected by the dead litter

5) Erosion risk is reduced

6) Weed invasion is reduced.

7) Fertility is undisturbed

8) Spraying can almost always be done, even on steep and rocky ground.

In 1943 Calcium Cyanamide was used as a herbicidal pasture improvement agent at 10 - 15 cwt/acre. When left over the winter it killed off the vegetation and its breakdown products had a fertilizing effect on a newly sown sward. This work does not seem to have been followed up. (12)

TCA. and 2,4-D.

The above chemicals, alone or in combination were the first modern herbicides to be used in sward improvement. 2,4-D used alone causes reduction in the herb and legume content of a pasture and an increase in the grass content results, particularly in the bent/fescue fraction. (73) Some time after the initial treatment the legume content of the sward will recover.

TCA has proved to be useful in the United States as an aid to grass establishment in worn out permanent pastures. It is sprayed in spring - alone or with Sodium Arsenate - and the area is disced and seeded to a new seeds-mixture.

(Sodium Arsenate is not now a permitted herbicide in this country). The number of discings required as compared with an unsprayed control is greatly reduced as is the regrowth of old material. (91) There has been observed, however, a considerable residual effect by TCA, especially on clovers, both in this country and in New Zealand. (19,67)

Dalapon.

This chemical has frequently been used for the destruction or checking of hill pastures in preparation for cultivation or seeding and also as a selective.

Hunter (56) suggests it may be used -

1) At a rate to suppress selectively Moor Mat Grass in a Moor Mat Grass/ Wavy Hair Grass/Bent sward.

2) At 5 lb per acre to suppress Moor Mat Grass and Flying Bent with the addition of lime and phosphate.

3) For complete kill followed by fertilisers and oversowing.

Other workers agree and 2-2.5 lb/acre for 1) and 20 lb/acre for 3) have been suggested. (40)

The effect of Dalapon on a sward varies with the time of year and the constituent grasses. It has been suggested that Moor Mat Grass may be reduced by $1\frac{1}{2}$ lb/acre (61) and it can definitely be controlled by less than 5 lb/acre. Between 5 and 7 lb/acre gives control of Flying Bent, Tufted Hair Grass and Rushes. (63,30) Sheeps Fescue and Common Bent are more resistant than the above requiring 5 - 10 lb/acre (30,63) and the fescue would be unaffected by a 3 lb/acre dose put on to kill out the Moor Mat Grass. (42)

If total kill were required as distinct from the selective effect demonstrated above 7.5 lb/acre would be a minimum dose.

Some plants are highly resistant even at rates up to 15 lb/acre e.g. Yorkshire Fog, Creeping Softgrass, Wavy Hair Grass, Sedges, Mosses, Heather, Blaeberry, Bedstraw, Tormentil and Sweet Vernal. (30,22) Not many of these, however, would form major constituents of a grassy hill sward. The susceptibility of some species varies with the time of spraying, Common Bent being more susceptible in May than in August whereas the opposite is the case with Sheeps Fescue. Moor Mat Grass is equally susceptible at all dates. (22) As an autumn spraying gives time for vegetation to decay it has been advocated in this country as against the New Zealand practice of spraying in the spring.

Treatment after spraying depends on the dosage used. At a high rate Dalapon can reduce greatly the number of cultivations and one pass with a rotovator can give successful seed establishment after spraying. Cultivation with tined implements is sometimes impossible because the dead surface mat tears up in strips and clods. (77)

In a fescue pasture Dalapon treatment has given a better clover establishment than discing though it is not usually necessary to give any herbicidal treatment to help clover establishment. (38) But when a grass/clover seedsmixture is sown into a Dalapon killed sward the grass component shows far more growth than in the untreated control. (26)

The optimum period between spraying and sowing is open to some doubt and is probably dependent on the weather. As little as 10 hours has been used successfully under heavy rainfall conditions and at the opposite extreme 13 weeks has been proved too long. (4,26) The manufacturers suggest 5 to 6 weeks but this does depend on the weather. (81)

Nearly all commercially produced weedkillers contain a wetter of some sort to make the spray spread evenly over the surface of the vegetation and not gather in droplets. This increases the toxicity of a given dosage. The presence or absence of a wetting agent can also alter considerably the selective effect of any herbicide. (35)

In at least one instance it has been found unnecessary to cultivate or sow seed of any kind to gain an improvement. (64) In this particular instance the experimental areas were fertilised and sprayed followed a few weeks later by the surface sowing of a seedsmixture. This failed to establish and on re-inspection the swards (which were originally Moor Mat Grass, Flying Bent and Heather dominant) were found to contain none of the original dominant plants. Bent, Fescue and broad leaved species had greatly increased. The areas were continually grazed during and after treatment, the animals showing a preference for the treated areas, including parts infested with broad leaved weeds.

Dalapon in combination with other weedkillers.

In an effort to prevent the invasion of broad leaved weeds mentioned above Dalapon has been used in combination with 2,4-D and MCPA. These experiments have met with little success. 2,4-D has no effect when added to Dalapon (81,76) and gives very poor control of broad leaves when sprayed separately as they recover from 2,4-D before the grass recovers from Dalapon. (76,48). MCPA does give control of Heath Rush.

Aminotriazole has also been added to Dalapon but at the rate of 1 lb Aminotriazole to 5 lb Dalapon there was no advantage in this country. (22) New Zealand Workers claim that the addition of Aminotriazole will hasten and increase the effect of Dalapon and in America 1 lb/acre Aminotriazole plus

4 lb/acre Dalapon gave a good kill. (90) Cacodylic acid has also been used as an additive in the States but it requires too high a temperature to be effective in this country. (88)

Aminotriazole.

On many grass species this herbicide is of equal toxicity to Dalapon. (39) It kills broad leaved weeds as well as grasses and thus prevents an invasion of these before seed can be established. (3) - hence its use in conjunction with Dalapon. To be fully effective it requires a dry period after spraying. (59)

Paraquat.

This chemical is the latest to be added to the range of those used for hill improvement work. It is reputed to be completely inactivated on reaching the soil and therefore it should not have any residual effect and sowing can take place shortly after spraying. (17,5) Its activity is increased at sub-lethal doses by a Relative Humidity of 80-90 %, and the herbicide works best when sprayed at a time when there is a low rate of incident light on the foliage. (5) Total absorption can take up to three weeks. (25) Paraquat is not very effective against broad leaved weeds.

It is highly effective against Moor Mat Grass and Flying Bent at 2 lb/acre and can achieve a good measure of control of these at $\frac{1}{2}$-1 lb/acre (25,26), Blaeberry is also susceptible. (82) Fescues are initially suppressed but 2 years after spraying there is a good recovery with a consequent swing in the balance of the sward towards the Fescues. (25, 82, 26) Clover is defoliated by the herbicide but will recover within 4 weeks. (47) The ley types of grass e.g. Cocksfoot and Perennial Ryegrass are more resistant to Paraquat. Yorkshire Fog and Bent are quite susceptible. (62)

Rotovation is advocated as the best cultivation following high doses of Paraquat but this depends on the pasture type, the advantage of rotovation being that it breaks up the surface Mat. (18, 25, 29) Surface seeding also gives good establishment after the dead surface herbage has been raked off (26) but it has been found that at lower doses less susceptible plants can smother surface sown seedlings on recovering. (82)

Some work has been done on the comparison of the action of Paraquat and Dalapon as these are the main herbicides used in hill improvement work. Dalapon is more effective in killing native herbage but Paraquat has given a better establishment of sown seed.(7) Dalapon is less toxic to broad leaved plants and is slower in action. Paraquats' quick action means that seeds can be sown at the spraying time and be covered by the dead vegetation. Dalapon therefore shows a slight advantage from surface cultivation as the seeds have to be sown some time after spraying. (62) Paraquat shows the greater degree of selectivity.

MECHANICAL/HERBICIDAL TECHNIQUES.

Sod seeding a grass/clover seedsmixture into a sward previously killed by Paraquat or Dalapon has met with little success. (50) This particular experiment was done on reasonably low-ground pasture and the quick recovery of the pasture is the possible cause of its failure. Rape and Kale were successfully established and this may be a means of sowing a pioneer crop on the hill.

In New Zealand band-spraying with a modified sod seeder has worked on low ground. Paraquat was sprayed in a 2 inch band in front of the disc coulters which were out of action. Establishment did not occur on those drills which were not sprayed.

E X P E R I M E N T A L

Experiment I :

To investigate the effect of paraquat on a hill sward at various dates and rates of spraying with particular reference to the killing of moor mat grass and hence the spread of more desirable species.

Method and Materials :

This experiment was on Castlelaw hill at an elevation of 1,100 ft. The area had been sod-seeded in 1959 with a seeds mixture consisting of white clover, rough stalked meadow grass, smooth stalked meadow grass and S50 timothy.

The drills were some 3 feet apart and establishment within the drills, particularly of the clover, was good. It was hoped to encourage the spread of the clover and, if possible, the other grasses from the drills though the meadow grasses were believed to be fairly susceptible to paraquat. The area had been limed and slagged in 1959.

The experiment was laid out as a 4 x 4 latin square. The main plots were sprayed on each of the dates 21st March 1963, 17th July 1963, 21st September 1963 and 1st December 1963. Each main plot contained 5 sub plots sprayed with 2, 4, 8, 12 and 16 oz. a.i/ac. paraquat and a control. The March spraying was done with an Oxford Precision sprayer at 20lb/sq.in. fitted with Allman no. 0 jets at an application rate of 30 gal./ac. (1 pint/plot).

The July plots had to be sprayed with a watering can and dribble bar at

90 gals/ac. (3pints/plot) as high wind prevented the use of the Oxford, the spray from which drifts very easily. The date originally intended for these plots was mid June but the weather held up the treatment till July. Both September and December sprayings were done with the Vermorel sprayer with the Oxford boom and no. 0 jets at an application rate of 30 gal/ac. (1 pint/plot). This sprayer works at a lower pressure and the spray is therefore less liable to drift. All plots were botanically analysed with a ten point quadrat before spraying.

The plots were analysed with a 10 point quadrat counting the first grass hit and taking ten quadrats per plot. This was done at intervals as the sward recovered. The analyses were carried out on the following dates :

Date of Spraying and original Analysis	Dates of subsequent Analyses
March 1963.	August 1963, May 1964, August 1964.
July 1963.	- May 1964, August 1964.
September 1963.	- - August 1964.
December 1963.	- - August 1964.

Ideally analyses should have been carried out at further dates but lack of time precluded this.

Results /

Results :

The appearance of the plots after spraying and their recovery time varied as follows :

March sprayed plots :

When these plots were sprayed the moor mat grass carried a mass of dead material from the previous year's growth. Thus the lower shoots of the plant were protected from the spray and by April they were showing green. The sheeps fescue had been grazed short previous to spraying and it appeared to be quite dead on all plots in April. As the clover had not been in leaf at the time of spraying it was unaffected and growth had begun in April. The plots recovered slowly and analysis was possible in August 1963. At this stage there was still much dead material in the plots sprayed with 8 oz. ai/acre and more, the greatest amount being in the 16 oz. ai/acre plot. By the second analysis in May 1964 there was considerably less dead material and in August 1964 there was practically none. In appearance all plots were indistinguishable from the control.

July sprayed plots :

These plots were sprayed when the sward was just past its full growth peak. The vegetation was all burned to a uniform brown within two days and by the beginning of September the plots were indistinguishable from the rest of the hill which was quite white owing to the bleached shoots of moor mat grass. The clover was defoliated by the spraying /

spraying but was recovering within 3 weeks. In the spring of 1964 the plots sprayed at 8 oz. or more showed considerable dead patches but these had almost entirely gone by the end of August. The re-growth of these plots took some 4 months less than the regrowth of the March sprayed plots.

September sprayed plots :

All these plots showed a uniform brown colour within a week. After the winter - in April-there was little noticeable difference between plots all appearing very dead. Recovery was slow bearing in mind that it occured during the spring when regrowth would be expected to be at its fastest. By July the plots were still too dead to be worth analysing, the total dead area ranging from 40% at the lowest rate to about 90% in the highest rate. Even in late August when the analysis was actually carried out there was still a very high proportion of dead material visible.

December sprayed plots :

The effect of the paraquat on this series did not really seem to be felt till the spring as the plots did not develop the typical light brown colour till March. In April there was again little difference between rates as the kill in all appeared to be at least 80%. In July these plots presented much the same appearance as those sprayed in September, though not quite so dead looking. When analysed in August /

Plate 1. experiment I. General view in July 1964 showing September and December plots still affected.

Plate 2.. Experiment I. July 1964 view of the September 1963 sprayed plots from left to right 16, 4 and 12 oz/acre.

Plate 3. Experiment I. Contrast between control and 16 oz/acre of September sprayed plots in July 1964.

August there was still a very high percentage of dead material. These plots were in August even more noticeably less dead than the corresponding plots sprayed in September. This would probably be due to the fact that the dead surface grass protected the growing points and did not absorb the weed killer.

In both the December and September sprayed plots at the higher rates the sod seeded strips showed up as a strong green against the surrounding dead vegetation, the rough stalked meadow grass being particularly noticeable. This could be due to the protective effect of the longer native grass overhanging the drills at the time of spraying or to the rhizomatous and stoloniferous habits of the meadow grasses and clover which were sown.

The results of the botanical analyses of the sward are given in the following tables. Only the figures for the 2 dominant species viz. moor mat grass and sheeps fescue and also for the sown species have been given. The figures for dead material a nd bare ground are also shown to indicate the degree of recovery of the various treatments at the time of the last reading. These figures are in strikes per 100 and show the interaction between rate of application and date of spraying in August/September 1964. Treatments are given in oz. a.i./ acre.

Table 1 SHEEPS FESCUE

	Treatment							
Date of Spraying	Control	2	4	8	12	16	Mean	S.E.M.
March	30.0	32.0	24.7	27.7	31.3	23.7	28.3	
July	31.3	46.5	54.0	56.7	59.5	66.0	52.3	±2.6
September	34.7	39.5	43.7	32.0	24.3	15.5	31.6	Sig at 0.1%
December	30.0	14.5	14.3	11.7	10.0	6.3	15.3	
Mean	31.5	34.4	34.2	32.1	31.3	27.9		
S.E.M.			± 1.5	Sig. 5%	(Date x Rate	Sig at 0.1%)		

Table 2 MOOR MAT GRASS

	Treatment							
Date of Spraying	Control	2	4	8	12	16	Mean	S.E.M.
March	33.3	36.0	48.0	39.7	36.0	40.5	38.9	
July	39.0	27.7	22.5	12.7	9.5	4.0	19.3	
September	37.5	26.7	12.3	12.7	4.0	5.0	16.4	±5.1 N.S.
December	34.5	40.3	33.0	25.3	20.7	17.3	29.3	
Mean	37.3	32.7	28.9	22.6	17.6	16.7		
S.E.M.			± 1.0	Sig 0.1%	Date x Rate	Sig at 0.1%)		

Table 3 BARE GROUND or DEAD

	Treatment							
Date of Treatment	Control	2	4	8	12	16	Mean	S.E.M.
March	1.0	0.3	1.5	1.3	2.0	3.7	1.6	
July	1.0	1.0	1.3	6.0	7.5	9.3	4.3	±2.0
September	0.7	7.0	12.7	30.3	43.5	51.3	24.3	H.S.
December	0.3	9.7	12.3	17.5	27.5	41.0	18.0	
Mean	0.7	4.5	6.9	13.8	20.1	26.3		
S.E.M.				±1.3	Sig 0.1%	(Date x Rate	Sig at 0.1%)	

Table 4 WHITE CLOVER

Date of Treatment	Treatment: Control	2	4	8	12	16	Mean	S.E.M.
March	11.5	8.7	8.7	10.7	9.0	8.7	9.6	
July	6.7	9.3	3.5	8.7	5.3	7.5	6.8	±1.3
September	6.0	4.7	6.0	1.3	3.0	3.0	4.0	N.S.
December	9.7	8.7	8.5	10.3	11.3	6.7	9.2	
Mean	8.5	7.9	6.7	7.8	7.1	6.5		
S.E.M.			±1.1 N.S. (Date x Rate N.S.)					

Table 5 SMOOTH STALKED MEADOW GRASS

Date of Treatment	Treatment: Control	2	4	8	12	16	Mean	S.E.M.
March	6.5	5.3	4.0	1.5	2.7	4.3	4.0	
July	7.3	4.3	4.0	6.7	7.5	5.0	5.8	±0.7
September	7.7	8.0	4.0	3.5	3.5	3.0	5.0	N.S.
December	6.5	4.5	9.7	8.7	3.5	4.3	6.2	
Mean	7.0	5.5	5.4	5.1	4.3	4.1		
S.E.M.			±0.8 N.S. (Date x Rate N.S.)					

Table 6 ROUGH STALKED MEADOW GRASS

Date of Treatment	Treatment: Control	2	4	8	12	16	Mean	S.E.M.
March	3.0	3.3	2.0	3.0	3.5	3.5	3.0	
July	4.3	3.0	5.3	1.3	2.5	1.0	2.9	±1.7
September	1.3	2.0	4.0	8.5	10.3	9.0	5.8	N.S.
December	2.0	4.3	6.0	8.3	5.5	8.3	5.7	
Mean	2.6	3.1	4.3	5.3	5.4	5.4		
S.E.M.			±0.9 N.S. (Date x Rate Sig. at 5%)					

The figures for moor mat grass and sheeps fescue show the most interesting changes particularly in the July sprayings. The moor mat grass is highly susceptible at this rate and the fescue is highly resistant with the result that the fescue increases as the mat grass decreases.

The last two sprayings are incomplete in respect of their records as they were still about 50% dead at the time the last readings were taken. At least another year will be necessary before these plots reach stability and the species which will recover first and fill in the dead areas cannot be foretold.

The greater dead ground in the September sprayings as compared with December is due to the sward being more dormant at the latter date.

The hoped for increase in the sown species has not occured to any great extent though there is a chance that this may yet occur in the September series.

The full figures for the analysis are given in the Appendix and from these it can be seen that there is a slight increase in the herb content of the March sprayed plots. The susceptibility of moor mat grass and sheeps fescue seems to be highly dependant on the date of spraying and at no rate in the July spraying was the fescue reduced.

Experiment II :

To investigate the effects of several herbicides on the establishment of a seeds mixture and of white clover alone in a hill sward after treatment with a forage harvester.

Method and Materials :

The site was on a slightly sloping area on Castlelaw hill at an altitude of 1,300 ft. The soil is peaty with a surface mat and the pH was 5.8, available potash was 289 lbs/ac. and available phosphate 16 lbs/ac. The lime required to raise the pH to 6.5 was 55 cwt. Calcium Carbonate per acre. The area is not very well drained and is soggy during and for a long time after rainfall. It is exposed to the south west wind.

On 15th May 1963 half an acre on this site was mowed with a flail type forage harvester set close.

The sward was mainly moor mat grass and sheeps fescue but also contained heath rush, heather, blaeberry and carnation grass. During the subsequent week the surface debris was raked into heaps and carried off.

On 5th June 1½ tons of ground limestone were spread on the area with a tractor and manure spinner i.e. at a rate of 3 tons/acre.

On 8th June paraquat was sprayed on 2 x 10 yd. plots at ½, 1, 1½ and 2lb a.i/acre with an Oxford Precision sprayer fitted with no. 0 jets. The application rate was 30 gals. per acre (1 pint per plot) and 4 replicates were sprayed, the plots being randomised within replicates.

On 10th June the following three herbicides were sprayed by the same means at the stated rates :

dalapon /

dalapon 3, 6 and 9lb a.i/acre.

Dalacide at 3.6, 7.2 and 10.8lb a.i/acre.

amitrole at 2, 4 and 6lb a.i/acre.

On 24th June 12cwt. of 12% basic slag were spread by tractor and spinner i.e. at a rate of 24 cwts./acre.

Six weeks after spraying, i.e. on 17th July, the seeding was carried out the seed being sown on the surface without any form of cultivation. It had originally been intended to sow the paraquat treated plots immediately after spraying but delay in obtaining some of the seed prevented this. The other plots were sown at this date to allow the residual effect to disappear. It is also advantageous to sow in July as it is nearly always a wet month and this will aid establishment.

For ease in sowing the replicates were split across the middle and clover was sown in one half and the seeds mixture in the other. The clover was sown at a rate of 4lb/acre, this being made up of 2lb/acre S100 and 2lb/acre Kent Wild White. The use of Kent Wild White alone would have been uneconomic under full scale conditions. The seeds mixture was made up of the following :

	lb/ac
S100 white clover - - - -	2
Kent wild white clover - - -	2
S50 timothy - - - -	4
Rough stalked meadow grass - -	2

The two grasses were chosen as they are palatable and apparently fairly easy to establish on the hill.

At /

At the beginning of September a clover count was carried out on all plots, there being insufficient grass seed germinated to show up in a count. The number of plants within a 6 inch square quadrat was recorded. The plots were visually divided into 10 sub-plots of 2yd. x 1 yd. and each throw of the quadrat was at random within one of these i.e. 10 throws were made per plot. Counts were again taken in June 1964 and this time the timothy and rough stalked meadow grass were included as they were now quite visible.

Results :

By the beginning of August 1963 the plots all showed signs of treatment. The two highest doses of paraquat were dead except for some sedges which are immune to this herbicide. The two lower rates showed a very high degree of kill. Clover plants had just started to germinate at this stage and they were rather exposed on the high rate plots. The other plots did not present such a dead appearance. The degree of kill was related to the dosage but the highest rates of dalapon and Dalacide were never so dead as the paraquat ones. The amitrole plots were even less killed. The kill on the dalapon, Dalacide and amitrole plots also took much longer to develop and, though the initial kill was related to the dosage, in the later stages of recovery i.e. in late autumn and early the following spring, it was hard to differentiate between the various rates by their appearance.

In the spring the regrowth on the paraquat plots was greater than on the other three treatments. By September the control plot was indistinguishable from the two lower rates i.e. $\frac{1}{2}$ and 1lb/acre. The $1\frac{1}{2}$lb/acre plot /

plot had slightly less moor mat grass and the 2lb/acre slightly less again. There did not appear to have been much selective effect even at the highest rate. There was a little bare ground between small tussocks of moor mat grass and sheeps fescue in the 2lb/acre plot but this was being filled in by the spread of the clover.

The dalapon and Dalacide plots appeared to have reacted similarly. In September 1964 they had no moor mat grass. The fescue on those plots treated with the higher rates was shorter than that in the lower rates and there was slightly more bare ground between the small fescue clumps but this was being filled up very quickly by spreading clover.

The amitrole treated plots at the lower rate were hard to distinguish from the control and there was very little difference between rates. The sward was rather more open than the control and contained more clover but the grasses originally present had all made similar recovery. The sward on the plot treated with the highest rate of amitrole was shorter than the others.

The clover germination counts for September and June and the grass counts for June only are given in the following tables. As there was a great variation in counts between all clover plots the figures for the clover in the seeds mixture have been added to those for the clover only plots. In the dalapon, Dalacide, amitrole series there was no significant difference in establishment between rates so the means of establishment for each herbicide were taken and these have been compared. In the case of paraquat there was a significant difference between rates.

PARAQUAT /

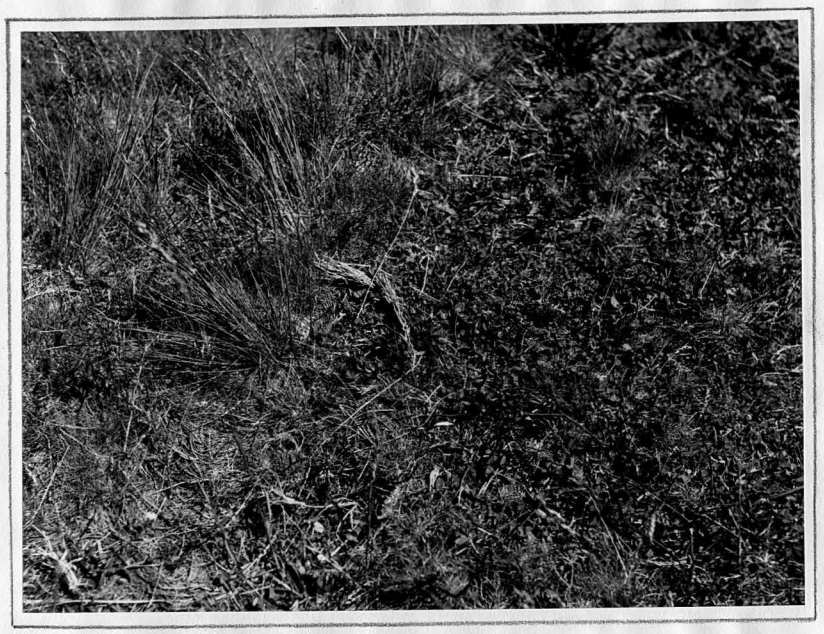


Plate 4. Experiment II. Clover spread on area bared by forage harvester in July 1964.

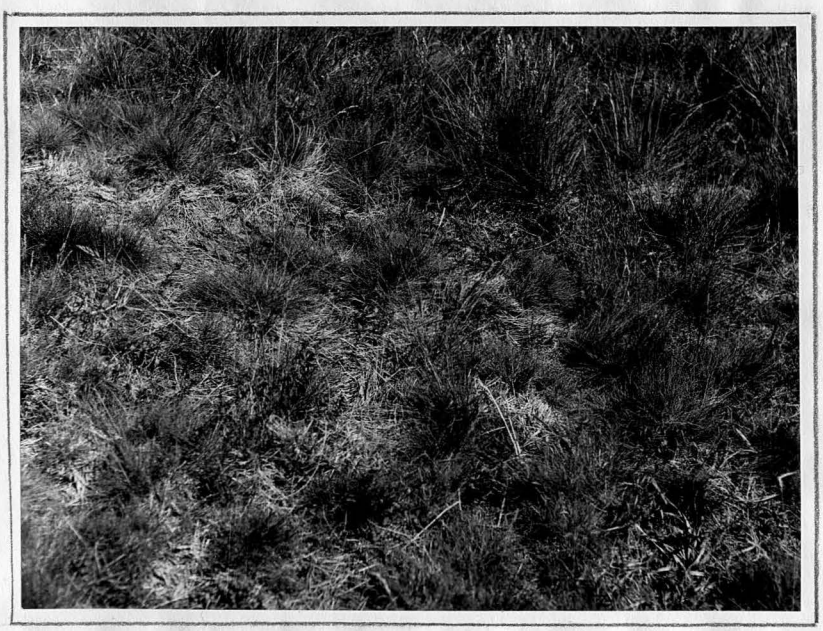


Plate 5. Experiment II. 9lb/acre dalapon plot showing kill of mat grass with fescue left in July 1964. Control plot in background.

Plate 6. Experiment II. establishment of seedsmixture on dalapon sprayed plot in July 1964.

PARAQUAT SERIES

No. of Seedlings per sq. yd.

Table 7

Rate (lb. a.i/ac.)	½	1	1½	2	Control	S.E.M.	
White clover (September 1963) -	81.5	63.0	92.5	91.0	23.0	± 13.3	sig. at 1%
White clover (June 1964) -	24.0	32.0	49.5	54.0	17.0	± 6.5	sig. at 1%
Rough stalked meadow grass (June 1964)	34.0	30.0	55.0	54.0	10.0	± 13.9	NS
Timothy (June 1964)	28.0	36.0	48.0	29.0	12.0	± 8.6	NS

DALAPON /

DALAPON, DALACIDE, AMITROLE SERIES

No. of Seedlings per sq. yd.

Table 8

Treatment (Rates in lb.a.i/ac)	Dalapon 3	Dalapon 6	Dalapon 9	Dalacide 3.6	Dalacide 7.2	Dalacide 10.8	Amitrole 2	Amitrole 4	Amitrole 6	Control	S.E.M.	
White Clover (September 1963)	65.5	86	75.5	101.5	79.0	97.0	81.5	43.0	82.0	50.5	± 11.3	Sig at 1%
Means -		75.7			93.5			68.8				
White Clover (June 1964)	43.0	42.0	43.0	18.5	37.0	53.2	37.0	20.5	30.0	21.0	± 10.0	Sig at 5%
Means -		42.7			35.9			29.2				
Rough stalked meadow grass (June 1964)	47.0	79.0	63.0	42.0	49.0	91.0	59.0	71.0	75.0	14.0	± 17.5	NS
Means -		63.0			60.7			68.3				
Timothy (June 1964)	19.0	45.0	50.0	25.0	48.0	45.0	18.0	31.0	16.0	7.0	± 7.7	Sig at 1%
Means -		38.0			39.3			21.7				

In /

In the case of clover paraquat treatment gives a better establishment than the control (which was forage harvested) but by June the lowest rate is not much better than the control though the final establishment increases with the rate of herbicide. With the grass seed there is not a significant difference but all treatments do give a much better establishment than control. With both grasses the 1½lb/acre treatment has given the best establishment.

The other three herbicides all give better clover establishment than control. Dalapon and Dalacide give slightly better results than amitrol though the difference is not significant.

The grasses have a rather dissimilar reaction as rough stalked meadow grass establishes consistently with all three herbicides but timothy has a lower establishment with amitrole. Both grasses do very much better with a herbicide than without though this is not shown significantly with rough stalked meadow grass.

The great variation in establishment figures between plots has meant that many of the results which show large differences are not statistically significant. However, very definite trends can be observed.

Experiment III :

An Investigation into the sward killing properties of several weedkillers and their effect on the establishment of clover when used in combination with a forage harvester. Also to investigate the effect of of band spraying with paraquat on the germination of clover.

Method and Materials :

This site was in a well-drained, level piece of ground at 900 ft. on Castlelaw Hill. The soil is a peaty mat overlying a mineral soil. The pH was 5.5 with a lime requirement of 45 cwt. of Calcium Carbonate to raise the pH to 6 and 85 cwt. to raise it to 6.5. The available phosphate was 5lb/acre and the available potash 187lb/acre. The sward was moor mat grass dominant but with a large proportion of sheeps fescue. It also contained sweet vernal, common bent, blaeberry and clumps of moss.

On 15th May 1963, 1/3 acre on this site was mowed with a flail type forage harvester. Most of the clumps of moss were completely removed to leave patches of bare ground. The debris thus formed was raked into windrows and much of it was burned off. On 5th June, 1ton of ground limestone was spread on the area with a tractor and manure spinner (approximately at 3 tons/acre) and on 24th June, 8cwt. of 12% basic slag was spread by the same means (approximately 1 ton/acre).

The area was divided into two, one half being used for the screening trial of herbicides and the other for the band spraying experiment.

Screening /

Screening Trial :

This section was divided into 33 plots each 2yds.x 5yds. and on these plots 11 herbicides were sprayed each at 3 rates. The spraying was done with a watering can and rose at about ½ gal. per plot. The trial was unreplicated and the herbicides and rates were as follows :

Herbicides	Rates		
amitrole/dalapon - -	2lb/acre	5lb/acre	7lb/acre
T.C.A. - - -	5 "	10 "	15 "
sodium 2,2,3 - trichloropropionate	15 "	3 "	5 "
E.P.T.C. - - -	2 "	4 "	6 "
Tillam - - -	.875 "	1.75"	3.5"
Thiuron - - -	.5 "	1 "	2 "
erbon - - -	45 "	75 "	120 "
fenac - - -	5 "	10 "	15 "
sodium monochloracetate -	16 "	15 "	20 "
Trixabon - - -	3 pints	6 pints	9 pints
Stellox C.C. - -	4 pints	8 pints	16 pints

All rates are given in pounds of a.i/ac. except for Trixabon and Stellox C.C. which are in pints of commercial formulation per acre.

Observations were made over the following weeks of the degree of kill of the various plots. On 5th August 1963, 4lb/ac. of white clover seed were sown broadcast on the whole area.

At /

At the beginning of October germination counts were taken of the clover plants by making ten throws with a 6 inch square quadrat per plot, each throw being at random within one of the individual square yards of the plot. As individual plants could no longer be distinguished by July 1964 the clover count was taken by a 10 point quadrat counting the number of strikes per quadrat and taking ten quadrats per plot i.e. counting the clover plants per 100 strikes.

Results :

20 days after spraying 5lb/ac. TCA, 5lb/ac. 2-2-3, trichloropropionate, 15lb/ac. sodium monochloracetate and 20lb/ac. sodium monochloracetate, all showed slight herbicidal burn. Aminotriazole/Dalapon at 2lb/ac. showed rather more burn. 5lb/ac. and 7lb/ac. amitrole/dalapon and all rates of erbon showed quite a severe degree of kill. None of the other plots appeared to be affected.

By the beginning of August the grass only in the 10lb/ac. and 15lb/ac. T.C.A. was still affected and in all the amitrole/dalapon plots the grass fraction was killed but there was a noticeable spread of Tormentil. All the erbon plots were quite dead. In September clover could be seen germinating on the bare areas particularly on the erbon plots; this latter however, was soon killed by the re-activation of the herbicide by rain. Continued re-activation kept these plots quite bare till July 1964 when slight recolonisation occured. The amitrole/dalapon plots were also showing some effect in July 1964 but all the others had completely recovered by then.

The /

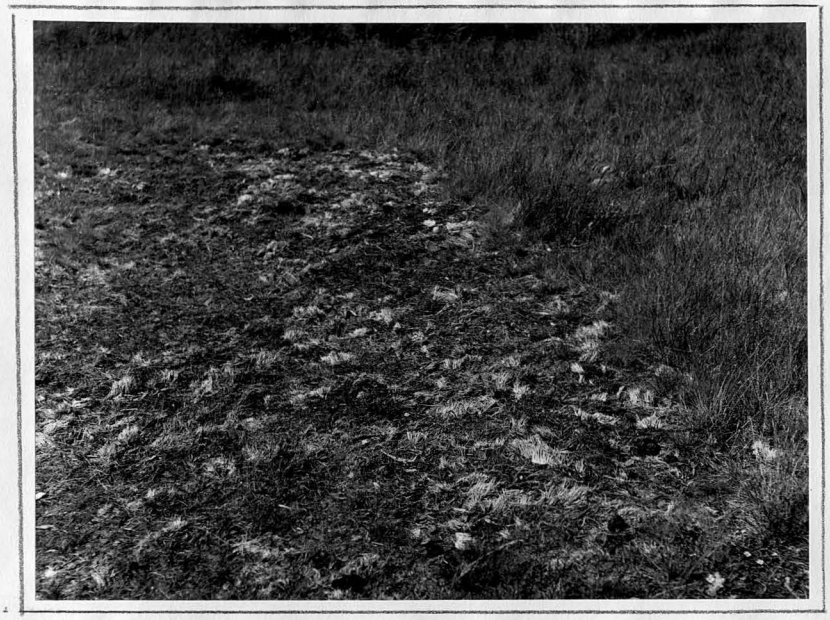


Plate 7. Experiment III. 100% kill on erbon plot in July 1964.

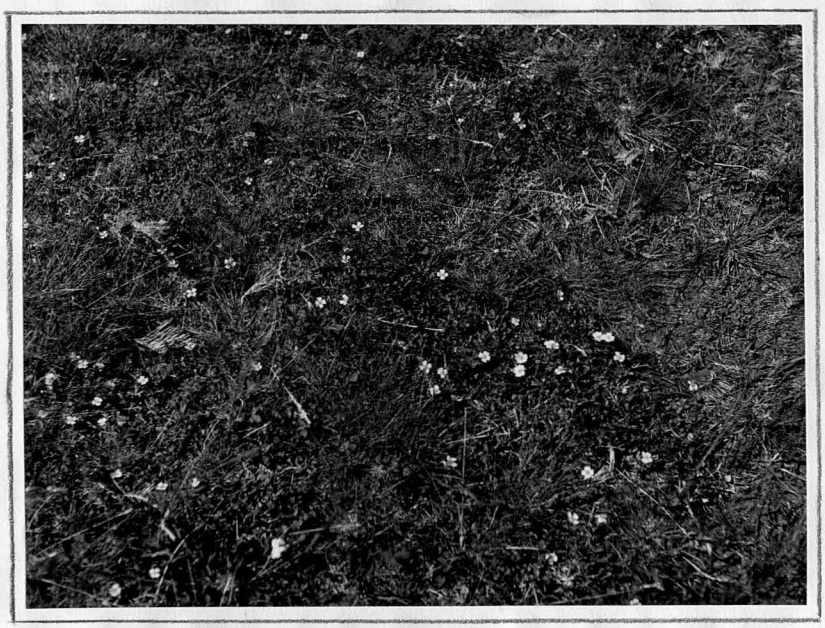


Plate 8 . Experiment III. amitrole/dalapon plots in July 1964 showing reduced vegetation and tormentil invasion.

The clover counts carried out in October and July gave results as follows :

Plot treatment		Clover germination plants/sq. yd. October 1963	Clover counts strikes/100 July 1964
amitrole/dalapon	2lb/ac.	120	18
do.	5lb/ac.	128	13
do.	7lb/ac.	180	25
T.C.A. -	5lb/ac.	164	28
do.	10lb/ac.	128	30
do.	15lb/ac.	112	22
Sodium 2-2-3, trichloropropionate -	1.5lb/ac.	128	15
do.	3lb/ac.	148	14
do.	5lb/ac.	180	14
E.P.T.C. -	2lb/ac.	52	14
do.	4lb/ac.	48	7
do.	6lb/ac.	60	10
Tillam -	.875lb/ac.	36	7
do.	1.75 lb/ac.	76	8
do.	3.5lb/ac.	32	6
Thiuron -	.5lb/ac.	120	17
do.	1lb/ac.	156	17
do.	2lb/ac.	92	9
erbon -	45lb/ac.	72	3
do.	75lb/ac.	4	4
do.	120lb/ac.	0	1

fenac /

Plot treatment		Clover germination plants/sq. yd. October 1963	Clover counts strikes/100 July 1964
Fenac	-	5lb/ac. 84	11
	do.	10lb/ac. 92	4
	do.	15lb/ac. 88	4
sodium monochloracetate		10lb/ac. 42	14
	do.	15lb/ac. 88	13
	do.	20lb/ac. 96	13
Trixabon	-	3 pints/ac. 68	8
	do.	6 pints/ac. 92	11
	do.	9 pints/ac. 84	17
Stellox C.C.		4 pints/ac. 108	12
	do.	8 pints/ac. 168	21
	do.	16 pints/ac. 188	24

The best spread of clover appeared to be on those areas left bare by the forage harvester.

The only herbicides which had any lasting effect - apart from erbon were T.C.A. and the amitrole/dalapon mixture. These both were fairly dead at the time of sowing of the clover and the germination and establishment figures for these two herbicides are the highest. Some of the herbicides such as fenac have had a residual effect. As this is only a screening trial and is unreplicated the results cannot be analysed statistically.

Three /

Three plots which were sown but not sprayed with herbicide gave a germination average of 62.7 and a clover count of 8% - both rather lower than average.

The great variation in results is due most probably to the differing amounts of bare ground left by the forage harvester rather than to any effect by the herbicides.

Band Spraying :

Method and Materials :

An attempt was made to score furrows in the sward with a cultivator to provide a comparison of clover germination and establishment in a furrow and in strips sprayed with herbicide but owing to the surface mat tearing up in large chunks the attempt was abandoned.

On 27th August 1963, 6 strips per plot were sprayed with 2lb/acre a.i. paraquat by means of the Oxford Micro-Sprayer. As the capacity of the sprayer was 200cc this was the application rate per 60ft. strip, the plots being 60ft. long by 7yds. wide. The space between strips was 14ins. and the width of the strips was 4ins. so far as possible, but the roughness of the ground made it difficult to maintain the sprayer at a constant height. The trial was replicated 4 times.

On the following day clover at the rate of 4lb/acre was sown along the sprayed strips which were by then faintly visible as dead areas. 4 control plots were sown in similar strips between the sprayed plots. In October 1963 and July 1964 counts were taken of clover plants on random 1ft. lengths, 1 random foot being taken per 60ft. strip.

Results /

Results :

The dead strips were very prominent by the beginning of September 1963 and were still so in July 1964.

The establishment counts gave the following figures :

	Sprayed	Unsprayed
October 1963 -	54	13
July 1964 -	25	12

Figures are number of plants in the 24 random 1ft. lengths.

The results are not statistically significant but this is due to the experimental layout. Had the strips been arranged at random and not in 4 plots the same result would probably have been obtained but a greater number of degrees of freedom would have allowed a better analysis. It is, however obvious that the initial establishment on the sprayed strips is much better than the unsprayed though there is a very much higher loss over the winter on the sprayed strips.

Experiment IV :

The aim of this experiment was to introduce clover into a clover-free sward which was of a higher standard than the average hill pasture. The residual effect of paraquat was also to be investigated.

Method and Materials :

The site was on sloping ground with a north easterly exposure at an altitude of 750ft. at Newarkburn on the Buccleuch Estates. The area had been limed and slagged in 1956 and was part of a large area which had been enclosed from the open hill. The soil was a mineral type the site being quite well drained but with a few clumps of rushes. The sward was a thick strongly growing one with sheeps fescue and common bent as the main constituents, there was also a good deal of sweet vernal and some herbs.

On 16th July 1963, 4 plots each 2yd x 24yd were sprayed with 2,4,8 and 16oz./ac.a.i. paraquat respectively. The spraying was done with a Vermorel Knapsack sprayer at an application rate of 44gals/acre (i.e. 7 pints/plot). The plots were randomised and an unsprayed control was included. The trial was not replicated.

On the same day 3 strips 3yd. wide were sown with clover at 2,4 and 6lb/ acre across the sprayed plots. An unsown control was included. This gave 5 plots each 3yd x 2yd with a different herbicide rate at each seeding rate of clover.

On 2nd August a further 3 strips were sown with the same rates of clover, another control being included. The time interval was to allow any residual effect to have disappeared.

Results /

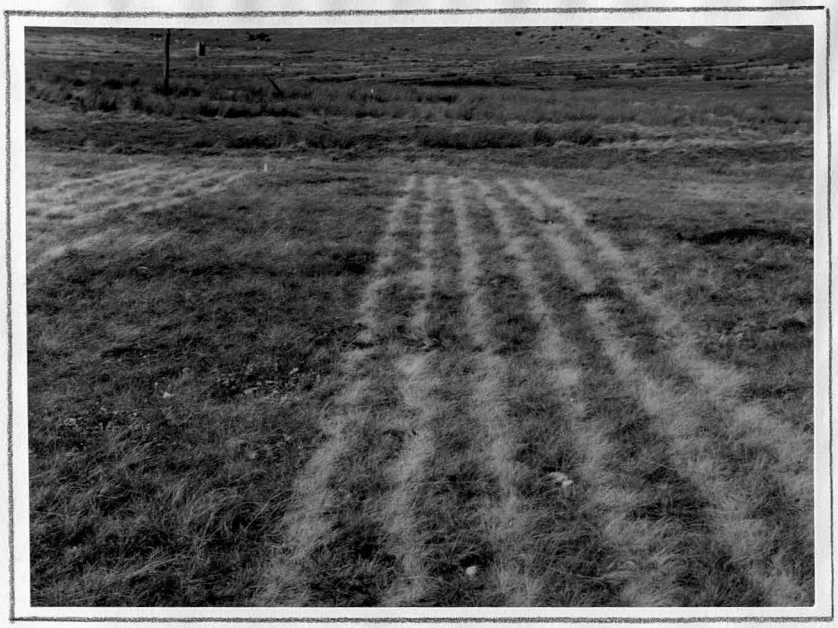


Plate 9. Experiment III. band sprayed strips in September 1963

Plate 10. Experiment III band sprayed strips in July 1964

Results :

At the beginning of August all plots showed severe herbicidal burn and the different rates could hardly be distinguished. By mid September a certain degree of recovery had occured and the kill appeared in proportion to the rates sprayed. Occasional clover plants could be seen at this stage but not enough to show up in any analysis. The following spring, in May 1964, the 8 and 16oz. a.i/acre rates were still showing dead and bare areas, especially the latter. These were particularly noticeable on the wetter areas of the two plots. There were also still a few dead patches showing on the 4oz. a.i/acre plot and though a few more clover plants could be seen they were still insufficient for analysis purposes.

In July 1964 the 8oz and 16oz./acre plots still showed dead patches but only where the plots were flushed by groundwater. The dead patch on the high rate was much larger but this may have had something to do with the ground moisture. Some newly germinated clover plants were visible.

The plots were not inspected again till September 23rd 1964. On this date it was found that the 2 patches of flushed ground on the high rates were still very noticeable, the sward on these areas being short and containing more herbs than the rest of the area. The other parts of these plots and the other plots were indistinguishable from control.

Clover /

Clover had increased considerably over the last two months. It had established at all rates and at both times of sowing. Establishment was noticeably better on the 4,8 and 16oz/acre plots but establishment had occured on the 2oz/acre plot and on the control. Though plants on these last two cases were not present in large numbers those which were there were healthy and good growing specimens which looked capable of further spread.

Clover establishment seemed to be better on the flushed areas of the plots treated with the 2 higher rates of paraquat. This is to be expected with less competition and more moisture. Clover counts would have been possible at least on the 3 high rate plots but time did not allow this to be done.

This experiment did not give the expected results as clover establishment was very slow and rather poor even when it got under way. There seems to have been some sort of interaction between the degree of kill and the amount of surface water present on the two higher rates - at least this is the only obvious explanation for the patchy effect on these plots.

Clover establishment was not accelerated much and the control in the long run will probably contain as much clover as the treated plots.

Experiment V :

This was a screening trial of some herbicides which had not been previously tried for hill improvement work and which, there was reason to believe, might be effective. It also included some herbicides which had just become available.

Method and Materials :

Twelve plots each 2yd x 2yd were sprayed with the following herbicides at these rates on 22nd November 1963 :

Crestol	-	2.5, 5, 7.5, 10 gal/acre.
T.W.-2	-	2.5, 5, 7.5, 10 do.
Fison's P.C.P.		1, 2, 3, 4 do.

All rates are in gallons of commercial formulation per acre. Fison's P.C.P. is 12½% active and Crestol is 15% active cresylic acid. T.W.-2 is a xylenol formulation containing carbamate and 2,4-D derivatives. The plots were sprayed with a watering can and rose at 1gal. per plot. At the date of spraying the vegetation was dead on the surface but as these were contact herbicides sprayed at high volume this was not expected to make too much difference.

In April 1964 the new herbicide Proxan was sprayed on 4 plots 2yd x 15yd each at 3.15lb a.i/ac., 6.31b a.i/ac., 9.45lb a.i/ac. and 12.61b a.i/ac these being equivalent to 1¾, 3½, 5¼ and 7 gals. commercial formulation per acre. The spraying was done with a watering can and dribble bar at 1 gal. per plot.

Both /

Both these experiments showed only very slight signs of kill by June 1964 and as there was reason to believe that the temperature at the time of spraying may have affected the toxicity, the experiments were repeated exactly as before on 11th June.

On 19th June 3 plots, 2yd x 5yd, were sprayed with 1, 2 and 3gal/ac. commercial formulation of TRI-PE using a watering can and rose at about ½ gal. per plot.

On 22nd June 4 plots, 2yd x 5yd, were sprayed by means of the watering can and dribble bar with ½ pint, 1 pint, 2 pints and 4 pints/acre commercial formulation of Preeglone. The application rate was about ½ gallon per plot.

Results :

The plots reacted as follows :

Crestol : No effect at any rate.

T.W.-2 : Showing herbicidal burn by end of June on all rates, greatest burn on highest rate. In September there was only a slight trace of any effect on the highest rate.

Fison's P.C.P. : There was some slight effect at the end of June but this soon disappeared.

Proxan : Showed burn on high doses at end of June but all effect gone by September.

TRI-PE : Slight burn in proportion to rate in June but all effect again gone by September.

Preeglone /

Preeglone : As this is a diquat/paraquat mixture the expected slight brown colour developed very soon after spraying but no very great degree of kill was achieved. There was sufficient at the higher two rates to make them stand out in September as being greener due to the regrowth induced by the initial kill.

None of these showed any potential use for hill improvement work as they had neither a selective effect nor a high degree of kill. Preeglone was the only one with any lasting effect but the related compound paraquat is much more useful.

D I S C U S S I O N

Herbicides can be used in hill pasture improvement in several ways. In the foregoing section they have been used (a) to alter the balance of a sward in favour of more palatable and productive species (b) to kill or check a sward to allow clover or grass seed to be sown and become established without competition from the native sward. For the former purpose low doses of a selective herbicide are used and the date of spraying is important as the effect of a herbicide may vary with the date. For killing or checking a sward a non-selective herbicide is more suitable and the date is only important insofar as the herbicide should be sprayed at a time of optimum toxicity to the sward as a whole. Higher doses of herbicide are often necessary.

The selective effect of paraquat on moor mat grass, sheep's fescue and several sown species.

In experiment I there has been a strong interaction between rate and date of application with both sheep's fescue and moor mat grass. The state of the sward in August/September 1964 is shown in Tables numbered 1 - 6. These results are necessarily incomplete as at least a further year of observations would be required but the state of the sward at that date is now considered.

In the March sprayings the moor mat grass increases up to the 4 oz. rate /

Fig.1.Dosage response of moor mat grass and sheep's fescue to spraying with paraquat in March 1963.

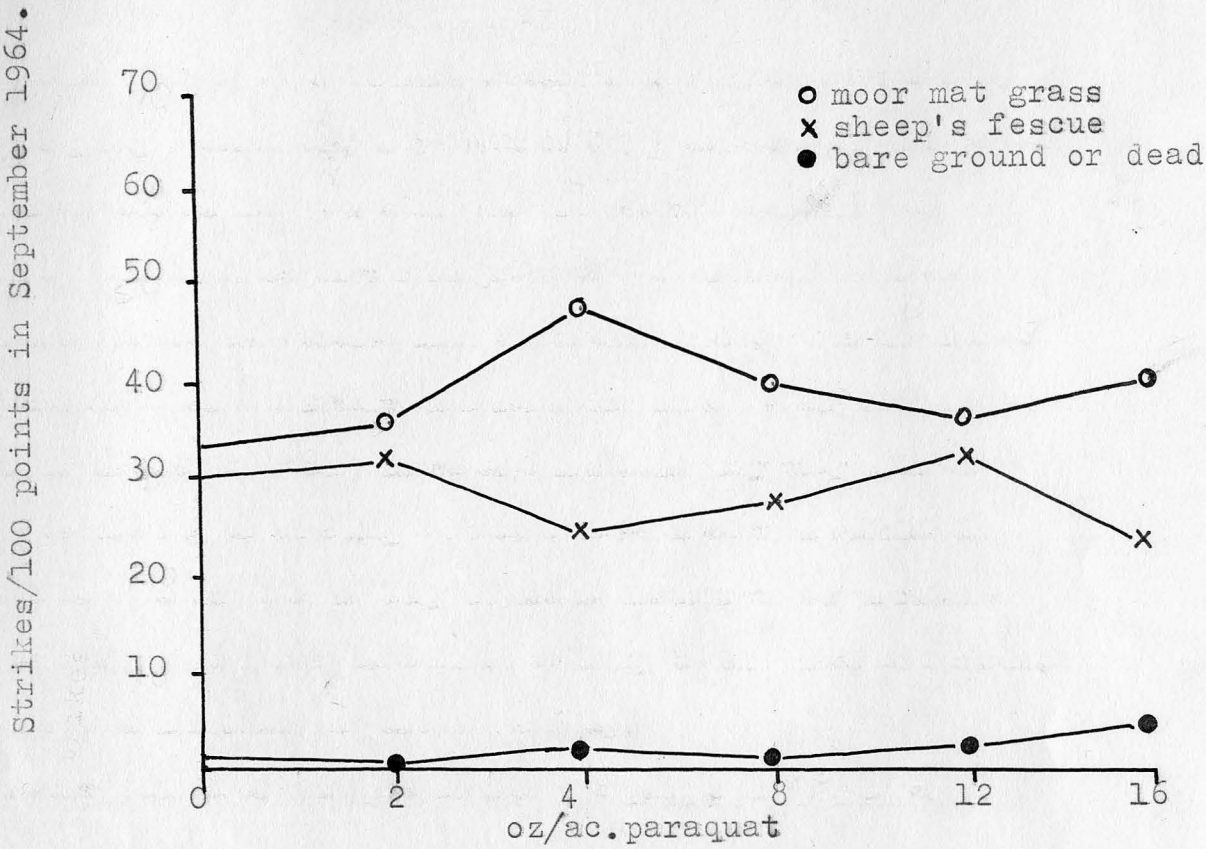


Fig.2.Dosage response of moor mat grass and sheep's fescue to spraying with paraquat in July 1963.

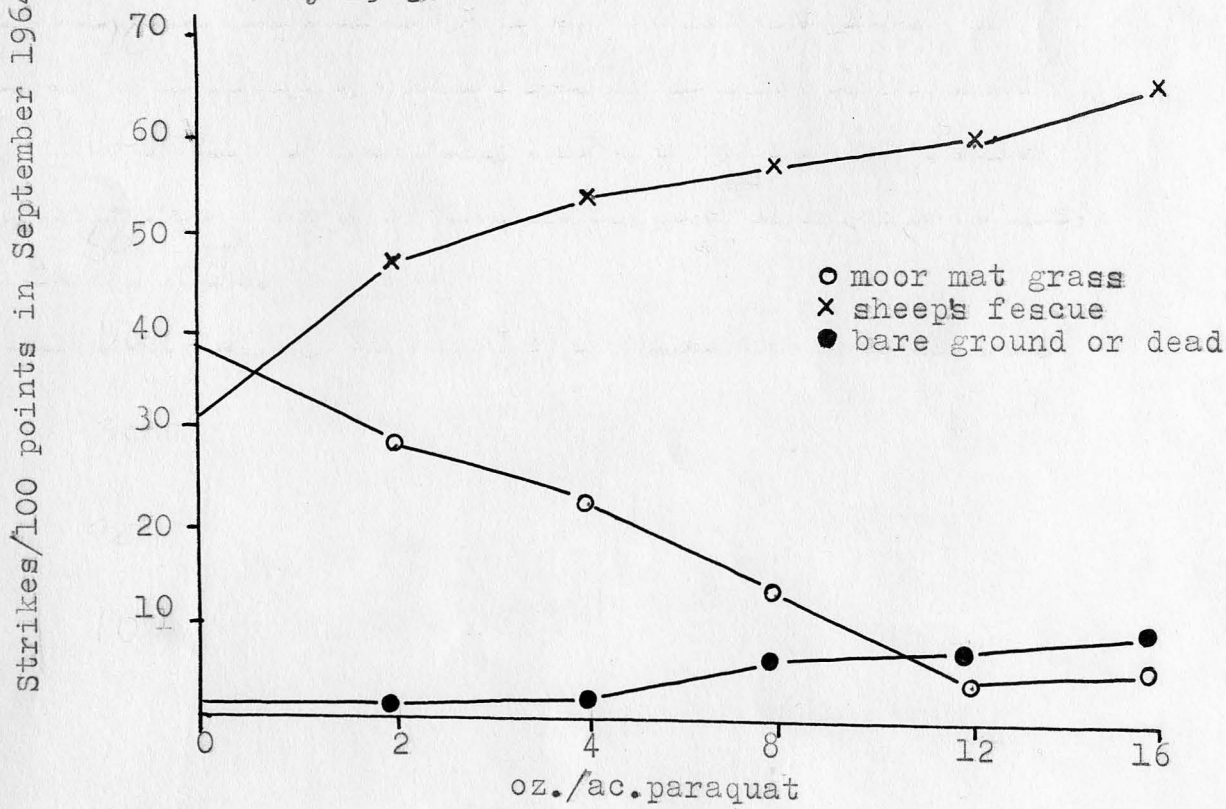


Fig.3.Dosage response of moor matgrass and sheep'sffescue to spraying with paraquat in September 1963.

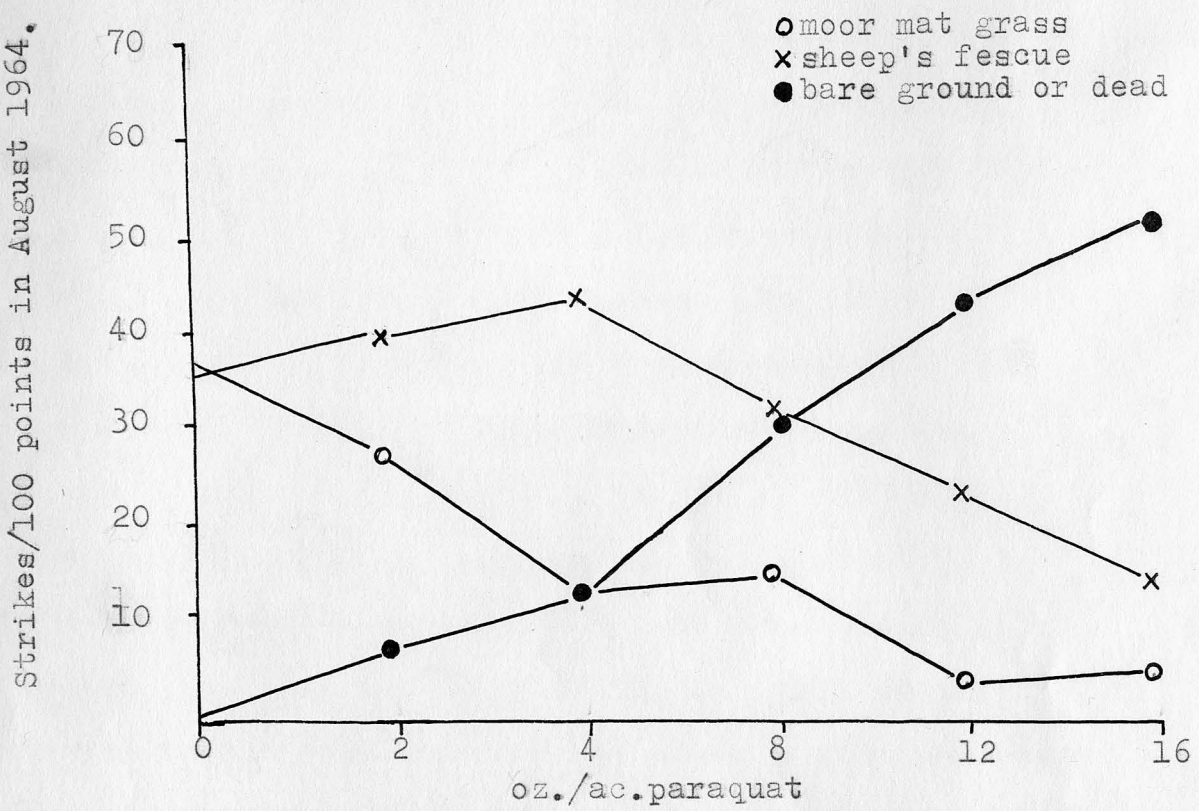
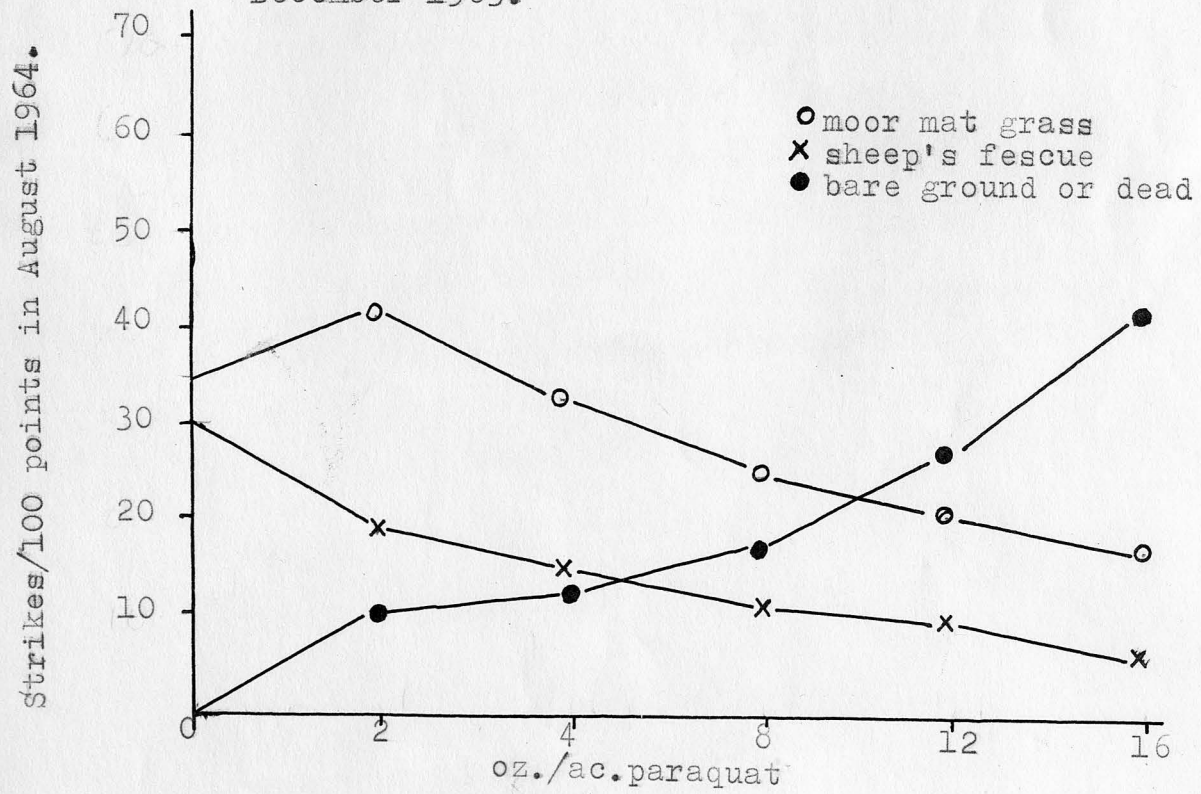


Fig.4.Dosage response of moor mat grass and sheep's fescue to spraying with paraquat in December 1963.



rate (see graph) but then drops ~~somewhat~~ slightly as the higher rates prove more toxic. However all rates have a higher value than control and the species is obviously very resistant to paraquat at this date. There was a considerable amount of dead growth from the previous year present in March and the protection this afforded to the young shoots is at least part of the reason for the resistance. The fescue had been grazed very short and was, therefore, much more exposed to the full effect of the spray. The sheep's fescue shows a drop as the rate increases except at the 2 oz./ac and 12 oz./ac rates. This species is quite susceptible at this stage and moor mat grass increases at its expense as at the highest rate there is only half as much sheep's fescue present as there is moor mat grass; in the control they are approximately equal in cover. Spraying at this date is quite un/satisfactory as far as changing the balance of the sward in favour of the more palatable sheep's fescue is concerned as the major result is a swing in favour of moor mat grass. Recovery was not complete even in these plots as the 16 oz./ac plots had nearly 3% more bare ground than the control.

The July sprayed plots present a very different picture from the above. Moor mat grass drops from 39 strikes/100 in the control to 4 in the 16 oz./ac plot. It is, therefore, very susceptible to paraquat when sprayed in July. All rates from 8 oz./ac upwards give a good control of moor mat grass. Sheep's /

Sheep's fescue has shown a proportionate increase in ground cover from 31 to 66 strikes/100 between control and 16 oz./ac. In this case it is the fescue which is increasing at the expense of the moor mat grass as it is very resistant to spraying at this date. The balance of the sward can, therefore, be advantageously altered in favour of sheep's fescue by spraying with paraquat in July. All doses up to 16 oz./acre give an increase but the difference between the 4 oz. and 12 oz./ac. rate is barely significant. At the rates above 8 oz./ac. there is still between 6% and 10% bare ground and it seems likely that this will be covered by sheep's fescue as the moor mat grass has a very slow rate of vegetative spread. If this were the case the fescue figures above 8 oz./acre would be proportionately increased and a greater difference between rates might occur.

The September sprayed plots have not yet reached stability as there is between 7% and 50% bare ground or dead material. The moor mat grass again shows a steep drop in proportion to the increase in rate which was almost the same as that appearing in the July sprayed plots. There is, however, a steep drop at the 4 oz./ac. level. Sheep's fescue shows an increase up to the 4 oz./ac. level but after that it falls away. As the bare ground and dead fraction variesfrom 7% to 51% it is possible that the fescue may spread to fill in much of this space.

In the December plots moor mat grass has not been so severely checked as /

as in the September series. This is possibly because the December ones were sprayed when there was more dead or dormant vegetation in the plots. Sheep's fescue shows a greater depression, the reduction being greater than from any other spraying date. No final conclusion can be drawn from these readings as the dead material varies from 9% to 41% and it is not certain what will fill in this area. The maximum percentage dead on these plots is some 10% less than on the September sprayed plots due to the dormancy of the vegetation already mentioned in connection with moor mat grass.

It does not seem likely that the last two dates of spraying will be as effective for improvement purposes as the July one though further data is required especially in the case of the September series.

Rate of Recovery of moor mat grass and sheep's fescue from paraquat spraying

From the graphs a more exact picture can be built up of the behaviour of the 2 dominant species during the period after spraying.

After the March spraying both grasses are checked, moor mat grass only slightly at the higher rates and recovering soon. Sheep's fescue is checked more severely than appears in the final results but makes an excellent recovery at all rates to just below the level of the control.

In the July sprayed plots the fescue does not show a drop at all in the following May even though the normal trend at that time of year is downwards. /

Fig.5. Moor mat grass sprayed in March.

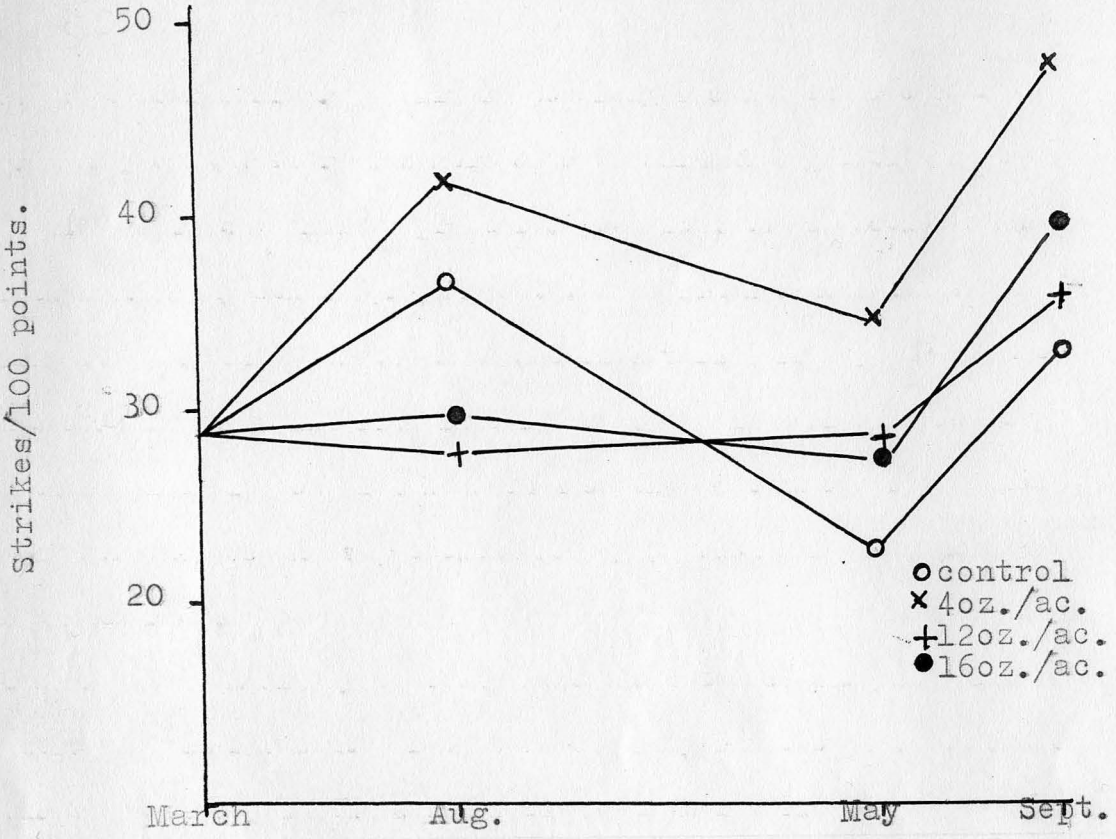


Fig.6. Moor mat grass sprayed in July.

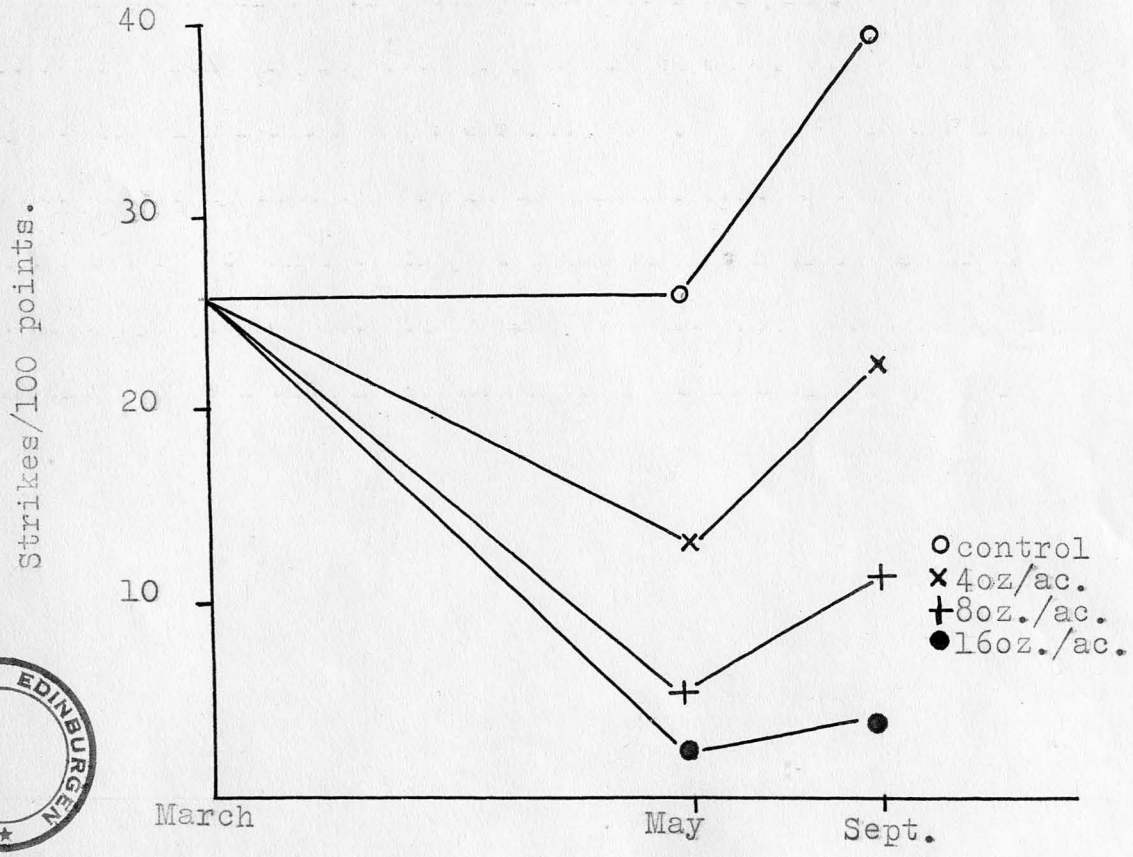


Fig.7.Moor mat grass sprayed in September.

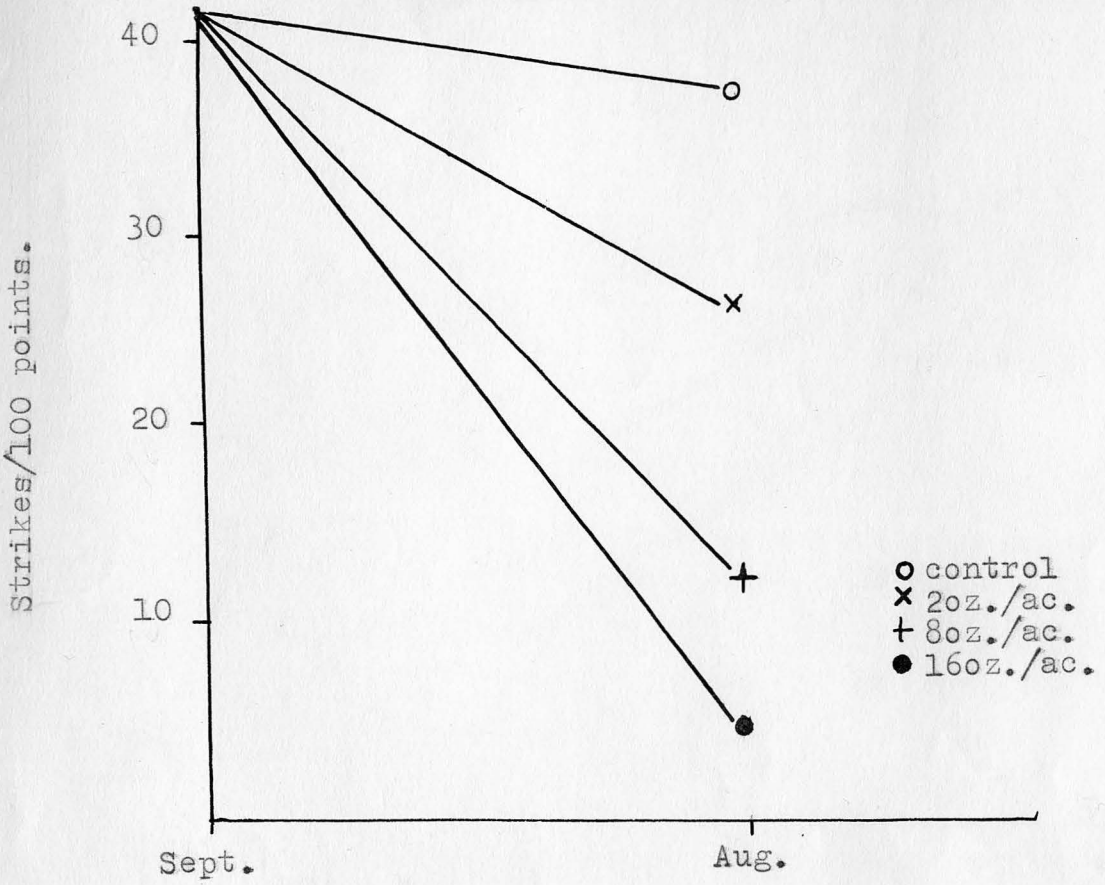


Fig8 .Moor mat grass sprayed in December.

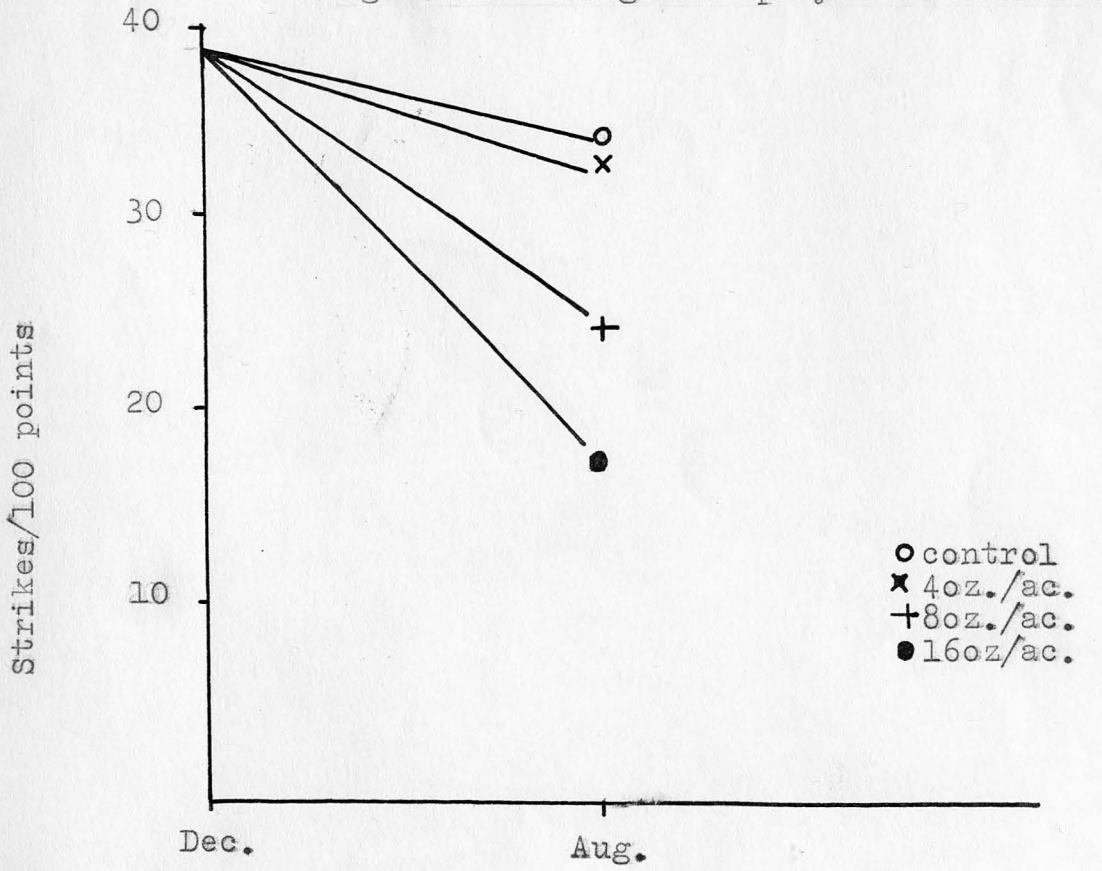


Fig. 9. Sheep's fescue sprayed in March

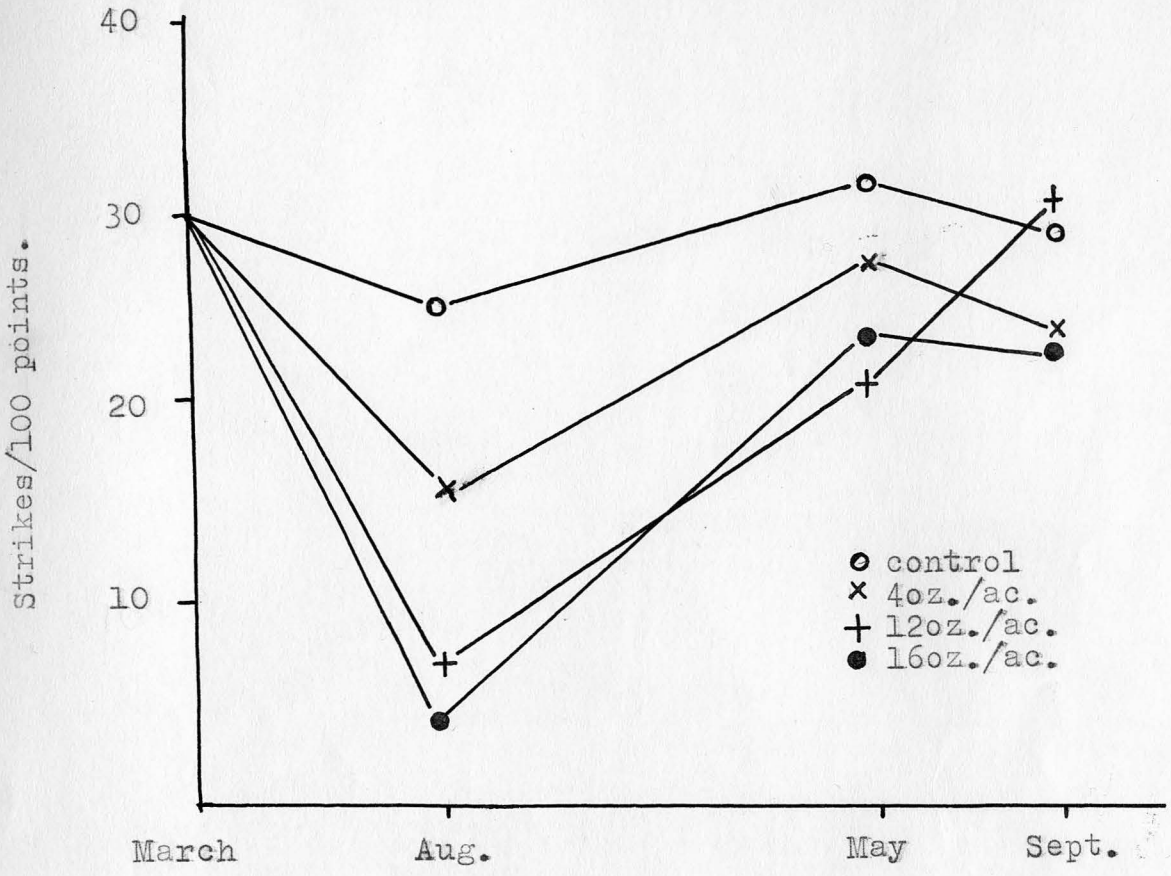


Fig. 10. Sheep's fescue sprayed in July.

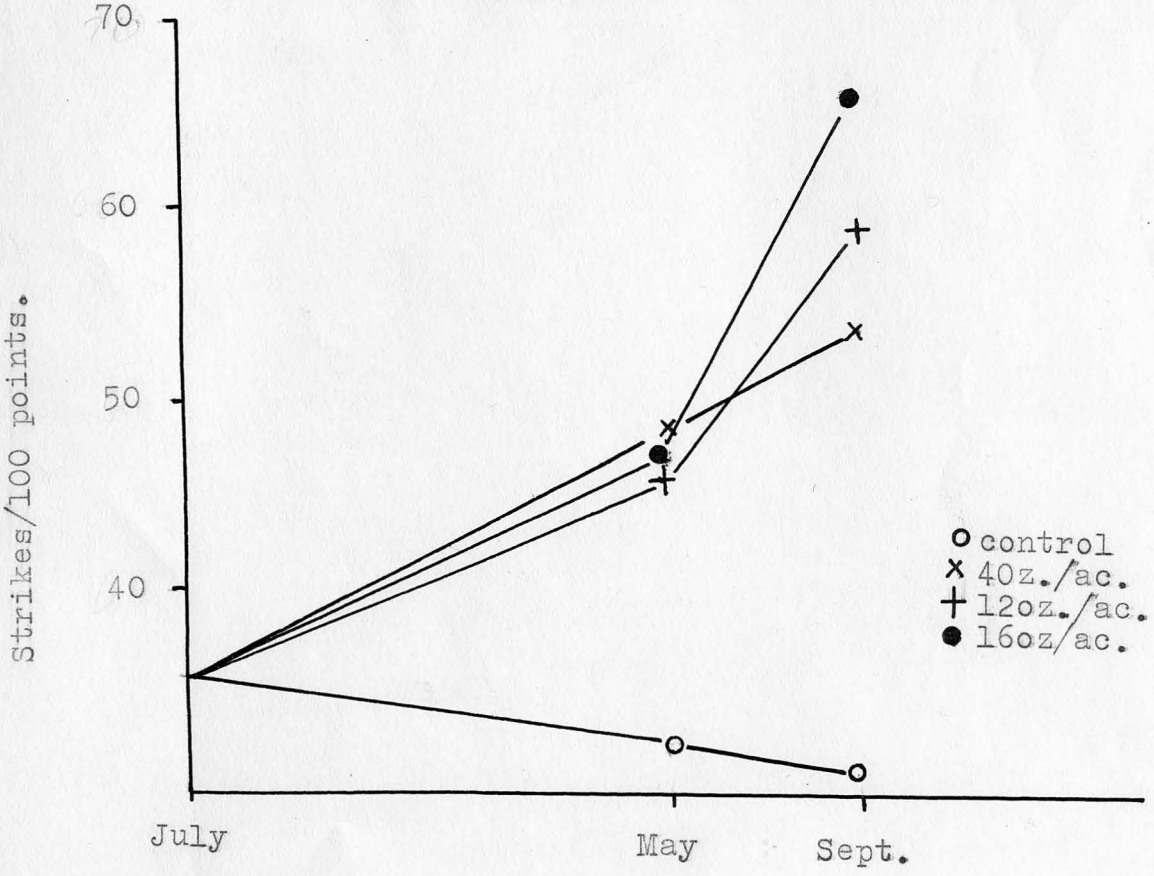


Fig.11. Sheep's fescue sprayed in September.

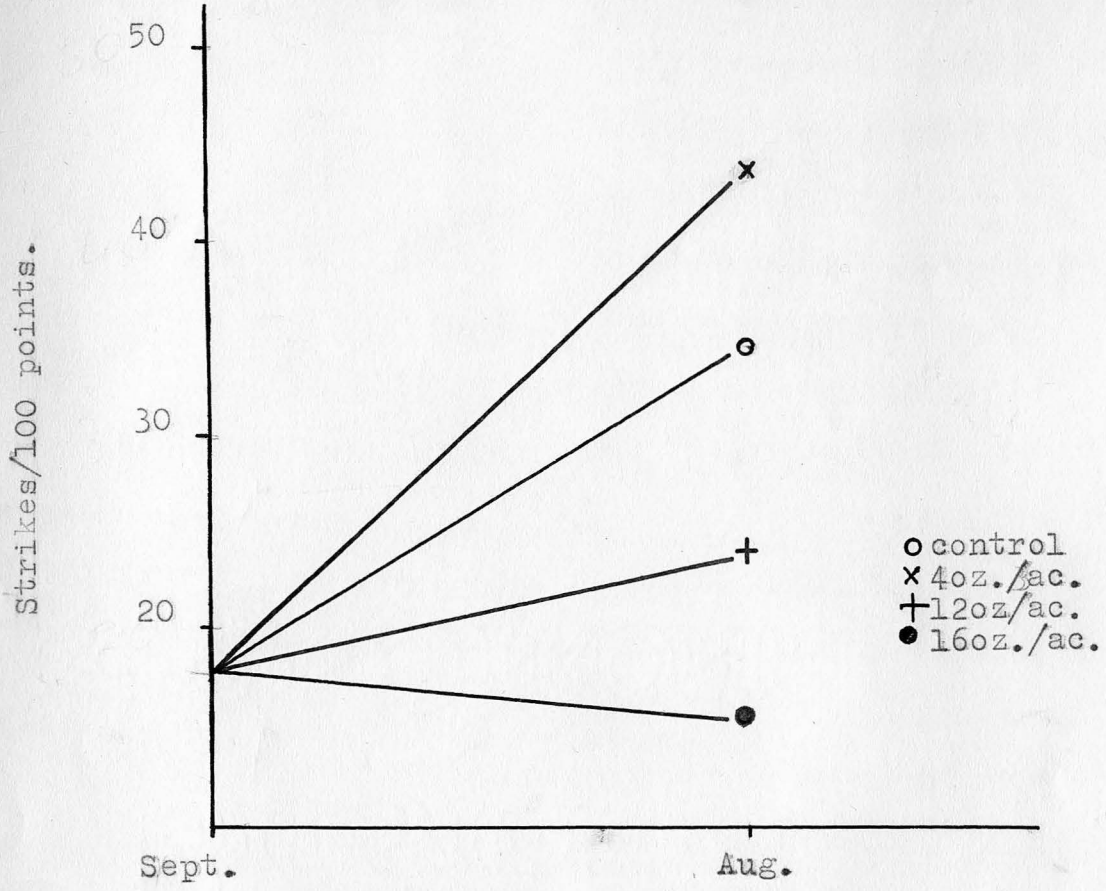
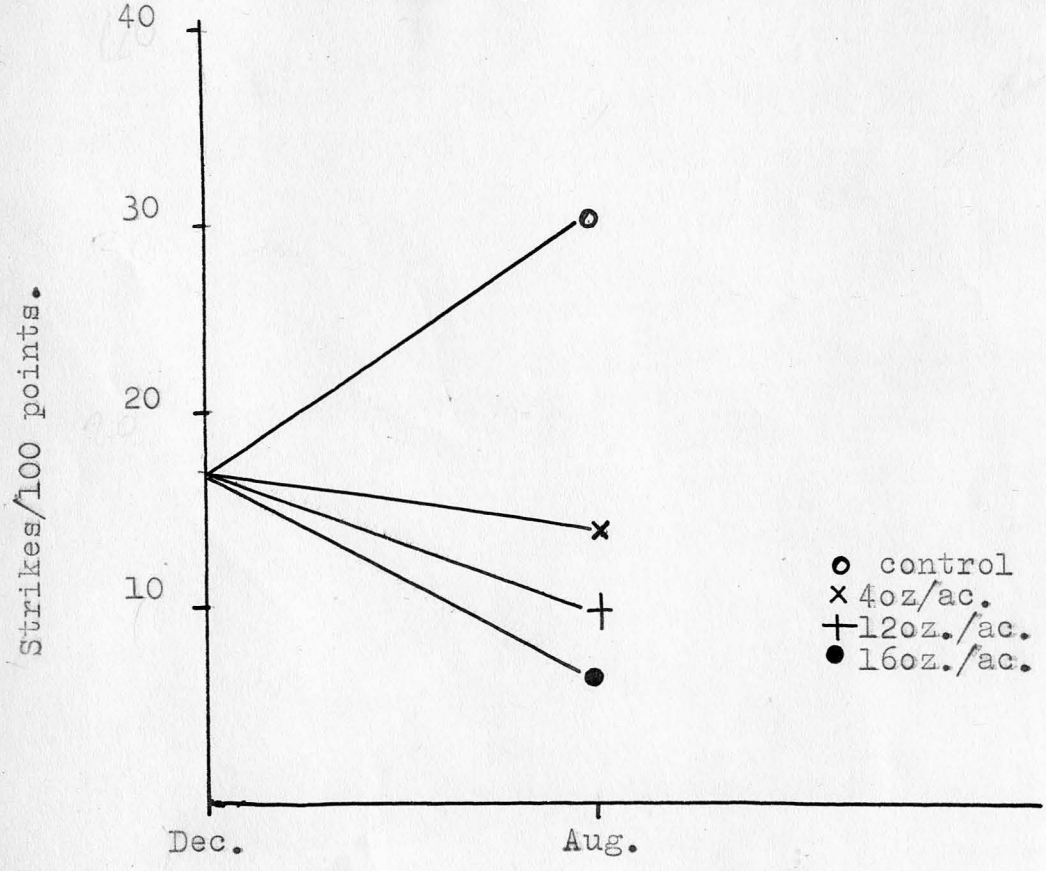


Fig.12. Sheep's fescue sprayed in December.



downwards. The initial kill of moor mat grass is greater than appears in the final results. While there may have been some actual recovery in this species the pronounced increase in the control plots indicates that the effect is in the main, a seasonal one. ~~It is more likely that the latter explanation is correct.~~ In the September and December plots only 2 readings have been taken and nothing definite can be said about the recovery. However, a possible recovery pattern can be postulated for both dates. The moor mat grass is greatly reduced in September and on the other occasion when there was a large reduction in this species - i.e., in July - it was a permanent one - assuming that the increase after May was in fact a seasonal fluctuation. There is a good chance that the September spraying will give just as good a reduction of moor mat grass as the July one. The poor vegetative spread of moor mat grass is another contributory factor to the permanence of the reduction. In September the sheep's fescue is only reduced by 8 oz. or more. In March and July it recovered quickly and these facts suggest that, given time, the sheep's fescue sprayed in September may make a good recovery and become the dominant plant in the sward. The recovery period must be longer as the spraying took place just before growth stopped for the winter.

In the December sprayed plots it is more difficult to propose a recovery pattern as the kill is considerable with both species. However, moor mat grass /

grass has not been checked nearly as much as sheep's fescue it may recover first.

Douglas and MacIlvenny (25) working in Wales have found that an appreciable invasion by dicotyledons occurs at rates of more than 8 oz./ acre after spraying in July. This has not occurred in the July plots in the present work and only to a slight extent in the March ones. It may, of course, still occur at the other 2 dates. The March increase in dicotyledons is nothing like the 16% level shown by these workers whose initial dicotyledon level was much the same as that on Castlelaw.

A toxic effect on sheep's fescue has also been observed by Douglas and MacIlvenny in their July sprayed plots at rates of more than 8 oz./ ac., this effect being still greatly in evidence some 15 months after spraying, whereas on Castlelaw 10 months after spraying the fescue content of all July sprayed plots had increased. The maximum rate in the Welsh trial was 2 lb./ac. and in this one only 1 lb./ac. Had this trial gone up to 2 lb./ac. a reduction might have occurred but there was no sign of it happening at 1 lb./ac. Under Scottish conditions the fescue seems to be capable of faster recovery than under Welsh conditions. When spraying in September, Douglas and MacIlvenny found that the fescue was permanently reduced - this suggests that the possibility proposed earlier in this discussion - /

discussion - that the September sprayed plots would recover with the fescue as the dominant - may be incorrect. But in view of the slow fescue recovery under Welsh conditions already mentioned this seems unlikely.

The drop in moor mat grass in the July sprayed plots occurs in the Welsh work as well and is particularly noticeable at 8 oz./acre and above. The behaviour of moor mat grass is, therefore, similar under both sets of conditions.

The effect of paraquat on the sown species.

There was very little spread of any of the sown species. It had been hoped that the clover would increase as it is reputedly resistant - and recovers from the herbicide, which causes defoliation within 4 weeks. If anything there has been a reduction in clover at the higher rates particularly in the September series. The recovery may be slower at that time of year but even so sufficient time should have elapsed (12 months) and clover seems to be susceptible to rates of 8 oz./ac. and above sprayed in September.

Smooth stalked meadow grass is reduced slightly at all dates though these reductions are not significant.

Rough stalked meadow grass shows a significant increase in the September and December sprayed plots and was most noticeable on these plots as the drills stood out as bright green against the surrounding semi-dead vegetation.

This /

This increase for rough stalked meadow grass does not agree with the published work on susceptibilities (Jones/Plant Protection Symposium 1962). Both species of meadow grass are given as susceptible to paraquat but the fact that these plants were in drills and protected from the spray by the overhanging native vegetation could account for the resistance of rough stalked meadow grass.

Botanical analysis of the sown species was complicated by their being sown in drills and the strikes recorded depended on how the quadrat happened to be placed in relation to the drill.

When paraquat was sprayed on the 10th June in Experiment II, it does not seem to have been so effective against moor mat grass as the July sprayings - indeed the results appear similar to the March treatments but no detailed analyses were made as the herbicide was merely being used to reduce the sward.

Dalapon, Dalacide and Amitrole as aids to seedling establishment.

When the experiment involving the above herbicides was set up it was known that clover could be established on the hill without any pre-treatment. The main interest was to see if a seeds mixture could be established without cultivation the clover only plots being included to see if the treatments would increase or hasten the clover establishment.

The /

The forage harvester treatment removed the tussocks and opened up the sward. It also produced an ideal medium on which to spray the herbicide as regrowth had just started and there was no dead material on the surface.

As there was a great variation in clover germination counts between plots the counts from both the clover only and the seeds mixture plots have been taken as a whole. There was no significant difference between the counts for the various rates of each herbicide so the means for all rates have been compared.

There is a significant difference in the September figures at 1% level of probability. Dalacide has given a better initial establishment than the other two possibly because of the greater kill of this herbicide. It is a mixture made up of 78% sodium, 2,2 dichloropropionate and 8% sodium, 2,2,3 trichloropropionate.

This gives it a broader spectrum of toxicity than dalapon which is 72% sodium 2,2 dichloropropionate. Both dalapon and Dalacide were applied at the same rate of commercial formulation hence a greater active content of Dalacide was applied. Dalapon gives a better establishment than amitrole though the difference is not significant. As amitrole has not killed the moor mat grass there will be less bare ground and more competition in these plots. The three weed killer treatments all give a better establishment than control, which was treated with a forage harvester.

By the following June the Dalacide plots had lost their initial advantage, as there had been a considerable loss in clover plants over the winter ranging from 61% in the Dalacide plots to 44% in the dalapon ones. The high loss in the Dalacide plots is due possibly to an exposure effect as the Dalacide plots had a slightly higher kill than the others. The final establishment figures in June show dalapon as giving the best establishment with Dalacide, next followed by amitrole. All the herbicides are still better than control but dalapon gives nearly twice as good an establishment and there is no difference between the various rates of this herbicide. The 3 lb. rate of dalapon, therefore, gives an improved establishment of white clover. Dalacide and amitrole also give an improvement over the control.

Rough stalked meadow grass gave very variable results and they were not statistically significant. It can, however, be taken that any herbicide gives a much better establishment than treatment with a forage harvester alone. In all three treatments the lowest rates give a lower establishment and with amitrole and dalapon there is no difference between the two higher rates. This suggests that the lowest rates do not give quite enough reduction in ground cover.

The Timothy figures show no difference between dalapon and Dalacide but amitrole is much lower though all are much better than the control. As there is a greatly reduced germination at the 6 lb./ac. rate of amitrole it seems likely /

likely that this herbicide has a residual effect. The other two herbicides have low counts on the low rates but there is again no difference between the higher rates. Application at the highest rate is, therefore, unnecessary.

Clover is not so sensitive as grass to the rate at which the herbicide is applied since in only one case of the six (Dalacide in June) does the lowest rate of herbicide give the lowest clover germination. The clover seed is a heavier one than either Timothy or rough stalked meadow grass and will, therefore, penetrate a thicker sward to reach moisture and germinate. The lighter grass seed must have a larger reduction in vegetational cover before it can penetrate to the moisture. Clover is possibly also a more aggressive species.

The most suitable herbicides for clover establishment is dalapon at 3 lb./ac. this giving as good an establishment as 3·6 lb./ac. Dalacide and a better one than any rate of amitrole. To establish Timothy a higher dose of dalapon or Dalacide is indicated; amitrole is not satisfactory.

Paraquat as an aid to seedling establishment.

Like the other herbicides used in Experiment II the paraquat plots have shown great variability in clover germination. The clover figures were again taken as a whole. There was a significant difference between rates /

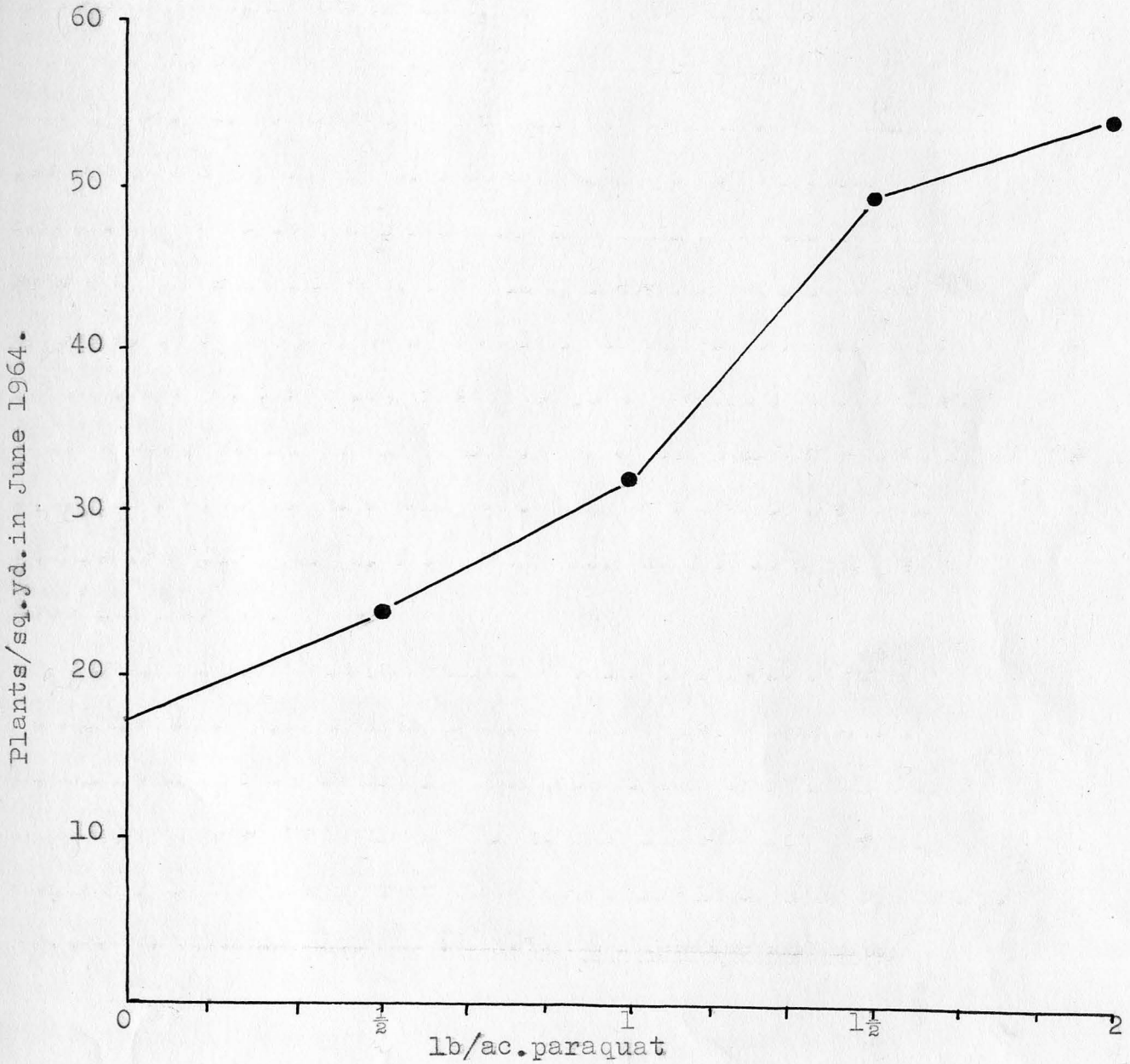
rates by June, the establishment increasing roughly in proportion to the rate of application. There is no significant difference between the initial germination figures on the sprayed plots and all are significantly better than the control. The June figures do not increase regularly (see graph) as there is a sharp increase between 1 and 1½ lbs./ac. followed by a levelling off to 2 lbs./ac. This increase is because the 1½ lb. rate causes the greatest reduction in competition and at the lower rates the high initial establishment is reduced by the competition of the quickly recovering sward. Above 1½ lb./ac. there is an exposure factor due to the great reduction in the natural vegetation which exposes the young seedlings to the effects of the weather and the grazing animal. Hence the increase between 1½ and 2lbs is not so great as the preceding one. The best results have been obtained from the 1½lb./ac. rate as the 2lb./ac. rate does not give a worthwhile increase.

The differences between application rates in respect of grass establishment are not significant but all rates give a much better establishment than the control. With both grasses there is an increase in seedling numbers up to the 1½ lb./ac. rate followed by a levelling off with rough stalked meadow grass and a sudden drop in the case of Timothy.

~~Dalapon, Dalacide and Amitrole as aids to seedling establishment.~~

~~When~~

Fig.13.Relationship between plants/square yard and rate of paraquat in June 1964.



Dalapon, Dalacide and amitrole as selectives.

Although it was known that dalapon would act as a selective herbicide against moor mat grass (42) the experiment in which the above herbicides were used was not intended to investigate the selective effect further. However, some interesting results were observed. Both dalapon and Dalacide killed moor mat grass at all three rates of application. This was to be expected but the highest doses of both herbicides did not permanently reduce the sheep's fescue. This does not agree with the literature (30,63) which suggests that sheep's fescue would be killed by a dose of between 5 and 10 lbs./acre. As the maximum dose of dalapon was 9 lb.ai./ac. and of Dalacide 10.8 lbs. ai./acre this would not appear to be the case under these conditions. As the kill of moor mat grass was the same at all rates this confirms that 3 lb./ac. dalapon is sufficient to suppress it (61). Dalacide will also suppress moor mat grass at 3.6 lb.ai/acre.

Amitrole did not show any selective effect as the grass regrowth appeared to be in the same proportions as before. Someslight change in the sward balance may have occurred but without a precise botanical analysis it is impossible to say. Amitrole is not, therefore, of any use in the selective improvement of a hill sward.

The forage harvester in hill pasture improvement.

A flail type forage harvester was used as a pre-treatment in two of the experiments and appeared to be of material assistance in the establishment /

establishment of clover in the sward. This was especially noticeable in the case where the herbicides had no effect yet in many plots clover establishment was excellent. Clover can, of course, be established without pre-treatment but the process takes some time and the spread is slow. This was demonstrated in the control plot at Newarkburn where only a few plants appeared in the thick sward over a period of some 14 months. These plants would spread in time but the open sward with frequent bare patches left by the harvester seems to offer a much better medium for clover growth provided phosphate and lime deficiences are corrected.

In the experiment involving the sowing of a seeds mixture it is doubtful if any grass would have established at all on the control plots if they had not been forage harvested as grass seeds do not establish readily if sown direct into a long and thick sward such as this was. As it was, the control plots gave a reasonable establishment of grass even though it was well below that on the herbicidally treated plots.

The cutting of a sward with a forage harvester has three results. It reduces competition from the native herbage; it allows the sown seeds to penetrate down to the soil surface where there is adequate moisture and and it permits light to reach the germinating seedlings as the shading plants have been effectively removed. For forage harvesting to be fully effective /

effective the trash must be removed by trailer, raking off or being allowed to rot away over the winter.

In both experiments the debris was raked away before any treatment was carried out. This had to be done before spraying to obtain full advantage from the regrowth which was induced. Goods results have been obtained on rough low ground pastures where the debris was left to rot and the seed sown before harvesting (8). A technique like this would be useful on the hill as it is cheap and convenient.

In experiment II there was a large percentage of moor mat grass in the sward. This grass is not resistant to mechanical treatment and recovers very slowly even from one or two passages of the Landrover wheels. This means that any species in the sward which recovers from defoliation more quickly will tend to smother the moor mat grass and this is the case with sheep's fescue. This in itself would constitute an improvement. Cattle were attracted to the areas which had been mown and fertilised and this helped in the improvement cycle.

In the photograph (Plate 11) the foreground shows that part which was cut but not used in the herbicidal treatments about 5 months after the cutting took place. It is still much shorter due to the slow recovery of the moor mat grass and the heavier grazing by cattle. The moor mat grass fraction seems to be reduced. The area used in the screening trial

was /

Plate 11. Experiment II forage harvested area in foreground kept short by grazing 4 months after cutting.

was also heavily grazed. This suggests that an improvement could be achieved by forage harvesting plus fertilising without sowing any seed and this is in agreement with the work done on low ground grazings already mentioned. The debris can also be burned off as was done on part of Castlelaw but this requires a dry spell to be fully effective.

The suitability of a range of herbicides as pre-treatments for clover establishment on a forage harvested sward.

The forage harvesting ensured a good regrowth on which the herbicides could act. As the experiment is unreplicated and the plots are unrandomised the results cannot be treated statistically. However, a general trend can be seen based on the means of the 3 rates for each herbicide as there does not seem to be much difference between rates.

	Mean germination plants/sq.yd	Mean percentage cover
amitrole/dalapon	142.7	19
TCA	134.7	28
sodium 2,2,3 trichloropropionate	152	15
EPTC	53.3	10
tillam	46	7
Thiuron	122.7	14
Trixabon	81.3	12
Stellox CC	154.7	19
erbon	25.3	3
fenac	88	6
sodium monochloroacetate	75.3	14

Erbon /

Erbon is totally unsuitable for re-seeding purposes as it remains in the soil and is reactivated by rain. The kill at all rates was 100% and it is a soil sterilant rather than a herbicide. The only other plots which showed any degree of herbage kill by the time of sowing were the amitrole/dalapon mixture and TCA. These show a high percentage clover cover - particularly TCA which is the highest by 9%. They appear, therefore, to have been of some advantage in the establishment of clover. This is only to be expected as these herbicides have been used for this type of work before and TCA was among the first to be used (91). A residual effect of TCA on clovers has been observed in this country (19,67) but the high establishment in this case indicates that any residual effect has had sufficient time to die out in the 10 week interval between spraying and sowing.

Stellox CC has given the same establishment as the amitrole/dalapon mixture and some of the other herbicides are not far behind. There was, however, no sign of any herbicidal kill on any/other plots than those already mentioned at the time of sowing. The high germination on these plots must, therefore, be due to a larger percentage of bare ground caused by the forage harvester and in the absence of any statistical analysis the variation between plots can only be ascribed to the different amounts of bare ground left by the harvester. It is possible that fenac had a residual effect as it is known to be a persistant herbicide. In this particular sward the forage harvester alone as a pre-treatment would probably have given a satisfactory clover establishment.

<u>The effectiveness of band spraying with paraquat as a means of introducing clover to a sward.</u>

As /

As already mentioned the results for the band spraying experiment are not significant due to the experimental layout. There is, however, a large enough difference in the results to indicate that the band spraying has given a better establishment than the control. There was a 50% loss in the sprayed strips over the winter whereas the control was unchanged. This drop in clover usually occurs in plots sprayed with herbicide but in this case a certain amount of protection from the surrounding vegetation could reasonably have been expected. The fact that the seed was not sown till late August meant that it was not so well established as it might have been and sowing at an earlier date might give better results. The use of the herbicide in strips makes the process much cheaper than general spraying but a better final establishment would be needed before the process could be considered useful. As the whole area had been forage harvested the control strips may have given a better germination than usual and if compared with a totally untreated control a larger difference might have been found.

Paraquat as an aid to establishing clover in a clover free sward without any other treatment.

In the experiment at Newarkburn on the Buccleuch Estates the aim was to introduce clover to a better class of hill land than had been used in the other experiments. The establishment was very poor on all plots initially and it was thought that lack of moisture could have caused this. However, the rainfall in August, the month of sowing, was 8.08 in. which is far higher than the mean August figure for 25 years of 3.48 in. Only occasional small plants appeared during the first year and never enough for a botanical analysis. This unexpectedly low establishment is hard to explain as clover did occur quite plentifully /

plentifully on other parts of the hill and it had been limed and slagged quite recently so low phosphate or high acidity seem unlikely causes of the low germination. The clover did pick up somewhat by the autumn of the following year and no difference could be seen between the 2 dates of sowing but in the absence of any actual figures no inference can be drawn as to the residual effect or otherwise of the herbicide. The difference in germination between the 3 rates of clover did not seem very great either and given time the whole area would contain a reasonable proportion of clover. In this particular case paraquat did not seem to be such an aid to establishment as usual - possibly due to the different sward which contained species with a greater resistance though a good kill was obtained at the higher rates. One interesting feature of the experiment was the two patches of greatly reduced vegetation which persisted on the 2 higher rates. They seemed to correspond with parts of the hill which were flushed with ground water and this, for some reason, must have increased the activity of the paraquat.

<u>The effectiveness of Preeglone, crestol, TW-2, Fison's PCP TRI-PE and Proxan as herbicides under hill conditions.</u>

None of these herbicides were effective in the destruction of a hill sward. The failure of Preeglone to be more than slightly effective is remarkable as it is a diquat/paraquat mixture and the latter compound has been most effective as a selective herbicide and also for total sward kill. As diquat is primarily effective against broad leaved plants the mixing of the two in this case probably means an effective dilution of paraquat.

CONCLUSIONS

1. Paraquat sprayed on a moor mat grass/sheep's fescue sward controlled the moor mat grass most effectively in July and September. The sheep's fescue fraction of the sward had greatly increased 14 months after the July sprayings. 16oz.a.i/ac. was the optimum rate for both these changes. There was no appreciable spread of the sown species in the sward.
2. After pre-treatment of a moor mat grass/fescue sward with a forage harvester, dalapon Dalacide and paraquat gave an increased establishment of clover timothy and rough stalked meadow grass.
3. Forage harvesting alone and in conjunction with T.C.A. gave an enhanced clover establishment on a somewhat better class hill sward than above.
4. Band spraying of paraquat gave an improved clover establishment within the sprayed strips.
5. The following herbicides were ineffective as pre-treatments for hill improvement work :

   sodium 2, 2, 3, trichloropropionate, E.P. T. C., tillam, Thiuron, Trixabon, Stellox C.C., erbon, fenac, sodium monochloracelate, Preeglone, Crestol, T.W.-2, Fisons P.C.P., TRI-P.E., Proxan.
6. Paraquat pre-treatment on a strongly growing bent/fescue sward did not give much assistance to the rapid and effective establishment of clover.

S U M M A R Y

Paraquat at 0, 2, 4, 8, 12 and 16oz/ac. was applied to a previously sod-seeded moor mat grass/sheep's fescue sward in March, July, September and December. The best control of moor mat grass was in July and September. March was ineffective and December inconclusive. A large increase in sheep's fescue occured with the July sprayings. The sown species failed to spread except rough stalked meadow grass after the September and December sprayings at higher rates.

A similar sward was forage harvested and sprayed with amitrole at 2, 4, 6lb/ac, dalapon at 3, 6, 9lb/ac. and Dalacide at 3.6, 7.2, 10.8lb/ac. The sward was sown with clover and with a seedsmixture. The treatments gave enhanced establishment of both.

A forage harvested area was sprayed with 11 herbicides each at 3 rates. The only ones to show effective kill were T.C.A. and amitrole/dalapon. The establishment of the clover which was subsequently sown was assisted by the forage harvesting and the two effective herbicides.

Paraquat at 2lb/ac. was sprayed in strips on a forage harvested hill sward and clover at 4lb/ac. was sown in these strips. The establishment of clover was better on the strips than on control.

Paraquat at 4 rates was sprayed on a bent/fescue sward and clover at 3 rates was sown at 2 subsequent dates. There was no difference in establishment between dates and little between rates. The clover establishment was very slow.

Five further herbicides were tested for hill improvement work and none of them were found to be effective.

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A C K N O W L E D G E M E N T S

The writer wishes to thank Professor S.J. Watson of the Edinburgh School of Agriculture for providing the facilities which allowed this work to be carried out, and Mr R.G. Heddle for his help and supervision. He also wishes to thank Mr D.S.C. Erskine and other members of the Advisory Botany department for their advice and assistance. Grateful acknowledgement must be made to the Buccleuch Estates for allowing one of the experiments to be set up on their land and to Mr G. Finnie for processing the photographic illustrations.

A P P E N D I X

The following is a list of the active ingredients referred to in the text by trade names. All other herbicides are referred to by their British Standard names.

Trade Name	Active ingredient (a.i.)
Aminotriazole	- amitrole
Crestol	- 15% cresylic acid.
Dalacide	- 78% sodium 2,2, dichloro propionate plus 8% sodium 2,2,3 trichloropropionate.
Fisons P.C.P.	- P.C.P.
Preeglone	- paraquat/diquat. (mollecular proportions).
Proxan	- Di-iso propyl xanthogen disulphide
Stellox CC	- a.i. not published.
Thuiron	- M.P.B.T.
Tordon	- 4-amino 3, 5, 6, trichloropicolinic acid.
Trixabon	- Dimexan, O.M.U., Bi P.C.
Tri P.E.	- Dimexan
T.W.-2	- Xylenol formulation plus carbamate and 2,4-D.
paraquat was sprayed as	- Grammoxone W.
Dalapon " "	- Dowpon.
Amitrole " "	- Weedazol T.L.

The /

The following is a list of the Latin names of the plants alluded to in the text.

Alpine cat's tail	Phleum alpinum
Buttercup	Ranunculus spp.
Blaeberry	Vaccinium Myrtillus
Common bent	Agrostis tenuis
Creeping softgrass	Holcus mollis
Daisy	Bellis perennis
Dandelion	Taraxacum officinale
Flying bent	Molinia caerulea.
Hawkweed	Hieracium spp.
Heather	Calluna vulgaris
Heath bedstraw	Galium saxatile
Heath rush	Juncus squarrosus
Lady's mantle	Alchemilla spp.
Moor mat grass	Nardus stricta
Moss	Acrocarpus/Pleurocarpus
Mousear	Cerastium vulgatum
Ribgrass	Plantago lanceolata
Rough stalked meadow grass	Poa trivialis
Sedge	Carex spp.
Sheep's fescue	Festuca ovina
Smooth stalked meadow grass	Poa pratensis
Sweet vernal	Anthoxanthum odoratum

Timothy /

Timothy (S50)	-	Phleum nodosum
Tormentil	-	Potentilla erecta
Tufted hair grass	-	Deschampsia caespitosa
Wavy hair grass	-	Deschampsia flexuosa
Woodrush	-	Luzula campestris
White clover	-	Trifolium repens
Yorkshire fog	-	Holcus lanatus

The cost of Hill Pasture Improvement using herbicides

Most hill improvement schemes start with the application of lime and slag. The cost of these will depend on the requirement of the soil and on Castlelaw it was £3 per acre for lime and £2.15/- per acre for slag.

If paraquat is applied to kill moor mat grass at 16oz/ac. the cost will be £3/ac. Dalapon will do the same at 3lb/ac. the cost for this being 30/-/ac. The application cost in both cases will be about 15/-/ac. There will also be a "cost" in lost grazing as any acreage sprayed is effectively rendered unavailable for grazing during the subsequent year.

If clover alone is sown this will run to £3/ac. for seed (4lb/ac.) and the seedsmixture used in experiment II cost £5/ac.

The use of herbicides may hasten an improvement scheme and on some hills it may give a better long term improvement than the more traditional methods but no definite conclusions can be drawn without reference to a specific case.

Table I

BOTANICAL ANALYSIS OF MARCH SPRAYED PLOTS

Strikes per 100. Mean of 4 replicates

	Control				2 oz/ac				4 oz/ac				8 oz/ac				12 oz/ac				16 oz/ac			
Date of Reading)	Mar. 63	Aug. 63	May 64	Sep. 64	Mar. 63	Aug. 63	May 64	Sep. 64	Mar. 63	Aug. 63	May 64	Sep. 64	Mar 63	Aug. 63	May 64	Sep. 64	Mar. 63	Aug. 63	May 64	Sep. 64	Mar. 63	Aug. 63	May 64	Sep. 64
Sheeps fescue	30.3	25.3	32.5	30	30.3	25.5	34	32	30.3	16.3	28	24.7	30.3	6.7	22.5	27.7	30.3	7.5	22	31.3	30.3	4.3	24	23.7
Moor mat grass	29.3	37	23	33.3	29.3	37.3	27.3	36	29.3	41.7	35.2	48	29.3	38.7	34	39.7	29.3	27.5	29.2	36	29.3	30.0	27.5	40.5
Common bent	4	8.3	6.5	6.5	4	8.7	9.5	9.5	4	4.7	6.3	4	4	8.5	9.5	8.3	4	3.7	8.5	1.5	4	3.7	9	9.5
Heath rush	8.3	11.3	8.7	4.7	8.3	1	1.5	1.3	8.3	2.7	1.3	4.3	8.3	4.5	.7	3	8.3	3	1.3	3.5	8.3	1.3	1.5	1
Blaeberry	3.5	4	3.7	1.5	3.5	4	2.5	1	3.5	3.7	1.3	-	3.5	5.3	4	.3	3.5	6.5	17	2.7	3.5	5.7	1.3	-
White clover	4.7	9	3	11.5	4.7	6.3	4	8.7	4.7	12.7	4.7	8.7	4.7	12.3	9	10.7	4.7	9.7	4.5	9	4.7	8.5	5.7	8.7
S.S.M.G.*	3	2.3	6.3	6.5	3	3.3	7.7	5.3	3	2.5	3	4	3	1.5	2.7	1.5	3	3.3	3.5	2.7	3	1.0	3.7	4.3
R.S.M.G.+	.7	1.3	4.7	3	.7	2.7	4.3	3.3	.7	0.5	3	2	.7	0.7	5.3	3	.7	1.5	5.3	3.5	.7	1.3	5.5	3.5
Woodrush	4.5	2	1.3	.7	4.5	.7	.5	.3	4.5	1.5	1.5	.7	4.5	1.3	.5	.5	4.5	1.5	.5	.3	4.5	1	1.7	1.5
Mosses	5	-	1	-	5	.5	1	.3	5	.5	2.3	.5	5	1.3	4.3	-	5	1	3	1.3	5	1.5	3	.5
s50TImothy	2.5	-	1.5	1.3	2.5	1.0	1.3	1	2.5	2.3	1	1.3	2.5	1.5	.7	.5	2.5	.7	.7	1	2.5	-	.5	1
Heath bedstraw	.7	.3	.5	-	.7	1.5	-	.7	.7	1.5	1.5	-	.7	2	1.3	1.3	.7	3	1	-	.7	4.7	2.7	1
Mousear	.3	-	.3	-	.3	-	-	-	.3	-	-	-	.3	-	-	1	.3	-	.3	-	.3	-	.7	-
Wavy hair grass	1	1.3	2.5	-	1	2.7	3	-	1	.7	2.3	-	1	1.5	3.3	-	1	1.5	3.3	1	1	1	4.3	.5
Heather	.7	.3	.3	-	.7	.3	-	.3	.7	.5	.3	-	.7	-	-	.5	.7	-	-	-	.7	-	-	-
Bare ground or dead	1	0.3	4.7	1	1	4.5	4.5	.3	1	8.3	6.5	1.5	1	12.5	6	1.3	1	28.	16.7	2	1	34.5	16	3.7
Tufted hair grass	.5	-	.5	-	.5	-	-	-	.5	-	-	-	.5	-	-	-	.5	.5	-	-	.5	-	-	-
Tormentil	-	.3	-	-	-	-	.3	.3	-	.7	-	-	-	1.5	-	.3	-	1	-	-	-	1.5	.3	.3
Annual meadow grass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.7	-

*S.S.M.G. Smooth stalked meadow grass +R.S.M.G. Rough stalked meadow grass.

Table II

BOTANICAL ANALYSIS OF JULY SPRAYED PLOTS

Strikes per 100. Mean of 4 replicates

	Control			2 oz/ac			4 oz/ac			8 oz/ac			12 oz/ac			16 oz/ac		
Date of) Reading)	July 63	May. 64	Sep. 64	July 63	May. 64	Sep. 64	July 63	May. 64	Sep. 64	July 63	May 64	Sep. 64	July 63	May 64	Sep. 64	July 63	May 64	Sep. 64
Sheeps fescue	36.5	32	31.3	36.5	42	46.5	36.5	49	54	36.5	52.5	56.7	36.5	46.5	59.5	36.5	47	66
Moor mat grass	28	26.2	39.0	28	27	27.7	28	12.5	22.5	28	5.5	12.7	28	2.7	9.5	28	2.5	4
Common bent	3.7	6.7	3.3	3.7	5.7	2.7	3.7	4.7	4.3	3.7	-	2	3.7	1.5	4	3.7	1.3	3
Heath rush	4	3.3	3.3	4	1.7	2.5	4	.3	.3	4	-	.5	4	-	-	4	-	-
Blaeberry	6.3	1.7	.7	6.3	.5	.3	6.3	2	.3	6.3	.5	.7	6.3	1.3	-	6.3	-	1.3
White clover	6.7	6	6.7	6.7	6.3	9.3	6.7	5.5	3.5	6.7	3.7.	8.7	6.7	5	5.3	6.7	6.5	7.5
S.S.M.G.	3.5	8.3	7.3	3.5	7.3	4.3	3.5	6	4	3.5	5.5	6.7	3.5	6.5	7.5	3.5	6.5	5
R.S.M.G.	1.7	8.7	4.3	1.7	4.7	3	1.7	1.7	5.3	1.7	.7	1.3	1.7	1.5	2.5	1.7	.5	1
Woodrush	.7	.7	.3	.7	.5	-	.7	.7	1	.7	-	.5	.7	-	.5	.7	.3	.5
Mosses	.3	1	-	.3	1.3	.5	.3	1.5	.5	.3	2.5	.7	.3	2	.7	.3	2.3	.5
S50 timothy	2.7	2.5	1.7	2.7	3.5	2.5	2.7	2	2.7	2.7	1.7	1.3	2.7	1.3	.7	2.7	.7	1.5
Heath bedstraw	.7	.5	-	.7	-	-	.7	.5	-	.7	1.7	.5	.7	.3	.5	.7	.5	-
Mousear	.3	-	-	.3	-	-	.3	-	-	.3	-	-	.3	-	-	.3	-	-
Wavy hair grass	2.7	.5	.5	2.7	1.5	-	2.7	1.3	-	2.7	1.7	.5	2.7	.7	.7	2.7	.3	.3
Heather	2	.3	.3	2	-	.3	2	.5	-	2	-	.5	2	-	-	2	-	-
Bare ground or dead	-	1.7	1	-	9	1	-	11.7	1.3	-	23.7	6	-	37.5	7.5	-	34.2	9.3
Tufted hair grass	-	-	.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tormentil	-	-	-	-	-	-	-	-	.3	-	-	.5	-	-	-	-	-	.3
Annual meadow grass	-	-	.3	-	-	-	-	-	.3	-	-	-	-	-	-	-	-	-
Sedge	-	-	-	-	-	.3	-	-	-	-	-	-	-	-	-	-	-	-

Table III

BOTANICAL ANALYSIS OF SEPTEMBER SPRAYED PLOTS

Strikes per 100. Mean of 4 replicates

	Control		2 oz/ac		4 oz/ac		8 oz/ac		12 oz/ac		16 oz/ac	
Date of Reading	Sept. 63	Aug. 64	Sept. 63	Aug. 64	Sept. 63	Aug. 64	Sept. 63	Aug. 64	Sept. 63	Aug. 64	Sept. 63	Aug. 64
Sheeps fescue	18	34.7	18	39.5	18	43.7	18	32	18	24.3	18	15.5
Moor mat grass	41	37.5	41	26.7	41	12.3	41	12.7	41	4	41	5
Common bent	4.5	2	4.5	6	4.5	9	4.5	4.8	4.5	5.2	4.5	1.5
Heath rush	3.7	4.1	3.7	2.5	3.7	.5	3.7	2.5	3.7	-	3.7	1.5
Blaeberry	1	1.5	1	.5	1	1	1	.5	1	1.5	1	1.5
White clover	14	6	14	4.7	14	6	14	1.3	14	3	14	3
S.S.M.G.	2.5	7.7	2.5	8	2.5	4	2.5	3.5	2.5	3.5	2.5	3
R.S.M.G.	2	1.3	2	2	2	4	2	8.5	2	10.3	2	9
Woodrush	3.3	-	3.3	.5	3.3	.2	3.3	1	3.3	0.2	3.3	2.8
Mosses	.5	.5	.5	.5	.5	2	.5	1.3	.5	.2	.5	2
S50 timothy	2.3	1	2.3	1	2.3	1.3	2.3	-	2.3	1.5	2.3	.5
Heath bedstraw	-	-	-	.2	-	.2	-	-	-	-	-	-
Mousear	-	-	-	-	-	-	-	.2	-	.2	-	1.2
Wavy hair grass	3.5	.5	3.5	-	3.5	.5	3.5	.2	3.5	.7	3.5	1
Heather	.7	.5	.7	.5	.7	.5	.7	-	.7	.2	.7	-
Bare ground or dead	-	.7	-	7	-	12.7	-	30.3	-	43.5	-	51.3
Tufted hair grass	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-
Tormentil	.5	-	.5	.7	.5	.2	.5	1.8	.5	1.5	.5	1.2
Annual meadow grass	-	-	-	-	-	-	-	-	-	.2	-	.5
Sedge	-	.2	-	-	-	-	-	-	-	-	-	-

Table IV

BOTANICAL ANALYSIS OF DECEMBER SPRAYED PLOTS

Strikes per 100. Mean of 4 replicates

	Control		2 oz/ac		4 oz/ac		8 oz/ac		12 oz/ac		16 oz/ac	
Date of Reading)	Dec. 63	Aug. 64	Dec. 63	Aug. 64	Dec. 63	Aug. 64	Dec. 63	Aug. 64	Dec. 63	Aug. 64	Dec. 63	Aug. 64
Sheeps fescue	17.3	30	17.3	19.5	17.3	14.3	17.3	11.7	17.3	10.0	17.3	6.3
Moor mat grass	38.7	34.5	38.7	40.3	38.7	33	38.7	25.3	38.7	20.7	38.7	17.3
Common bent	6.3	2.2	6.3	5.2	6.3	5.8	6.3	7.8	6.3	7.5	6.3	3.2
Heath rush	5.3	2.2	5.3	3.3	5.3	2.8	5.3	5.8	5.3	4.5	5.3	6
Blaeberry	1.3	1	1.3	.5	1.3	1	1.3	.7	1.3	.3	1.3	2
White clover	11.7	9.7	11.7	8.7	11.7	8.5	11.7	10.3	11.7	11.3	11.7	6.7
S.S.M.G.	6.3	6.5	6.3	4.5	6.3	9.7	6.3	8.7	6.3	3.5	6.3	4.3
R.S.M.G.	2.7	2	2.7	4.3	2.7	6	2.7	8.3	2.7	5.5	2.7	8.3
Woodrush	2	-	2	.5	2	.3	2	.5	2	1.5	2	1.2
Mosses	1.7	-	1.7	1	1.7	.5	1.7	.7	1.7	.2	1.7	1
S50 timothy	.5	2.7	.5	.5	.5	1.3	.5	1.3	.5	2.7	.5	1.3
Heath bedstraw	.3	-	.3	.7	.3	.7	.3	1.7	.3	.5	.3	1.2
Mousear	-	.2	-	-	-	.2	-	-	-	-	-	-
Wavy hair grass	2	.2	2	-	2	1	2	.2	2	1.5	2	..7
Heather	1.7	.5	1.7	1	1.7	1.2	1.7	.2	1.7	.7	1.7	.2
Bare ground or dead	-	.3	-	9.7	-	12.3	-	17.5	-	27.5	-	41
Tufted hair grass	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-
Tormentil	.5	-	.5	-	.5	.5	.5	.5	.5	2	.5	1.2
Annual meadow grass	-	.2	-	-	-	-	-	-	-	-	-	-
Sedge	-	-	-	.2	-	.7	-	.5	-	.3	-	-