WEED CONTROL IN GRASSLAND IN UNITED KINGDOM

By H. P. ALLEN

At first glance grassland weed problems in New Zealand would appear to be very closely similar to those which face us in the United Kingdom. Of course they are in that many of the weeds are common to both countries. On closer inspection, however, it is evident that the magnitude of the problems of grassland weeds is basically different in the two countries. A glance at comparative statistics will make my point clear.

In New Zealand the acreage of pasture land is 31,000,000, of which 18,000,000 are sown pastures and 13,000,000 in natural grassland. Over and above this you have 5,000,000 acres of land which you describe as fern and scrub. Your sown pastures apparently include both surface-sown hills and lower lying land of better fertility put down to good grass mixtures (ryegrass, white clover, etc.) and improved by good grazing management and topdressing with artificial fertilisers. In both groups of sown pasture white clover is playing a most important role in the economy of the sward; in fact, much of the nitrogen utilised by the sward grasses is provided by the clover, which is fed by topdressing with phosphates. Throughout New Zealand, more particularly in the North Island and the northern part of South Island, I am told that grass growth is continuous for the greater part of the year, due to your equable climate and to the absence of prolonged drought. Dairy stock in particular depend almost entirely on pastures for feed; fresh grass supplemented by hay and silage in the late summer. They seldom need to be wintered indoors; hence the pastures never receive the prolonged rest that *must* be given to grass during the British winter.

Admittedly the poorer type of your surface-sown hills may not be rich in clover; nevertheless, wherever it occurs I am sure it is guarded jealously.

In the United Kingdom the grassland is divided in our agricultural statistics into "temporary" (that is sown) pasture, either undersown in cereals or seeded direct (without a cover crop); "permanent pasture" sown or "tumbled" down at one time far back), and "rough grazings" which correspond reasonably closely to your fern and scrub. We have 6,000,000 acres of temporary pasture, 13,000,000 acres of permanent pasture, and 17,000,000 acres of rough grazings in England, Scotland, Wales, and Northern Ireland. Eleven million acres of the rough grazings are in Scotland and 10,000,000 acres of the permanent pasture are in England and Wales.

Only a mere 25 years ago in England ideas as to what constituted good grassland management were astonishingly restricted in their scope. Many years before Gilchrist's memorable work at Cockle Park had demonstrated how by the use of phosphates wild white clover could take a major part in contributing to the value of a permanent pasture. Basic slag and wild white clover were regarded as the basis of grassland management when I was a student in 1938. To suggest anything else would have been heresy.

The argument was and is absolutely sound. But in those days the English farmer's conception was on a field by field basis. He tended to concentrate his attack on one field, and, having slagged it and produced his clovery sward, he considered he had reached his goal.

Then came Stapleton and William Davies with their exhortations that the farmer consider grass as a crop. They pointed out how rotation

grass could produce food in and out of season and at the same time help to increase the fertility of the land. Martin Jones showed conclusively how intensity and nature of stocking could influence sward composition. Nitrogen was shown to be invaluable in helping to extend the period at which grass was available for grazing. In short, in recent years the conception of grassland management on a *farm* basis has gradually superseded the idea of *improvement* on a field by field basis. It is now realised that "slag and wild white clover" is only one facet of the story.

When a farmer considers increasing the productivity of his grassland he has to look further than the mere calculation of the amount of phosphate that he must apply to his 20-acre paddock. He has to work out what the extra productivity will mean in terms of extra stocking, extra buildings for his cattle, extra storage space for hay and silage, etc. He has to consider his best method of tackling the improvement. In short he must plan. Some fields will obviously be ploughed and re-seeded. Others not so well placed for this will require draining, liming, pitchpole harrowing, and *weeding*. The control of weeds on many of these pastures scheduled for improvement must be achieved somehow. It is here that the hormone weedkillers can and do play their part.

I mentioned a few minutes ago that in the United Kingdom there were 13,000,000 acres of permanent pasture. This permanent pasture, however, is of mixed quality. Much, too much, of it is producing less than its maximum, and nitrogen is not available for the sward either from the clovers (which, alas are often conspicuous by their absence) or from the bag.

This state of affairs has tended to complicate the issue as far as chemical weed control is concerned. Most of our sown pastures stay down for 3 to 6 years before being ploughed out. In the seeding year the major weeds are usually annuals which may be dealt with culturally (though not always so). In the later years (second and third especially) perennial weed problems may arise, especially creeping thistle, buttercup, and docks, and our difficulty in tackling such weeds has always been danger of damage by hormone weedkillers to the clover component of the sward. I shall deal with this point at length later. I bring it in here only to indicate one of our major obstacles to chemical weeding of temporary grass. On our permanent pasture where weed problems arise the clover is not always present in sufficient quantity to warrant its consideration. The main snag has been the farmer's doubt about the economics of using weedkillers to remove weeds from his permanent grass.

I should say that the position is, on the whole, more straightforward in New Zealand and that the case for hormone weedkillers on your pastures, where weeds are a problem, is rather more obvious than it is at present in Great Britain. The main reason for this surely lies in the fact that in New Zealand quite a large proportion of your sown pastures are of high value economically and that, though safety to clovers is of prime importance, the removal of weeds is of obvious economic benefit to the farmers concerned. In Britain, on the other hand, by far the majority of our weedy grass comes under our definition of permanent pasture and many farmers, quite rightly, consider the use of weedkillers to be justified *only as part of an extensive grassland improvement programme*; that is, when associated with intensive management and ultimately increased stocking.

The use of hormone-type weedkillers MCP and 2, 4-D against grassland weeds developed very slowly in Britain. Templeman's discovery of these chemicals in 1941 and 1942 respectively was followed up by their extensive use against weeds of cereal crops from 1946 onwards, but though work was in progress at Jealott's Hill, at the A.R.C. Unit of Experimental Agronomy at Oxford under Professor Blackman, at

Fernhurst, and elsewhere as early as 1946, it was not until 1950 that ICI undertook extensive demonstration trials. These established on a farm scale the useful nature of these weedkillers on buttercups, rushes, creeping thistle, and other troublesome pasture weeds.

The reasons for this slow development were first, that much had to be ascertained concerning safety of MCP and 2,4-D to sward, stock, and stock products; and second, that before 1950, no cheap type of low volume sprayer was available to apply the chemicals.

In 1945 feeding trials at Jealott's Hill indicated that cattle could ingest large quantities of MCP, far larger than those used in practice, without suffering any harm.

Between 1946 and 1949 information was compiled concerning the susceptibilities of our main grassland weeds and, by the latter date, quite a lot of *general* knowledge had been gathered. It was known that creeping buttercup, tall buttercup (giant buttercup), creeping thistle, and the common rush were susceptible to dosages of 1 to 2lb. active equivalent per acre of MCP and 2,4-D, mainly water soluble salts of these chemicals; that broad-leaved dock was exceedingly stubborn, as was bulbous buttercup. This knowledge was really the "shell," very little detail was known about periods of maximum susceptibility and advantages and disadvantages of combining cultural treatment with chemical treatment, etc.

In 1950 when grassland spraying suddenly became a very practical proposition we in Britain began the task of building up our constructive case for presentation to farmers and since that date information has been collated on specific aspects of the problem, namely:—

1. The economic factors connected with grassland weed control.
2. The effect of weedkillers and chemical-cultural techniques on the main weeds and the persistence of these effects.
3. The effect of weedkillers on the clover components of swards and methods of minimising risk of damage.

The case for spraying much of our permanent pastures in Britain is, as I have mentioned earlier, inextricably bound up with the need for all-round improvement of the grass. There is seldom a case for spraying *unsupported* by at least fertiliser application. For those who must have facts and figures, it has proved exceedingly difficult to produce clear-cut evidence that the removal of weeds by chemicals has resulted in extra milk yields or extra liveweight increase, or extra cow or sheep-grazing days. As you well know, it is difficult enough to compare pasture productivity on a quantitative basis when one is concerned only with different systems of management. To attempt to segregate the effects of removing weeds is a task for which we have no sufficiently precise technique as yet.

TABLE 1—BUTTERCUP TRIALS OF ICI, JEALOTT'S HILL, AND C.A.C. SUMMARY OF RESULTS

Average yields (dry matter) cwt./acre MCP application lb. acid equivalent per acre.

Dates and rates	Autumn			Spring		
	0	2	4	0	2	4
Total useful herbage ..	17.6	22.8	22.4	19.0	18.8	19.4
Buttercup*	8.3	2.3	1.7	7.0	1.9	2.0
Clover*	2.4	1.8	0.5	2.8	0.6	0.3

*Average of centres whose yields were recorded.

However, some attempts have been made to measure pasture yields; leaving the grazing animal out of the pasture and relying on cuts. In 1946-47 Templeman of the ICI Research Station at Jealott's Hill and colleagues in ICI Central Agricultural Control carried out a series of 9 trials (1) in which 2 and 4lb. acid equivalent per acre of MCP sodium salt were applied in autumn 1946 and spring 1947 to control creeping buttercups (*Ranunculus repens*). The hay yield of the treated pasture was measured in 1947. These results are shown in Table 1.

It will be seen that autumn application of MCP at both rates has increased markedly the total herbage and has decreased the weight of buttercups. Yield of clover was depressed, especially with the 4lb. rate of MCP. Spring treatment reduced buttercup and clover, but had little effect on yield of total useful herbage. The reason for the discrepancy between autumn and spring results is that grass on all treatments was cut in June 1947, which meant that plots sprayed in September 1946 had had 9 months in which to benefit from weed removal, whereas those sprayed in spring (May) 1947 had been treated less than 6 weeks at the time of cutting. The buttercup had been killed, but grasses had not had time to recolonise the areas vacated by the weeds.

This short interval between spraying and cutting has obviously affected the clover recovery. The position is clearly aggravated by the fact that the pastures were put up for hay almost immediately after spraying, thus allowing the grass to grow and keep the clover in check. Clover depression by autumn spraying was still evident, but comparative figures (that is, 2lb. MCP autumn and spring) show that the clover was recurring on the autumn treatments.

In think I am right in saying that hardly any data relating weed removal and animal productivity are yet in existence, though a few workers have measured herbage yields in a manner similar to that described above. I prefer to view the matter from a different angle. I shall base my point on Table 2 which illustrates degree of control of creeping thistle (*Cirsium arvense*) with MCP (2).

TABLE 2—CONTROL OF CREEPING THISTLE WITH MCP
(Sodium Salt at 1.5lb. acid equivalent per acre)

Sites sprayed	Average percentage of weed control in		
	Summer 1950	Summer 1951	Autumn 1952
1950 only	54	62	94
1950 and 1951	46	83	98
1951 only	—	37	79

It will be seen that by summer 1951 sites sprayed in summer 1950 and 1951 showed an average of 83 per cent. control of the weed; by autumn 1952 even the sites sprayed only in 1950 were almost clear of the weed. Creeping thistle, except when very young, is of little value as herbage. It is unpalatable, unattractive because of its sharp "spines," and discourages grazing in the immediate vicinity of the plant. An 83 per cent. control *must* mean a very considerable increase in the available grazing area of the affected field. Obviously the weedkiller will not influence the quality of the herbage which remains. The improvement of that is up to the farmer, but with the removal of offending weeds the way is wide open for such an improvement.

The control of the common rush (*Juncus effusus*) is another illustration of the clear-cut value of the rapid removal of weeds from permanent pasture.

A considerable amount of land in the south of Scotland, south Wales, Ireland, and south-western England is infested with the common

rush. Much of this land suffers from impeded drainage, but a large area is of very reasonable agricultural value. Some of the affected land (particularly at the 600 to 900ft. contour) was reseeded with ryegrass, timothy, etc., and clovers, but rushes have triumphed in the end. MCP and 2,4-D will suppress the common rush very satisfactorily and very rapidly, leaving the pastures clear and ready for improvement by topdressing and well-planned management. It is interesting to note that in Scotland the Department of Agriculture have accepted some MCP and 2,4-D derivatives as being eligible for grant aid, as part of the Marginal Land Improvement Scheme, a notable step forward in the recognition of the value of selective weedkillers in pasture.

We have naturally been very interested in comparing various salts and ester formulations of 2,4-D on our main pasture weeds. S. J. Willis (3) in 1949 tested MCP sodium salt and ethyl ester of 2,4-D against both creeping and bulbous buttercups. The weeds were treated with the chemicals in both spray and dust form at rates of 1lb. and 2lb. acid equivalent per acre. The creeping buttercup (along with some tall buttercups) was treated before flowering, and the bulbous species was treated at flowering time. Assessments in 1950 gave the following results (see Table 3).

TABLE 3—PERCENTAGE CONTROL OF BUTTERCUP WITH MCP AND 2,4-D

		Experiment 1		Experiment 2	
		Oaklands		Buntingford	
		Creeping and tall buttercups		Bulbous buttercup	
Average of rates	Treatments				
	MCP	82		64	
	Dust 2,4-D	79		38	
Average of forms					
	MCP	96		76	
	Spray 2,4-D	77		72	
Average of forms					
	1lb. MCP	84		64	
	2,4-D	71		20	
	2lb. MCP	94		78	
	2,4-D	84		90	

Willis drew from his work the inference that both MCP sodium salt and 2,4-D ethyl ester would control creeping, tall, and bulbous buttercup. Results from experiments carried out by other workers and ourselves confirm that creeping and tall buttercups may be suppressed by MCP and 2,4-D, but Willis's results on bulbous buttercup were far better than the normal. The Agricultural Research Council Unit of Experimental Agronomy at Oxford (4) reported that MCP is markedly superior to 2,4-D for the control of creeping buttercup, as determined in the year following spraying. They indicate that both creeping and tall buttercups are susceptible to MCP at 1 and 2lb. acid equivalent per acre. The 1lb. rate, giving satisfactory suppression of the weeds, can be sprayed in spring when they are growing actively but before they are in full flower. Later spraying is probably slightly easier on the clover component (3), but a higher dosage rate will probably be necessary. Oxford also point out that satisfactory control of bulbous buttercup has not been achieved.

CREEPING THISTLE (*Cirsium arvense*)

The general method of tackling this weed in English grassland is to apply the chemical when the thistles are in the "tight bud" stage; that is, when the buds are visible but well before they burst. We believe that

in that way we are hitting the weed when its creeping rootstock is at its most vulnerable. Even so, experience has taught us that regrowth must be watched very carefully in the following late spring, and if it is at all extensive, we advise a repeat spraying. There is no advantage in using more than 2lb. acid equivalent per acre of either MCP or 2,4-D, nor is anything to be gained by using other than sodium or potassium salts or amines. There are some indications that MCP is slightly superior to 2,4-D on creeping thistle, and on the same weed in Canada MCP is stated to be superior to 2,4-D in its effect.

Table 2, to which I referred earlier, summarises the results of trials carried out between 1950 and 1952 by ICI Ltd. and Plant Protection Ltd. Willis (5), reporting on the results of a single experiment on creeping thistle, indicates a tendency for optimum control of the weed to be obtained with 1lb. acid equivalent per acre of MCP or 2,4-D, whether salts or esters. His results show a *tendency* for control to fall off at higher rates. Ochiltree at Fernhurst, again in a single experiment, also noted a falling off in effect with rates of 1½ and 2lb. acid equivalent per acre of MCP and 2,4-D derivatives, as compared with 1½lb. acid equivalent per acre. It is necessary to emphasise that these results came from two isolated trials, but it does suggest that our knowledge concerning sensitivity of creeping thistle to hormone weedkillers is by no means complete. One point arising from trials by the Oxford unit (4) is that spraying creeping thistles as they stand, at the "tight" or early bud stage, is superior to spraying immediately after cutting or even some months after.

We are blessed with many other species of thistle, but the only other thistle of importance as a weed of pastures is the spear thistle (*Cirsium vulgare*) a biennial. This plant is a prodigious seeder, but is moderately susceptible to hormone weedkillers and 1½lb. acid equivalent per acre of metal or amine salts of either MCP or 2,4-D, applied just before the flowering shoot is sent up, should suppress the weed successfully.

I have already alluded to rushes and to their importance as economic problems on land which is potentially of reasonable value. The common or soft rush (*Juncus communis*) and related strains succumb to 1½ to 2lb. acid equivalent per acre of any of the derivatives of MCP and 2,4-D, and its disappearance from the sward is speeded up considerably by cutting 2 to 3 weeks before, or even after, spraying. Recolonisation of

TABLE 4 — AVERAGE PERCENTAGE INFESTATION OF COMMON RUSH (*Juncus communis*) ON 3 SITES AFTER TREATMENT WITH MCP SODIUM SALT

(Figures represent frequency of occurrence expressed as a percentage.)

Cultural treatment	Date of spraying	Date of assessment					
		Summer 1950 (August)		Spring 1951 (May)		Summer 1951 (August)	
		Untreated	*MCP	Untreated	*MCP	Untreated	*MCP
Uncut	June 1950	85	65	85	35	70	22.5
†Cut before spraying	June 1950	86	43.3	73.3	20	68.3	25.0

*MCP sodium salt at 1.5lb. acid equivalent per acre in 6 gallons water per acre.

†Untreated rushes left uncut.

the rush stools is made easier and more rapid by this combination of spraying and cutting, but it is important to rake away the cut rushes. On a long-term basis spraying uncut rushes can produce an equally good control, but the process is very gradual, and the plants take a very long time to die.

Table 4 shows means of results on sites where rushes were sprayed with MCP sodium salt (a) in 1 year only and (b) 2 years in succession.

There is *some* evidence of *speed* of kill of cut rushes as compared with uncut rushes in the tables.

The hard rush (*Juncus inflexus*), though less common than the soft or common rush, is nevertheless a considerable nuisance on the sheep pastures of the Romney Marsh, also in East Anglia, and in parts of south-west England. It has been classed as virtually resistant to the hormone weedkillers, but an experiment laid down by my colleague, Ochiltree, in 1953 has indicated success with MCP potassium salt and 2,4-D butyl ester sprayed on the uncut rush in May 1953 and again in May 1954, each time at 3lb. acid equivalent per acre in 18 gallons of water. An essential part of the treatment is that cutting of the rushes should follow 3 to 4 weeks after spraying, and that the cut rushes should be raked away.

Horsetail (*Equisetum palustre*) infests some of the lower lying land with a higher water-table and its presence in a pasture is a real menace. Stock find it difficult to graze selectively on the infested pastures and the weed can cause most serious scouring. MCP or 2,4-D water based salts at $\frac{3}{4}$ lb. acid equivalent per acre will kill the aerial growth if applied when the barren shoots are at their full growth in spring. Root kill is negligible and the weedkiller may have to be applied each spring, but farmers troubled with the weed have taken to the practice quite enthusiastically.

Finally, and most tantalising of all the pasture weeds of Great Britain come ragwort (*Senecio jacobaea*) and the docks (*Rumex* spp.).

Ragwort growth in Britain is seldom consistent from year to year. Though the plant is a biennial, botanically speaking, the influence of man and animals usually causes the weed to perennate by offshoots. Seed germination may take place in autumn and/or spring, depending on climatic conditions obtaining. The result of all this is that in early midsummer a ragwort population in a given field may consist of very young seedlings, young first-year rosettes derived from autumn germinated seed, second-year rosettes about to shoot, "shot" plants about to flower, and young growth from "offshoots." The susceptibility of ragwort to hormone weedkillers in these different stages is unfortunately not uniform, and it has been our experience that the vigorously growing rosette stage is the most susceptible. Spraying in one season only is usually quite inadequate, and a repeat spraying in the second and even the third year is necessary to ensure a real reduction in the ragwort population. The second spraying should catch those plants which as seedlings or young "offshoots" escaped the first application. We in Great Britain do not feel in a position to be at all dogmatic about ragwort control. At Fernhurst we have not found any one hormone derivative markedly superior to any other, but Blackman and his colleagues (4) found 2,4-D to have a slight advantage. As to rate, though improved results have been obtained with increasing rates up to 4lb. acid equivalent per acre, there seems little point in exceeding $1\frac{1}{2}$ lb. acid equivalent per acre in any one application. Volumes of around 18 to 20 gallons per acre have given satisfaction in commercial practice.

Attempts to control established broad-leaved docks in pasture have caused many headaches. Main true dock species in Britain are the curled-leaved dock and the broad-leaved dock. Both docks succumb to MCP and 2,4-D when in the seedling stage and the curled dock is moderately responsive even when established. The broad-leaved dock, once established, is most obstinate, and attempts with sodium, potassium, and amine salts and with esters of MCP and 2,4-D have produced most inconsistent results ranging from a very high degree of control to complete absence of effect.

Encouraged by your reported success with low volatile forms of 2,4-D, we at Fernhurst tested low volatile MCP and 2,4-D against the more volatile (butyl and iso-butyl) esters on established broad-leaved docks of varying age. In addition, we applied our chemicals in April, in May, in June, and in July in the hope of selecting an optimum growth stage for treatment. Finally we tested single applications against double applications separated by intervals of 10 days. These experiments began in 1954 so that the important assessments are only now (July) being made, but preliminary indications from counts made in the autumn of 1954 were not very illuminating. Low volatile 2,4-D (alphanyl ester) was showing up on a par with normal butyl ester of 2,4-D, MCP derivatives were slightly inferior, and MCP potassium salt was only mediocre. There was a slight tendency for April application (rather early for hormone weedkiller application in Britain) to produce better results, but this technique was only tested with MCP potassium salt.

I have devoted a considerable amount of time to describing the background to grassland spraying in Great Britain and to a description of our recommendations for the application of MCP and 2,4-D derivatives to our main grassland weeds. There remains the most important question of all, namely, the effect of the weedkiller on the sward, by which, of course, I mean the clover component of the sward. I have read with great interest a draft of a report by Maclean, Fitzgerald, and Matthews describing trials carried out at Invermay and at Marton, and I am greatly encouraged to see how closely their results agree with general experience in United Kingdom.

Research work carried out from Fernhurst on clover has been in two phases. First, the effect of MCP sodium salt on established wild white clover in permanent pastures was studied in the series of 105 demonstration trials carried out between 1950 and 1952. It was in this series that a lot of the weed control information was gained.

Briefly, we noted that with $1\frac{1}{2}$ lb. acid equivalent per acre of sodium MCP applied in spring or early summer there was an initial check to the clover, manifested mainly by a slight retarding of flowering. It was equally obvious that this initial check was seldom long lived, and that speed of recovery depended (a) on the plant nutrient status of the pasture and (b) on the management of the pasture following treatment with weedkiller. If the pasture had received adequate phosphate and potash to meet the needs of the clover, recovery was quite rapid. If clover was surviving in the sward with difficulty, then the weedkiller effect was much more pronounced. Any factor stimulating grass competition following weedkiller treatment rather naturally slowed down the recovery of the clover; for example, putting up a grass field for hay immediately after application of weedkiller. Though these points were qualitative observations rather than quantitative estimates, they seem to have been borne out in commercial agricultural practice. Table 5 gives an indication of speed of recovery of wild white clover after spraying with MCP sodium salt at $1\frac{1}{2}$ lb. acid equivalent per acre in 6 gallons water (a) for one season and (b) in two successive seasons.

TABLE 5—EFFECT OF MCP SODIUM SALT AT 1.5lb. ACID EQUIVALENT PER ACRE ON WILD WHITE CLOVER IN ESTABLISHED SWARDS (FIGURES REPRESENT FREQUENCY OF OCCURRENCE EXPRESSED AS A PERCENTAGE)

Sites sprayed in	Summer 1950		Spring 1951		Summer 1951	
	Untreated	MCP	Untreated	MCP	Untreated	MCP
1950 only (10 sites) ..	65.6	56.6	39.4	36.6	71.8	60.25
1950 and 1951 (8 sites)	68.1	65.0	31.3	24.0	65.5	47.9
1951 only (12 sites) ..					63.2	54.4

The figures require some explanation, as at first glance they may seem to indicate clover dominance. Estimation of weeds and clover in this trial-demonstration series was made on the basis of "frequency of occurrence." Twenty quadrat estimates were made across each plot; that is, treated and untreated. Each species was marked up where it occurred in a quadrat. Abundance of occurrence was also allowed for. Thus in 20 quadrats clover may score 140 points; that is, 140 out of 200 possible. This figure is expressed as a percentage, 70 per cent.

Table 5 shows a 10 per cent. reduction on sites sprayed in 1950 only, which reduction is maintained through to the summer of 1951. Spraying in two successive years has produced a rather more severe check.

The second phase of our work concerned the investigation of the effects of MCP and 2,4-D salts and esters on various varieties of clover grown pure and in combination with grasses. These results have been reported in the Proceedings of the 1st and 2nd British Weed Control Conferences of 1953 and 1954 and the implications of the work will be reviewed in brief here. Ochiltree (6) and (7), who carried out the work, drew the following conclusions from the trials over the two years.

1. Broad and late flowering red clovers are much more susceptible to damage *at all stages of growth* from the application of 2,4-D triethanol amine and n-butyl ester than from MCP potassium salt and n-butyl ester at equivalent dosage rates (as acid equivalent).
2. Seedling white clovers are more susceptible to MCP derivatives than to 2,4-D derivatives, but the difference in effect is less marked than with red clovers.
3. Once white clovers are established, particularly in their second and third year of growth, there appears to be little difference in effect between MCP and 2,4-D derivatives (other than esters) at equivalent dosage rates.

The following tables bear out these conclusions:—

TABLE 6—SHOWING EFFECT OF 2,4-D TRI-ETHANOLAMINE AND MCP POTASSIUM SALTS ON THREE CLOVERS IN THE SEEDING YEAR OF A LEY (1953)

Chemical	S100 white clover			Broad red clover			Late flowering red clover		
	4wks.	8wks.	12wks.	4wks.	8wks.	12wks.	4wks.	8wks.	12wks.
2,4-D amine									
at ¾lb. ..	90	80	95	35	43	91	27	33	65
at 1½lb. ..	38	33	56	8	30	40	9	11	18
MCP K salt									
at ¾lb. ..	100	94	85	65	87	154	100	90	107
at 1½lb. ..	28	30	36	39	60	94	36	73	65
Control ..	100	100	100	100	100	100	100	100	100

Treatments given in lb. acid equivalent per acre

TABLE 7—SHOWING EFFECT OF MCP AND 2,4-D DERIVATIVES ON DIRECTLY RESEEDED LEY IN ITS SEEDING YEAR (1953). FIGURES SHOW PERCENTAGE COVER 4 WEEKS AFTER SPRAYING

Treatment	Broad red clover	Late flowering red clover	S100 white clover
2,4-D amine at $\frac{3}{4}$ lb.	12	7	65
2,4-D amine at $1\frac{1}{2}$ lb.	1	7	30
MCP potassium at $\frac{3}{4}$ lb.	118	85	80
MCP potassium at $1\frac{1}{2}$ lb.	101	116	33
2,4-D n-butyl ester at $1\frac{1}{2}$ lb.	3	3	32
Control	100	100	100

Treatments given in lb. acid equivalent per acre

TABLE 8—SHOWING THE EFFECT OF MCP AND 2,4-D DERIVATIVES ON S100 WHITE CLOVER IN A THIRD YEAR HARVEST LEY (1953). FIGURES SHOW PERCENTAGE COVER 3 WEEKS AND 7 WEEKS AFTER SPRAYING

Treatment	After 3 weeks	After 7 weeks
1. 2,4-D n-butyl ester at $\frac{3}{4}$ lb.	12	53
2. 2,4-D n-butyl ester at $1\frac{1}{2}$ lb.	12	42
3. MCP potassium at $\frac{3}{4}$ lb.	20	70
4. MCP potassium at $1\frac{1}{2}$ lb.	11	43
5. MCP n-butyl ester at $\frac{3}{4}$ lb.	21	68
6. MCP n-butyl ester at $1\frac{1}{2}$ lb.	11	34
7. Control	100	100

Treatments given in lb. acid equivalent per acre

In his 1954 trials on clovers Ochiltree found that the difference between effects of 2,4-D and MCP derivatives on *seedling* white clovers was in favour of 2,4-D derivatives at the $1\frac{1}{2}$ lb. acid equivalent rate, but at $\frac{3}{4}$ lb. per acre the difference was not at all marked. One rather unusual point arose which is being checked again this year, namely, that in the case of seedling S100 and wild white clovers, 2,4-D butyl ester at $\frac{3}{4}$ lb. acid equivalent was less damaging than either MCP butyl ester, MCP potassium, or 2,4-D *tri-ethanol amine* at equivalent rates.

On established white clovers (in second and third harvest year leys) both in 1953 and 1954 Ochiltree found that though initial depression was severe whatever the derivatives used, nevertheless, recovery took place often in as short a time as 8 weeks where fertility and management were alike of a high standard.

Considerable interest has been taken in the clover susceptibility problem in the past 2 to 3 years, not only from the angle of spraying pastures but also with regard to the use of hormone weedkillers on undersown cereal crops. E. B. Scragg (8) and (9) and K. Holly (10) each reported work on this problem at the 1953 British Weed Control Conference. Scragg found that *red clovers* were not seriously impaired by MCP sodium or amine salts at 1lb. acid equivalent per acre, either in an undersown crop or in a direct reseed. He, like Ochiltree, noted that 2,4-D was definitely more harmful than MCP on seedling red clovers and that the converse was true, though much less marked, with seedling white clovers. Holly's results were along similar lines with regard to relative toxicity of MCP and 2,4-D on red and white clovers.

In Germany Kersting (11), working at Westfalen Hippe, tested an MCP metal salt, a 2,4-D amine, and a 2,4-D/2,4,5-T mixed ester product

on red and white clovers. Somewhat naturally he found that on both clovers the mixed ester was the most toxic and his results support the general view that on red clovers the 2,4-D formulations are more toxic than MCP formulations.

In a nutshell then it is apparent that on established pastures where the main clover component of the sward will be white varieties, there will be some slight depression whether MCP or 2,4-D derivatives are used, but that differences in effect between MCP and 2,4-D metal and amine salts are so slight that the choice can be based on the weeds requiring treatment. We in Britain do not have your experience with low volatile forms of 2,4-D; therefore we use salts and amines of MCP and 2,4-D and occasionally the ethyl, butyl, or iso-butyl ester form of 2,4-D on established grassland. It is clear from our experience, as it is from yours, that clover suffers least damage when established if the pasture is sprayed soon after hard grazing.

On newly sown leys choice of derivative must be governed by the clover component. In short-term leys where red clovers are dominant the MCP water metal salts at $\frac{3}{4}$ lb. acid equivalent per acre form quite a safe treatment. Higher rates may be used under ideal conditions, but 2,4-D preparations are far too toxic. Where seedling white clovers are dominant, neither MCP nor 2,4-D is really a safe proposition unless the weeds themselves protect the clover.

The truth of the matter is that until very recently there has not been a really safe and effective weedkilling technique that could be recommended for use on newly sown pasture. The discoveries of Professor R. L. Wain at Wye College (12), reported in the Proceedings of the 1954 British Weed Control Conference, have brought to light a new factor determining selective action, namely, the differential ability of various crop plants and weeds to break down the biologically innocuous phenoxy butyric compounds into biologically active MCP, 2,4-D, and 2,4,5-T. Wain has shown that red and white clover and celery are hardly affected at all by derivatives of 2-methyl, 4-chloro phenoxy butyric acid (MCPB), and 2,4-dichloro phenoxy butyric acid (2,4-DB) and that MCPB, 2,4-DB, and 2,4,5-TB are worthy of trial on peas, though oddly enough lucerne is severely damaged by MCPB and less so by 2,4-DB.

The implications of these new discoveries are obvious, particularly as a fair number of arable and grassland weeds are apparently able to break down MCPB and 2,4-DB to MCP and 2,4-D thereby bringing about their own destruction.

Cereals undersown with red and white clovers and leys newly seeded to grass/clover mixtures are obvious candidates for such chemicals and very extensive tests are being carried out through Britain (and, I believe, in the United States) this season. In hopeful vein, one could think of broad-leaved docks in young leys being tackled in the seedling stage by MCPB or 2,4-DB without fear from clovers. On a more sober note, however, it must be obvious that these new chemicals will be rather more restricted as *weedkillers* than MCP and 2,4-D because their toxicity to weeds is dependent on their being broken down to the latter active chemicals.

In this very long discourse I have tried to indicate what developments have taken place in the use of hormone weedkillers on grassland in Great Britain. I have pointed out that a lot of our permanent pasture weedkillers *must* be considered as part of a general renovation programme on land which for one reason or another cannot be ploughed. Fertiliser treatment and cultural treatments are essential factors in the renovation of such pasture, and weedkillers can and do help to speed up this renovation by removing the offending weeds quickly.

REFERENCES

1. Templeman, W. G., J.Sci. Food Agric. 5 Aug. 1954, p. 387.
2. Allen, H. P., and Ochiltree, W., Agriculture Vol. 60, No. 9, 1953, p. 412.
3. Willis, S. J., Agriculture Vol. 57, No. 8, Nov. 1950, p. 359.
4. Holly, Woodford and Blackman, Agriculture Vol. 59, No. 1, April 1952, p. 19.
5. Willis, S. J., Proc. 2nd Brit. W.C.C. 1954, Vol. 1, p. 95.
6. Ochiltree, W., Proc. 1st Brit. Weed C.C. 1953, p. 124.
7. Ochiltree, W., Proc. 2nd Brit. Weed C.C. 1954, p. 125.
8. Scragg, E. B., Proc. 1st Brit. Weed C.C. 1953, p. 107.
9. Scragg, E. B., Scottish Agriculture Vol. 32, 1952-53, p. 124.
10. Holly, K., Proc. 1st Brit. Weed C.C. 1953, p. 116.
11. Kersting, F., Nachrichtenblatt des Deutschen Pflanzenschutzdienstes, April 1954 6 (4) pp. 59-62.
12. Wain, R. L., Proc. 2nd Brit. Weed C.C. 1954, Vol. 1, p. 311.

DISCUSSION

Q.—Most commercial firms use standard test plants such as tomatoes, cucumbers, and beans to test for toxicity of newly developed materials. Would it not be better to use for this purpose the weeds which these materials will be called on to eradicate?

A.—The old attitude is changing now and many firms are using important weed plants to test their new materials. For instance, in U.S.A. in areas where mesquite is a problem this is being used as a test plant. However, there is often difficulty in providing environmental conditions suitable for germinating and growing such weed plants. The standard test plants, such as cucumbers and tomatoes, are still used, but mainly in the first stage of research to eliminate unsuitable materials.

Q.—Dr. Went spoke of the value of the phytotron in weed research in supplying information about the susceptibility of weeds in controlled climatic and environmental conditions. Would Dr. Allen agree that such controlled environment work has considerable advantages over normal weed research in the field?

A.—I quite agree but at present such controlled environment work is neither being done nor contemplated in England. I understand, however, that in Australia such a method is being used effectively in developing techniques for the control of skeleton weed.

Q.—I think more critical work should be done in New Zealand on rates of application, in particular with a view to reducing rates to a figure more in keeping with New Zealand conditions.

A.—There is a school of thought in England that holds it is sufficient simply to put on just enough material to shift the environmental balance against the weed and let the crop do the rest. However, if the weather becomes unsuitable or something goes wrong with the operator or the machine, this technique of using the minimum application rate leaves no room for error. I think in practice it is better to go a little higher than is strictly necessary.

Q.—Have you any information on the use of sulphuric acid for kale crops?

A.—In England sulphuric acid is sparingly used for weeds in brassicas. The rate used is 7 to 10 gallons of sulphuric acid in 100 gallons of water. As a rule it would only be used if the weeds were so high as to cover the crop completely, so without spraying the crop would be a write-off. Recently potassium cyanate has been used successfully against weeds in kale. Potassium cyanate has been used in the past for weeds in daffodils and tulips, but this is the first reference I have seen to a really suitable post-emergence spray for brassica crops.