previously untreated plots was to increase the loss of leaf by scorching by an average of about ten per cent on all varieties. No data was obtained on effect on yield.

Effect on rate of maturation - Tenderometer readings revealed that none of the herbicide treatments had any significant effect on ripening. Differences recorded did not represent more than one day since at around the "practical canning stage", tenderometer readings advance, on average, about 7 - 8 points per day.

On the basis of the results of these experiments, provided the correct recommended dose is used it would appear safe to treat all varieties tested with propham (pre-sowing) or mixtures of chlorpropham/fenuron or chlorpropham/diuron (pre-emergence). So far as the other herbicide treatments employed in peas are concerned, it seems that the varieties may be classified provisionally as below.

Variety	TCA	MCPB	Dinoseb ammonium	Dinoseb amine
Used for vining green				
Dark Skin Perfection	A	C	B	A
Gregory's Surprise	A	B	D	C
Kelvedon Wonder	C	C	C	B
Lincoln	C	B	B	A
Meteor	B	C	B	A
Onward	B	B	B	A
Perfected Freezer	D	C	B	A
Thomas Laxton	C	B	D	C
Victory Freezer	B	B	B	A
Witham Wonder (tall)	A	B	B	A
Used for harvesting dry				
Big Ben	D	A	A	A
Pauli	D	A	B	A
Rondo	A	A	A	A
Zelka	D	A	A	A

Key

A = Tolerant
B = Inclined to be slightly sensitive
C = Moderately susceptible
D = Susceptible

It is suggested that varieties placed in categories C and D should be treated with circumspection, reducing the dose of the herbicide chosen by 10-20 per cent.

In the case of TCA, the dose should remain at the recommended 7.5 lb/ac but only be applied if other factors favour its use rather than propham (Reynolds 1960). Where dinoseb is applied on TCA - treated land, the dose of the former should be reduced by about half; with the less tolerant varieties the dose should be cut by at least a half.

Acknowledgments

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REFERENCES

BUTLER, A.J. (1960). Chemical control of wild oats by pre-sowing treatments. Proc Brit Weed Control Conf, 1958, 167-170

CARPENTER, K., SOUNDY, M. and WILSON, C. (1957). The effect of MCPB on the yield and maturity of vining and picking peas. Proc Brit Weed Control Conf, 1956, 515-521

HIRST, R.H., MARTIN, D.L., GATHERGOOD, A.L. and UPTON, R.A. (1957). Weed control in peas with dinoseb and phenoxybutyric acid derivatives. Proc Brit Weed Control Conf, 1956, 523-529

PROCTOR, J.M. (1958). Unpublished data.

PROCTOR, J.M. (1960). Personal communication.

PROCTOR, J.M. & ARMSBY, W.A. (1960). Control of wild oats in peas: progress report, 1957-58. Proc Brit Weed Control Conf, 1958, 156-161.

REYNOLDS, J.D. (1960). A guide to weed control in peas. Proc Brit Weed Control Conf, 1958, 143-148

REYNOLDS, J.D., PROCTOR, J.M. and HIND, R.A. (1957). Studies with phenoxybutyric herbicides in peas, 1955-56. Proc Brit Weed Control Conf, 1956, 499-513

ROBERTS, H.A. (1959). Evaluation of dinoseb for the control of annual weeds in market-garden peas. Exp Hort, 2, 19-25.

ROBERTS, H.A. and WOODFORD, E.K. (1951). DNBP for the control of weeds in peas. J Minist Agric, 63, (6), 268-273

CHLORPROPHAM/DIURON MIXTURES FOR PRE-EMERGENCE WEED CONTROL IN PEAS, BEANS AND BULBS.

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Summary. The results of one year's commercial experience with a proprietary formulation of a CIPC/diuron mixture* applied as a selective residual pre-emergence weed control treatment in ornamental bulbs and spring sown peas and beans are reviewed. Crop safety, weed control, and residual toxicity are discussed in relation to soil and agronomic factors, rainfall, and the crop and weeds present. Results were highly satisfactory on bulbs, and largely so on peas and beans. Crop damage occurred only with faulty application. Where unsatisfactory weed control occurred on peas and beans low rainfall was the most important factor. The best control was obtained on lighter soils and later-sown crops. Increased dose rates are indicated for heavy soils or those high in organic matter and for early-sown crops, together with more latitude in timing of application relative to sowing.

INTRODUCTION

A proprietary formulation of a mixture of chlorpropham and diuron was introduced to the United Kingdom market in the autumn of 1959 with recommendations for the control of germinating weed seedlings in spring-sown peas, broad beans and tick beans, and on ornamental bulbs. The results of commercial applications are reviewed in relation to the various climatic and agronomic factors affecting performance, of which the two most important appear to be soil type and rainfall.

In recent years chlorpropham/fenuron mixtures have shown considerable promise as residual pre-emergence treatments in relatively deeply-sown large-seeded crops, such as peas and beans, and crops which have underground storage organs, such as bulbs. The selectivity of these mixtures appears to depend partly on the physical properties of the components which govern their movement in the surface layers of various soil types, and partly on the inherent physiological tolerance of the crops to the herbicides.

The suitability for selective uses of the four substituted urea herbicides: fenuron, monuron, diuron and neburon, is largely determined by their ability to resist leaching in the soil. The order of preference for selective uses is neburon, diuron, monuron, fenuron. Table I, which summarises the solubility and soil adsorption characteristics of these herbicides, helps to explain the differences observed in selectivity. (Wolf, D.E. et al 1959)

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* as "Residuren", (Farm Protection Limited).

TABLE I. PHYSICO-CHEMICAL CHARACTERISTICS OF FOUR SUBSTITUTED UREA HERBICIDES.

Compound	Solubility in Water (25° C.)	Adsorption on Keyport Silt Loam*
	ppm	ppm*
Fenuron	3850	0.3
Monuron	230	2.6
Diuron	42	5.2
Neburon	5	16.0

*ppm (active ingredient) present on soil in equilibrium with 1 ppm in soil solution. Studies were conducted at 72°F.

A careful consideration of the combined characteristics of chlorpropham/substituted urea mixtures under the wide variety of factors encountered in practical use, determined the choice of a chlorpropham/diuron mixture as the preferred treatment for development and commercialisation for the above-mentioned uses.

The mixture was formulated as an emulsifiable concentrate, based on 32 ounces of technical chlorpropham and 8 ounces of diuron 80 per cent wettable powder+ per Imperial gallon=.

RESULTS.

Peas and Beans

On spring sown peas, broad beans, and field or tick beans, the mixture was recommended as a pre-emergence treatment, applied at four pints in 100 gallons of water per acre, within 48 hours of sowing or drilling.

Treatment was not recommended on soils where there was any element of doubt as to their ability to retain the herbicide in the surface layers. Such soils are those low in clay or organic matter, for example, light, sandy soils and certain silts.

Growers who practised unusually shallow drilling, at a depth of 1 in. or less, were advised not to use the mixture.

Late treatment, i.e. after mid-May, was not recommended, because of limited experience.

The mixture was applied commercially in all the major pea and bean growing areas of the country, but naturally the predominant use was in East Anglia.

+as "KARMEX" Diuron, Du Pont.

Weed Control

In general, weed control was satisfactory. The best results were obtained on the lighter soils, many of which received only three pints of the mixture per acre. On heavier soils, the results were more variable, and the small proportion of unsatisfactory results occurred mainly on such soils.

Undoubtedly the most important factor influencing weed control was soil moisture, as residual herbicides, which rely on root absorption for their activity, must have moisture to produce lethal concentrations in the top inch of soil where most weed seeds germinate. Following sowing, rainfall was low over most of the principal pea and bean growing areas. Representative data are shown in Table II.

TABLE II. RAINFALL, 1960

(Expressed as a percentage of the long-term average)

	February	March	April	May
Manston, Kent	91	93	43	127
Felixstowe, E.Suffolk	70	146	36	63
W. Raynham, Norfolk	78	65	39	25
Mildenhall, W. Suffolk	79	95	23	34
Finningley, Notts.	114	97	52	50
Scarborough, N. Riding, Yorks.	97	84	37	51

In addition, cold, dry winds blew during much of the early growing season and soil dried out quickly after light rain. The germination of many summer annual weeds was delayed under these conditions, frequently it would appear, until much of the activity of the chemicals had been lost, especially that of chlorpropham which is volatile.

The sowing of peas and beans, however, was not delayed, nor was emergence, but subsequent growth was much slower than one would normally expect. Where weeds germinated late, and were not satisfactorily controlled by the chemical, the crop was often insufficiently well developed to smother them. The period of residual activity was therefore too short in early sown crops, particularly under slow growing conditions. In later sowings, where the weeds germinated soon after application, control was excellent and later germinating weeds could not compete with the crops.

Under marginal conditions, the weeds showing greatest tolerance were: fumitory (*Fumaria officinalis*), speedwells (*Veronica* spp.) and groundsel (*Senecio vulgaris*); but under optimum conditions they were well controlled. Under average conditions, consistently good control was obtained of the following weeds: mayweeds (*Matricaria* and *Anthemis* spp.), knotgrass (*Polygonum* aviculare), black bindweed (Polygonum convolvulus), redshank (Polygonum persicaria), chickweed (Stellaria media), annual meadow grass (Poa annua), poppies (Papaver spp,), shepherd's purse (Capsella bursa-pastoris). Some reductions in population of wild oats (Avena spp.) were observed presumably from kill of seeds near the soil surface. Fathen (Chenopodium album), charlock (Sinapis arvensis), runch (Raphanus raphanistrum) and hempnettle (Galeopsis tetrahit) were well controlled, except where germination took place long after application.

Crop Safety

There was no suggestion of crop damage where a satisfactory spray mixture was applied according to the recommendations. No damage was reported at any time from overlap of the spray swathes. Occasionally in beans, but not peas, small areas of damage were observed, which clearly could be attributed to spraying while turning on headlands.

Although excluded from the recommendations, a considerable area of light sandy soil in the East Midlands was sprayed at the reduced rate of three pints of the product per acre, without apparent damage. Nevertheless, a wider range of experience is required before making firm recommendations for treatment on such soils.

Residual toxicity was suspected in three fields sown to susceptible catch crops, two of kale and one of mustard, immediately after harvesting preceding pea crops treated with the mixture about sixteen weeks earlier. The damage symptoms were slight chlorosis, particularly of the cotyledons, and a temporary check to growth. A careful search of catch crops with a similar history revealed no further evidence of damage. In the suspect fields the soil was exceedingly dry following the pea harvest and, ploughing being considered impracticable, the cultivations employed prior to sowing were rotavations and harrowing. There were no obvious factors peculiar to these sites to explain the implied persistence of phytotoxic residues in the soil for so long a period after such small initial applications of the chemicals.

Bulbs

Narcissus, Iris, Tulips

On narcissus, daffodils, bulbous iris and tulips, two applications, each at one gallon of the mixture in 100 gal of water/ac, were recommended. The first application was advised immediately after planting on new beds, or after late summer cleaning on established beds, to control autumn and winter germinating weeds. The second application was advised as near to crop emergence as possible to obtain optimum control of winter and spring germinating weeds.

Generally, a single application just prior to emergence was employed, as many growers used contact herbicides, for example sodium arsenite, to kill weeds which were already established.

The residual treatments gave consistently good weed control and there was no evidence of damage to crops. Many treated beds were maintained in a clean state for six months after treatment. Excellent control was obtained of mayweeds (Matricaria and Anthemis spp.) which are not well controlled by pre- or post-emergence treatments of chlorpropham alone.

Gladiolus

On gladiolus, treatment was recommended immediately after planting, with a second application after emergence, provided the crop plants were not more than 4 in. high. For each treatment, the recommended application rate was one gallon of the mixture in 100 gal of water/ac.

Weed control treatments based on these recommendations were highly satisfactory.

There was only one report of damage, which took the form of severe scorch to the leaves. This resulted from a late post-emergence application to a crop 18 in. to 24 in. high. Very high temperatures followed immediately after spraying.

DISCUSSION

The successful use of selective residual pre-emergence weed control depends on certain basic requirements: consistent control of weeds, a wide margin of safety to crops, a rate of disappearance from soils that permits the normal growth of subsequent crops, and use-cost competitive with existing control methods. Commercial experience with a chlorpropham/diuron mixture during the past year suggests that these requirements are met in bulbs.

They are met in peas and beans, except for some inconsistencies in weed control. Accordingly, our recommendations for peas and beans for 1961 will be modified to improve weed control over a wider variety of soil and weather conditions. For soils high in clay or organic matter, the rate of application will be raised to six pints per acre throughout the season. The six pint rate will also apply to crops sown early, i.e. before March 15th. The restrictions on the interval of two days between sowing or drilling and application will also be relaxed to allow spraying up to seven days before the expected time of emergence of the crop, provided weeds have not emerged. This will often allow up to three weeks delay in the application to slow-growing early sown crops providing an additional period of residual herbicidal activity. Commercial and experimental work has indicated that both peas and beans have an adequate margin of tolerance to the increased rate of application.

While retaining the same concentration of active ingredients the chlorpropham/diuron mixture has been formulated to withstand water hardness corresponding with a maximum of 450 ppm of calcium as $CaCO_3$ and 1,600 ppm of magnesium as $MgCO_3$. This should confer adequate tolerance to the great range of water hardness encountered.

Despite the apparent tolerance of peas and beans to doses of the mixtures in excess of those recommended, there should be strict observance of all precautions designed to prevent possible damage to crops. The depth of sowing should be carefully controlled and never less than one inch below the soil surface. For this reason, broadcast sowing followed by harrowing is unsuited to residual pre-emergence treatment. The seedbed should be left with a fine, even tilth and it is advisable to roll before treatment to ensure moderate consolidation of the soil. Uniform application with properly agitated spray equipment is important, and over-dosing particularly at headlands and by generous overlapping of spray swathes must be avoided.

Limited commercial experience has shown that medium and low volume application can give satisfactory results; but further investigations are required before a reduction in the volume rate can be recommended.

The development of reliable methods of residual pre-emergence weed control in row crops eliminates the need for post-emergence spraying and post planting cultivations which unavoidably cause crop damage. Rows are generally spaced to facilitate cultivations; but plant population studies have shown that such spacing may limit maximum growth and yield per acre. The new technique of weed control should help to promote the development for practical use of research findings on seedbed preparation and plant spacing.

REFERENCE

WOLF, D.E. et al (1959). Herbicidal properties of neburon. Proc. 15th N. Central Weed Control Conf., (1958), 7-8.

PRE-EMERGENCE AND POST-EMERGENCE WEED CONTROL IN MAIZE

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Summary. Weeds, not birds, are the worst enemies of maize. Inter-row cultivation is of limited value and hitherto only tentative recommendations have been issued for the use of herbicides for weed control in maize in this country. During 1959-60 experiments carried out in the South East Region have tested the value of (i) simazine as a pre-emergence herbicide and (ii) three substituted phenoxy-acetic acids for post-emergence application.

A classification of weeds, commonly found in maize crops, is presented, based on their susceptibility to simazine. There are indications that simazine benefits maize other than by mere removal of weeds. The stage of growth of the crop, at the time of spraying, appears to be of greater importance than the choice of herbicide when MCPA or 2,4-D is used for post-emergence weed control. Crop yield data indicate the likely responses following the application of herbicides in the maize crop.

INTRODUCTION

The acreage of maize (Zea mais) grown for ensilage in this country is growing rapidly. It has been estimated that 5,000 acres of maize, as a fodder crop, were grown in the south of England in 1960. The impetus for this sudden increase in crop acreage is derived, no doubt, from (i) improved methods of harvesting and (ii) the introduction of double-cross hybrid varieties. These new varieties are capable of producing, in terms of dry matter, from 4-5 tons per acre of a high-energy value fodder crop that is comparatively easy to conserve by ensiling.

There are many problems of crop production, under conditions in this country, remaining unsolved. Paramount amongst these are the means of attaining (1) freedom from bird damage and (2) freedom from weed competition. The increase in maize acreage in any one locality (10-20 acre units) has tended to reduce the intensity of bird damage to any one crop. This, coupled with combinations of bird-scaring methods, has done much to remove one of the greatest obstacles in maize production in this country. Maize, in its young stages of growth, cannot tolerate competition from weeds. Down-the-row cultivations can eliminate weeds in the inter-row area but leave undisturbed the weeds in the maize drill where they are least desired. Some doubts still exist about the wisdom of moving soil in the vicinity of the spreading roots of maize. There is wide scope, therefore, for the use of herbicides to attain early control of weeds in the maize crop.

An experiment, laid down in Berkshire during 1959 alongside variety and manuring trials, tested the value of simazine as a pre-emergence herbicide in maize. Despite the very dry conditions that prevailed during the immediate post-spraying period a successful control of weeds coupled with increased crop yield was attained. The experiment has been repeated at the same site during 1960.

TABLE II. CROP AND WEED GROWTH - AT POST-EMERGENCE SPRAYING

Crop and Weed species	Berkshire 1960				Hampshire 1960	
	First stage-30th May		Second stage-13th June		Single stage-16th June	
	Plants /sq yd	Stage of growth and height	Plants /sq yd	Stage of growth and height	Plants /sq yd	Stage of growth and height
MAIZE	8.5	4th leaf appearing 3-4 in.	8.4	mean 6.3 leaves 6-10 in.	6.6	6th leaf appearing 4-6 in.
Chenopodium album (Fathen)	13	1st true leaf 1 in.	18	6-8 leaves 3-4 in.	232	3-6 true leaves 2-4 in.
Cirsium arvense (Creeping Thistle)	10	3-5 leaf 2 in.	11	4-6 leaf 4-5 in.	2	4th leaf 5 in.
Veronica agrestis (Speedwell)	196	cotyledon to 2 true leaf	288	70 per cent - 3rd pair 20 per cent - cotyledon	21	1-2 true leaf 1½ in.
Thlaspi arvense (Pennycross)	-	none present	-	none present	95	2nd whorl 1-2 in.
Matricaria maritima (Mayweed)	-	none present	-	none present	57	3-4th pair leaves 1-2 in.
Stellaria media (Chickweed)	43	1-2 runners 2 in. length	72	2-4 runners 1-4 in.	-	none present
Fumaria officinalis (Fumitory)	13	4-6 leaf 2-3 in.	18	early flower 3-6 in.	-	none present
Urtica urens (Annual nettle)	11	cotyledon	54	2nd pair true leaves ½-1 in.	-	none present
Sonchus arvensis (Sow Thistle)	6	2 leaf rosette	8	2 true-leaves ½ in. postrate	- -	none present

Weather conditions at and following spraying are obviously of some importance where a low-solubility pre-emergence herbicide is used during late spring. In the case of maize weather conditions post-spraying govern to a large extent the recovery of the crop in the event of any initial setback due to spray toxicity. Meteorological data, for each centre, are therefore given in detail in Table III.

TABLE III. WEATHER CONDITIONS AT EACH SITE - DURING AND AFTER SPRAY APPLICATION

Period T=dry temperature RH=Relative Humidity	Pre-emergence applications		Post-emergence applications		
	Berks		Berks - 1960		Hants - 1960
	1959 7th May	1960 5th May	1st stage 30th May	2nd stage 13th June	single stage 16th June
Day of spraying	T - 68°F RH - 58 per cent Soil knobly dry to 2in. depth	T - 70°F RH - 36 per cent Fine seed-bed moist 2 in. deptch	T - 66°F RH - 36 per cent Dry foliage warm sunny	T - 64°F RH - 41 per cent Sunny after heavy rain dry foliage	T - 71°F RH - 77 per cent Dry foliage overcast
For 48 hours post-spray	overcast warm dry	sunny warm dry	very dry sunny	warm showers 0.08 ins.	sunny warm dry
First appreciable rainfall post spray	21st May 0.24 in.	11-12th May 1.14 in.	7-8th June 0.52 in.	22nd June 2.83 in.	22nd June 0.62 in.
Rainfall during one-month post-spray General Conditions	0.56 in. Showers on 4 days otherwise dry and warm	2.13 in. Dull showery then dry warm period	4.36 in. Dry at first then heavy showers warm-with thundery spells	5.36 in. Alternating periods of heavy rain and dry periods	3.68 in. Thundery spells. Wet, cool at end of the period

RESULTS

Pre-emergence

Weed Control. During the dry period following spraying in 1959 no visual effects of the herbicide could be observed 14 days post-sowing. By this time numerous seedlings of Stellaria media (Chickweed) and Veronica agrestis (Speedwell) had become established in all plot areas. Maize had fully emerged by the 26th May. Towards the end of June however visual differences in weed population and vigour were observed in treated areas. A careful record of weed species surviving, with an indication of plant vigour, was made on the 17th July in each yard length of each logarithmic plot.

Conditions post-spraying, in 1960, were much more favourable for a soil-acting herbicide such as simazine. A considerable difference in weed population, within a logarithmic plot, showed clearly during early growth stages. On the 13th June an assessment of species distribution and plant vigour in each yard length of a plot was recorded.

From these observations, in both years, a classification of weed species, according to the degree of control given by simazine at various concentrations per acre, has been compiled in Table IV.

Whereas a dose range of 2.0-2.5 lb/ac simazine was required to give complete eradication of Cirsium arvense (creeping thistle) in both years of tests - 1.5-2.0 lb/ac simazine gave a useful control of the same species and reduced the vigour of the remaining plant. A lower dose range 1.0-1.5 lb/ac simazine whilst not reducing plant population of creeping thistle to any extent, was nevertheless capable of depressing the growth of the weed such as to allow the crop to dominate and eventually crowd out the species. This principle, relating to the effect of reducing doses, could be applied to all the other weed species enumerated in the table.

TABLE IV. WEED SPECIES CLASSIFICATION - COMPLETE ERADICATION BY SIMAZINE APPLIED AS A PRE-EMERGENCE SPRAY TREATMENT

Dose range of simazine	1959 - Berks	1960 - Berks
2.5-3.0 lb/ac	Rumex obtusifolius Agropyron repens	Agropyron repens (patches)
2.0-2.5 lb/ac	Polygonum aviculare; Polygonum convolvulus; Galium aparine Cirsium arvense, Thlaspi arvense Hypochaeris radicata	Polygonum convolulus; (14) Cirsium arvense (patches)
1.5-2.0 lb/ac	Chenopodium alba; Urtica urens, Fumaria officinalis; Solanum nigrum; Ranunculus repens	Sonchus arvensis (6); Galium aparine (occasional) Chenopodium album (10) Fumaria officinalis (11)
1.0-1.5 lb/ac	Sinapis arvensis; Raphanus raphanistrum; Myosotis arvensis	Stellaria media (31) Urtica urens (81) Veronica agrestis (225)

An indication of weed population in control plots Berks 1960 is given in brackets as plants/sq yd

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Post-emergence weed control - doses in oz/ac.

(i) Hants centre:- An assessment one month post-spraying (13th July) recorded Chenopodium album 18 in. high in early flower stage and dominating maize (10-13 in. high) in the control plots. In sprayed plot this weed species was absent or moribund at rates above 12 oz MCPA; 8 oz 2,4-D-amine and 6 oz 2,4-D-ester. Thlaspi arvense (Pennycress) had succ umbed to all treatments above 6 oz level. Veronica agrestis (speedwell) was eradicated by 2,4-D-ester above 16 oz. There was an arrest of growth, resulting in spindly development of Matricaria maritima (scentless mayweed) following treatment with MCPA 24 oz; 2,4-D-amine 16 oz and 2,4-D-ester 12 oz.

(ii) Berks centre:- Here, by mid-July, it was evident that the control obtained by the second stage application was much superior to that resulting from the earlier application. This was due partly to late germination of many weeds. Some indication of the efficiency of treatments at the Berks centre is given in Table V.

TABLE V. BERKS CENTRE. MINIMUM DOSES (OZ/AC) REQUIRED TO GIVE DEGREES OF CONTROL

Post-emergence application	MCPA		2,4-D-amine		2,4-D-ester	
Degrees of control	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage
Good overall eradication of weeds	40 oz	36 oz	32 oz	24 oz	20 oz.	20 oz.
Kill of Chenopodium album and Cirsium arvense. Serious retardation of growth of Veronica agrestis and Urtica urens	32 oz	24 oz.	24 oz	20 oz	16 oz.	12 oz
Arrest of growth of all weeds causing yellowing of foliage and failure of normal flowering	24 oz	16 oz	16 oz	16 oz	10 oz.	8 oz

Note:- Stages of growth of all weed species at time of spraying are given in Table II.

Perhaps the most outstanding features at the Berks centre were (i) the considerable resistance shown by Fumaria officinalis (fumitory) to all spray treatments and (ii) in contrast, the efficiency of the herbicides used in arresting the growth of Veronica agrestis (speedwell) and Urtica urens (annual nettle) - species not generally classified as being very susceptible to the action of substituted phenoxyacetic acids.

Visual effects of Treatments on growth of Maize

There were no visual toxicity symptoms during the growth period of maize at the Berks centre (1959/1960) following pre-emergence application of simazine at doses up to 3 lb/ac. By mid-August maize plants in the simazine treated areas, in particular where doses of active chemical applied exceeded 1½ lb/ac, showed vigorous healthy growth.. Crop foliage in these areas had assumed a dark olive green colour suggestive of heavy nitrogenous top dressing.

Severe leaf rolling and other toxicity symptoms were observed where post-emergence treatments, at certain doses, had been applied at both centres. These symptoms were at their maximum intensity during mid-July when the maize plants were 15-18 in. high and carrying 7-8 leaves. An indication of the severity of the symptoms, at various doses, is given in Table VI. Delaying the application of treatments until maize was in the 6th-7th leaf stage, at the Berks centre, aggravated crop toxicity symptoms compared to those observed following earlier application when maize was showing 4th leaf. These differences far exceeded any differences between types of herbicides at any one dose.

TABLE VI. CROP TOXICITY SYMPTOMS - POST-EMERGENCE APPLICATION (doses in oz)

Centre	Berks - 21st July						Hants - 15th July		
Application	1st Stage			2nd Stage			Single Stage		
Maize stage at spraying	4th leaf - 3 to 4 in.			6-7 leaves 6-10 in.			6 leaves 4-6 in.		
Symptom group	MCPA	2,4-D -amine	2,4-D -ester	MCPA	2,4-D -amine	2,4-D -ester	MCPA	2,4-D -amine	2,4-D -ester
	oz	oz	oz	oz	oz	oz	oz	oz	oz
1. Severe rolling of leaf; Scorch areas on older leaves yellowing of young leaves - very brittle stems	none	none	above 30	above 24	above 27	above 20	above 32	above 26	above 20
2. Slight rolling of leaves - some yellowing and brittle stems	above 40	near 48	22 to 30	20 to 24	22 to 27	12 to 20	24 to 32	20 to 26	16 to 20
3. Occasional young leaf rolling	24 to 40	24 to 48	18 to 22	14 to 20	16 to 22	8 to 12	16 to 24	16 to 20	12 to 16
4. No visual symptoms	below 24	below 24	below 14	below 14	below 16	below 8	below 8	below 16	below 12

At equal doses per acre 2,4-D-ester was much more toxic than 2,4-D-amine, particularly following the second stage application in Berks. At this stage also 2,4-D-amine was less toxic than MCPA but very little difference was observed between these herbicides following their application at an earlier crop stage of growth. In Hampshire MCPA was slightly less toxic than 2,4-D-amine at doses above 16 oz/ac.

Treatment effect on yield of Maize

The fall in concentration in a logarithmic plot is in an exponential manner allowing for a selection of a plot area to represent a desired range of dose application. Thus it is fairly easy to pin-point an area of the crop which was treated with 2-3 lb/ac of active ingredient of any herbicide. Similarly an area treated with 1-1½ lb/ac of the same chemical can be located and these areas would be equal in size. In the experiments reported upon dose range plots, described above, covered an area of 4 rows of maize along 4 yards length of row equal to $\frac{1}{360}$ acre. These areas, using the four centre rows from six sprayed, were harvested from each logarithmic plot at each centre together with a similar harvest area selected in each control plot. Yields of green crop and dry matter per acre of maize, harvested during the last week in September in each year, are given in Table VII.

The plots harvested from inter-row cultivated areas, in Berks, adjoined the post-emergence treated plots but were some distance from the simazine trial. All harvested areas, at this centre, had however been grown under equal cultural conditions apart from different methods of weed control.

Yields from the Hants centre were rather low. Here the trial was sited in a crop that had received no basic manuring but followed a well managed ley. No explanation can be advanced for the reduced yield following the application of 2,4-D-amine at 1-1½ lb/ac at this centre. All three replicate plots gave similar yield of green crop and dry matter per acre.

DISCUSSION

Weather conditions post-application play an important role in the efficiency of simazine. In 1959 0.56 in. rainfall was recorded, at the Berks centre, during one-month period post-spraying whilst rainfall at the same centre during a corresponding period in 1960 was 2.13 in. This difference between seasons is reflected in crop yield responses and accounts for any variation in the susceptibility of some weed species as indicated in Table IV.

Following a dry May-June period the increase from a 1.0-1.5 lb/ac to a 2.0-3.0 lb/ac level of application resulted in a much improved control of some of the more resistant weeds coupled with a crop yield increase of 11 per cent dry matter/ac. In 1960 however yields of maize showed no significant response from a corresponding increase in the rate of simazine applied. Some weed species - Agropyron repens (couch grass), Cirsium arvense (creeping thistle) and the late germinating Polygonum convolulus (black bindweed) - did however succumb more readily to the higher doses. Commercial applications of simazine for weed control in maize have not in all cases met with equal success to that reported in the experiments. Investigation of these failures however indicates that in the majority of cases the herbicide had been applied from 7-14 days post-sowing. In the Berks trials spraying followed immediately on sowing before rolling of the seed-bed and before the latter had dried out excessively. This may be of significance with a crop that is sown during, generally, the driest period of the year. In wet seasons Solanum nigrum (black nightshade) can be a troublesome weed in fodder crops such as maize. Simazine at 1.5 lb/ac gave a complete eradication of this weed in the 1959 trial despite the late germination of the weed as noted in the control plots during June and July. Visual crop toxicity symptoms were not observed in any of the trials following the

TABLE VII. MEAN YIELDS OF MAIZE AS HARVESTED FOR ENSILING – TONS/AC

Centre	Stage of application of spray	Dose range/ac	Number cobs per stem	GREEN CROP				DRY MATTER			
				Cob	Stover	Total		Cob	Stover	Total	
						Ton/ac	per cent control yield			Ton/ac	per cent control yield
Berks 1959	Pre-emergence	Simazine 1-1½ lb 2-3 lb Control-same blocks	0.9 1.0 0.8	5.4 5.9 4.2	6.6 7.8 5.7	12.0 13.7 9.9	121 138 100	2.23 2.33 1.66	1.57 1.88 1.34	3.80 4.21 3.00	126 140 100
Berks 1960	Pre-emergence	Simazine 1-1½ lb 2-3 lb Control-same blocks	1.1 1.2 1.0	10.3 10.1 6.6	15.3 16.2 11.1	25.6 26.3 17.7	145 149 100 (a)	2.20 2.03 1.31	2.87 3.03 2.14	5.07 5.06 3.45	147 147 100 (a)
Berks 1960		No herbicide treatment Cultivation Inter-row 27th May	1.2	9.0	12.2	21.2	120 (a) 137 (b)	1.91	2.32	4.23	123 (a) 140 (b)
	Post-emergence	Control-same block	1.0	5.8	9.7	15.5	100 (b)	1.17	1.85	3.02	100 (b)
		MCPA 1-1½ lb 1st Stage 2-3 lb	1.1 1.3	6.0 7.6	9.2 10.1	15.2 17.7	99 114	1.29 1.63	1.74 1.90	3.03 3.53	100 117

(78178)

Berks 1960	Post-emergence	MCPA 1-1½ lb	1.1	7.1	10.8	17.9	116	1.54	1.94	3.48	115
		2nd Stage 2-3 lb	1.2	8.1	11.6	19.7	127	1.68	2.13	3.81	126
		2,4-D-amine 1-1½ lb	1.2	6.5	9.8	16.3	105	1.36	1.95	3.31	110
		1st Stage 2-3 lb	1.4	8.4	11.2	19.6	126	1.71	2.22	3.93	130
		2,4-D-amine 1-1½ lb	1.4	8.4	11.1	19.5	126	1.67	2.16	3.83	127
		2nd Stage 2-3 lb	1.2	8.8	11.0	19.8	128	1.75	2.13	3.88	128
		2,4-D-ester 1-1½ lb	1.1	6.6	9.0	15.6	101	1.51	1.73	3.24	107
		1st Stage 2-3 lb	1.3	7.9	10.0	17.9	116	1.67	1.84	3.51	116
		2,4-D-ester 1-1½ lb	1.3	8.2	10.7	18.9	121	1.79	2.10	3.89	129
		2nd Stage 2-3 lb	1.3	7.7	10.1	17.8	115	1.66	1.81	3.47	115
Hants 1960	Post-emergence	MCPA 1-1½ lb	1.7	8.0	10.6	18.6	200	1.04	2.09	3.13	194
		MCPA 2-3 lb	1.8	7.6	11.1	18.7	201	1.37	2.08	3.45	214
		2,4-D-amine 1-1½ lb	1.5	6.1	8.2	14.3	154	0.82	1.59	2.41	150
		2,4-D-amine 2-3 lb	1.8	9.6	11.6	21.2	228	1.41	2.31	3.72	231
		2,4-D-ester 1-1½ lb	1.7	8.9	11.3	20.2	217	1.17	2.12	3.29	204
		2,4-D-ester 2-3 lb	1.7	8.7	11.4	20.1	216	1.16	2.26	3.42	212
		Control same block	1.3	3.7	5.6	9.3	100	0.46	1.15	1.61	100

application of up to 3 lb/ac of simazine. Doses of the chemical exceeding 1.5 lb/ac appeared to give an added boost to the growth of the crop. The vigour of the crop in treated areas compared favourably with that of the farmers crop adjoining which was favoured with a topdressing of 34 units of nitrogen per acre and where weed control was by interrow cultivation. Gysin and Knusli (1958) have suggested that the metabolites of simazine are utilised by the maize plant for its further growth.

The hitherto high cost of simazine products, in this country may be a deterrent to wider usage in the maize crop. The Berks trial in 1960, however, indicates that the cost of chemical for a 1.5 lb/ac application is amply covered by the yield response of 1.6 ton dry matter /ac. [A valuation of £6 per ton dry matter ex-field can be considered low.] The danger, consequent on maize failure, to other crops must be emphasised. A careful survey of other trial centres in the dry year 1959 indicated however that there was no likelihood of damage to cereal crops sown in October after application of doses below 3 lb simazine/ac in the previous May.

The trial in Hampshire has shown that, where weeds susceptible to MCPA and 2,4-D dominate in a maize crop, post emergence spraying with these herbicides can lead to worthwhile increases (200 per cent) in dry matter yield. In such a case there is little to choose between MCPA and 2,4-D-amine provided the crop is sprayed at or before the 6-leaf stage. Doses of these two herbicides, below 24 oz/ac, are unlikely to cause any serious effects on the crop when applied during the early crop growth stages. Growth conditions during a 4-6 weeks period post-spraying are likely to have some bearing on the degree of crop damage and the ability of the maize to recover from any temporary setback.

At the Berks centre early application of 2,4-D or MCPA did not give a good control of weeds since some weed species were late germinating. The second stage application of growth regulator herbicides did however arrest the growth of the majority of weeds present and allowed for crop responses of the order of 15-30 per cent dry matter increase over control yield.

Summarising the results of these experiments we find that simazine is an extremely efficient herbicide for weed control in maize provided it is applied soon after the crop is sown. At rates required to give satisfactory control of weeds, normally found in the crop, there is unlikely to be any crop toxicity. Indeed simazine appears to be a stimulant to maize growth. Post-emergence control with MCPA or 2,4-D-amine can also prove satisfactory particularly if supported by inter-row cultivation. Crop damage is likely to increase however if the spraying is delayed much beyond the 5th-6th leaf development of the maize.

REFERENCES

G. S. HARTLEY, R. K. PFEIFFER AND P. T. BRUNSKILL (1956)
The Chesterford Logarithmic Sprayer. Proc 3rd Brit Weed Control Conf. 2.1956.

H. GYSIN AND E. KNUSLI. Activity and mode of action of Triazine Herbicides. Proc 4th Brit Weed Control Conf. 1958.

APPLICATION OF HERBICIDES IN CONJUNCTION WITH PRECISION DRILLING IN KALE, TURNIPS AND SWEDES

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Summary. The results of seven experiments using P.C.P. as a pre-emergence weed control material in kale and turnips are discussed. The outcome of the investigations has been the development in practice of a modified technique of application where spraying is the first operation after ridging and drilling carried out soon afterwards. The application of herbicides in conjunction with precision seeding is becoming established as a means of further reducing the costs of root growing and results from general practice are discussed. Preliminary work with diquat suggests that this herbicide may replace P.C.P. in the future.

INTRODUCTION

The use of the precision drill in kale and root growing areas is rapidly replacing the usual cup or brush feed implement. This change means that instead of the usual 4 lb/ac seed rate a ½ lb seeding can be quite adequate provided conditions for growth are near ideal. (Prytherch, E.I. 1959).

The new drill which deposits single seeds at pre-determined spacings, demands that competition from weed growth be kept at a minimum if full advantage is to be taken of its impact in lowering growing costs. A weedy crop requires a heavy input of labour, particularly for inter-plant cleaning if the crop is to flourish. Timely cultural operations, of course, are all important to attain excellent soil conditions as well as a low weed seed population at the time of sowing and very often, under the best husbandry practices, weeds do not present a problem. But cultural difficulties sometimes arise as a result of the place of the crop in the rotation. Where kale or roots follow a one-year ley or a winter cereal crop for spring grazing the period for the preparation of the seed bed often becomes limited so that a satisfactory reduction of the weed population in the soil cannot be accomplished by the traditional methods. Complementary therefore to cultivation in the destruction of weeds for the creation of good conditions for the normal development of the crop, come weed-destroying chemicals.

The usual growth regulator types of herbicide which are at present available are unsuitable for use in brassica crops. The use of residual herbicides is dependent on their quick breakdown in soil if any measure of success is to be achieved and this in turn is greatly influenced by soil and weather conditions which cannot be predicted. The contact herbicide, provided a suitable technique for its application was devised, appeared of potential value.

METHODS AND MATERIALS

In 1955 a pilot study was carried out with PCP (pentachlorphenol) as a pre-emergence weed control agent in a crop of kale. The land was ridged up for drilling 15 days before spraying at which date there was a considerable cover of annual weeds. The kale was drilled in the weedy seed bed three days before spraying. There was a complete kill of weeds with only slight subsequent weed competition with the crop and no apparent loss of vigour in growth of the crop.

Subsequent experimental work in Wales during 1956/8 in association with the ARC followed the same pattern. The technique in the case of brassica crops was essentially a modified pre-emergence system. This was found necessary as brassica seed will germinate simultaneously with the majority of weed seeds. After sowing in the weedy seed bed when weed seedlings were about 1 in. tall, spraying effectively disposed of a large population of weed before the crop seedlings emerged. The technique of drilling in the weedy seed bed just before spraying was followed in each of the trial years.

Seven experiments were conducted in Wales over the period, five in kale and two in turnips. Details of the field operations are given in Table I.

TABLE I. DETAILS OF EXPERIMENTS

YEAR	1956			1957			1958
CENTRE	1	2	3	4	5	6	7
Date of ridging	16 June	8 July	2 July	8 July	4 June	10 June	10 July
Date of drilling	4 July	17 July	14 July	20 July	20 June	30 June	3 Aug.
Date of Spraying	8 July	20 July	17 July	23 July	24 June	2 July	4 Aug.
State of weed growth at spraying	1st leaf	Cotyledon	True leaf emerging	Cotyledon	4th leaf	Cotyledon	2nd leaf

Dry weather conditions retarded the growth of weed after the preparation of the seed bed in 1956, whilst in both 1957 and 1958, June and July were wet months and weeds flourished. Weed densities were assessed at the time of spraying, and also some 14 to 21 days later. This period will be accepted as a critical period in crop establishment, and the experiments were designed to determine the effect of the removal of early weed competition on yield of crop.

Preliminary tests with new herbicides had indicated the possible role of pentachlorphenol PCP as a useful contact herbicide in brassica crops and the trials were designed to determine the value of this chemical at two doses.

The treatments were as follows:-

A - PCP 1½-2 lb a e/ac) Applied in 40 gal/ac at 25 psi
B - PCP 3-4 lb a e/ac)
C - Control, no hand weeding until singling
D - Control, weeds removed by harrowing after sowing

The crop at each centre was precision drilled and singled at the normal time. Cleaning was incidental in the sprayed plots as well as in the control where weeds were removed by harrowing after sowing (D). Control C represented traditional practice where weeds are allowed to compete with the crop until the usual singling time.

The weed population at each centre consisted of a variety of species, the main constituents being Polygonum persicaria (redshank), Sinapis arvensis (charlock), Brassica cleracea (wild cabbage), Spergula arvensis (spurrey) and Chenopodium album (fat hen).

RESULTS

The main results are illustrated in Table II. The effect of the herbicides on each species was very similar and consequently no individual records of herbicidal effect on different species are given in this paper.

The experiment at each centre showed that the herbicide was efficient in destroying weed growth even at a fairly advanced growth stage. The counts for the second crop of weeds which were made 14-21 days after spraying show a substantial reduction in the sprayed plot compared with the unweeded control plots 'C'. The differences were statistically significant at four centres. Moreover, the fresh crop of weeds would be in a very early growth stage at singling time compared with those in the unweeded control plots and this feature would be reflected in considerably lower costs of cleaning and singling in these plots than in those representing traditional practice plots 'C'.

A residual effect was deemed to exist where the increase in the weed population of the unweeded plots was substantially greater than the fresh populations of weed which arose after spraying. This was indicated at three centres viz. centres 1, 2 and 7.

The removal of weeds by surface cultivation soon after drilling did not reduce the weed population at singling time but being in a considerably younger stage of growth they were less competitive.

The effect of the treatments on crop plant vigour is illustrated in the scoring made soon after crop emergence. The higher dose per acre of the herbicide had a greater depressing effect on vigour at each centre than the lower. In general, this adverse effect was less than that occasioned by the competition from weed. The reduction in vigour in the initial growth stages of the crop, however, was not reflected in the total yield of crop. Comparing both sprayed treatments with the control that represents traditional practice, it was noted that yields were generally higher in the former. In fact out of 14 comparisons yields were significantly higher on 7 occasions. It must also be noted that yields per centre were generally low due to a prolonged dry weather period in 1956 which inhibited the growth of weed thus delaying the sowing date for the crop and to adverse conditions in 1957 and 1958 when prolonged rainy weather hindered the drilling and spraying operations.

DISCUSSION

The results obtained from experiments were very encouraging despite the fact that there was one obvious shortcoming to the method. This was the physical obstruction caused by the weed growth to the efficient operation of the drill. Moreover, under inclement weather conditions the crop would have germinated before spraying could be undertaken. Such experiences led to the

TABLE II. CONTROL OF WEEDS, CROP VIGOUR AND CROP YIELD

	1956				1957		1958	
	1 (Kale)	2 (Kale)	3 (Kale)	4 (Turnips)	5 (Kale)	6 (Turnips)	7 (Kale)	REMARKS
Weeds at spraying time (Range/sq ft)	11.0-19.4	16.8-24.8	23.2-40.8	30.8-97.6	11.2-24.8	10.2-21.3	21.0-30.1	
Weeds at spraying time (Mean count per sq ft)	13.8	20.1	31.5	60.4	17.0	14.0	25.5	
Mean weed count per sq ft 14-21 days after spraying treatment:					±4.0	±2.5	±2.2	
A	16.0	8.3	18.7	6.3	13.7	18.1	5.1	
B	8.7	6.3	8.2	2.5	11.5	16.6	4.1	
C	89.7	31.0	28.3	18.9	20.2	22.5	42.8	
D	83.3	23.7	11.6	10.1	16.2	18.3	13.5	
Sig. Diff.	14.2	12.7	24.5	13.2	-	-	-	
Mean score for plant vigour immediate post emergence treatment: (0-10; 10 = Maximum Vigour)								Mean Scores
A	8.3	8.7	9.3	9.7	5.7	8.0	8.0	8.2
B	6.7	7.0	7.7	8.7	5.0	7.7	7.0	7.1
C	7.3	7.0	6.7	9.7	4.0	7.3	3.0	6.4
D	9.7	10.0	10.0	10.0	7.0	8.0	8.0	8.9
Mean yields (tons/ac) treatments:					±1.2	±0.6	±6.0	Kale Yield at 13 per cent D.M. Turnip Yield at 10 per cent D.M.
A	7.4	6.7	6.9	8.2	11.7	8.8	4.0	
B	7.8	6.6	6.6	9.3	12.8	8.8	4.0	
C	4.4	6.9	5.1	8.4	7.5	7.9	3.4	
D	7.9	7.7	6.9	9.4	12.2	9.6	4.2	
Sig. Diff.	1.8	0.7	0.4	0.5	-	-	-	

practice of spraying the weedy growth as the first operation after ridging, to be followed soon afterwards by drilling. It was found that this period could vary from a matter of hours on a hot sunny day to 1-3 days under cloudy conditions. This pre-sowing spraying technique is now established as a very satisfactory method of weed control in swedes in Breconshire, although as yet, the number of farmers who have adopted the practice is relatively small. At the moment the practice is more or less confined to certain districts and its adoption is a credit to J. W. Hibler, District Advisory Officer, who has been instrumental in furthering its application.

A field survey of the results obtained this year has shown conclusively that spraying weed growth just before precision seeding, is a combined operation of practical importance. It means that the costs of growing kale, swedes and turnips can be substantially reduced by almost complete elimination of hand labour. The experience of a farmer in the Trecastle district may be cited as typical of the kind of result which is being obtained.

A field heavily infested with Polygonum persicaria, (redshank), Spergula arvensis (spurrey) and Stellaria media (chickweed) was sprayed on 10th June, 1960, under ideal weather conditions for spraying. Swedes were precision drilled at 6 in. spacing on the 11th June, 1960. Weed control was excellent and subsequent cleaning was limited to inter row cultivations once only. The contractor's charges for spraying was 15 shillings/ac plus the cost of material used.

Current Pilot Studies

Reference has been made by A. J. Butler (1958) to the commercially acceptable level of control of a number of weeds by diquat. Weeds enumerated included Polygonum convolvulus (black bindweed), Chenopodium album (fat hen), Polygonum persicaria (redshank), Urtica urens (annual nettle), Sonchus oleraceus (annual showthistle), Stellaria media (chickweed) and Galium aparine (cleavers). As this list contains most of the troublesome weeds found in root crops, the chemical was tested in preliminary trial work at two centres in Wales in 1960. Doses/ac were ½ lb, 1 lb and 2 lb in 25 gall of water at 30 psi

At the first centre, under ideal weather conditions, 1 lb/ac affected a complete kill of Brassica oleracea (wild cabbage), Polygonum persicaria (redshank), Fumaria officinalis (fumitory), Galeopsis tetrahit (hemp nettle), Stellaria media (chickweed), Chenopodium album (fat hen) and Atriplex patula (orache) within 2 days of spraying. 75-80 per cent of the weeds were destroyed at the ½ lb rate. The crop was sown two days after spraying.

At the second centre a kale crop failure had resulted in a heavy infestation of fat hen and wild orache. These weeds were at their 4th leaf stage of growth when a trial comprising the following treatments was laid down:-

A diquat - 2 lb/ac
B diquat - 1 lb/ac
C diquat - ½ lb/ac
D PCP - 2 lb/ac
E Control

Conditions for the experiment were unfavourable. Rain had fallen 2 hours prior to spraying and the leaves were still damp at spraying time. Further heavy rain fell within 6 hours of the operation but the efficiency of the product did not appear to have been impaired. A complete kill of weed was achieved at the 1 lb dose and a 65 per cent control obtained at the ½ lb dose. The kale crop was sown a day after spraying. An assessment some 28 days later of the fresh weed population, together with plant population and vigour scores for the kale crop is given in Table III.

TABLE III. WEED CONTROL, PLANT POPULATION AND VIGOUR FOLLOWING THE USE OF DIQUAT AND PCP

Treatment	Weed population/12 in. x 3 in. quadrat	Plant population/ft of drill	Plant vigour 10 = Max
A	0.57	10.7	8.7
B	1.10	10.6	8.0
C	1.90	10.4	7.7
D	1.30	11.8	7.3
E	5.30	8.0	7.0
S.E.	±0.35	±0.11	

The weed flora had undergone a complete change during the period, the dominant weed at the date of assessment being Capsella bursa-pastoris (shepherd's purse). Moreover, this weed was only 2 in.-3 in. high compared with 30 in. high weeds on the control, threatening the existence of the kale.

GENERAL CONCLUSIONS

The experiments have shown that PCP is an effective herbicide for weed control in brassica crops. The improved technique of application which has emerged from the experimental work described has shown without doubt that spraying just in advance of sowing is decidedly more efficient than precision seeding in a weedy seed bed just before spraying. The roll of diquat in conjunction with precision seeding appears highly promising.

Acknowledgments

The writers acknowledge their thanks to the several farmers who made their land available and to others who gave freely of their experience with the new techniques.

REFERENCES

PRYTHERCH, E.I., Spaced Seeding in Swedes, Agriculture 1959.

BUTLER, A. J., Potato Haulm Destruction and Pre-Harvest Weed Control with Chemicals Proc. 4th Brit Weed Control Conf pp. 254-259

Discussion on all papers in Session 2

A. L. Abel. Have any of the contributors any experience of the use of granular herbicides for controlling weeds in Sugar Beet?

C. Parker. As far as I know very little, if anything, has been done with granular herbicides in this country. Perhaps Dr. Buckholtz or Dr. Warren could tell us what sort of results they have had in the U.S.

G.F. Warren We have done a great deal with granular materials in the U.S. on a number of crops. Shall I try to summarise this now or should I wait? (until Session 10 - Editor). On sugar beet in particular I am sorry that I cannot give you details except to say that some of the materials which you have been using on sugar beet here have been effective as granular formulations in our trials. I think that is as far as I can go on that one.

G. A. Toulson. It is unfortunate that the endothal/propham mixture has been formulated in such a way as to cause frequent nozzle blockage especially when the tank is nearly empty. Has anything been done to correct this drawback in more recent formulations?

B. H. Bagnall. There will certainly be an improved formulation by 1961. The results to date do not show poorer weed control results than those obtained with the formulations used during 1959.

G. B. Lush. For the record we have during the last two years carried out just under 200 trials with the OMU/BIPC mixture referred to earlier by Mr. Parker. There is, as indicated by Mr. Parker, a rainfall requirement but where this is adequate this mixture does control, very satisfactorily, a wide weed spectrum which includes Chenopodium album and Stellaria media two very important weeds in sugar beet. We have not abandoned this mixture as we are still trying to resolve the rainfall problem.

S. Everest-Todd. Most important is the time between the last rainfall and the application of the herbicide. Provided you can get your herbicide onto a fairly dry soil it does not matter how much rain there is afterwards. If the soil is dry at the time of application there is less damage to the sugar beet and good control of weeds.

G. W. Cussans. The last statement over-simplifies the position regarding the effect of rainfall.

S. Everest-Todd. When using mixtures of two chemicals the solubility of those two chemicals is hardly likely to be the same. We need a lot more experience of mixtures of propham and substituted ureas. Substituted ureas are insoluble in water. Propham is more water soluble. These two chemicals move through the soil at different rates and if you have a wet soil at the time of application then you emphasise the variation in the movement of these chemicals through the soil. One chemical catches the beet at one stage the other chemical at another stage. If both affected the beet at the same stage of growth then there is a fair chance of plant recovery. When the beet gets two knocks it does not stand much chance at all.

and reseed. However, the permanent grassland includes a large acreage which has remained unploughed because of physical conditions (e.g. topography, high water-tables, etc.). Such swards may be improved by oversowing in conjunction with spraying and/or surface cultivations. (Elliott 1960), and such techniques are particularly appropriate where the swards consist of inferior grasses and dicotyledonous weeds alone. There is, however, a large acreage of unploughed permanent grassland (particularly of the Agrostis/ryegrass type) which although infested with dicotyledonous weeds, also contains clover and some of the better grasses, e.g. Lolium perenne and Phleum pratense. Many of the dicotyledonous weeds in these pastures can be controlled by spraying. Although this spraying may temporarily reduce the clover content it should be possible to improve the sward gradually by encouraging the development of better grasses and clovers, thereby eliminating the blank period of production which follows surface killing and reseeding.

J. G. Elliott. Could Mr. West clarify the question of taint in potato tubers? There appears to be some discrepancy on the question of taint, following the use of herbicides, in the two papers presented.

W. J. West. There is no conclusive evidence.

G. W. Cussans. Could it be that moulding-up early will produce a higher percentage of elongated internodes and subsequently of green tubers?

W. J. West. We have not experienced this difficulty in our trials.

M. C. Cade. Sugar beet is grown very successfully in Australia and there good results have been obtained where CDEC is used for weed control.

C. Parker. CDEC certainly has been screened here but has not proved satisfactory in controlling a wide enough spectrum of weeds. Against most of the annual grasses it does not look as promising as propham or endothal.

The object of the present series of experiments is to study the long-term effects following the application of MCPA to permanent pasture which is infested with dicotyledonous weeds (particularly Ranunculus repens and R. acris) containing some clover and better grasses. Changes in herbage production and the botanical composition are studied under different nitrogenous and grazing treatments.

This paper presents the final results from a trial already reported (Baker and Evans 1960) together with current results from a second trial.

METHODS AND MATERIALS

The two sites were both in old permanent pastures in the Thames Valley.

Initial botanical composition. Site I (1957 - 1959). The sward contained Lolium perenne, Dactylis glomerata, Festuca rubra, Poa trivialis, Agrostis stolonifera, Holcus lanatus, and Deschampsia caespitosa. Both Trifolium repens and T. pratense were present. The predominant dicotyledonous weeds were Ranunculus repens, R. acris, Taraxacum officinale and Crepis spp.

Site II (1959 - 1960). The same grasses and clovers were present as in Site I except Deschampsia caespitosa. The main dicotyledonous weeds were Ranunculus repens, R. acris, Bellis perennis, Plantago major, P. lanceolata, Circium arvense, and Urtica dioica.

Treatments. Site I: 1) Unsprayed, no nitrogen, 2) Unsprayed + 104 lb. nitrogen/acre/annum, 3) Sprayed, no nitrogen, 4) Sprayed + 104 lb. nitrogen/acre/annum.

Site II: The same treatment as for Site I plus 2 grazing managements: A. Continuous grazing and B. Rotational grazing.

The grazing managements formed the main plots and each was split for the application of spraying and fertiliser treatments.

On Site I each plot measured 30 yd. x 20 yd. Each sub-plot of Site II measure 30 yd. x 15 yd.

Spraying. Both sites were sprayed with 24 oz of MCPA - potassium per acre in 22.4 gal of water, Site I was sprayed on 8th May, 1957 and Site II was sprayed on 29th May, 1959.

Fertilisers. A uniform dressing of 54 lb of P_2O_5 and 54 lb of K_2O was supplied to all treatments at each site at the begining of the experiments.

Nitrogen was applied to the appropriate plots at 52 lb per acre on the following dates:-

Site I	Site II
14 May and 25 July 1957	8 June and 16 July 1959
16 April and 9 July 1958	21 April and 25 July 1960
10 April and 7 August 1959.	

Grazing management. Site I was grazed by beef cattle, which had free access to all plots from May to September. Site II was grazed by both sheep and cattle. Stock had free access to the plots continuously grazed from the commencement of the trial to December, 1959 and from March onwards in 1960 (except for periods during June and August). The rotational plots were grazed four times in 1959 and 1960.

Sampling. Botanical analyses and herbage yields were obtained by methods previously described (Baker and Evans, 1960).

RESULTS

Site I. The detailed yields and botanical assessments for 1957 and 1958 have been given in the previous report. Table I shows the total yields for all years and the yield of individual species in 1959.

The yields in 1959 on the sprayed plots were the same as on the control treatment; a reduced weight of the *Ranunculus* species being accompanied by a corresponding increase in that of grass. The application of nitrogen alone produced the highest yields because of an increase in growth of the grasses and of the other weeds (especially *Taraxacum* and *Crepis* species). On the sprayed plots yields were similar whether or not nitrogen had been applied.

Site II. The specific frequency of weeds both before spraying in May 1959, and twelve months later are given in Table II. Herbage yields during 1959, after spraying on 8th May, are given in Table III, together with herbage production from March to October 1960.

Twelve months after spraying the frequency of both *Ranunculus repens* and *R. acris* was drastically reduced (Table II) and the total yields of *Ranunculus* in the two seasons following spraying were negligible (Table III). The yields of clover were considerably reduced after spraying (Table III - 1959) but in the following spring the frequency of *T. repens* on the sprayed areas was 50 per cent to 70 per cent of the control, whilst the frequency of *T. pratense* was unaffected (Table II). The yields of clover in the second year showed a considerable improvement on the sprayed plots.

The yields of dicotyledonous weeds other than *Ranunculus* were reduced by spraying to negligible levels during the first year, but had increased in both frequency and yield by the second season.

The major effect of applying nitrogen was to increase grass yield, but there was also a cumulative depression of clover, Spraying plus nitrogen produced a very grassy sward, particularly under rotational grazing.

Total herbage yields were reduced by spraying but were considerably increased by nitrogen alone or nitrogen plus spraying.

DISCUSSION

It was evident from both sites that spraying with MCPA provided a good control of *Ranunculus* species throughout the duration of the experiments. The other dicotyledonous weeds (particularly *Compositae*) were initially reduced by spraying, but tended to increase again during the second and third years. The clovers were also reduced by spraying, but they returned more rapidly than the broad-leaved weeds. Jeater (1958) found that spraying weed-infested swards did not alter the total herbage yield, but the proportion of grasses increased at the expense of weeds. In the present trials the total herbage yields of the plots sprayed without the addition of nitrogen, did not normally equal those of the control plots, and only at Site I in 1959 was the reduction in yield of dicotyledonous species matched by a corresponding increase in grass yield.

The application of nitrogen resulted in increased total yields, primarlly due to the extra growth of grasses. Ranunculus and clovers were both reduced by nitrogenous fertilising, but other weeds were encouraged by nitrogen on the continuously grazed plots, particularly Taraxacum officinale on Site I, and Cirsium arvense at Site II. In mid-season 1959 over 20 per cent of the dry matter in the herbage on the nitrogen plots at Site I consisted of Compositae and other weed species. The presence of a high proportion of such weeds would probably lead to the rejection by animals of grasses in the immediate vicinity of the weeds and would eventually lead to sward deterioration.

At Site II the responses to nitrogen were more consistent and greater than on Site I and an average of over 20 lb. of extra herbage was produced per pound of added nitrogen. This was possibly associated with the better utilisation of herbage at Site II where the herbage on all plots was consistently well grazed. As indicated in the previous report, the nitrogen plots at Site I were grazed harder than the non-nitrogen plots. Nevertheless, throughout the duration of the trial at Site I all plots appeared undergrazed.

The combination of nitrogen and spraying always produced a grassy sward with very little clover and few weeds. Generally the total herbage yields were relatively high. There were, however, certain anomalies. At Site I in 1959 the grass yields on plots which were sprayed and which received nitrogen were no higher than those of plots only sprayed and not as high as the plots which received nitrogen alone. Similarly on the rotationally grazed treatment at Site II in 1959, the yields of all species, including grasses, were considerably reduced on the nitrogen plus spray plots when compared with nitrogen alone. The reasons for these differences are not clear, although the dry summer of 1959 may have contributed to them. It should however, be noted that in July, 1959, 12 per cent of the dry matter on the nitrogen plots at Site II consisted of clover and this may have stimulated additional grass growth.

Grazing utilisation on all plots at Site II was good throughout the 2 years under review. On the continuously grazed control plots there was frequently a vigorous growth of Ranunculus spp. within the sampling cages, but outside these species were eaten down to ground level. The rotationally grazed plots responded well to nitrogen, but the yields of all treatments were considerably less during 1959 than those of the continuously grazed plots. This may have been partly due to variations caused by the drought, thus within one block the rotational grazed plots burned badly, whilst the corresponding continuously grazed plots remained green.

On plots which received nitrogen there was a general increase in the percentage of ryegrass and cocksfoot in the swards. At Site II in particular the amount of cocksfoot on the areas rotationally grazed increased considerably, whilst on the uncontrolled grazed plots which received no nitrogen, there was a considerable amount of Agrostis and of fine-leaved fescues.

The evidence so far accumulated indicates that the control of weeds by the application of sprays alone does little to raise total herbage productivity. Nitrogen increased the quantity of grass present, although it also encouraged the development of undesirable weeds e.g. *Cirsium arvense* and *Taraxacum officinale*. A combination of spraying and nitrogen was the best treatment for controlling weeds, although the clovers were depressed. The best responses to nitrogen occurred at Site II where all the plots were well grazed by stock. It thus appears therefore, that the control of weeds by spraying must be accompanied by application of nitrogen and the resulting extra grass adequately utilised.

Acknowledgements

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REFERENCES

BAKER, H. K., (1960). Permanent grassland in England. Proceedings of the Eighth International Grassland Congress. (in press).

ELLIOTT, J. G., (1960). The evaluation of herbicidal activity on a mixed sward. Proceedings of the Eighth International Grassland Congress. (in press).

BAKER, H. K. & EVANS, S. A. (1958). The control of weeds in permanent pasture by MCPA and the subsequent effect on herbage productivity. Proc. 4th. Brit. Weed. Control Conf. p.16.

JEATER, R. S. L., (1958). The effect of MCPA, MCPB, and 2, 4-DB on the productivity and botanical composition of permanent pasture. Proc. 4th. Brit. Weed. Control Conf. p.11.

TABLE I. THE EFFECT OF SPRAYING AND NITROGEN APPLICATION ON THE YIELDS OF HERBAGE FROM A PERMANENT PASTURE. SITE I.

(Dry Matter, lb/ac)

Year		Control	MCPA	Nitrogen	Nitrogen + MCPA	Standard Error
1957	Total spp.	5310	5020	6590	6800	± 300
1958	Total spp.	7000	6640	8830	8800	± 300
1959	Grasses	3170	3610	3900	3600	± 80
1959	Clovers	80	70	40	30	± 16
1959	*Ranunculus* spp.	400	60	260	20	± 75
1959	Otherwweeds	70	50	380	40	± 67
1959	Total spp.	3720	3790	4586	3690	± 107

TABLE II. SPECIFIC FREQUENCY (PER 30 X 3 IN. QUADRATS) OF THE OCCURENCE OF WEEDS AND CLOVER IN THE SWARD. SITE II

		Continuous grazing				Rotational grazing			
Species	Date	Control	MCPA	Nitrogen	Nitrogen + MCPA	Control	MCPA	Nitrogen	Nitrogen + MCPA
Ranunculus repens	1 May 1959	20	16	16	18	16	19	13	14
	5 May 1960	17	2	8	1	12	1	8	1
Ranunculus acris	1 May 1959	5	7	3	8	10	7	12	8
	5 May 1960	6	1	3	2	10	2	7	1
Trifolium repens	1 May 1959	27	23	26	27	23	22	26	25
	5 May 1960	29	20	25	17	29	18	21	14
Trifolium pratense	1 May 1959	2	3	1	1	4	3	3	5
	5 May 1960	2	3	2	4	5	6	1	5
Various spp.	1 May 1959	11	15	16	8	21	12	19	13
	5 May 1960	17	14	24	4	28	13	12	8

1 May 1959 :- pre-spraying assessment

THE USE OF CHEMICALS IN THE RENOVATION OF DIFFICULT SWARDS IN THE EAST MIDLANDS OF ENGLAND

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INTRODUCTION

In a paper given to the Fourth British Weed Control Conference (Ormrod 1958), field experiments on six sites were described, in which dalapon plus 2,4-D-ester was applied as a sward killer and followed by re-seeding after surface cultivations. Cultivations were actually carried out on four sites, two of which were successfully re-seeded. The work described below was designed to answer some of the problems encountered in the six experiments.

METHODS, MATERIALS AND RESULTS

1. Study of time of application of dalapon

As the earlier trials were sprayed in autumn, two experiments were carried out to determine whether spraying at other times of the year would permit the employment of lower doses of dalapon than were found necessary in the autumn. The treatments were:

Dates of spraying - 1958

late spring - 29th May
mid-summer - 19th July
early autumn - 17th September

Chemicals (lb/ac)

7½ lb dalapon)
15 lb ") + 1½ lb 2,4-D-ester.

Both chemical treatments were sprayed at each date at 20 gal/ac volume rate with unsprayed controls arranged in a randomised block design with three replications and a plot size of 20 yd x 5 yd. These small plots were not cultivated or re-seeded.

Two contrasting sward types were chosen:

Hill sward: Altitude 1,350 ft. Low fertility, very wet, thick acid mat. Dominant grasses *Nardus stricta*, *Deschampsia flexuosa*, *Agrostis* spp., *Anthoxanthum odoratum*, *Festuca ovina*. No clover or broadleaved weeds.

Lowland sward: Altitude 350 ft. Moderate fertility, well drained, no acid mat. *Agrostis*/ryegrass type with clover and broadleaved weeds, especially *Ranunculus repens*, *Cirsium arvense* and *Prunella vulgaris*.

Assessment was by regular observations and final score on a whole plot basis on June 16th 1959. The table below summarises the degree of kill of grass species on that date, each figure being the mean of scores for 3 plots.

Treatment	per cent kill Hill Sward	per cent kill Lowland Sward
7½ lb dalapon May	5) mean	1) mean
15 lb " "	10) 7½	3) 2
7½ lb " July	53) mean	3) mean
15 lb " "	87) 70	53) 28
7½ lb " September	63) mean	17) mean
15 lb " "	93) 78	42) 29

Conclusions

There were no appreciable differences between times of application in the degree to which the top growth of grass was killed initially. 15 lb. dalapon gave a complete kill of top growth and 7½ lb about 80 per cent kill.

There were big differences between dates of spraying in the speed of re-growth after the initial kill of top growth. Recovery was rapid after late spring application and was practically complete after about six weeks on the lowland sward. Recovery was much slower after the summer application and slower still after the autumn application. Late spring was therefore less satisfactory for spraying as a pre-treatment for re-seeding because of the short period during which new seeds could establish before competition from the old sward began. This period would, however, be lengthened in proportion to the severity of any surface cultivations that followed.

The lowland sward reacted to the treatment much more rapidly than the hill sward but also recovered more quickly.

2,4-D-ester mixed with the dalapon was ineffective in controlling broad-leaved weeds at all times of application. These weeds spread rapidly after the kill of grass on the lowland sward and would have constituted a serious problem on a farm scale, since further spraying with MCPA also failed to control them.

2. Study of Mixtures of dalapon and other herbicides

The trials already referred to had indicated that mixtures of dalapon and 2,4-D-ester were ineffective in controlling broadleaved weeds of known suscepti-bility and also that their rapid spread after spraying such a mixture would constitute a serious practical problem in re-seeding. In order to determine whether this finding also applied to other herbicides similar to 2,4-D-ester, observation plots were laid down in duplicate on 29th August 1958 comparing standard rates of the following chemicals each sprayed without dalapon and with dalapon at 20 lb/ac on a grass sward with a heavy infestation of creeping buttercup (Ranunculus repens):-

MCPA-sodium 2 lb/ac
MCPA-amine 2 lb/ac

2,4-D-amine	2 lb/ac
MCPB-sodium	2 lb/ac
2,4-D-ester	1½ lb/ac

The plots were observed at intervals with a final eye assessment on a whole plot basis a year after spraying.

Conclusions

All chemicals without dalapon controlled buttercup satisfactorily. None did so when mixed with dalapon and many other weeds, including arable weeds, appeared in the plots.

3. Study of re-seeding without cultivations

The earlier trials had revealed the difficulties and limitations of surface cultivations after dalapon application in areas where suitable implements are often not available. Two large plot trials were therefore laid down in the spring of 1959 to investigate the feasibility of establishing grass and clover seeds without previous cultivations. Two half-acre plots were sprayed with dalapon at 5 lb and 10 lb/ac at 20 gal volume rate in March 1959 on each of two contrasting sites, a fairly good hill sward at 1,300 feet and a lowland sward at about 350 feet. Six weeks were allowed for decomposition of dalapon and a seeds mixture and complete fertiliser broadcast. The fields were then stocked and it was expected that the combined effect of rainfall and stock trampling would enable the seeds to establish. In fact the sowing was followed by an unprecedented drought with the result that establishment was generally poor, though good in small areas where soil moisture and stock treading were adequate.

Assessment was by regular observations and a final inspection on a whole plot basis.

Conclusions

10 lb dalapon was satisfactory but there was considerable regrowth of the old sward on the 5 lb. plots. In the absence of cultivations to bury them the new seeds largely failed to establish because of the long drought that followed. Broadleaved weeds spread rapidly on both sites after dalapon application, were not controlled by subsequent spraying of MCPA and presented a serious problem in re-seeding.

4. Study of dalapon plus amino triazole and subsequent cultivations

In the autumn of 1959 a trial was laid down to test the inclusion of amino-triazole to control broadleaved weeds in a hill sward and also to assess further the value of cultivations in establishing a new ley after killing the existing sward. Two one-acre plots were sprayed in October 1959 whth 8 lb dalapon plus 4 lb activated amino-triazole per acre and with half these amounts. By early spring there appeared to be a good kill of all species except for some broadleaved weeds. The sprayed plots were crossed at right angles by two strips, one of which received surface cultivations with spike and pitch-pole harrows while the other was left untouched. On 24th March a seeds mixture and complete fertiliser was sown over the whole of the sprayed plots, and the cultivated plot harrowed again. The cultivations completely failed to penetrate the tough, undergrazed mat of vegetation in spite of burning-over beforehand and the seeds on both strips remained above the soil surface and dependent on the normal heavy rainfall for germination and establishment. In fact there was practically no rainfall from sowing until early July, by which time the old sward, including broadleaved weeds, had regenerated completely and there was practically no establishment of sown grasses.

Assessment of this trial was by regular observations on a whole plot basis.

Conclusions

Both mixtures used gave a satisfactory kill of top-growth. Amino triazole did not satisfactorily control broadleaved weeds. Neither spike nor pitch-pole harrows gave satisfactory surface cultivation. The seeds failed completely over the whole area owing to prolonged drought.

DISCUSSION

The problem

The aim of this series of trials has been in the main to develop a technique which could be used to improve grassland in the marginal and hill lands of the East Midland Region, which lie wholly in Derbyshire. In this, as in similar areas elsewhere, the farms are mostly small, with limited capital, labour and machinery. It was hoped that re-seeding after dalapon application would prove to be within the capacity of such farms and at least as satisfactory and consistent as conventional methods. It was not visualised as an alternative to ploughing where that was practicable, but as a possible means of quickly improving the many thousands of acres of such land which for one reason or another were not suitable or likely to be ploughed.

The type of sward in the area is very variable, even at comparable altitudes reflecting the geology, climate and, in particular, the past management of the land. Some of the improved fields are basically similar to lowland swards with an open type of sward amenable to surface cultivations and establishment of new seeds. At the other extreme are swards with an acid mat forming a tough carpet several inches thick while in between there is a whole range of swards of varying degrees of difficulty.

The more dense and matted the sward the more important are the implements available for surface cultivation. Unfortunately the typical farm of the area is not likely to have implements strong enough to make much impression on a tough sward. Only the pitch-pole harrow and more especially the rotavator are suitable and these are rare in hill and marginal areas. Capital is also very limited on such farms and the land is inherently of low productivity, so that the cost per acre of improvement methods must be kept down. Such methods must also be reliable, for the farmer has too low a margin to risk complete failures owing to weather or other unknown factors. Neither must an acceptable technique demand the same skill and technical knowledge that might reasonably be expected of a farmer on better land experienced in cultivations and establishment of leys.

The problems to be solved is therefore a difficult one: how far it has been solved must now be discussed.

Sward killing

Though individual plants may be completely killed by dalapon and similar chemicals, the normal sward is a mixed community and cannot be killed in the absolute sense by normal rates of any of the known grass killers. The effect of dalapon on a grass sward is to kill all vegetation above ground and inhibit vegetative re-growth for a period of weeks or months. Successful re-seeding depends on making use of this period to establish new seeds sufficiently strongly for them to be able to suppress this re-growth. When cultivations follow dalapon the effect is two-fold; firstly, if severe enough they add to the killing effect (especially rotavation which attacks the root system directly) and secondly they help to create suitable conditions for establishing seeds. By and large it may be said that the degree of kill of top growth of grass obtained by 10-20 lb/ac of dalapon is satisfactory, though it would often be desirable for re-growth to be suppressed for a longer period.

Broadleaded weeds

Most swards contain a proportion of broad-leaved weeds and the effect of applying a grass-killer is to allow them to spread rapidly so that in the absence of severe cultivation they may dominate the sward. The experiments reported have failed to discover a satisfactory way of preventing this by including another herbicide with dalapon. It would seem that the degree of control of susceptible perennial broadleaved species usually achieved is dependent on the competitive power of the grass sward completing the job started when a severe check is given by a chemical such as MCPA. In the absence of grass competition most perennial species recover more quickly from MCPA and similar chemicals than does the grass from dalapon. Amino-triazole in one experiment sprayed in autumn seemed little more effective.

The most hopeful method in sight so far seems to be to spray with MCPA or 2,4-D in the spring or summer before the application of dalapon and allow a few months to elapse for grass competition to do its work.

Time of application

Within wide limits it seems that the time to apply dalapon can be chosen to suit local conditions and subsequent re-seeding. On balance autumn spraying seemed most suitable as it allowed cultivations and re-seeding to be carried out while the land still had its winter moisture, but the experience of long spring and early summer droughts in the last two years suggests that late summer sowings may possibly be less risky.

Cultivations and re-seeding

This seems to be the crux of the problem as applied to marginal and hill land. Even if the sward can be effectively killed can the land be satisfactorily re-seeded within the limitations described?

On the basis of the experiments without cultivations, it seems unlikely that broadcast seeds can be reliably established over a wide range of dense swards by relying on stock trampling and rainfall alone. With an open type sward and a well distributed high rainfall the position might be different. The method would also stand a greater chance if seeds could be cut into the true soil by a suitable disc drill, but in marginal areas these implements are not common and the discs would certainly not cut into the tougher type of sward even when killed by dalapon.

Trials 3 and 4. Susceptibility of Species

The data arising from trials 3 and 4 are shown in Tables II and III respectively. This data was collected about 12 months after spraying and this delay was deliberate. In reseeding a sward pretreated with dalapon, the important feature is not the apparent suppression of the species in the second or third month after spraying but the genuine reduction in ground cover from the level initially afforded by the natural species. If they survive, they survive as competitors with the sown species and over which they have a competitive advantage.

The observations on the susceptibility of the various species given below arise from the statistical examination of the data in Tables II and III where this procedure is applicable or from visual estimates among all the trials.

A. tenuis is more susceptible to a May than to an August spraying ($P < 0.01$; trial 3 data for July recording, Table II). There is a significant dates x rates interaction ($P < 0.05$). It appears that a considerable reduction can be achieved by a 5 lb dose in May.

F. ovina is more susceptible to an August than to a May spraying ($P < 0.01$; trial 3 data for July recording Table II). This was also apparent in trials 4 and 5. The rates x dates interaction was not significant. For a considerable reduction a 10 lb dose in August appears to be the lowest suitable rate.

In trial 4 the first spraying date at the lowest rate was too early to affect Molinia but it at later dates, and Nardus at all dates were suppressed by the lowest dose (5 lb /ac). This was also observed in trials 1 and 2.

The 1 lb amino triazole addition to the 5 lb dalapon dose appeared to be no advantage.

Species which appear to be highly resistant to at least a 10 lb rate are Holcus lanatus, Holcus mollis, Anthoxanthum odoratum and Deschampsia flexuosa among the hill grasses while Carex spp., Galium hercynicum, Potentilla erecta and Vaccinium myrtillus are also resistant. Agrostis canina appears to be as susceptible as A. tenuis.

Trials 5 and 6. Reseeding

Trial 5 This trial was on a larger scale than the other four and covered 2 acres sited on a peat podsol at 1700 ft. The main grasses were N. stricta, A. canina, A. tenuis and Festuca ovina. These were more or less co-dominant. Other grass species were F. rubra, D. flexuosa, A. ordoratum, Molinia caerulea and Poa pratensis. Dicotyledonous plants were sparse.

In the spring of 1959, the trial with the exception of the control plots received 2 tons Carbonate of lime and 7 cwt of basic slag/ac and in the spring of 1960 it received an additional dressing of 1½ cwt/ac triple superphosphate.

Treatments

1. Sprayed at 10 lb /ac on 26th May 1959. Burnt on 8th July 1959 and sown with grass and clover seeds mixture on 14th July 1959.

2. Sprayed at 10 lb/ac on 26th May 1959. Sown with grass and clover seeds mixture on 14th July 1959.

3. Sprayed at 10 lb/ac on 14th July 1959. Burnt on April 17th 1960 and sown on April 20th 1960.

4. Sprayed at 5 lb/ac on 26th May 1959. Sown with clover seed on 14th July 1959.

5. No treatment except manures.

6. Control.

Plots containing treatments 1, 2 and 4 were split, one half being harrowed with a heavy Wilder pitch-pole on 13th July 1959.

Treatment 4 was sown with 4 lb Wild White Clover/ac.

Germination in the autumn of 1959 was very poor with the result that all the plots sown in the autumn had later to be resown in April 1960.

The whole area was grazed by cattle and sheep for short periods during the summer of 1960.

Observations at the end of August 1960 were that harrowing had been effective on most plots in getting rid of F. ovina, in breaking the surface mat and giving a better take of grass and clover seeds that burning had had little effect on the establishment of a sown sward even where combined with harrowing and that the 5 lb/ac dose with or without harrowing was completely ineffective in the establishment of clover.

Trial 6 This trial was sited at Blythe, Lauder, at 1,000 ft on a podsolic brown earth and the area employed extended to 2 ac.

Predominantly a bent-fesque sward, it contained a large proportion of P. pratensis, H. lanatus, and A. odoratum. The presence of these resistant species is perhaps one of the reasons for the failures encountered in this trial. The area had been manured in 1957 with 4 ton/ac magnesium limestone and was given a further 1 ton of carbonate and 10 cwt of 19 per cent P205 basic slag in the spring of 1959.

The 8 treatments were:

Dalapon		Cultivation (by Wilder pitch-pole)		Oversowing Mixture (sown July 1959)
20) 10) lb/ac in May	x	Harrowed Not Harrowed	x	1) Grass and clover as in trials 1 and 2. 2) 2 lb/S184/Wild White Clover.

There was an almost complete failure in germination following the July 1959 sowing. A resowing in late April 1960 was again a failure.

The cause of these failures is difficult to assess, but the dry weather following sowing, the species composition of the original sward and the failure of the harrow to deal with the dense deep incompletely killed turf at the site were all contributory.

DISCUSSION

Doses After improvement, hill swards are liable to revert. This reversion will be the more rapid, the greater the proportion of original vegetation not killed by ploughing or in this case by the dalapon pretreatment. If the take of sown species is good and their subsequent growth luxuriant, they may effectively compete with the hill species. This has not been the case in the trials now reported and, although a large proportion of some swards are now composed of sown species, the remaining hill species, mainly by selective grazing are likely to spread at the expense of those sown.

Except in an almost pure *Nardus* or *Molinia* sward where 5 lb/dalapon/ac might suffice, serious competition can be expected from resistant hill species at all doses up to and including 20 lb dalapon/ac, and the inclusion of a herbicide to deal with the dicotyledonous weeds would be necessary when they were present to any extent.

Harrowing We have not yet found a satisfactory technique for treating the turf, killed or weakened by the dalapon, to improve the establishment of the sown species. There is no doubt that the pitch-pole harrowing greatly increased the effectiveness of the spray by tearing up plants of resistant species, principally *F. ovina*, temporarily weakened by the spray and also improved the establishment of the sown species. However, it was not effective at all sites and the more effective it was, the greater the problem of dealing with the trash which, in our work, was left in rows by tripping the pitch-pole harrow.

Dates of spraying Due to the susceptibility of *Nardus* at all dates of spraying and to *A. tenuis* and *F. ovina* being susceptible at different periods of the summer no differences were apparent in reducing the vegetative ground cover among different spray dates. For purposes of oversowing, however, autumn spraying followed by spring sowing would be preferable in the S.E. of Scotland and as autumn sowing might be followed by a severe kill of the sown species (especially clover) over winter.

Burning Burning appeared to confer no advantage in establishing the sown species. It was found impossible to burn a sward in July which had been sprayed in May but one sprayed in August burnt readily the following spring. Even in the driest weather, it is impossible to reduce the tussocks by burning although the dead grass lying above them can be burnt.

Our work has led us to think that it is yet too early to come to a firm conclusion on the advantage of dalapon as an aid to oversowing. We have had both successes and failures with sufficient of the former to make continuation of the work worthwhile.

REFERENCES

GARDNER, A. L. (1959). Dalapon to help oversowing. J. Min. Agri. 66, 118-122.

TABLE I

(see pages 162-3)

TABLE II

EFFECT OF DALAPON ON THE PERCENTAGE GROUND COVER AFFORDED BY DIFFERENT SPECIES SPRAYED ON 26/5/59 AND 4/8/59 AND RECORDED ON 2/5/60 AND 7/7/60. PERCENTAGE GROUND COVER ASSESSED USING 10 POINT QUADRAT.

Trial 3

Species	Recorded 1960	Dose lb dalapon/ac								
		2½ Sprayed		5 Sprayed		10 Sprayed		20 Sprayed		Control
		May	Aug	May	Aug.	May	Aug	May	Aug	
Bare ground	May	13	31	47	59	59	74	80	87	10
	July	8	12	29	13	35	41	52	47	6
A. tenuis	May	25	26	8	18	1	12	0	1	45
	July	20	25	18	43	8	39	8	27	42
F. ovina	May	35	14	25	3	14	1	8	2	22
	July	37	32	29	20	28	7	17	5	32
P. pratensis	May	10	8	4	7	2	2	0	0	7
	July	15	10	7	4	4	3	6	4	7
Other species	May	17	21	16	13	24	11	12	10	16
	July	20	21	17	20	25	10	17	17	13

TABLE I.

Trial No.	Soil	Pasture type	Date of spray	Treatments dalapon lb/ac
1	Peaty podsol	*Molinia* + *Agrostis spp.* and *F. ovina*	27.5.59	5, 10 and 20
2	Peat	*Molinia* tussock	24.6.59 1.7.59 8.7.59 15.7.59	5 and 10
3	Podsolic brown earth	*A. tenuis* + *F. ovina* *P. pratensis* and others.	26.5.59 4.8.59	2.5, 5, 10 and 20
4	Peaty gley	*Molinia*, *Nardus* and *F. ovina*	27.5.59 2.7.59 4.8.59	5, 10, 15 and 20 lb dalapon. 5 lb dalapon + 1 lb amino triazole

DETAILS OF TRIALS 1 - 4

Object of trial	Seeds mixture per acre	Manurial rates	Remarks
Residual effect on germination of sown species and susceptibility of natural species.	)2 lb S184 W.W.C.)3 lb S59 R. fescue)3 lb S50 Timothy)3 lb S48 Timothy)5 lb S23 P.R.G. 5 lb D. Cocksfoot 1 lb R.S.M.G. ¼ lb Yarrow	)2 tons $CaCO_3$)per acre.)5 cwt. triple)superphosphate)per acre.)2 cwt. N. chalk)per acre.)	)Because of bad)germination in)spring 1959)residual)effects could)not be)determined and the two trials were manured and resown in spring 1960.
)))))Susceptibility of)grass species.))))			

In November 1954 different phosphate treatments were applied in duplicate on ⅛th acre plots, with and without lime. The phosphate treatments consisted of basic slag, ground mineral phosphate and superphosphate, each at 200 lb P_2O_5 / ac, the lime treatment was 3 ton/ac of magnesium limestone. In May 1955, one duplicate of each treatment was oversown with seed cleanings at the rate of 50 lb/ac. These cleanings contained approximately 50 per cent *Lolium perenne* (Perennial ryegrass, S.23), 40 per cent *Dactylis glomerata* (Cocksfoot, S.143) and 10 per cent Trifolium repens (Kent wild white clover), the per cent germination ranging from 42-60.

Site 2. Nardetum on open hill, grazed by sheep and cattle

This area was at an altitude of 1,000 ft near Bala, Merioneth. The soil was a medium loam with a thin layer of peat, overlying shale. The natural herbage was similar to that at Site 1, except that it had been closer grazed. The phosphate treatments at this site were as in Site 1 but equivalent to 100 lb P_2O_5/ac, and the lime was in the form of ground limestone at 2 ton/ac.

Site 3. Callunetum, grazed by dairy cattle

This was sited on a heather moor in N. West Carmarthenshire at an altitude of 900 ft. The most abundant plants in the association were *Calluna vulgaris*, *Molinia caerulea*, *Deschampsia flexuosa*. The soil was mainly peat, which was rather shallow in parts.

The trial area was dressed with 4 ton/ac of ground limestone and basic slag at 120 lb P_2O_5 /ac in the winter of 1955, and in spring 1956 at time of reseeding, muriate of potash and nitrogenous fertiliser were applied each at 2 cwt/ac.

The mixtures sown were:-

		lb/ac	
A.	*Lolium perenne* (Perennial ryegrass S.23)	20	+ 2 lb Alsike (*Trifolium hydridium*)
B.	*Phleum pratense* (Timothy S.48)	10	
C.	*Dactylis glomerata* (Cocksfoot S.143)	15	+ 1 lb White Clover (*Trifolium repens*)
D.	Control - no seeds	-	

No surface cultivation was employed.

Site 4. Nardetum on enclosed hill, grazed by sheep

This site was on an exposed hill in N.W. Denbighshire at an altitude of 1,300 ft. The soil was thin peat overlying gley soil. The natural herbage was composed of *Nardus stricta*, *Festuca* sp., *Agrostis* sp., *Agrostis tenuis* and *Juncus squarosus*. There was also a proportion of *Galium saxatile*, *Potentilla erecta* and *Polytrichum*. This herbage contained rather more *Nardus* than the sites referred to earlier. The trial area was dressed with 2 ton/ac of ground limestone and 6 cwt/ac of a 6 : 15 : 15 complete fertiliser. The full range of treatments can be listed as follows:-

A. 6 lb/ac dalapon - fertiliser 7 days before spraying and seeds 24 hr after spraying

B. 6 lb/ac dalapon - fertiliser 4 weeks after spraying and seeds 24 hr after spraying

X. 12 lb/ac dalapon - fertiliser 4 weeks after spraying and seeds 4 weeks after spraying

Y. 12 lb/ac dalapon - fertiliser 4 weeks after spraying and seeds 10 weeks after spraying

Control - lime and fertilisers, but no spraying.

There was no surface cultivation on this site. The seeds mixture used was composed of perennial ryegrass, timothy and white clover.

RESULTS

Effect of lime and phosphate and seed cleanings on Nardetum (Sites 1 and 2)

The effects of selective grazing became apparent about twelve months after treatment. These become more noticeable later, particularly at Site 2. The phosphate treatments, in the absence of lime, encouraged closer grazing at Site 1, but no major botanical changes were observed. At both sites, the assessments made in October 1959 showed the following general pattern:-

1. The proportion of Molinia caerulea had been reduced and, to a lesser extent Nardus stricta, particularly on plots which received phosphate and lime.

2. The amount of Festuca sp. had increased at the expense of Agrostis sp. on the limed plots at Site 1. This was less true of Site 2 where the mixed grazing kept the sward very tightly grazed.

3. The establishment of sown grass was poor at both sites.

4. In the absence of lime or basic slag, white clover establishment was poor. The best development of clover was on the phosphate plus lime treatments.

5. At Site 1, white clover accounted for no more than 8 per cent.of the herbage following the best treatment, whilst the proportion of clover on corresponding plots at Site 2 was from 20 - 24 per cent. This brought out the value of cattle treading in the reclamation of hill swards.

The Establishment of grass and clover on Callunetum (Site 3)

The dry weather which followed the sowing of the seeds in 1956 delayed the germination but by the end of October of that year the sown plots could be easily distinguished from the unsown controls, mainly because of the development of Trifolium repens and Trifolium hybridum. The grasses, although present, were lacking in vigour and remained so until the following year, after which they improved progressively and competed well with the native species. Table I illustrates the frequency of different species on the plots in October 1959.

TABLE I. PER CENT FREQUENCY OF SPECIES (POINT QUADRAT METHOD)

Species present	Mixtures sown			
	A	B	C	D
	S.23	S.48	S.143	No seeds

REFERENCES

CROMPTON E. (1953). Some Pedological Aspects of Marginal Land Improvement. Agriculture 60, 301-8.

DAVIES, R. O., JONES, D. I. H. & MILTON, W. E. J. (1959). Factors Influencing the composition and nutritive value of Herbage from Fescue and Molinia areas. J. Agri. Science, 1959. 53, 2, 268-285.

GARDNER, A. L., HUNT, I. V. & MITCHELL, I. W. (1954). The "Muirfeed" Technique of Peatland Improvement. J. of B.G.S. 9, 3.

GARDNER, A. L. (1959). Dalapon to help oversowing. Agriculture, 66, 118-119.

MILTON, W. E. J. (1947) et al. Journal of Ecology. 35, 65.

THE USE OF DALAPON FOR GRASSLAND IMPROVEMENT IN THE SOUTH WEST OF SCOTLAND

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Summary. The use of dalapon as a means of reducing interplant competition in the improvement of hill land by the over-sowing technique is discussed. The limitations and problems involved with this technique and hill land improvement in general are outlined. A method of improving permanent pasture by using dalapon to kill selectively undesirable plants is reported.

INTRODUCTION

Dalapon with its grass killing properties has given grassland improvers a new weapon with which to attack the problem of renovating or replacing unproductive grassland. In trials, attempts were made to fit the use of this substance into existing techniques of grassland improvement.

Trials with dalapon have been on areas where, for one reason or another, it has been considered impossible or undesirable to plough; from a farmer's point of view this is the only outlet for this chemical in view of the present subsidies on ploughing and the certainty with which a seed bed can be obtained by ploughing.

The objects of this paper are (a) to summarise results to date, (b) to indicate some of the general problems involved and (c) to assess the potential use for the chemical technique under the conditions of the south west of Scotland.

RESEEDING UPLAND GRAZINGS

The oversowing technique

The essence of a good improvement technique is that it be simple, certain in its effect and economic. The oversowing method whereby the lime, fertilizer and seed are merely broadcast on the undisturbed soil surface may meet these requirements and can be very successful provided there is ample surface moisture and the existing herbage does not compete too severely with the sown seed.

Such conditions exist on wet peat carrying a sward of short heather, sedges, rushes, moss and some grass. Here seeds can penetrate easily to the soil and the natural herbage which does not grow vigorously acts as a nurse crop to the young seedlings rather than a competitor. The replacement of the original herbage by better grasses and clover can be achieved within 2 years of sowing without any surface cultivations other than that supplied by the hooves of the grazing animals, (Gardner et al, 1954).

When this technique is applied to a dense grassy sward difficulties are encountered by competition from the existing species, so that if the sown seeds ever reach the soil they are rapidly crowded out by the existing grasses. It is at this point that the use of dalapon is justified in removing or reducing interplant competition. Where such competition does not exist, there is no need for prior chemical treatment.

The initial trial work has already been reported, (Gardner, 1959) and since then, the technique used in those small plot experiments has been repeated on a larger scale on different areas. The sites chosen have been dominantly flying bent (Molinia caerulea) and moor mat grass (Nardus stricta) with smaller amounts of tufted hair grass (Deschampsia caespitosa), sheeps fescue (Festuca ovina) and bent (Agrostis spp.). These trials have confirmed the original findings that, despite heavy applications of lime and fertilizer, the oversowing technique will fail on grassy swards unless the competition is removed by chemical or mechanical methods.

Doses of dalapon

The amounts of dalapon used have been restricted to what might be considered economic levels since, despite all that may be discovered regarding the tolerance of one species or another, cost will determine the rate at which hill farmers will apply it. It is fortunate that our poorer hill grasses, which are in most need of replacement, are susceptible to low doses of the chemical. A Nardus/Molinia sward can be adequately dealt with by 4 lb dalapon/ac applied in the autumn. Bent/fescue swards which can be considered good hill grazing are not so susceptible and, depending on the amount of fescue present, would require considerably higher rates (8 - 10 lb) in order to ensure a sufficiently long dormancy and a take of sown seed. At the present cost of the chemical this may well put them outside the economic limit.

Timing

The timing of spraying and seeding are obviously important as the optimum time for both must be considered. The best kill of Nardus and Molinia has been obtained when sprayed in automn allowing the sowing of grass seed to be made, in perfect safety, early the following spring. In the conditions of south west Scotland late February or early March is not too soon for oversowing as this ensures the seeds receiving adequate rainfall during their establishment period and being well grown to face the following winter.

DIFFICULTIES OF IMPROVING UPLAND GRAZINGS

Low fertility

It is important to remember that spraying with dalapon is only one stop towards more productive hill grazings and that it does not, in itself, bring about improvement. If the fertility of the soil is not raised a return to the original position is inevitable.

In hill land reclamation the first essential is lime, usually 2 - 3 ton/ac to bring the pH of the top soil up from 3 - 3.5 to 5.5 - 6.0. Secondly, phosphate is almost always deficient and basic slag (upwards of 1 ton/ac) is usually necessary. Copeman et al (1960) show similar conditions to exist in the north of Scotland.

The results in table I which are typical of oversowing highlight this fertility problem. This area was sprayed with 3.75 lb dalapon/ac in April 1959 and the seeds and fertilizer sown a month later. No cultivations were given and the area was grazed throughout the winter 1959-60.

Better establishment has resulted where the higher rate of slag was applied. As the summer of 1959 was exceptionally dry and the area subjected to hard grazing these results can be considered quite satisfactory. It is of interest to note that under these conditions the slower establishing species timothy (Phleum pratense), meadow fescue (Festuca pratensis) and cocksfoot (Dactylis glomerata) have not fared as well as the ryegrass (Lolium perenne).

TABLE I. PERCENTAGE GROUND COVERED BY SOWN SPECIES
14 months after sowing

Seed mixture lb/ac		Fertilizer treatment: 2 tons ground limestone		
		1 ton slag	½ ton slag	means
12 lb S.24 perennial ryegrass				
8 lb S.23 " "		28.0	12.0	20.0
2 lb S.184 wild white clover		19.5	8.0	13.8
20 lb S.143 cocksfoot		14.5	8.5	11.5
2 lb New Zealand white clover		18.0	17.5	17.8
10 lb Danish meadow fescue		5.0	3.5	4.2
8 lb S.48 Timothy		2.0	1.0	1.5
2 lb New Zealand white clover		9.0	15.0	12.0
Means	Sown grass	16.5	8.3	
	Clover	15.5	13.5	

Grazing control

If full use is to be obtained from reseeded hill land then fencing is essential otherwise reseeded areas, which naturally draw stock to them, are so severely punished that reversion takes place. Fencing is also necessary to permit rest periods in preparation for out of season grazing.

When the cost of grass and clover seed (and possibly drainage) are added to these items of fertilizer and fencing it can be appreciated why expensive chemical sprays are unlikely to be accepted by hill farmers especially when mechanical forms of cultivation are subsidised.

Acid mat

The areas tackled by the chemically-assisted oversowing technique were chosen to avoid heavy acid mat formations. Cultivation difficulties reported by other workers (Elliott, 1958; Hunter 1960; Ormrod, 1958) which result from the thick mat of dead material left by spraying have not been encountered.

If such areas are to be tackled then reduction of the mat should commence several years in advance by the use of lime and phosphate. Once this first phase has been passed reseeding after ploughing, cultivating or spraying will be more easily and safely achieved. Crompton (1960) has underlined the need to encourage the decomposition of a mat so providing more suitable conditions for plant growth.

Aerial techniques

In New Zealand the use of the aeroplane to distribute light dressings of phosphate has brought land, previously considered un-improvable, into economic production but it is doubtful if this approach will be successful under west of Scotland conditions for the following reasons.

To be economic aerial spraying or top-dressing requires that large blocks of land be tackled and as far as spraying is concerned this presupposes large areas of species susceptible to dalapon. Areas are difficult if not impossible to find under our conditions where heather, moss, bracken, Molinia and Nardus communities can occur within a few acres of the same hill. Aerial spraying of this land would be wasteful as much of the spray would fall on resistant or valuable species.

Another factor militating against the improvement of large tracts of country is the necessity to stock the improved areas adequately, not only to cash in on the improvement, but also to promote a strong clover growth by judicious hard grasing. The capital outlay required to meet these needs might well prove prohibitive.

The large quantity of lime required on most U.K. hill land would also render the aeroplane uneconomic even if the requirement could be halved by the use of pelleted seed.

It therefore seems unrealistic to envisage large scale improvement schemes being undertaken by aeroplane in western Scotland at present.

IMPROVEMENT BY SELECTIVE CONTROL

There are thousands of acres of permanent pasture which carry a herbage composed mainly of bent, red fescue (*Festuca rubra*), crested dogstail (*Cynosurus cristatus*), sweet vernal (*Anthoxanthum odoratum*), meadow grasses (*Poa* spp.), Yorkshire fog (*Holcus lanatus*), perennial ryegrass and wild white clover and are often rush (*Juncus* spp.) infested. Ploughing such land without drainage often results in an even worse rush infestation and farmers prefer to improve it by applications of lime and slag which promote clover growth and encourage the better grasses.

A field of this type was sprayed with MCPA in the autumn of 1958 to eliminate the rushes, then 2 ton of ground limestone and 1 ton slag were applied. In April 1959 an acre of this field was sprayed with 3.75 lb dalapon. This gave a very temporary set-back to the grasses which had apparently recovered completely by the end of June. Due to this very poor 'kill' and the subsequent dry weather grass seed sown in May did not establish. This left two comparisons 1) sward limed and slagged and 2) sward limed, slagged and sprayed with dalapon.

The sprayed area rapidly took on a green fresh appearance which was apparently associated with a luxuriant clover goowth. A botanical analysis was carried out in May 1960 when the sprayed area could still be readily picked out from the rest of the field. From table II can be seen the botanical changes that have taken place as a result of dalapon spraying.

TABLE II. PERCENTAGE GROUND COVER 1 YEAR AFTER SPRAYING

Treatment	Perennial ryegrass	Wild white clover	Agrostis spp.	Other grasses	Dicotyledonous weeds
3.75 lb dalapon	28	20	6	28	17
No dalapon	10	16	40	22	12

The *Agrostis* has been greatly reduced and its place largely taken by perennial ryegrass. It is possible that the unsprayed area will eventually reach the same botanical composition as the sprayed area due to the raising of the fertility. Further interest in this field will be centred on seeing if and when this takes place.

CONCLUSIONS

Where the establishment of sown seed is impeded by competition from existing grasses the use of dalapon to reduce or remove this competition will greatly help the establishment and spread of the better species. Although the technique is sound on technical grounds the economics are open to question and may limit the use of the chemical to swards that are readily killed by low rates of application.

Grassland improvement by selectively killing less desirable types with small doses of grass-killing chemical combined with accepted practices of good husbandry shows promise. When more information becomes available on the relative tolerance of different species it may be possible to eliminate unwanted grasses without retarding the growth of the sward as a whole.

REFERENCES

COPEMAN, G. J. F., ROBERTS, H.W. (1960). The development of surface seeding. J. Brit. Grassl. Soc. 15, 163-168.

CROMPTON, E. (1960). Soil features associated with the development of good permanent pasture in moorland areas. Proc. 8th Int. Grassl. Cong. (in press).

ELLIOTT, J. G. (1958). Use of Herbicides in the surface reseeding of old pasture. Proc. 4th Brit. Weed Control Conf. 234-238.

GARDNER, A. L., HUNT, I. V., MITCHELL, I. W. (1954). The "Muirfad" technique of peatland improvement. J. Brit. Grassl. Soc. 9, 161-171.

GARDNER, A. L. (1959). Dalapon to help oversowing. Agriculture, 66, 118-122.

HUNTER, R. F. (1960). The place of oversowing on hill farms. Proc. 1st British Conference (organised by Dow Agrochemicals Limited) on the improvement of marginal land by oversowing after dalapon treatment, 17-23.

ORMROD, J. F. (1958). Field experiences with dalapon in reseeding difficult land. Proc. 4th Brit. Weed Control Conf. 241-244.

Discussion on preceeding four papers

Mr. H. M. Lawson I would like to ask the authors of the various papers to what extent slug damage to seedlings was responsible for poor establishment of new swards in their trials, and whether much of the failure attributed to poor seedbed conditions might be due to slug damage.

Mr. J. F. Ormrod We have not had any evidence of slug damage.

Professor W. Ellison Part of our work this year has been sod-seeding kal into pasture after dalapon spraying. Unfortunately the kale seedlings suffered severely from slug damage, to such an extent that the crop was virtually a failure.

Dr. M. Neenan Four years ago we tried at 25 centres applications of 2,4-D and superphosphate to pasture. The quality of the hay was decidedly improved. On another pasture dominated by Agrostis gigantia, we sprayed dalapon and followed with clover oversown at weekly intervals but the clover did not succeed owing to the slow kill produced by dalapon. A previous trial was more successful but the clover suffered competition from broad-leaved weeds.

Mr. J. G. Elliott After much experimental work on sward renovation, the situation is being clarified. All our grass killing has been based on one chemical-dalapon. Dalapon is extremely toxic to Deschampsia caespitosa, Molinia caerulea and Nardus stricta; but Agrostis spp. and Festuca spp. are more resistant. Against dalapon are its slow action and persistence in the soil. We want chemicals with grass killing powers that are quick acting with no persistence in the soil.

Mr. G. D. Holmes In our experiments, slow-acting herbicides, when applied to heavy swards, have resulted in a dry surface mulch of persistent dead remains, which are not ideal for reseeding. Recent trials with diquat at 2 lb/ac alone and in combination with dalapon on Molinia, Nardus and Agrostis swards have shown greatly accelerated break down and disappearance of the dead grass.

Mr. G. A. Toulson I cannot agree with the chemical destruction of Molinia. This moorland grass gives a useful contribution to grazing. Lime and heavy stocking cause Molinia to give place to more useful species, and then seed cleanings can be introduced with surface cultivations.

Dr. S. H. Crowdy Following Mr. Holmes comment, we have a second dipyridyl which is very much more effective against grasses than is diquat. (Editor - see "The Control of Perennial Grasses with Dipyridyl Herbicides Alone and in Mixtures" by R. S. L. Jeater and H. C. McIlvenny, Session 6).

SESSION 4

Chairman: Professor W. Ellison

BRACKEN

ECONOMIC ASPECTS OF BRACKEN (PTERIDIUM AQUILINUM) IN UPLAND FARMING

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Summary: Some of the economic aspects of bracken are discussed, though no precise measure of its importance can be obtained. The origin and extent of the problem, together with costs of eradication are outlined. The effects of bracken infestation are discussed and it is pointed out that both the distribution pattern on the farm and botanical considerations affect the suitability for improvement. It is emphasised that eradication should be regarded as the first step in a programme of improvement involving measures to establish and maintain a useful pasture in its place. In many cases the elimination of bracken might bring about an increase in the productivity of the hill, but to ensure a permanent improvement positive measures to maintain fertility are essential. A proper balance must be achieved between immediate economic advantages and the long term demands of sound land use.

INTRODUCTION

A precise assessment of the significance of bracken in upland farming is not possible. Where open hill pasture is concerned, the environment of production consists of many interacting factors both difficult to measure and incapable of decisive management control. Thus, the various components of production cannot be assigned realistic economic values. In examining the economic aspects it is important to distinguish between short-term and long-term considerations. The farmer is primarily concerned with the first, as he must operate within the immediate economic framework. The second involves ecological implications which may have important repercussions on future production from the uplands. This should concern the state and should have due consideration in framing land use and agricultural policy.

The bracken problem does not differ essentially from that of controlling the other plant communities composing upland pasture. The special interest in bracken arises from its occupation of some of the better soils, capacity for rapid spread with consequent depletion of the sward, and its tendency to poison cattle. In many respects the problem of bracken differs from that of other communities only in degree and our present inability to control it is one example among many of the inadequate control we have at present on ecological trends in upland pasture and therefore on the quality and productivity of its herbage.

ECOLOGICAL STATUS OF BRACKEN

The existence of bracken in this country can be traced back to early times (Godwin), 1956) but the present problem, induced by changes in land use, is of comparatively recent origin. Historically, it is a woodland plant but on removal of the tree canopy, and being unpalatable to stock, an extensive grazing environment provides little hindrance to vigorous growth and spread. The former climax woodland vegetation of Britain rose to an elevation of 1000 - 2000 ft. Destruction of the tree cover has taken place over an extended period in Wales and in the Southern Uplands of Scotland which have a long history of grazing use, while in the Scottish Highlands deforestation is a much more recent event. The coming of extensive sheep farming to the uplands 150 - 200 years ago is generally regarded as the begining of the present problem, while changes in grazing use within this period, including the disappearance of wether flocks and herds of ponies, and reduction of cattle have enhanced the opportunities for spread. Attention has been drawn on many occasions to the spread of bracken since the beginning of the century (Stapledon, 1944: Report, 1944) and many such soils today provide abundant evidence of the former dominance of other plants. During the depression, extensive areas of permanent pasture became infested and destruction of much of this by ploughing up during and after the war may have offset to some extent encroachment on the hill. Indeed, a recent enquiry in Wales (Report, 1958) found no evidence of spread on a significant scale, and in parts some contraction was said to have occurred. Nevertheless, there is evidence of continued encroachment on the hill itself, often associated with heather burning, but the magnitude is impossible to judge.

ACREAGE AND DISTRIBUTION

Available figures for bracken infestation are only rough approximations and it is unfortunate that the figures for England and Wales on the one hand and Scotland on the other are not strictly comparable owing to the different methods of estimation. The most recent estimate for Scotland (Hendry, 1958) is 442,000 acres of rough grazings affected and over 8,500 acres of permanent grass. About 20 years ago in surveying the grasslands of England and Wales (Davies, 1941), the aggregate acreage of dense bracken was estimated at 406,000 together with a further 45,000 acres of mixed fern and gorse, while in an earlier survey in Wales (Davies, 1936) the figure of 152,000 acres of dense bracken was arrived at. In 1956, the Welsh bracken acreage was estimated at 144,000 (exclusive of common land) of which 25,000 acres were accessible and could be ploughed.

In the Scottish counties of Selkirk, Argyll and Kirkcudbright, one quarter to two thirds of the farms are affected, but in the north and east the infestation rate is only one in twenty farms. Three quarters of all bracken in Scotland is found in these counties, together with Inverness, Perth, Roxburgh, Wigtown and Dumfries. Taking Sootland as a whole, on those farms which report a bracken problem, one acre in every twelve is affected.

If the upper limit of bracken is taken as 1,500 ft, on the basis of figures for percentage land below this level in Wales (Ashby and Evans, 1944) and Scotland (Halstead, 1959), the percentage infestation of the total permanent grass and rough grazings is 4.7 per cent for both countries. In view of the considerable area of peat in Scotland, however, within the bracken altitudinal zone, the intensity of infestation would seem to be greater than in Wales.

Unfortunately, it is not possible to calculate a similar figure for England. Considering that bracken occupies the better soils and that on many soils, including wet peat, it will not grow at all, the overall infestation is by no means light.

FORMS OF INFESTATION AND SOIL POTENTIAL

Bracken is generally considered indicative of productive soil for cultivated grass, crops and trees. Indeed, the annual dry matter production of bracken is itself high. For example, 2 ton/ac is not exceptional for moderately dense bracken, while a denser stand may produce 4 ton or more/ac. Under crops and grass during the war a considerable area of the more accessible bracken land demonstrated the inherent potential for crop growth. Boyd and Ellison (1954) give estimated values for mean starch equivalent production per acre from reseeded bracken land compared with other similarly treated hill communities as follows:-

Mean S.E. in cwt/ac/annum	
Bracken	17.4
Nardus/fescue	14.2
Molinia	10.6

In one case at 1,000 ft an area of bracken gave a yield of 30 cwt/ac S.E. in the first year after improvement, the estimated production before treatment being 3 cwt/ac S.E. In comparison, the estimated net yield of starch equivalent in the U.K. (excluding rough grazings) is about 15 cwt/ac (Baker and Ferguson, 1954). Although not considering bracken land in particular, it is interesting that the great potential value of certain hill soils has also been demonstrated recently by Crompton (1958).

Though examples of cultivable bracken land provide a useful measure of potential, the real problem of bracken is its infestation of extensive grazing land which must continue to be used for this purpose, and where the economic limit of exploitation is well below its potential under cultivation.

In relation to topography and location of inbye land, three distribution types of bracken infestation can be recognised as follows:-

1. Restriction to the lower slopes forming a belt between the arable and the open hill.

2. Presence of a similar altitudinal belt on more broken terrain, dissected by deep valleys. Much of the area in this case is not easily accessible and also remote from the inbye land.

3. Occurence of more discreet areas widely scattered over the hill.

Botanical differences in the ground vegetation are also associated with these distribution patterns according to soil, accumulation of litter and density of the upper canopy. The herbage varies from bent/fescue pasture unaffected by the associated bracken to scattered plants or none at all. Both the distribution and botanical nature of the communities must obviously be borne in mind when considering improvement programmes.

The first distribution category is the type most frequently the subject of past reclamation projects involving ploughing, fencing and incorporation into the arable or acreage of permanent pasture. Bracken in such circumstances need not raise any special problem. Fencing and the more intensive use, while continued, will effectively prevent re-establishment. The cost of such treatment has been studied in many situations (e.g. Grant, 1955) and prediction of the economics of the operation does not raise special difficulties.

The second and third distribution patterns present a problem of extensive pasture management, not properly understood, and represent the crux of the bracken problem.

SOME EFFECTS OF BRACKEN

The problems associated with bracken infestation are well known and include not only impairment of growth of the underlying sward, but complete destruction where the density is great enough, sometimes leading to a reduction of stock in severely infested areas. Less dense stands may provide useful grazing in spring and autumn (Hunter, 1954), but if Holcus mollis is abundant, the sward is of little value in winter. Interference with herding may also be a problem and occasional fatalities to cattle by poisoning occur. Light infestation, however, may not be without its benefits owing to the tendency for earlier growth of pasture in such areas and in periods of drought a moderate canopy may provide some insulation from the worst effects on herbage growth. Despite such advantages, if the stand is dense enough to exclude stock in summer, grazing from good land is denied at a time when nutritious pasture would be beneficial to growing lambs.

Although the influence of bracken on the soil profile is obscure, and no experimental evidence has been adduced to show the effects of bracken invasion of soil with marked podsolic features, it has been suggested that benefical changes in profile characteristics may develop. The presence of bracken has also had a protective effect from long continued extractive sheep grazing to which other hill communities have been exposed. On the other hand, where cutting for litter is practised the loss is much heavier than under sheep grazing. It has been suggested (Campbell, 1959) that the eradication of the Scottish acreage might permit an increase of 100,000 breeding ewes, but without the simultaneous application of real management of hill pastures (Nicholson, 1959), including fertiliser application, it is doubtful whether a future decline in productibity could be avoided.

COST OF ERADICATION AND EXTENT OF WORK

Various schemes of grant aided bracken clearance have been in operation since 1936, including assistance as part of comprehensive improvements under the Hill Farming and Livestock Rearing Acts. Apart from comprehensive assistance, the current scheme introduced in 1941, offers a 50 per cent grant in aid of bracken control.

The gross costs of double cutting bracken in 1952 on West of Scotland farms were found by McCreath and Martin (1954) to vary from 13s 0d to 21s 8d for farmer's own tractor work and from 20s 0d to 35s 0d by contract. Duthie (1954) studied the comparative operating costs of four different machines under experimental conditions in south east Scotland in the same year. He showed the range of costs to vary from about 7s 6d per acre for the Holt breaker to 20s10d for the Ferguson mower. A rough approximation of the "average" cost in Scotland can be calculated from the figures for annual grant paid (D.O.A.S., 1960) and on this basis the cost in 1952 was 22s 4d per acre for double cutting. These figures also indicate the upward trend of cost between 1948 and 1959 (see graph), the most recent estimate being 31s 6d per acre. At this rate the total gross cost for completing an approved scheme over three years would be about 95s 0d per acre.

Accurate figures for the acreage of bracken land which has received the full three year treatment, since the inception of assisted bracken eradication, are not readily available. The following estimates, however, are calculated from information supplied by the Department of Agriculture for Scotland and the Ministry of Agriculture, Fisheries and Food.

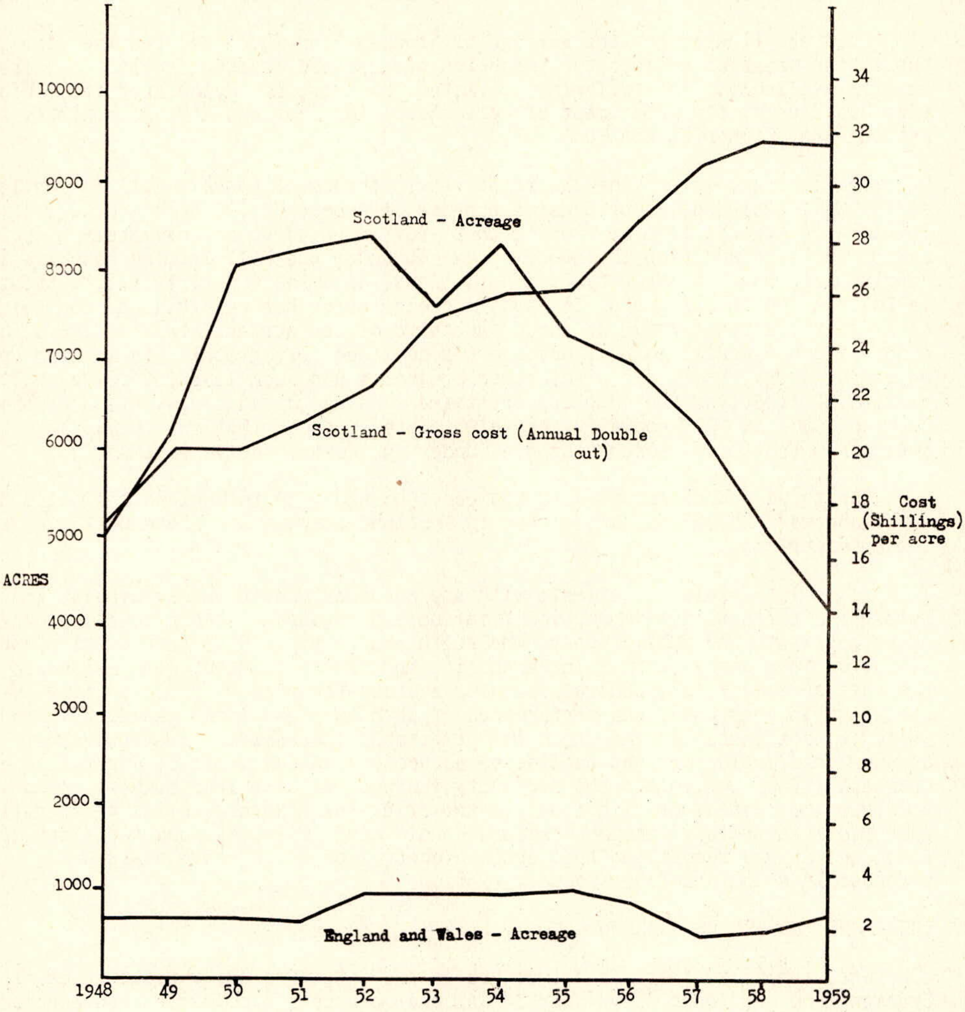
The acreage, completing the first year's treatment (double cut) in Scotland since 1948, excluding comprehensive schemes, is about 82,000 acres (D.O.A.S. 1960). The acreage treated from 1936 until that year amounted to approximately 45,500 acres, while in addition the annual area cut under the Hill Farming and Livestock Rearing Acts has been over 2,000 acres. Thus, assuming the first year's treatment is followed up in all cases, the total acreage which has received the complete three year treatment would be about one third of the current bracken figure, but since 1954 the annual rate of cutting has declined (see graph). In England and Wales (M.A.F.F., 1960) the eradication programme has been less intensive, only about 9,500 received the complete treatment (making the same assumption as above) between 1948 and 1959 and a further 4,900 acres between 1941 and 1947. In addition there is the acreage treated under the comprehensive schemes.

The total annual grants paid between 1948 and 1959 in England and Wales have varied between £1,345 and £2,383 and in Scotland between £10,266 and £19,226 in the same period.

It is impossible to estimate with any accuracy what economic benefit the farmer and the nation have derived from the expenditure of these considerable sums of both private and public money. McCreath and Martin (1954) have examined the situation in a sample survey in Perthshire and provided encouraging evidence. In the case of some farms, control measures avoided the necessity of reducing the ewe stock and in many cases the performance of both ewes and lambs was much improved, while in some instances the stock was profitably increased. In a few cases, bracken eradication was not considered economic. On the basis of a specific case, McCreath (1958) worked out the necessary increase in both lamb numbers and prices to cover the cost of eradication. In the drier Roxburghshire hills the benefits appeared less decisive though eradication did tend to improve the fertility of the ewes, and it was recognised that bracken control on a long term basis was undoubtedly sound practice (Corner, 1956).

TREATMENT AND USE OF BRACKEN LAND

Unfortunately, there is no measure of the extent of the various types of bracken land mentioned above. As far as the more open communities are concerned it is very doubtful whether clearance would provide an economic return and as Corner (1956) points out complete eradication may not be sought. With increasing frond density, however, the prospects of profitable improvement are enhanced. Where there is little or no herbage beneath the canopy, additional treatment to produce a worthwhile sward is needed. Where such areas are on the open hill there is no reason to expect that treatment will ensure permanent clearance so long as the grazing regime remains unaltered. For this reason, the treatment of bracken with an effective spray is not necessarily a "once only" job.



BRACKEN CUTTING Estimated Approximate Annual Acreage Receiving Double Cut in First Year of Treatment and Gross Cost for 1948-1959 (Excluding work under Hill Farming and Livestock Rearing Schemes

A proportion of the bracken land in the first category above could be improved for out of season grass, by ploughing or by the slower management techniques including fencing. In view of the present high cost of hogg-wintering (Grant 1960) its use for that purpose would be of considerable benefit on many farms.

As regards bracken distributed more widely on the hill, the value of eradication is a rather open question. An increase in production of sheep and cattle from the uplands at lower cost is an aim to be pursued, but the large scale clearance of this land for further exploitation, without the integration of improved areas into a sound system of hill pasture husbandry, could lead to unfortunate ecological effects.

CONCLUSIONS

Although the acreage of bracken infestation throughout Britain is extensive, the area on the hill itself which could be profitably destroyed may be more limited than would at first appear to be the case. There is no doubt that routine bracken control is an essential element in maintaining production on hill grazings, but large scale clearance is unrealistic without measures to improve the husbandry techniques which are the fundamental cause of its existence. Theoretically, extensive eradication would be the means of temporarily increasing production from hill grazings, but immediate economic advantages should not make more difficult the long-term requirement which is the adoption of pasture management techniques capable of progressively improving the status of rough grazings under pastoral use.

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REFERENCES

ASHBY, A. W. AND EVANS, I. L. (1944). The Agriculture of Wales and Monmouthshire, Cardiff.

BAKER, A. S. AND FERGUSON, W. S. (1954). The contribution of grazing to the nutrition of farm animals. Proc. Nutr. Soc. 13, 6 - 10.

BOYD, D. A. AND ELLISON, W. (1952). Possibilities of marginal land reclamation. J. Royal Agric. Soc. England 113, 26-43.

CAMPBELL, COLIN J. (1959). Under bracken lies gold. Blackface sheep. The Journal, Blackface Sheep Breeders' Assn. No. 12, 17.

CORNER, H. H. (1956). Experiments on the control of bracken. The Edinburgh and East of Scotland College of Agriculture.

CROMPTON, E. (1958). Hill soils and their production potential. J. Brit. Grass. Soc. 13, 229 - 237.

DAVIES, W. (1936). The Grasslands of Wales. In, A survey of the agricultural and waste lands of Wales. Ed. R. G. Stapledon, London.

DAVIES, W. (1941). The grassland map of England and Wales. J. Minist. Agric. 48, 112 - 121.

DEPARTMENT OF AGRICULTURE FOR SCOTLAND (1960). Private communication.

DUTHIE, W. B. (1954). Economics of bracken eradication, 1951, 1952 and 1953. Edinburgh and East of Scotland College of Agriculture. Economic Report No. 28.

GODWIN, H. (1956). History of the British flora. London.

GRANT, A. (1955). Some land reclamation costs. North of Scotland College of Agriculture, Aberdeen. Economic Report No. 10.

GRANT, A. (1960). Hill sheep farming in the north of Scotland. North of Scotland College of Agriculture, Aberdeen. Economic Report No. 84.

HALSTEAD, C. A. (1959). Private communication.

HENDRY, G. F. (1958). The size of Scotland's bracken problem. Scottish Agricultural Economics, 9, 25 - 28.

HUNTER, R. F. (1954). The grazing of hill pasture sward types. J. Brit, Grass. Soc., 9, 195 - 208.

McCREATH, J. B. AND FORREST, J. D. (1958). Bracken Control. Machinery Trials West Perthshire, 1952-55. West of Scotland Agricultural College, Research Bulletin No. 24.

McCREATH, J. B. AND MARTIN, D. J. (1954). Bracken cutting on west of Scotland farms. An economic and botanical survey of past work. West of Scotland Agricultural College. Report No. 15.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1960). Private communication.

NICHOLSON, I. A. (1959). Hill pasture improvement and the significance of aircraft. Proc. Int. Aviation Conference, Cranfield. Int. Agric. Aviation Centre - The Hague.

REPORT OF THE COMMITTEE ON HILL SHEEP FARMING IN SCOTLAND (1944). H.M.S.O., Edinburgh.

REPORT (1958). Technical problems of Welsh agriculture. H.M.S.O., London.

STAPLEDON, R. G. (1944). The Land, now and tomorrow. London.

CONSIDERATIONS IN JUDGING CONTROL METHODS OF PTERIDIUM AQUILINUM

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Although the usual methods of judging control methods of Pteridium aquilinum, the common bracken fern, are by frond counts from unit areas, it is now widely recognised that the expanded fronds of Pteridium aquilinum are only seasonal and temporary organs, and that effective attack must be directed towards the massive underground stem. This paper is an attempt to present some considerations that must be borne in mind in evaluating methods of control, and a primary consideration is the form of this underground stem, the plant's central organ. It is this organ from which the fronds arise, and it is the agent responsible for invasion as well as for the plant's ability to pass the winter in a healthy state ready to begin further growth and expansion the following year.

The tangled mass of rhizome which is found when bracken land is dug is really a large number of branches, each with a marked growing-point at the tip and each capable of forming a new and separate centre of growth and development. These branches can be divided into three categories: (1) thick ones that run deeply into the soil and are the main agents responsible for the outward expansion of the the colony. Normally, they carry few fronds or frond-buds; but if any factor causes them to grow up towards the surface of the soil, they initiate frond-buds that later come above the soil as expanded fronds; (2) thinner, smaller branches running near the soil surface: these are the main frond-bearing branches; and (3) intermediate branches linking (1) and (2) and capable of developing into either as environmental factors act on them. Branches (2), with their frond-bearing function, are those of immediate interest, though branches of type (1) are those which give the plant its considerable resistance to extermination.

In the West of Scotland, fronds expand on branches (2) during May from frond-buds already initiated in the previous year. The branch axes elongate from late May or early June onwards, and new frond-buds become visible (one or two on each apex) late in July. Growth of the stem axis appears to slow down (though not necessarily to stop) during the early part of the autumn, while development of the frond-buds continues markedly as long as the soil temperature and drainage remain at a high enough level. Closer examination of branches of type (2) at the end of a season show that they may be divided into two categories:
(A) certain of the branches are those carrying expanded fronds with one or more frond-buds on the same axis and nearer to its apex. Usually each axis bears only one expanded fonnd each season, though if that frond dies or is removed, the adjacent frond-buds are stimulated and expand to replace the earlier frond.
(B) Intermingled with branches A, other similar axes can be found that carry frond-buds but no expanded fronds. Such frond-buds appear capable of remaining below ground in a healthy state for undetermined lengths of time, only developing into expanded fronds in response to some environmental or other factor. It is clear, then, that the number of expanded fronds on a unit area gives no adequate picture of the reserve of front-buds below ground; and in almost all areas, this large reserve of frond-buds is a constant feature.

During the past few years, the development of the rhizone in the field has been examined in a number of areas in the West of Scotland and the North of England, by digging out unit areas of 1 sq yd and analysing branches A and B.

Some examples of the extent of the variability in the number of stem axes and frond-buds present is shown in Table I. From this, the chief points for comment are (1) the variations are great enough from plot to plot in any area to call for individual explanation of drainage, soil type and fertility as well as litter-cover and other factors of micro-environments. For instance, site C of the Dumfriesshire areas was found to be near a winter water course: the water-logged state of the soil through the cold season had slowed down and curtailed development, so that the analysis of the underground organs showed much reduced development of stem tips and frond-buds. Similarly, the Yorkshire site analysed was on land known to have been cut yearly for many years. The very high degree of frond-bud initiation is in line with results from other areas of prolonged cutting (Conway & Stephens, 1954). (2) From all the sites analysed, the number of healthy branch apices and frond-buds was high; numbers of dead branch tips or frond-buds were very small indeed. (3) The reserve of underground frond-buds was marked on all the sites and the ratio of frond-buds to expanded fronds was higher than normal replacement would suggest. Such high ratios suggest either that a considerable number of frond-buds die before expansion or that many can remain in a quiescent and dormant state for undetermined periods, expanding only on receiving some form of stimulation. (4) The majority of frond-buds are carried by branches that do not show an expanded frond of the current year, branches of type B. It is clear that these branches cannot be directly affected by methods of control that act only on the expanded fronds.

The point of primary consideration to the agriculturalist, and the acid test of any form of attack on Pteridium aquilinum, is the degree to which healthy fronds are found on treated areas in the years after treatment. And so, in considering the value of any form of treatment, it is clear that we must know, not only the way in which the treatment affects the underground frond-buds and the stem apices that continue to form frond-buds, but also something of the extent of the reserve of frond-buds. Table 2 shows an analysis of the state of branches A and B dug out from experimental areas treated both by cutting away the fronds and by chemical spraying with a translocated growth-regulating compound, 4-chlorophenoxyacetic acid. This table shows that (a) cutting has no lethal effects on the growing points of the underground stem though it may slow up the rate of development. This point can be seen in the slightly fewer frond-buds visible on the branch tips of both A and B types. (b) Spraying of a translocated herbicide has marked lethal effects on the stem apices and on the frond-buds which they carry. In this way further development of the axes concerned is stopped. (c) The rate of damage caused in the apical tissues of axes adjacent to a current year frond - i.e. to the point of application of the chemical - is high; but damage caused to branches of type B is markedly less. Experimental work has shown that translocated compounds such as 4-CPA are carried with ease to the apex of an axis on which a treated frond is borne; but that there is much less translocation in a basal direction or to the tip of an axis without a point of direct application. (Conway & Forrest, in the press).

It thus becomes clear that evaluation of treatment made by counting fronds on a unit area in the following years reflects the number of frond-buds that escaped the effects of treatment and are later able to expand. This number is further conditioned by the extent of the rhizome development in the treated area before treatment was applied; for example, the areas shown in table I by Dunbartonshire C or the Yorkshire area, with their high ratio of frond-buds on branches of type B, are likely to show extensive regrowth in the first year or two after any form of treatment. The very great advance shown by foliar spraying with certain of the translocated herbicides is that the branches affected are killed and are unable to develop further. In the case of defoliation treatments, the growing points are not killed: though their rate of development may be reduced they remain as growth-centres, and sooner or later fully formed fronds will again expand from the apices of all the branches.

In judging methods of controlling bracken, then, it is important that two primary considerations shall be (a) appreciation of the development of the underground stem in the area to be treated, and (b) recognition of the damage caused by treatment and the degree to which it is lethal. Only if these points are known and understood can the worth of any form of control really be judged.

REFERENCES

CONWAY, E. & STEPHENS, R., (1954). How the Bracken Plant reacts to Treatment. N.A.A.S. Quart. Rev., 25, 1 - 15.

CONWAY, E. & FORREST, J. D. (1961). The Effects of 4-Chlorophenoxyacetic Acid (4-CPA) on the Rhizome of *Pteridium aquilinum* (L.) Kuhn. Weed Research (in the press).

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TABLE I. FROND & FROND-BUD POPULATIONS OF 1 SQ YD IN SEPTEMBER

	Argyll		Dunbartonshire			Dumfriesshire				Yorkshire
	(i)	(ii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(iv)	(i)
No. of expanded fronds	28	14	30	40	22	27	34	18	25	40
No. of living stem apices	88	75	246	198	174	138	204	66	118	282
No. of living frond-buds	60	51	164	110	156	106	124	30	68	132
Ratio: expanded fronds to frond-buds	1:2.1	1:3.6	1:5.5	1:2.7	1:7.1	1:3.9	1:3.6	1:1.7	1:3.6	1:3.3
Ratio: frond-buds on branches A to frond-buds on branches B.	1:2.7	1:4.7	1:4.4	1:1.9	1:5.0	1:3.2	1:2.0	1:1.0	1:4.0	1:8.2

TABLE. II. THE EFFECTS ON STEM APICES & FROND-BUDS OF MECHANICAL & CHEMICAL TREATMENT

	Mean figures from sites analysed in September:							
Treatment (data from not less than 5 sites in each case)	Branches type A				Branches type B			
	Rhizome-tips/20		Associated frond-buds		Rhizome-tips/10		Associated frond-buds	
	Healthy	Dead or dying	Healthy	Dead or Dying	Healthy	Dead or Dying	Healthy	Dead or dying
Untreated	20	-	17	-	10	-	9	-
Twice Cut (End of June and early August)	20	-	16	-	10	-	8	-
Foliar spray in early July with 4-CPA (Butoxyethanol ester):- 10 lbs. a.e. " "	3	17	2	8	4	6	3	3

SOME ASPECTS OF THE CHEMICAL CONTROL OF BRACKEN

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A. H. Marks & Co. Ltd.

Summary: Trials have been continuing since 1955 in Scotland and 1958 in England on the control of bracken by chemicals. Hormone-type herbicides have been found to be most effective, in particular, emulsifiable ester formulations of 4-chlorophenoxy-acetic acid. The extensive rhizome system of bracken with its large number of frond buds invariably possesses an unfavourable ratio of growing fronds to potential frond buds. To give control of a high order a chemical must be capable of being easily translocated at lethal dosage over relatively long distances within the rhizome. The amount of chemical translocated is, within limits, dependent on the quantity penetrating the frond cuticle and this in turn is probably dependent on the stage of maturity of the bracken. These and other factors limit the degree of control obtained with chemicals. To date a reduction in the bracken density of 70-80% appears to be possible under normal climatic conditions. Reductions of a higher order have been obtained and investigations are in hand to evaluate the conditions under which these higher reductions take place.

INTRODUCTION

In 1955 Coulson (1956) acting on a suggestion by Amchem Products Inc. laid down a set of bracken trials at Moffat, Scotland, involving a range of herbicides. A visual inspection of the plots in 1956 indicated that 4-chlorophenoxyacetic acid (4-CPA) was markedly toxic to bracken. An extensive study of the effect of herbicides on bracken, in particular 4-CPA, was initiated in 1957 and this work is still actively proceeding. This paper is an interim progress report of these investigations.

As details of Coulson's now famous plots have not previously been published, a brief summary of the work is given. Plots of 1/40th acre were sprayed with a watering can at 100 gals total volume per acre using the following herbicides ;

Plot	
1	6 lb MCPA/ac as emulsifiable butyl glycol ester.
2	12 lb MCPA/ac as emulsifiable butyl glycol ester.
3	9 lb 4-CPA/ac as emulsifiable butyl glycol ester.
4	18 lb 4-CPA/ac emulsifiable butyl glycol ester.
5	1¼ lb 3-amino 1,2,4-triazole/ac + 1¼ lb sodium sesqui-carbonate/ac.
6	2½ lb 3-amino 1,2,4-triazole/ac + 2½ lb sodium sesqui-carbonate/ac.
7	As Plot 1 + Plot 5.
8	As Plot 3 + Plot 5.

Frond counts were not recorded in 1956 but visual examination indicated a reasonable reduction in plots 1, 2, 7, and 8 and an excellent reduction in plots 3 and 4. The plots were inspected in August 1960 when four still showed good control. The reduction in frond density for these plots based on randomised frond counts is given in Table I.

TABLE I. REDUCTION IN FROND DENSITY IN AUGUST 1960 FOR COULSON 1955 PLOTS

Plot	Percentage Reduction
2	65
3	82
4	93
8	89

METHODS AND MATERIALS

To obtain a representative selection of bracken growing under a variety of different climatic and soil conditions, five sites have been used in Scotland since 1957, namely Langholm, Dumfrieshire; Moffat, Dumfrieshire; Callander, Perthshire; Kilmelfort, Argyllshire and Tobermory, Isle of Mull. In England, Ramsgill, Yorkshire, has been used since 1959. Single plot experiments were made at each site on 1/40th acre plots and in the main experiments were repeated on each site. Whilst it is appreciated that replication would have been ideal, the size of the programmes and our limited resources did not make this feasible. In 1957 and 1959 plots 10 x 12 yd were used and in 1958 4 x 30 yd. The latter size has now been discarded as encroachment of fronds from the perimeter makes accurate assessment difficult, if not impossible, in future years.

Although some screening trials have been made, the main experiments have involved low volatile 4-CPA ester formulations containing 5 lb 4-CPA/gal. All formulations were applied with the Oxford Precision Sprayer as aqueous emulsions at total volume rates of 20 - 100 gal/ac.

The reduction in frond density has been assessed in years subsequent to treatment by six randomised one square yard frond counts in the plot and six in the adjacent untreated bracken. This method of assessment gives fairly consistent results in uniform bracken but can give a false picture where growth is patchy and interspersed with dense clumps. Where an obvious reduction in density has been obtained, the growth the following year normally shows typical growth regulator effects and is less vigorous than adjacent untreated bracken. Although the reduction in vigour has not been recorded as a routine, it has been observed that the greater the density reduction, the less vigorous is the regeneration.

The emergence of fronds from rhizomes at different depths takes place over an extended period and treatment with hormone herbicides often further delays emergence of fronds the following year. In order to obtain a true assessment it has been found necessary to delay counting until late August or early September. Table II illustrates the difference in reductions obtained at Ramsgill when counts were taken in late June and early September 1960.

TABLE II. PERCENTAGE FROND REDUCTIONS FOR 1959 RAMSGILL PLOTS AT DIFFERENT ASSESSING DATES

Spraying date 1959	5 lb 4-CPA/ac		7½ lb 4-CPA/ac	
	June 1960	Sept 1960	June 1960	Sept 1960
29th July	73	55	76	59
13th August	51	17	70	38
19th August	57	30	49	38
7th September	32	55	9	42
7th September	23	38	38	52

This delay in obtaining a true assessment of the previous year's treatment results in a two year interval between the treatment and any subsequent treatment based on the initial results.

RESULTS AND DISCUSSION

The complex nature of the bracken rhizome with its large reserve of potential frond and apical buds presents a formidable herbicide problem particularly when coupled with the many other variables well known in the weed control field, viz. stage of growth, climate, soil type, aspect, drainage, etc. The Conway method of rhizome analysis (Conway, E. 1958) has been applied to all the material excavated from one square yard plots of untreated bracken at various sites, and some of the results are summarised in Table III. At dosage levels of 5 - 10 lb 4-CPA/ac rhizome analysis has shown that a high percentage of the frond buds associated with the current fronds are destroyed. This is not the case, however, with frond buds attached to older rhizomes where translocation of the herbicide over relatively long distances is required. The destruction of these frond buds is usually of the order of 50-90 per cent, i.e. a number of healthy frond buds always remain underground after treatment and can approximately equal the number of fronds above ground at the time of treatment (Table IV). Such healthy frond buds are responsible for regeneration and some will appear as fronds the year after treatment, or in future years. Several years' work has confirmed the indication obtained by digging analysis, i.e. it is not possible to obtain consistently complete or near complete eradication of the rhizome with the materials tested. Of the latter 4-CPA esters have been found to be most effective. Occasionally conditions combine to give a reduction in excess of 90 per cent, but on average reductions are below this figure.

TABLE III. TYPICAL 1 SQ YD RHIZOME ANALYSIS FOR 1958 SCOTTISH SITES

	Langholm	Callander	Moffat	Kilmelfort	Tobermory
No. of fronds/sq yd	21	25	27	28	45
Rhizome at base of current year frond.					
Stem apices	16	26	30	30	38
Frond buds	16	22	26	20	34
Older parts of rhizome.					
Stem apices	94	126	114	56	154
Frond buds	60	80	84	42	112
Ratio current fronds : Older rhizome frond buds	1 : 2.9	1 : 3.2	1 : 3.1	1 : 1.5	1 : 2.5

TABLE IV. ANALYSIS OF FROND BUDS ATTACHED TO CURRENT FROND AND OLDER RHIZOMES

Average results obtained over five sites in 1958 Scottish Trials for late June and July Treatment.

Treatment	Percentage of Frond Buds healthy or only slightly affected			
lb 4-CPA/ac	Attached to current frond.		Attached to older rhizome	
	June	July	June	July
5/Formulation A	10	0	50	30
5/ " B	15	0	40	20
5/ " C	10	5	40	30
5/ " D	0	0	40	20
7½ " A	5	0	50	20
7½/ " C	5	10	40	40
7½/ " D	5	0	50	20
10/ " A	0	0	40	10
10/ " C	0	0	30	20
10/ " D	0	0	-	10

To date only a limited number of the variables associated with 4-CPA ester formulations have been examined and these are summarised as follows:-

(a) Rate of Application

In 1957 trials were made involving dosage rates of 5, 7½, 10, 15 and 20 lb 4-CPA/ac as low volatile ester formulations. Although higher dosage levels gave better control, the increase was not pro rata and for economic consideration future work was restricted to 5, 7½ and 10 lb 4-CPA/ac. (Table V).

TABLE V. COMPARISON OF FROND REDUCTIONS AT DIFFERENT DOSAGE AND VOLUME RATES

Treatment	Percentage Reduction in Frond Density	
lb 4-CPA/gal H_2O/ac	August 1958	August 1960
Moffat 23rd July 1957		
7½/20	85	85
7½/50	85	77
7½/100	71	54
10/20	92	72
10/50	98	81
10/100	69	56
20/20	98	82
20/50	95	81
20/100	97	83
Tobermory 21st June 1957		
5/20	41	74
5/50	56	64
5/100	52	72
6.25/20	59	69
6.25/50	44	59
6.25/100	59	66

(b) Total Volume of Application

As shown in Table V trials were made in 1957 at different total spray volumes per acre. There did not appear to be any significant difference in the level of reduction obtained at 20 and 50 gal/ac. In some cases a lower reduction was obtained at 100 gal/ac due presumably to a greater loss by run-off from the fronds. Tractor application at rates from 5 to 30 gal/ac have confirmed that in this range spray volume is not critical. Since 1958 the total volume rate has been standardised at 20 gal/ac.

(c) Respraying in the year of application

A series of trials were made at Tobermory and Callander in 1957 involving two and three treatments of the same plot during the same season employing small dosage rates. The reduction obtained was usually lower than with the same total amount of 4-CPA applied in one application (Table VI).

TABLE VI. EFFECT OF MORE THAN ONE APPLICATION OF 4-CPA IN ONE SEASON 1957

Treatment lb 4-CPA/ac	Date(s)	Percentage Reduction in Frond Density August 1958
Tobermory		
5 x 1 treatment	28/6	70
5 x 1 "	28/6	67
6.25 x 1 "	28/6	67
2.5 x 2 "	14/6, 28/6	44
2.5 x 2 "	14/6, 5/7	52
3.75 x 2 "	7/6, 21/6	41
3.75 x 2 "	14/6, 28/6	45
3.75 x 2 "	14/6, 5/7	48
3.75 x 2 "	21/6, 12/7	79
2.5 x 3 "	7/6, 21/6, 19/7	67
5 x 2 "	28/6, 19/7	
Callander		
2.5 x 1 treatment	1/7	43
5 x 1 "	30/7	71
10 x 1 "	2/7	97
2.5 x 2 "	10/6, 25/6	55
3.75 x 2 "	3/6, 17/6	-70 (increase)
3.75 x 2 "	10/6, 1/7	44
3.75 x 2 "	26/6, 9/7	50
5 x 2 "	17/6, 17/7	64

(d) Time of Application

The stage of development of the bracken frond at the time of spraying is a most critical factor. The 1957 trials were made between June and July, and there did not appear to be any obvious differences in the results obtained over that period. In 1958 trials were made on two dates at each site, using different plots on each occasion. The first spraying was in the period 23rd June - 5th July and the second 21st July - 1st August. Intense scorch of the plots sprayed in the first period was observed by the second spraying date, whereas the scorch produced by the second spraying was not nearly so pronounced even a month later. At the early spraying the fronds were some 50-70 per cent unfurled and the immature fronds were extensively damaged by the heavy dose of 4-CPA. At the later spraying a high proportion of the fronds were fully unfurled and scorch was less extensive, presumably due to the development of a thicker cuticle. The effect of spraying at different stages of development was shown by rhizome analysis in the treated areas the following September (Table IV) and by the frond density reduction figures the following year (Table VII).

TABLE VII. EFFECT OF TIME OF APPLICATION ON FROND DENSITY REDUCTION.

(a) Application dates 1958

	Late June - Early July.	Late July - Early August
Langholm	4th July	1st August
Callander	1st July	27th July
Kilmelfort	23rd June	21st July
Tobermory	27th June	23rd July
Moffat	3rd July	31st July

(b) Results giving percentage reduction in frond density, September 1959: Formulation A

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac		10 lb 4-CPA/ac	
	June	July	June	July	June	July
Langholm	22	50	39	62	60	69
Callander	45	87	46	78	46	82
Kilmelfort	27	62	31	68	40	61
Tobermory	58	76	78	88	83	96
Moffat	68	75	83	78	90	86
Average	44	70	56	75	64	79

A preliminary count of the 1958 trials was made in early July 1959 and in view of the results obtained the 1959 trials were retimed in an endeavour to cover the stage of maximum susceptibility. As the bracken was rather late in developing a small number of plots were treated in mid July, the majority being sprayed either early or late August. The mid July application (Table VIII) gave reductions comparable with the late July 1958 application. On average the order of reductions was mid July > early August > late August. On the west coast of Scotland the bracken in 1959 reached maturity earlier than normal and started to die back before the end-of-August application (see Kilmelfort and Tobermory). At Tobermory autumnal tints were observed even at the early August spraying and at the second spraying 90 per cent of the fronds were dead. In the above 1959 Scottish Trial the reductions in frond density were greater than those obtained at Ramsgill (Table II) and workers in other parts of the country also obtained lower average reductions with the same dose of comparable 4-CPA ester formulations.

There is little doubt that the abnormally hot, dry summer of 1959 had an important effect on the bracken cuticle as evidenced by the results obtained and the small degree of scorch observed. In many cases it is highly probable that the herbicide was not applied at the period of maximum susceptibility. The latter will vary with the season and locality. From the present state of our knowledge it would appear that maximum susceptibility is coincident with full expansion. The duration of the period of high susceptibility after the frond is fully unfurled is an unknown factor. Extensive time trials have been conducted this season in both Scotland and England in an attempt to obtain further information on this important aspect.

TABLE VIII. PERCENTAGE REDUCTION IN FROND DENSITIES FOR 1959 TRIALS.

Results based on counts made 22-26th August 1960.

(a) Application dates 1959

	July	Early August	Late August
Langholm	9th July	30th July	24th August
Callander	13th "	3rd August	27th "
Kilmelfort	15th "	4th "	29th "
Tobermory	17th "	6th "	30th "
Moffat	11th "	1st "	26th "

(b) Results.

	5 lb 4-CPA/ac			7½ lb 4-CPA/ac			10 lb 4-CPA/ac		
	July	E.Aug	L.Aug	July	E.Aug	L.Aug	July	E.Aug	L.Aug
Langholm	50	69	56	71	84	72	64	95	69
Callander	68	66	55	82	60	48	90	79	74
Kilmelfort	59	47	7	72	60	54	77	72	59
Tobermory	45	27	34	96	-11	41	75	-11	11
Moffat	84	82	72	83	91	74	79	88	72
Average	62	59	47	81	57	58	78	64	57

negative value indicates increase over control.

(e) Respraying in the following year

Half of each of the 1958 plots detailed in Table VII were resprayed at the corresponding original dosage level in either early or late August 1959. The percentage frond reduction results based on late August 1960 counts are given in Table IX.

TABLE IX. EFFECT OF RESPRAYING IN THE YEAR FOLLOWING TREATMENT

(a) Respray dates 1959

	June 1958	July 1958
Langholm	28th July	25th August
Callander	2nd August	27th "
Kilmelfort	5th "	29th "
Tobermory	6th "	30th "
Moffat	31st July	26th "

(b) Results giving percentage reduction in frond density, August 22-29, 1960.

1S = Half plot receiving one treatment
2S = " " " two treatments

TABLE IX (continued)

	5 lb 4-CPA/ac				7½ lb 4-CPA/ac				10 lb 4-CPA/ac			
	June		July		June		July	June	June		July	
	1S	2S	1S	2S	1S	2S	1S	2S	1S	2S	1S	2S
Langholm	10	46	24	46	20	78	22	57	48	87	42	72
Callander	37	67	45	83	32	69	40	75	43	63	40	77
Kilmelfort	53	55	36	44	12	44	35	40	26	58	29	57
Tobermory	38	70	67	74	60	77	56	72	60	68	79	75
Moffat	74	87	65	76	64	88	59	78	91	97	82	83
Average	43	67	50	66	67	73	45	67	58	77	60	74

A further reduction in frond density is obtained by a second treatment but this does not appear to be in direct relationship to the dose applied, presumably due to the smaller number of fronds available for transporting the second treatment of herbicide. Half of each plot in the 1959 trials was resprayed in 1960 to obtain further information on this aspect.

(f) The Effect of different Formulation Types

A number of formulations involving different esters of 4-CPA in different oil-in-water emulsifier systems have been employed and there does not appear to be any significant difference in their herbicidal activity to bracken. An amine salt formulation of 4-CPA was tested in 1959 and this under dry weather conditions gave reductions of a similar order to the 4-CPA ester formulations. When applied to wet bracken or when rain following spraying, the efficiency of the amine formulation was considerably reduced. As it was not possible to always spray bracken under ideal dry weather conditions, work on amine formulations has been suspended in favour of water resistant formulations. The latter are, of course, the invert or water-in-oil formulations, developed by Amchem Products, Inc.

When an invert formulation is diluted with a hydrocarbon oil and water, a viscous water-in-oil emulsion is formed. The viscosity of the emulsion can be decreased by the addition of more oil or increased by the addition of more water. Such an emulsion produces a droplet in which the outer boundary is an oil solution of the herbicide with an inner water droplet. This emulsion is very resistant to water, adheres tenaciously to foliage, is not removed by rain and quickly wets out the cuticle.

Invert formulations of 4-CPA were tested in 1958 and were found to give higher and more consistent reductions in frond density than oil-in-water type formulations (c.f. Tables VII and X).

TABLE X. PERCENTAGE FROND REDUCTIONS USING AN INVERT TYPE FORMULATION SCOTLAND 1958

Frond counts taken September 1959

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac		10 lb 4-CPA/ac	
	June	July	June	July	June	July
Langholm	66	84	79	88	65	91
Callander	84	89	84	92	86	91
Kilmelfort	47	84	40	86	44	92
Tobermory	56	76	67	92	73	95
Moffat	46	74	17	92	53	87
Average	60	81	58	90	64	91

These trials were repeated at the same sites in 1959 but reductions of a much lower order were obtained, being in some instances inferior to the normal ester formulations. (c.f. Tables VIII and XI). Invert formulations have been included in the 1960 time trial programme in an endeavour to find an explanation for the discrepancy between the two years.

TABLE XI. PERCENTAGE FROND REDUCTIONS USING AN INVERT TYPE FORMULATION SCOTLAND 1959

Frond counts taken late August 1960

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac	
	Early Aug.	Late Aug.	Early Aug.	Late Aug.
Langholm	58	25	62	25
Callander	94	77	67	61
Kilmelfort	19	49	32	39
Tobermory	36	49	14	16
Moffat	71	58	74	69
Average	58	52	43	44

(g) Screening of other Chemicals

During the course of the above trials some other chemicals have been applied to bracken. No chemical more toxic to bracken than 4-CPA has been found. The following formulations have shown only a low toxicity at the levels tested.

(a) 4-CPP ester formulation at 5, 7½ and 10 lb/ac
(b) 2,4-D ester formulation at 5, 7½ and 10 lb/ac
(c) Emulsifiable DNBP formulation at 5 lb/ac
(d) Emulsifiable DNOC formulation at 5 lb/ac
(e) Emulsifiable Pentachlorophenol-3-Amino-1,2,4-triazole at 2.5 lb of each/ac.

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REFERENCES

COULSON, W. (1956.) Private Communication.
CONWAY, E. (1958.) Proc. Fourth Brit. Weed Control Conf., p.182.

THE CONTROL OF BRACKEN - A PROGRESS REPORT ON HERBICIDE AND POST-SPRAYING MANAGEMENT TRIALS

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Summary. Dalapon, aminotriazole (with and without ammonium thiocyanate) and 4-CPA are compared at two sites as bracken killers, each being sprayed at two dose levels, and at two dates. These trials are identical in design to those laid down in England and Wales by the A.R.C. Unit of Experimental Agronomy at Oxford. On assessment of frond density a year after spraying it was found that (a) none of the chemicals gave a satisfactory control, (b) reduction in frond density increased with dose level and earlier spraying, (c) at site 1 (the 'later' in terms of stage of bracken growth) reductions in frond density were greater, amino triazole application giving maximum control, and (d) "activation" of amino triazole with ammonium thiocyanate decreased its effectiveness, not markedly but consistently. It would appear that the chemical did not reach, or did not enter the rhizome frond buds in sufficient quantity to have a toxic effect. The period of susceptibility of the plant may depend on such factors as stage of frond maturity and rhizome frond-bud development. The variation in results obtained between sites may be due to the influence of environment on these factors.

Results showing the influence of litter removal and fertiliser treatments on sward germination and establishment on sprayed bracken land are presented. Litter removal by fire or mechanical raking had little effect on sward establishment, removal by molasses application however, resulted in an increased yield 6 months later (Box trial). Lime and slag, but not "Nitrochalk" significantly increased sward yield.

PART I. HERBICIDE TRIALS

INTRODUCTION

Two trials of the type suggested by the International Research Group of Weed Control (1959) were laid out in 1959 in co-operation with the A.R.C. Unit of Experimental Agronomy at Oxford. The aim was to test several chemicals which had shown promise as bracken killers either in this country or in Europe.

METHODS AND MATERIALS

The trials were laid down at Dunoon, South Argyll (Site 1) and Ballachulish, North Argyll (Site 2) plot size being 6 x 4 yd, with 1 yd paths between plots. Sites had been selected for their uniformity of stand but at site 2 the bracken was generally of a shorter, more wiry nature than that of site 1. In each case the experiment was of a randomised block design having three replicates, there being one control plot per replicate.

Four chemicals tested were dalapon-sodium, amino triazole, amino triazole plus ammonium thiocyanate ⁑, each at 10 and 20 lb/ac, and 4-CPA-nonyl ester + at 5 and 10 lb.

Using an Oxford Precision Sprayer, application of each chemical was made at the rate of 20 gal/ac with 00 ceramic jets at 30 psi. Dates of spraying were 30th July and 30th August, 1959 at site 1, and one day later in each case at site 2. The weather at time of spraying and for at least 24 hours later was warm, dry and sunny. Assessment of the trials (19th and 20th July, 1960, site 1 and 2 respectively), was carried out using a quadrat 3 x 5 yd on size, border discard being 18 in. The quadrat was divided into three sections, and all fronds within each counted. The average height of the bracken was noted in each plot as an indication of vigour.

RESULTS

The effect of spraying dalapon, amino triazole and 4-CPA at two sites with identical dosage levels and spraying dates is seen in Table I.

TABLE I. THE EFFECT OF DOSE AND SPRAYING DATE (1959) ON FROND DENSITY (1960) AT SITES 1 AND 2.

(Figures in parenthesis are percentage reductions in relation to the controls).

	Frond Number (mean of 3 replicates)							
Chemical	Site 1 Dose 1	Site 1 Dose 2	Site 1 Spraying date 1	Site 1 Spraying date 2	Site 2 Dose 1	Site 2 Dose 2	Site 2 Spraying date 1	Site 2 Spraying date 2
Untreated	435	435	435	435	389	389	389	389
Dalapon	390 (10.5)	309⁑ (29.0)	242⁑ (44.4)	456 (-5.0)	353 (9.6)	340 (12.7)	354 (8.9)	338 (13.1)
Amitrole	280⁑ (35.8)	220⁑ (49.5)	219⁑ (50.0)	281⁑ (35.5)	441 (-12.6)	415 (-6.6)	443 (-6.5)	443 (-14.0)
Amitrole + NH_4SCN	285⁑ (34.5)	287⁑ (34.1)	270⁑ (38.0)	303⁑ (30.5)	468 (-20.0)	428 (-9.9)	422 (-8.5)	473 (-21.7)
4-CPA	443 (11.8)	396 (9.0)	393 (9.6)	446 (-2.5)	357 (8.1)	331 (15.0)	290 (25.5)	399 (-2.5)
LSD (P=0.05) between:-								
1. Control and treatments (⁑)	± 129.20				N.S.			
2. Treatments	± 105.42				N.S.			

⁑ As "Dowpon", "Weedazol" and "Weedazol T.L." respectively

+ As "Weedone Brackontrol"

(78178)

At site 1, dalapon and amino triazole (both with and without ammonium thiocyanate) significantly ($P = 0.05$) reduced frond density. Generally reductions increased with dose level and with earlier spraying. Amino triazole appeared less effective when "activated" with ammonium thiocyanate.

At site 2, no spray treatment had a significant effect. Dalapon and 4-CPA tended to reduce frond density, whereas all amino triazole applications tended to increase density, especially the activated formulation, at the lower dose and later spraying date.

DISCUSSION

Previous trials with 4-CPA, and current experiments with amino triazole as reported at this conference by Erskine and Hodgson, have shown promising reductions in frond density. The results for these chemicals presented in Table I are disappointing in comparison. The following hypotheses are put forward as possible explanations.

When a translocated herbicide is applied to bracken, it is translocated from the fronds, down into the underground rhizome system where ideally it should accumulate in the meristematic regions leading to their eventual death. It would appear in this case that the chemicals did not reach, or did not enter the rhizome frond buds in sufficient quantity to have a toxic effect.

Taking firstly the hypothesis that the chemical did not reach the buds. McIntyre (1960a) using radioactive 2,4-D found that translocation was 'considerably reduced as the frond approached maturity' Apparently cuticle penetration was the limiting factor. It is possible that this finding would apply to the action of other plant growth regulators. With regard to the present trial, the growing season of 1959 was exceptionally dry. It may be that the cuticle thickened more rapidly than normal, thereby retarding even at the first spraying date, the entry of the chemical into the frond.

Another explanation, perhaps complementary to the first, may be that the chemical could not enter the rhizome frond-buds. Watt (1940) and McIntyre (1960b) have charted the activity of rhizome frond-buds throughout the growing season. The latter, for example, found in 1957 that bud formation activity (and presumably carbohydrate intake) commenced in early June, reached a maximum around mid-end July, and rapidly declined in activity during August. He suggests that soil moisture may have a marked effect on this activity curve, and that up to a point increased soil moisture will cause a later peak in activity of the bud. As the season of 1959 was exceptionally dry, it may be that the peak of maximum activity had passed even at the first spraying date, and that entry of chemical to the bud was retarded.

Both of these hypotheses would indicate that time of spraying was too late for effective movement of the chemical from the fronds into the rhizome frond-buds. The dates of spraying were based on results from trials sprayed in 1958, unfortunately the marked difference in nature of the 1958 and 1959 seasons was not taken into account. In the West of Scotland, the growing season of 1959 was some 10 - 14 days earlier, it is estimated, than average, and that of 1958 some 10 days later than average. The early summer of 1959 was characteristically dry and that of 1958 wet. Thus what was the optimum spraying period for 1958 trials may in fact have referred to a stage of frond cuticle and rhizome bud development occurring some 3 - 4 weeks earlier in the 1959 season. This divergence would be more, or less, aggravated by such ecological factors as 'aspect' and 'altitude.' The broad difference in results between the two sites in the present trials emphasises the latter point. Although no record was taken of time of emergence, it was noted in 1959 that the bracken at Ballachulish (site 2) began to 'go back' sooner than at Dunoon (site 1). Presumably the cuticle thickened and the rhizome buds entered a state of dormancy at an earlier period also.

PART II. POST-SPRAYING MANAGEMENT

INTRODUCTION

The need for a follow-up programme has been more fully discussed elsewhere (Kirkwood and Fletcher, 1960); it is sufficient perhaps to say that the rapid establishment of a sown sward, or rapid improvement of an existing pasture would be expected to have two main consequences. First, it should allow early and increased stocking, especially with cattle. Obviously this would be advantageous from two points; first, in enabling a more rapid return of the cost of bracken spraying, and second in minimizing the regeneration of bracken from the possibly remaining 25 per cent not killed. Second, it should prevent the possible recolonisation of the treated area with weed infestations such as foxglove (Digitalis purpurea) and willow herb (Chamaenerion angustifolium).

As a preliminary approach to this problem, bracken turfs placed in boxes in a greenhouse were subjected to various litter removal and fertiliser treatments. From these experiments it was hoped to gain information on the influence of these treatments on grass-clover germination and establishment. Following this experiment a comprehensive field trial was laid down to test these treatments on a field scale and to provide information on the influence of stocking on the developing sward and bracken regeneration.

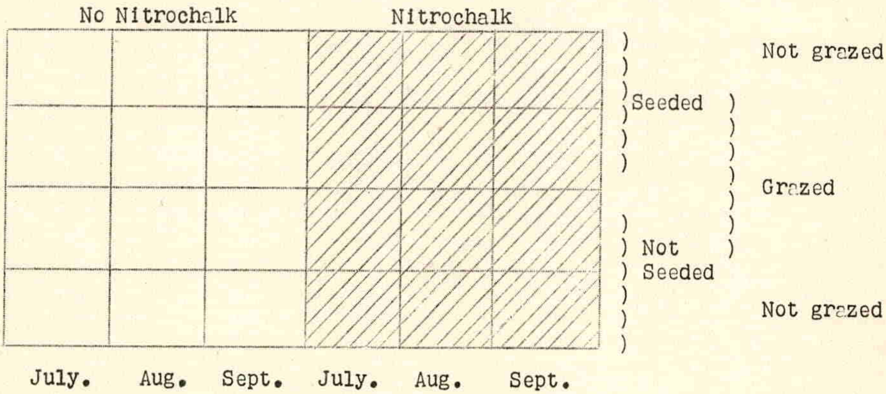
METHODS AND MATERIALS

Preliminary greenhouse trial

The treatments for litter removal were carried out on 29th January and comprised removal by fire, mechanical raking, and application of molasses (equivalent of 48 cwt/ac). Lime and fertiliser treatments were applied at the same time; hydrated lime (30 cwt/ac) and superphosphate (3 cwt/ac) being added separately and in combination. The experiment was of a randomised block design having two replicates. A uniform seeds mixture of perennial ryegrass (L. perenne) S.23 12 lb/ac, cocksfoot (D. glomerata) S.143 8 lb/ac and white clover (T. repens) Cert. Mother. N.Z. 2 lb/ac was applied to all boxes on 9th March. The watering regime was adjusted to the equivalent to 55 in. rainfall per annum, application being made twice weekly until the boxes were transferred to the field in late April. All seedlings within a 12 x 6 in. quadrat were counted on 16th and 23rd March. In late August the boxes were harvested and the dry matter yield of each grass species taken.

Field Trial

This trial, laid down at Dunoon (South Argyll) was superimposed on a bracken eradication experiment which had been laid out in 1959. The original trial comprised 6 plots (5 x 20 yd, 2 yd separation between plots) which had been sprayed with 4-CPA* in late July, August, and September at the rate of 2 gal/ac (applied as 20 gal of spray/ac).



The diagram outlines the layout of the field trial. Litter removal and fertiliser treatments were carried out on the 30th March, the methods being identical to those of the box trial except that the molasses treatment was omitted, and 20 cwt/ac of low grade basic slag was applied instead of superphosphate. These treatments made up the basic randomised block, replication being confounded with seeding, grazing and application of "Nitrochalk". The seeds mixture applied on 33rd May had a higher proportion of perennial ryegrass (16 lb/ac) than that used in the box trial. The "Nitrochalk" top dressing was applied some four weeks later.

Germination estimates were made by counting the seedlings in a 12 x 6 in quadrat. Two quadrats were counted on each plot. The harvesting procedure was identical to that outlined above, the samples being the bulked cuts of 3 (12 in. x 6 in.) quadrats per plot.

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* As "Teridox"

RESULTS AND DISCUSSION

Preliminary Greenhouse Trial

TABLE II. THE EFFECT ON GRASS/CLOVER GERMINATION AND YIELD OF (a) LITTER REMOVAL, AND (b) FERTILISER TREATMENTS

	Treatment	Germination ǂ No. of seedlings Grass	Clover	Sward yield (gm/sq ft)
A	Untreated	25.0	6.0	6.8
A	Mechanical	54.0	5.5	6.5
A	Fire	18.0	6.5	6.2
A	Molasses	17.0	4.0	9.0
B	Untreated	28.0	9.0	6.2
B	Lime	29.0	8.8	5.8
B	Slag	32.0	7.9	8.2
B	Lime and Slag	24.0	6.0	8.3
	L.S.D. (P=0.05)	± 10.7	± 3.1	N.S.

ǂ Figures represent seedlings present in 12 x 6 in. being the mean of four replicates.

The effect of litter removal and fertiliser treatments on grass/clover germination and yield is shown in Table II. It will be seen that removal of bracken litter, by raking, significantly (P = 0.05) increased grass/clover germination, presumably because of the improved seed bed. Subsequent establishment, however, was not affected. Although application of molasses depressed grass/clover germination, an increase in yield resulted 6 - 7 months later from this treatment. This increase though not significant was found consistently for all molasses treatments and may be worthy of comment.

A possible explanation may be that the application of such a readily available carbohydrate increased the size and activity of the soil microbial population. When this added source of energy was used up, the activated population turned to the original organic material present in the soil, and presumably bracken rhizomes and litter were decomposed with greater rapidity than normal. This explanation based on work by Broadbent and Norman (1947) and Stotzy and Mortensen (1957) is perhaps substantiated by the fact that a highly significant increase in soil carbon dioxide evolution was noted subsequent to molasses treatment (Table III).

TABLE III. THE EFFECT OF LITTER REMOVAL TREATMENTS ON SOIL RESPIRATION

Litter removal treatment	Carbon dioxide evolved ǂ	Fertiliser treatment	Carbon dioxide evolved
Untreated	3.3	Untreated	5.0
Mechanical	2.6	Lime	5.0
Fire	3.4	Slag	5.5
Molasses	11.0	Lime & slag	5.9
L.S.D. (P=0.05)	± 2.4	L.S.D. (P=0.05)	N.S.

ǂ Expressed as ml of 0.05 N HCl.

Some indication of the extent to which decomposing bracken rhizome and litter may donate minerals to the soil is given by the results noted in Table IV.

TABLE IV. ANALYSIS OF BRACKEN COLLECTED BY RANDOM SAMPLING FROM THE SAME SITE AS BOX TRIAL TURFS.

Item	Analytical results (per cent in DM)		
	Fronds	Stems	Rhizome
Per cent Nitrogen	1.39	0.45	1.61
Per cent Phosphate as P_2O_5	0.20	0.08	0.24
Per cent Potash as K_2O	0.10	0.07	1.28
Per cent Calcium as CaO	0.45	0.29	0.31

Field Trial

TABLE V. THE EFFECT OF LITTER REMOVAL AND FERTILISER TREATMENTS ON (a) GRASS/CLOVER GERMINATION (b) SWARD YIELD (RESULTS ARE EXPRESSED AS YIELD IN THE PRESENCE (+ N) OR ABSENCE (- N) OF NITROCHALK)

Treatment	Germination ≠		Yield ǂ		
	Grass	Clover	-N	+N	(-N) - (+N)
Untreated (U)	4.5	0.5	0.40	0.10	0.30
Mechanical (M)	8.0	1.3	0.80	0.20	0.60
Fire (F)	5.0	1.5	0.35	0.45	-0.10
U.L.S.	10.5	1.8	3.40	0.80	2.60
M.L.S.	12.0	2.8	2.10	0.90	1.20
F.L.S.	13.5	3.3	0.55	2.10	- 1.55
L.S.D. (P=0.05)	± 6.80	± 1.26	± 1.29	± 0.88	± 1.44

≠ Figures represent seedlings present in 2 x (12 x 6 in.) being the mean of 12 replicates.

ǂ Figures for yield represent dry matter (gm) present in 3 x (12 x 6 in.) being the mean of 3 replicates.

Section C reports three trials in which 4-CPA nonyl ester, 4-CPA butyl ester, dalapon and amino triazole were applied at the manufacturer's recommended rates to unreplicated plots of one acre. These trials were sprayed by normal tractor mounted sprayers at an average of 30 gall water/ac.

In the tables which follow, the control of bracken has been calculated from frond counts in the early and late summer of 1960, the percentage reduction being derived from counts on the treated and an adjacent untreated (control) plots. Observations were also made on the effect of the various treatments on the underlying grass sward and, where this has been significantly affected, details are appended.

RESULTS

A. Time of application trial

(Location: Caerketton Hill, near Edinburgh, Midlothian)

TABLE I. THE RELATION OF DATE OF APPLICATION TO EFFICIENCY

Spraying date (1959)	Percentage frond reduction (as at July 1960) ester	amine	Notes
June 30	39	-	Chemical scorch observed on ester treated fronds, one week after treatment
July 8	47	-	
" 15	53	-	
" 23	60	73	
" 30	74	70	
August 5	82	72	Fronds fully open
" 13	80	66	
" 19	74	56	
" 27	51	40	
September 2	66	29	
" 9	24	35	
" 16	36	34	Frost damage noted on untreated fronds
" 23	47	28	

(at July 1960, control plots averaged 45.2 fronds per sq yd)

The amine formulation was not available until the 23rd July, thus no figures exist prior to this date. The bracken was 39 in. high at the beginning of August 1959 and very little increase in height took place after that date. During the assessments in 1960 it was noticeable that all treated plots had bracken which was in general not as tall as the untreated control bracken, although there was considerable variation of height within the treated areas.

From the results of this trial it would appear that the optimum time of application under the conditions ruling in 1959 was at the beginning of August when the frond had fully unrolled, although reasonable results were obtained over a period of about four weeks. It was considered that the chemical scorch given by the ester in the early summer was seriously damaging the frond before sufficient herbicide was translocated to the rhizomes.

B. Rate of application experiment

(Location: Portmore, near Eddleston, Peeblesshire).

Dalapon and amino triazole were applied on 1st July, 1959, and the 4-CPA formulations were applied on 1st August 1959. Frond counts were made during the first week of July 1960 and again during the last week of August 1960. The figures given for the amino triazole treated plots are derived from the actual number of emergent fronds, and do not take into consideration any of these emergent fronds which show serious amino triazole chlorosis. If these chlorotic fronds were regarded as 'dead' the percentage reductions would be considerably higher than those given below.

TABLE II THE EFFECT OF DOSE RATE ON EFFICIENCY

Material	Dose rate lb/ac a e	Percentage Frond reduction		Average height (August) in.
		July	August	
Dalapon	20	10.4	34.6	17
	15	18.8	25.3	22
	10	- 6.0	25.9	26
	5	- 9.0	4.6	31
Amino triazole	15	90.9	94.8	8
	10	87.4	91.3	10
	7.5	81.3	92.3	14
	5	84.6	90.3	14
4-CPA (nonyl)	10	46.7	22.8	26
	7.5	30.3	36.4	26
4-CPA (butyl)	8	48.9	45.4	27
	6	40.6	54.5	23
4-CPA (amine)	10	61.4	68.1	22
	7.5	74.4	72.8	22

(at August 1960, control plots averaged 28.2 fronds per sq yd and a height of 35 in.)

At the end of August 1960 it was noticeable that the bracken on the dalapon treated plots was withering sooner than other bracken. At the two high rates of dalapon, almost the entire grass sward was wiped out, the remaining vegetation being predominantly dicotyledonous; at the lower rates the grass received a bad check although little was actually killed. All

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DALAPON, 4-CPA AND AMINO TRIAZOLE FOR THE CONTROL OF BRACKEN - AN INTERIM REPORT.

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Summary. Dalapon, 4-CPA and amino triazole have been tested for the control of bracken in 13 randomised block trials, distributed in ten counties of England and Wales. The design of the trials had been agreed upon at the 1959 meeting of the International Research Group on Weed Control held in Stuttgart. Delapon was applied at 10 and 20 lb/ac, 4-CPA at 5 and 10 lb/ac and amino triazole at 10 and 20 lb/ac "activated" with ammonium thiocyanate. Spraying was carried out on two occasions and replication was threefold. Drought conditions during most of the season may have affected the results and this should be borne in mind in the interpretation of results. Although the application of dalapon delayed frond emergence, final reductions in density were not high and varied from site to site. These results are in accord with those of earlier trials and the conclusion is reached that the sodium salt of dalapon is not promising for the control of bracken. Three ester formulations of 4-CPA were tested and differences in their effectiveness were not important. Agreement between results from site to site was poor. The maximum, as well as the average frond density was low when compared with the results of trials in previous years. Early application was effective at the lower dose but time of treatment had less influence at the 10 lb/ac dose. The "activated" amino triazole gave most promising results, control being consistantly good when applications were made in late June to early July. When treatment was delayed until late August to early September control was invariably poor and variations in the results from site to site increased. Trials are now needed to test this chemical under a wide range of climatic conditions.

INTRODUCTION

During the past seven years three chemicals have shown distinct promise for the control of bracken. Beatty (1953) first suggested 4-CPA (4-chlorophenoxyacetic acid) for the control of bracken and later Schofield (1956) reported on the effectiveness of this chemical in New Zealand.

In a series of trials Fryer et al (1959) found that applications of delapon (sodium 2,2-dichloropropionate) gave an appreciable reduction in frond density in the following year.

Although Forrest (1959) has reported that amino triazole has shown little promise as a herbicide for bracken in Scotland, Bylterud (1958) has demonstrated its effectiveness on bracken at low rates in Scandanavia.

At a meeting of the International Research Group on Weed Control in Stuttgart in 1959 it was agreed that trials of a standard design should be laid down on the Continent, in Scandanavia and in the United Kingdom to compare the effectiveness of these three chemicals for the control of bracken under a wide range of environmental conditions. This paper reports on 13 such trials laid down by the A.R.C. Unit of Experimental Agronomy in 1959.

METHODS AND MATERIALS

The trials were of a randomised block design with plots 6 x 4 yd in size, separated by 1 yd paths. The three chemicals were applied at two doses, namely dalapon at 10 and 20 lb/ac, 4-CPA nonyl ester at 5 and 10 lb/ac and amino triazole "activated" with ammonium thiocyanate in the ratio 100:95 *. All the treatments were tested at two dates of application and replication was threefold for all treatments and control plots. All applications were made at a volume rate of 20 gal/ac with an Oxford Precision Sprayer. Table I gives the location and a brief description of the sites together with the dates of spraying.

At five of the sites (Ruthin, Lydney, Barden, Eggleston and Capheaton) the following treatments were also included in the trials:- 4-CPA butyl ester+, and an ester of 4-CPA formulated as a water in oil emulsion ("Invert emulsion", supplied by Messrs. A.H. Marks & Co., Ltd). Both formulations were applied at 10 lb/ac on each occasion of spraying, except that at Ruthin the invert emulsion was not included at the earlier date of application. At Ruthin and Lydney the 4-CPA butyl ester was also applied at the later date at 5 lb/ac. At one further site (Cartmel Fell) the invert emulsion was applied at 10 lb/ac on both spraying occasions. At the Euston Park site no amino triazole treatments were included as it was not possible to find a uniform area of bracken of sufficient size to accomodate a complete trial.

Each trial was assessed twice during 1960; an initial count was made during the period June 14th-30th, soon after the fronds began to emerge, and a final assessment was carried out from August 8th to September 9th when it was considered that frond emergence was virtually complete. In the most uniform stand of bracken the distribution of fronds is somewhat uneven and so to avoid subjective bias when making the counts the assessments were made by counting all the fronds within a 5 x 3 yd quadrat placed centrally within the plot. In all the plots the height of emerged fronds during 1960 was related to the effectiveness of the treatment and at the time of the final assessment an estimate was made of the mean height of the fronds within the quadrat.

RESULTS

Dalapon. (a) June assessment. The initial counts in 1960 showed that there was a very wide variation in results from site to site as well as between treatments at individual sites (Table II). At one site an early application of 10 lb/ac gave a 91 per cent reduction in frond density but at seven other sites the decrease in density was less than 30 per cent. Similar anomolies were recorded in each of the other treatments. However these early counts did indicate that delaying the application of 10 lb/ac had increased the effectiveness o. the chemical but where the dose was increased to 20 lb/ac the effects of varying the time of application were far less marked.

(b) August - September assessment. The results of the later assessment (Aug-Sept) showed that the number of fronds had increased greatly on treated plots and that, whilst the variations from trial to trial were still great, the difference due to the various treatments was much reduced (Table II).

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* As "Dowpon" "Weedone Brackontrol" and "Weedazol TL" respectively.
\+ As "Teridox"

In general all treatments caused a reduction in the height of the bracken but in a few instances the treatments had had no visible effect on the height of stand. Grasses and associated species, where present below the bracken, were completely killed at both 10 and 20 lb/ac, irrespective of the time of application.

4-CPA nonyl ester. (a) June assessment. At the time of the first assessment it was clear that, although the effectiveness of all treatments varied greatly from site to site, both the 5 and 10 lb/ac doses had given a higher degree of control when applied at the earlier date (Table IIIa). At 5 lb/ac, although the early application was more successful at the majority of sites the maximum reduction recorded (57 per cent) was little affected by time of application. On the other hand, at the higher dose, spraying on the earlier occasion caused a reduction in density of over 70 per cent at four sites but when spraying was delayed the decrease in density was less than 41 per cent at all sites.

(b) August-September assessment. The later assessment showed that the general pattern of control remained the same but that there had been some further emergence of fronds. The maximum percentage reductions for early and late applications of 5 and 10 lb/ac had fallen from 59, 56, 84 and 41 per cent to 45, 37, 67 and 40 per cent respectively. Each of the treatments had reduced the height of the fronds to some extent but the greatest effect was noted at the higher dose when applied at the earlier date (Table III b). Grasses, where present, were seemingly unaffected by any of the treatments.

4-CPA butyl ester. A comparison was made between the nonyl ester and the butyl ester of 4-CPA at five sites and from an inspection of Tables IIIa and IIIb it can be seen that both formulations give a very similar measure of control.

4-CPA-Invert emulsion. The water in oil formulation of the nonyl ester of 4-CPA was applied at 10 lb/ac in six of the trials. It should be noted that the emulsion was sprayed at a higher viscosity than was intended by the suppliers and this may have had some effect upon the degree of control recorded in these trials. Under these conditions the reductions in frond density conformed very closely with those reported for the oil in water emulsion (Tables IIIa & b).

"Activated" amino triazole. (a) June assessment. The effects of the activated formulation of amino triazole are given in Table IV. Frond counts in June-July indicated that the 10 lb/ac application had given a high degree of control at the earlier date of spraying and that in general increasing the dose to 20 lb/ac had not effectively increased the "kill". A reduction in density of over 85 per cent was recorded at several sites for both doses and at only one site was the reduction below 60 per cent.

The effectiveness of the herbicide was considerably reduced when applications were made at the later date and the variation from site to site was appreciably greater. For example at one site the number of fronds was reduced by 84 per cent in contrast to several of the trials where there was no appreciable control.

(b) August-September assessment. On the earlier treated plots there was only a slight increase in the number of fronds during July but on the later sprayed plots the density of fronds increased and the maximum reduction in density recorded at the later assessment was 53 per cent, compared with a value of 88 per cent in June.

On treated plots those fronds that had emerged showed the characteristic chlorosis associated with amino triazole and on the plots treated in the period

June-July many of the pinnae were badly deformed. In many cases the pinnules were completely absent and usually, where present, they had failed to expand. None of the treatments appeared to have had any adverse effect upon the associated grasses and herbs.

DISCUSSION

Delapon. From a series of trials (Fryer et al 1959) it was concluded that, in many instances, although delapon gave a very high reduction in the number of fronds in the early part of the season the continued emergence of fronds during the growing season greatly reduced these early effects. He also noted a wide variation in the effectiveness of the chemical from site to site. The results of the trials reported here are fully in accord with those of Fryer et al.

As spraying techniques were standard throughout the series and weather conditions were virtually uniform during both the early and late spraying periods it seems unlikely that any of these factors could be responsible for the variable results at the 13 sites. Early in the season it appeared that where the applications had been delayed until the later period they had given a greater reduction in density. However towards the latter part of the growing season, when many fronds had emerged, this differential effect had largely disappeared, possibly due to the different time intervals between spraying and assessment. The trials have brought out the extent of the variation which may be expected from applications of dalapon under various environmental conditions but they have shed no further light on the underlying reasons for such variations.

4-CPA esters. In this particular year there were no important differences in the performance of the three ester formulations when compared at the 10lb/ac rate. The application of 10 lb/ac of 4-CPA in late August-early September gave no better control than 5 lb/ac sprayed in the period late June-early July. Thus it is apparent that the susceptibility of the plant varies greatly during the growing season but little is known of the physiological factors or morphological characters which govern its response to the chemical. More work of a fundamental physiological nature is needed to gain information on this aspect. The large variation in results from site to site may well be due to differences in the physiological activity of the rhizome systems at the various sites but with the available labour force it was not possible to engage in extensive digging operations.

The maximum reduction in density achieved in these trials is low when compared with the results of trials made in previous years (Fletcher 1959). Why the activity of the chemical should be impaired by the dry conditions of 1959 is far from clear but the trials do demonstrate that in this particular year, at 5 and 10 lb/ac, the ester formulations tested were not reliable herbicides for the control of bracken.

"Activated" amino triazole. In previous trials in this country amino triazole has not shown promise for the control of bracken but in these trials application was made only to mature bracken (Fryer 1956, Forrest 1959). In the trials reported here, the results were most encouraging where applications were made before the fronds had reached maturity. However it must be pointed out that the "activated" formulation used in the present work was unknown at the time of the earlier trials. At the present time it is not known whether the addition of the activator results in any increase in the toxity of amino triazole to bracken. The negligible increase in control with increased dose suggests that the optimum rate for acceptable control may be lower than those tested and the wide difference in the results at the two spraying occasions indicates that the susceptibility of the plant is far from constant during the growing season. Trials are now in progress to investigate these aspects of the problem; applications of 5 and 20 lb/ac have been made at short intervals over the major part of the growing season. From the chlorotic and stunted appearance of those fronds which have emerged on treated plots it seems that the chemical is both persistant and readily translocated within the bracken rhizome system. It is possible that the treatment effects may be even more pronounced in the second year after spraying. However, it should be borne in mind that these tests were made under somewhat exceptional weather conditions and the reliability of the chemical has yet to be proved under more normal conditions.

In conclusion it may be stated that:

a) Doses of 10 and 20 lb/ac of dalapon gave variable results. Although frond emergence was delayed the continued emergence of fronds during the season resulted in an unsatisfactory level of control by the end of the season. Where grasses and other species were present they were completely suppressed. The sodium salt of dalapon does not appear particularly useful for the control of bracken.

b) The three ester formulations of 4-CPA tested showed similar activity on bracken but the results were, in general, very disappointing compared with the promising results in earlier trials. It is clear that the control of bracken with 4-CPA is liable to vary from site to site and from year to year and until further evidence is forth coming on the principal factors responsible for this variation it cannot be considered a reliable herbicide for bracken up to 10lb/ac.

c) June and July applications of activated amino triazole at 10 and 20 lb/ac gave an excellent control. Later applications gave a reduced control. Further work is in progress to assess the optimum dose for acceptable control, to determine the period of maximum susceptibility and to test the reliability of the chemical under various environmental and climatic conditions.

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REFERENCES

BEATTY, R. H. (1953) Proc. int. div. convention. Amer. Chem. Paint Co.

BYLTERUD, A (1958) Ugras bekjempelse med kjemiske midler på plantefelter. (Chemical control of forest weeds in plantations). Norsk. Skogbe. 4. 11. 347-56.

FLETCHER, W. W. (1959) Some recent developments in Brachen Control. Scot Fmr. 67. No. 3496. 1252.

FORREST, J. D. (1959) Chemical treatment of bracken (pteridium aquilinum) in Scotland. II. Effects of various herbicides on field bracken. 4th Brit. Weed Control Conf. 1958. 184-189.

FRYER, J. D. (1956) Private communication.

FRYER, J. D. CHANCELLOR, R. J. and EVANS, S. A. (1959) The effect of dalapon on bracken (Pteridium aquilinum) - preliminary field trials. Proc. 4th Brit. Weed Control Conf. 1958. 189-193)

SCHOFIELD, R. C. (1956) Cleaning irrigation races N.Z. J. Agric. 92. 3. 227.

TABLE I. CONDITIONS AT EACH SITE AT THE TWO SPRAYING DATES

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Darley Dale	Derbyshire	1,000	Moderate S slope without shade or shelter	29.6	2½	Fine with possibility of thunder showers
				17.9	3	Overcast but dry light S wind
Edale	"	1,300	Moderately steep S slope without shade or shelter	10.7	2½	Overcast but dry. Wind-speed negligible
				17.9	3	Overcast but dry. Light E wind
Ruthin	"	400	A very slight slope, almost on the brow of a ridge. No shade or shelter	30.6	2½	Fine and dry. Light N E wind
				3.9	3	Fine and dry. Light E wind
Machynlleth	Montgomery	400	Steep S slope without shade or shelter	1.7	3	Overcast, clearing later, Light W wind
				3.9	3	Drought conditions. No wind
Pontesbury	Shropshire	1,500	Moderate E slope. Sheltered to the N and E by trees. No shade	2.7	3	Fine with light S W wind
				2.9	3½	Drought conditions. No wind
Leebotwood	"	1,200	Moderate N W slope without shade or shelter	2.7	2-2½	Warm, dry and settled. Moderate S W wind
				2.9	2½	Drought conditions. No wind.

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TABLE I (Contd.)

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Lydney	Gloucestershire	300	Moderate E slope without shade or shelter	3.7	4	Warm, dry and settled. Light N E wind
				24.8	4½	Drought conditions. Light N E wind
Barden	Yorkshire	1,000	Moderate S slope without shade or shelter	7.7	2	Warm, dry and settled. Light S S W wind
				15.9	2½	Cool and overcast. Light N wind
Cartmel Fell	Lancashire	500	Moderate N E slope without shade or shelter	8.7	4	Warm, dry and settled. Moderate W wind
				15.9	4	Drought conditions. Moderate N E wind
Eggleston	Durham	1,200	Level site with no shade or shelter	9.7	2	Cool, overcast but dry. Light W wind
				16.9	2	Cool, overcast with light drizzle after spraying. Moderate N E wind
Capheaton	Northumberland	700	Slight S slope without shade or shelter	10.7	4	Cool, cloudy but dry. Light S wind
				16.9	4	Drizzle in a.m. following drought. Dry at time of spraying. Moderate N wind

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TABLE I (Contd.)

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Euston Park	Suffolk	100	Level site. Shelter to S and E but no shade	15.7	3½	Warm, dry and settled. Light, variable wind.
				27.8	3½	Drought conditions. No wind
Bruton	Somerset	500	Steep N slope in fairly narrow valley. Ridge of valley provides some shelter. No shade	23.7	1½	Hot and dry. Moderate S wind
			Bracken had been cut annually for many years previously	24.8	1½	Hot and overcast. Very light S W wind

TABLE III (a). EFFECT OF 4-CPA ON BRACKEN AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT.

Results (mean of 3 replicates) expressed as percentage reduction compared with control at the time of assessment
N.C = No apparent control. No count made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond number									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	25 24	18 16	50 50	26 18						
Edale	24.6 13.9	10.7	17.9	35 29	15 8	72 66	24 21						
Ruthin	16.6 8.8	30.6	3.9	30 30	7 8	32 32	2 12	18 14	- 11 - 12	23 15	- 12 - 2		10 12
Machynlleth	17.6 9.8	1.7	3.9	26 20	5 26	34 32	12 21						
Pontesbury	15.6 10.8	2.7	2.9	60 26	12 0	44 28	14 9						
Leebotwood	15.6 9.8	2.7	2.9	54 30	8 12	84 59	26 16						

TABLE III. (a). (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond number									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Lydney	14.6 7.9	3.7	24.8	42 N.C	31 N.C	63 42	30 N.C		30 N.C	49 N.C	34 N.C	53 N.C	45 N.C
Barden	20.6 16.8	7.7	15.9	34 24	56 14	58 20	41 16			45 15	50 11	62 26	56 30
Cartmel Fell	21.6 17.8	8.7	15.9	56 42	6 20	76 67	30 40					80 67	18 16
Eggleston	22.6 18.8	9.7	16.9	49 44	22 N.C	74 64	13 26			84 75	18 N.C	76 64	23 N.C
Capheaton	22.6 18.8	10.7	16.9	48 39	4 10	63 59	18 14			66 62	20 22	63 52	22 20
Euston Park	30.6 9.9	15.7	27.8	0 N.C	- 2 N.C	- 1 N.C	28 N.C						
Bruton	13.6 8.9	23.7	24.8	6 6	32 36	41 52	32 25						

TABLE III (b). EFFECT OF 4-CPA ON BRACKEN AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT

Results (mean of 3 replicates) expressed as percentage compared with control at the time of assessment.
N.C = No apparent control. No counts made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in mean height of fronds									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	22	19	42	0						
Edale	24.6 13.9	10.7	17.9	20	16	36	12						
Ruthin	16.6 8.8	30.6	3.9	19	4	38	14	19	10	42	- 4		14
Machynlleth	17.6 9.8	1.7	3.9	5	10	32	10						
Pontesbury	15.6 10.8	2.7	2.9	45	10	25	15						
Leebotwood	15.6 9.8	2.7	2.9	25	12	62	12						
Lydney	14.6 7.9	3.7	24.8	0	0	8	0		0	0	0	8	0
Barden	20.6 16.8	7.7	15.9	25	25	30	11			28	30	42	25

TABLE III (b). (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in mean height of fronds									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Cartmel Fell	21.6 17.8	8.7	15.9	48	16	60	31					54	24
Eggleston	22.6 18.8	9.7	16.9	32	14	36	4			54	14	40	0
Capheaton	22.6 18.8	10.7	16.9	24	0	42	0			39	21	39	0
Euston Park	30.6 9.9	15.7	27.8	0	0	0	0						
Bruton	13.6 8.9	23.7	24.8	20	20	53	36						

TABLE IV. EFFECT OF AMINO TRIAZOLE ON BRACKEN
AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT.

Results (mean of 3 replicates) expressed as
percentage reduction compared with control at time of assessment.
N.C = No apparent control. No count made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	64 78	22 20	82 90	24 18	64	36	66	28
Edale	24.6 13.9	10.7	17.9	76 76	12 8	84 82	27 24	66	0	66	16
Ruthin	16.6 8.8	30.6	3.9	72 70	42 32	64 64	36 27	52	28	52	24
Machynlleth	17.6 9.8	1.7	3.9	84 82	44 38	80 80	42 42	78	26	84	36
Pontesbury	15.6 10.8	2.7	2.9	92 68	84 17	92 64	88 14	85	65	85	60
Leebotwood	15.6 9.8	2.7	2.9	94 85	66 24	97 91	77 27	81	50	81	56
Lydney	14.6 7.9	3.7	24.8	84 82	60 44	92 87	54 36	62	8	56	38
Barden	20.6 16.8	7.7	15.9	12 10	34 29	24 23	33 12	38	25	52	36

TABLE IV. (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Cartmel Fell	21.6 17.8	8.7	15.9	89 82	54 40	96 90	60 53	66	48	69	33
Eggleston	22.6 18.8	9.7	16.9	85 78	6 N.C	74 70	12 8	64	9	72	9
Capheaton	22.6 18.8	10.7	16.9	74 64	18 12	80 71	16 6	58	3	58	12
Bruton	13.6 8.9	23.7	24.8	73 78	4 7	67 58	- 4 5	60	26	33	13

Presentation by G. L. Hodgson of preceding three papers

All three papers deal with the effectiveness of dalapon, 4-CPA and amino triazole in the control of bracken. In general dalapon gave disappointing control when applied at doses up to 20 lb/ac. From these and previous results (Fryer J. D. et al. 4th British Weed Control Conf. 1958) it seems reasonable to conclude that the sodium salt of dalapon shows little promise for bracken control. The effectiveness of 4-CPA varied considerably from site to site and the general level of control achieved was poor when compared with the results of trials made previously in the West of Scotland. Amino triazole "activated" with ammonium thiocyanate gave most encouraging results at a high proportion of the sites but the trials show that time of application may be extremely critical. The majority of applications were made at 10 and 20 lb/ac and the results suggest that these doses may be greater than the optimum required to give a satisfactory level of control. It should be borne in mind that this compound has been tested in a rather unusual season and we must await the results of further trials before attempting to assess its reliability for the control of bracken.

The trials demonstrate that we have three chemicals which are, under certain circumstances, toxic to bracken. However it is obvious that bracken varies in its susceptibility to these compounds and as yet we have no reliable information as to the factors affecting this susceptibility. In a single unreplicated trial Erskine has compared the effectiveness of 4-CPA applied at 7½ lb/ac at short intervals from the end of June to late September. In this isolated trial it appeared that there was a definite pattern of susceptibility of the bracken to the herbicide with susceptibility increasing to a maximum in early August and remaining steady for approximately 14 days, before decreasing again as the season advanced.

Further work must now be designed to (a) assess the extent to which this general pattern is modified by variations in the environment and (b) to determine the morphological and physiological factors which control the penetration and uptake of the three chemicals.

Discussion on preceding six papers on bracken

Mr. A. F. J. Wheeler. We have heard much of the erratic behaviour of chemicals towards bracken and of bracken towards chemicals. In the limited amount of work that I have done on bracken it appears to me that two other major variables exist. I refer to volume of application used and formulation, particularly with regard to 4-CPA.

Mr. J. Norris. We found no differences from various volumes of application in 1957 and so decided to adopt 20 gal/ac for trial purposes. Other workers have tried higher and lower volumes; some say one thing, some say another, but, at the moment, we are not sure what the right answer is. This year we have again put down trials at application rates from 5-100 gal/ac to gain further information on this point. I think that there is no doubt that formulation can affect results. In 1958 we observed different results between the normal oil-in-water ester formulation and the 'invert' water-in-oil ester formulation. In fact these effects did not show up again when we repeated the work in 1959. We therefore blamed the season for the previous years erratic results.

Mr. F. C. Cooke. There are yet other variables, viz droplet size and method of application. The various chemicals have been compared at two or three doses but the results might well be different with more effective coverage at these doses.

Dr. G. L. Hodgson. All the trials made by the Unit of Experimental Agronomy were sprayed with the Oxford Precision sprayer. We have not as yet done any detailed work on droplet size or various methods of application but I agree that it could well have some effect.

Mr. J. Norris. We have done no detailed work on droplet size. However we have seen results by various methods of application. Our own trials have largely been sprayed with the Oxford Precision Sprayer but we have observed that trials with tractor driven sprayers have given consistently better results than the Oxford Precision Sprayer. In some cases fixed wing aircraft applications have been very disappointing and the rotary atomizer does not appear to be entirely suitable for this work. If may be that the terrain was not very suitable and that the pilot was more anxious about his own safety than about spraying. In 1957 and again in 1958 we did trials using a helicopter with a conventional spray boom. Here the plane was able to get near to the bracken and the results were quite good.

Dr. Elsie Conway. One word on formulation: there may be some people here who will remember that two years ago Mr. Forrest and I reported on amino triazole. We had had no results at all and said that we did not consider that this chemical should be considered very much further. This was when we were using one particular formulation but lately we have been working with another formulation with quite different results. I would say that the question of formulation is a very pertinent point.

Mr. S. Everest-Todd. The main problem associated with 4-CPA and bracken lies in the transportation of the chemical from the frond to the rhizome. One of the difficulties to be overcome is the entry of a lethal quantity of the chemical without it causing necrosis of the leaf tissue. Impurities in formulations of 4-CPA, such as the chemical intermediates, phytotoxic solvents or wetting agents, could reduce the effectiveness of the application to the bracken plant.

Information is not yet available as to the quantity of 4-CPA required to kill a given volume of bracken nor do we know how much of the chemical reaches the rhizome. I am convinced that in many cases the 4-CPA applied has failed to reach the rhizome, or even enter the vascular tissue, due to chemically induced necrosis of the leaf occuring shortly after application. In some of my own experiments where I used pure 4-CPA in a formulation free from contact herbicidal properties and possessing a resistance to climatic interference the absorption and translocation within the plant system was sufficient to produce a toxic effect over an extensive section of rhizome. In some cases this has been observed 2 ft from the point of entry.

Dr. Elsie Conway. That is a very interesting point. I am quite certain that the whole crux of the matter is the extent to which we can get the chemical along the rhizome. I would be interested to know, when Mr. Everest Todd says he has traced 4-CPA in the plant, whether the chemical was travelling apically or basically. We have found that the chemical will go very quickly towards the apex from below a treated frond but so far we have not been able to trace much basal movement. We have only traced movement of up to 16 cms.

Mr. S. Everest-Todd. I am pleased to report that the movement in this case was basal.

Mr. E. B. Scragg. On the subject of methods of application of bracken control chemicals, we, in the North of Scotland, carried out trials in 1959 using a knapsack-type engine-driven air-blast sprayer. The rate of application was 1½ gal of a proprietary 4-CPA formulation in 20 gal water/ac. Results were similar to those described by other speakers and varied from no apparent control to a fair degree of suppression. There appeared to be some correlation between the degree of control achieved and the vigour of the bracken before spraying. Where the bracken was very tall and dense, poor control was achieved, where it was short and open a better result was obtained. Drift spraying using the air blast machine proved quite ineffective.

Mr. G. D. Holmes. Experiments comparing amino triazole, dalapon and 4-CPA were carried out by the Forestry Commission on two sites in Southern England in July 1959 and the results broadly confirm those described by Dr. Hodgson. The main points emerging have been (1) the superiority of amino triazole at 10-20 lb/ac over dalapon (10-20 lb/ac) and 4-CPA (5-10 lb/ac) (2) no compound gave a degree of control which would be of great practical importance (in forestry), the best amino triazole treatment giving a 50 per cent reduction of frond height and only a 15 per cent reduction in frond numbers in the season following treatment (3) no harmful residual effects were found on larch, Corsican pine, and Norway spruce planted in October, 3 months following spraying.

The possibility of aerial application of herbicides to bracken has been mentioned, and I would urge caution in the application of aerial sprays in the vicinity of young forest plantations owing to the risk of damage by spray drift. We have made tests on the susceptibility of major tree species to drift of 4-CPA and amino triazole and find that larch, Douglas fir, pine and to some extent spruce are all liable to injury, notably foliage scorch and shoot malformation from sprays applied in July or August. This type of damage could be of great economic importance if malformation extends to the leading shoots of young crops.

Dr. R. C. Kirkwood. Dr. Hodgson did point out that some of our treatments caused an increase in the number of fronds in the year following treatment. Perhaps the stimulation of frond bud development was indicative of the usual growth regulator effect with small doses, as compared with large doses which have a toxic effect.

Mr. R. Prasad.. In reply to Dr. Kirkwood's suggestion that the prevailing environmental conditions might have contributed to the diverse and conflicting results of Dr. Hodgsons trials, I may add that at Oxford we have examined the effects of some environmental factors on the effectiveness of dalapon. Using two aquatic weeds, Lemna minor and Salvinia natans, we have found that both temperature and light intensity enhance the inhibitory action of dalapon, the effects of temperature being greater than those of light intensity.

SESSION 5

Chairman: Sir James A. Scott Watson

PROBLEMS OF ADVICE AND EDUCATION

PROBLEM OF ADVICE AND EDUCATION: THE FARMERS' POINT OF VIEW

G. E. Limb
National Farmers Union
(Read by Mr. H. C. Mason)

Having been asked to speak on the problems of advice and education, it appears evident to me that the organisers of this Conference are very conscious of the fact that such problems exist, and are doing a very good thing in bringing these problems into the open so that we can see what they are and what should be done to overcome them.

It is, of course, one of the prime objects of the British Weed Control Council to disseminate information and it must be a matter of concern to the Council if the farmer's needs for advice and education are not being met to the full.

Since it is my purpose today to draw attention to problems I must tend to be critical of the present state of affairs but I hope none of you would be misled into thinking that I am prejudiced, either against herbicides or against the agricultural chemicals industry which has so eagerly developed these new products and whose research is still carrying forward the frontiers of knowledge on this fascinating subject of selective weed control.

We must remember that the introduction of these potent new tools to agricultural practice has in so small measure been responsible for the great increase in output from our industry, which is now producing nearly 70 per cent more than pre-war in spite of a reduction in labour and land resources. Indeed, I think the development of chemical weed control has been one of the most remarkable post-war developments affecting agriculture, and the rapidity with which these products have been taken up by our farmers surely makes nonsense of the often repeated statement that there is a 20-years gap between research and application of the results in agriculture.

Prior to the introduction of CLC (MCPA) towards the end of the war we had only traditional methods of weed control available, supplemented by the uncertain results obtained from copper sulphate or sulphuric acid sprays and the occasional use of finely powdered kainit as a scorching agent.

How little we knew about chemical weed control in those days, and yet how far we have progressed in the last 15 years in the development of this new science and its application on a world-wide scale.

The earliest reports on CLC (MCPA) seemed to suggest that all one had to do was to apply it to corn crops, when all the corn would grow and all the weeds would die, and had it all been as simple as that no problems of advice and education would have arisen.

We have now got to the state when there are some 70 or more separate chemicals recognised for their herbicidal properties, most of which have names as long as your arm, so that special committees have to sit on both sides of the Atlantic to evolve cryptic common names and that strange blend of letters and numerals so beloved by the herbicide chemist, so that not surprisingly one chemical may sometimes be known by more than one name.

Of the score or so chemicals in regular use in this country there may in some cases be as many as 50 separate brands of one chemical, each being offered under its own distinct brand name, many of which bear no connection with the name of the chemical.

Just as the variety of products available to the farmer is tremendous so also the variety of weeds to be controlled is formidable, running into hundreds, involving problems of recognition and identification, particularly at the seedling stage. Having located a product which will control the major weeds, problems of finding the correct dilution and the best time of application in relation to both crop and weed and consideration of possible long-term effects on the crop or injury to neighbouring crops have to be taken into account, while precautions have to be considered to protect the operator when using toxic chemicals.

This new science has been developing so fast that for the fifth time since 1953 the technical workers in this field of weed control are gathered together to rub shoulders and hear of the latest research and fresh developments in the use of weedkillers, but we must recognise that this Conference is designed primarily to attract people at a scientific level. The need for a regular exchange of views at this level emphasises the need for a regular channel of information to be established to the ultimate users who are continually extending the commercial application of weed control and spraying millions of acres of crops each year on the 400,000 agricultural holdings in Great Britain. The occupiers of these holdings, however, are men skilled in animal and crop husbandry with generally but little basic knowledge of chemistry, although few can be as ill-informed as the mass of the public, which appears to suspect all chemicals used in agriculture as something undesirable and harmful.

On the one hand we have this rapidly expanding new science in which it is not easy for the technicians themselves to keep abreast of all the new developments, while on the other hand we have a multiplicity of relatively small farmers to whom the whole process of selective weed control with growth regulating substances and the like is, if not something unnatural, at least something very different from all traditional husbandry practice.

We must examine, therefore, to what extent this complex subject has been presented in understandable terms and not insulated by its own technical jargon and see how effective the channels of communication have been in ensuring that the requisite information is made available to the man in the field.

Looking back to the original CLC (MCPA) when this was introduced during war-time, it was shrouded in mystery and secrecy, and I sometimes suspect that the trade has never really tried to dispel this aura of mystery from agricultural chemicals, and indeed, by adding a surfeit of fancy names, they have made an already complex subject a maelstrom of confusion.

Let us congratulate the ingenuity of the coiners of brand names but let us recognise that they are largely responsible for creating the confusion and obscuring the name of the basic chemical in a product. Indeed, there seems to have been a surprising reluctance by some manufacturers to name the active chemical ingredient in a herbicide and only recently the A.B.M.A.C. have, at the request of the N.F.U., agreed to recommend their members to name the chemical ingredients on the labels of containers, but advertisements still appear for products without any reference to ingredients, and presumably farmers are expected to have sufficient confidence in the herbicide trade to buy a pig in a poke and use such materials.

I do not really mind you having all these trade names if you really want them, although I would have thought it sufficient for a manufacturer to identify his products with the name of the firm, such as Smith & Brown's MCPA, Smith & Brown's MCPB etc., but I am sure it is wrong for the brand name on a label to be in larger print than the name of the basic ingredient. Surely there must be a parallel between the agricultural chemicals and fertilisers, and while a fertiliser may be designated as 'X' brand basic slag or superphosphate, there is no attempt made to disguise that it is slag or superphosphate and the sooner this state of affairs becomes the practice with the herbicides the better, so that we farmers do not have to waste our time learning lots of fancy names for products which are basically the same.

Perhaps we should first look at education to see to what extent the rudiments of the subject are being taught to the new entrants to agriculture who may be attending part time Day Release Courses, Farm Institutes or Agricultural Colleges, and while it is reassuring to find there is reference to weed control in the syllabuses, the time devoted to it as a separate subject must be limited and student experience in the practical application cannot be extensive. These young people have at least had some basic training in this science and must have an advantage over the many established farmers who completed whatever formal technical training they had before the advent of these products and in consequence have had to pick up their knowledge of the subject as they go along, and that largely from commercial sources. Even with students, the multiplicity of brand names must cause confusion in their minds, as they are taught to recognise a spray by the chemical name or symbol of its active ingredient (e.g. mecoprop) and the use of brand names if carefully avoided, whereas when the student has to deal later with these materials it is by their particular brand names that they are bought and used.

I think a permanent series of demonstration plots at each of the Institutes and Colleges might be sponsored by an independent organisation such as the British Weed Control Council, and that these would serve a very useful purpose in illustrating the full scope of chemical weed control and giving future farmers an opportunity of seeing what a range of products there are available to supplement the MCPA with which they are undoubtedly familiar.

When we come to consider the needs of the established farmer it may be suggested that farmer-representation at a conference such as this should be stronger but let us make no mistake, this conference is pitched at a research and technical level and the farmer is only concerned with the practical application of materials that are already in commercial production. There is therefore a gap to be bridged between this conference and the final user, and we could have hoped that these Weed Control Conferences would have been followed by regional conferences promoted by the N.A.A.S. for the benefit of farmers in each locality; indeed, since we have to look to the officers of that organisation for the practical and independent interpretation of so many of the matters being discussed at this Conference, it is disappointing to find that they are not more strongly represented here today. Several of the larger commercial firms marketing spray chemicals have their own well-trained staff available to give advice to farmers and I fear that farmers often turn to the commercial advisers on this subject rather than to the independent advisers in the N.A.A.S. Sometimes, however, the boundary between adviser and salesman is difficult to distinguish and the salesman is frequently but ill-equipped on the technical side.

If we are to examine the printed literature on the subject of weed control, the Handbook published by this Council is undoubtedly the most up-to-date and comprehensive reference book on the subject, but unfortunately it has been prepared for the use of technical people and its practical value to the farmer is limited. As has often been pointed out, the susceptibility of different species of weeds listed in this book is related to stated doses of active ingredients and yet information on such content of chemicals is only available in the case of the MCPA and 2,4-D products included under the Approved Scheme. When this vital information is sought for other products we are assured that the content of active ingredient can be misleading on account of the over-riding differences due to methods of formulation. If this is so, are the recommendations in the Handbook as valuable as we have been led to believe?

Why all this mystery, which inevitably breeds distrust, so making education and advisory work in an already complicated subject more difficult. At a time when there is public criticism of the use of chemicals in crop protection farmers would be well advised to have nothing to do with products for which information on the active chemical content is not available or obtainable.

Since the Weed Control Handbook has to be such a scientific work, I would welcome a popular edition possibly published as a Ministry bulletin, which would then supplement the few official advisory leaflets on this subject. There is, of course, no overall shortage of paper devoted to information on herbicides and I have stacks of literature from some of the leading agricultural chemical firms.

Some of the handbooks published by these firms are excellent but would be very much more valuable if they were published by some independent authority.

While referring to publications I must congratulate Mr. Bradford on the excellent handbook he has prepared which sets out clearly basic information on the use of different chemicals and includes the different brands available and prices. The Weed Control Council or the A.B.M.A.C. could provide a useful service by making more information of this type available.

The National Farmers Union has for many years looked on the Approved List published by the Crop Protection Products Approval Scheme as being a most valuable guide to help in sorting out the great variety of products on the market and even greater reliance might have been placed in this list had it not been for the fact that new products could not be officially approved for some time after their introduction. With the new Agricultural Chemicals Approval Scheme we trust that these difficulties have been overcome and that there will be no reason why every worthwhile chemical should not be quoted in the Approved List; indeed, once the new scheme has come into force I can see no justification at all for any farmer purchasing a product not approved under this scheme, and I hope that the List will be a standard work of reference by farmers before any purchases are made.

Information is needed, not only to assist in the selection of the best product for use in specified circumstances but a major advisory problem is presented by the need to ensure their correct use to avoid unnecessary damage to neighbouring crops, birds and other livestock and also of course to the people who apply the chemicals and those who finally consume the crop which has been sprayed.

Much information is given in the instructions printed on the container or provided in a separate leaflet, and there is bound to be difficulty in putting over all the requisite information in sufficiently precise terms on a container label.

If all the varied circumstances of usage are to be taken into account the volume of information must inevitably detract from the attention given to items of detail but it is of vital importance that the users can be left in no doubt as to the dangers arising from the handling or application of the product. Spray drift is a problem that has been with us since selective herbicides were first introduced, and while I am encouraged by some of the research that has been undertaken on this subject, the problem is by no means solved as yet and the combined efforts of all concerned with herbicides must continue both to find sprays less liable to drift and to ensure that the conditions under which such hazards can arise are more fully understood by all responsible for their application.

Under the Notification Scheme conditions are laid down under which toxic products may be used, so that there is no fear that harmful residues may remain on the crop at the time of marketing. This information is of vital importance but these recommendations cannot be considered in isolation from the chemical and here again the user must rely on the advice given in the instructions for use, and so long as he can be sure that provided he carries out these instructions in every particular detail, that no harmful consequences can arise, then this aspect of the problem of advice and education is much simplified.

Selective weed control by herbicides has made tremendous progress and these new developments have been introduced at the same time as the mechanical revolution of the industry which has also raised education and advisory problems of its own.

Much remains to be done, and I am sure further progress will be made as some of the confusion of nomenclature can be eliminated, and that the more discerning farmer of the future will demand more precise information about products before he buys or uses them and that the gullible farmer who will buy an unknown product with a fancy name will soon be a thing of the past.

PROBLEMS OF ADVICE AND EDUCATION. A MERCHANT'S POINT OF VIEW

M. S. Bradford
National Association of Corn and Agricultural Merchants

First of all I must emphasise that this short paper expresses only my own opinions and ideas on the subject. These ideas have sprung from personal experience, gained since the exciting day when I first saw the effect upon charlock in winter wheat of applying MCPA formulated as a dry powder.

What are the particular problems relating to the education of the user in the application of herbicides from the point of view of the often much maligned middle man, or merchant, who sells to him? There are no problems if the merchant believes that it is outside his province to provide anything more in the way of a service than delivery of the herbicide he is requested to provide, at the right time, and at the right price, whatever that may be. I firmly believe that the remaining few who trade under that particular misapprehension are already finding their chemical business rapidly disappearing and rightly so.

Given then that there is a problem relating to user-education, in what way can your merchant play his part, and what does he consider his part to be? Basically the requirement is for the man on the tractor to apply through an efficiently working spray-machine, the chemical which will give the greatest return in profit to the man who bought it. This does not necessarily mean the chemical which will give the best purely technical control of the weed-problem present.

Is it the merchant's job then to get this knowledge to that man - and if so, how? My view is that the merchant has a vital role in disseminating sufficient knowledge to the man who does the actual work. Gone is the fools paradise of the days when virtually only MCPA was available to the farmer, and was principally used for the control of weeds which were highly susceptible. The farmer is now offered herbicides which enable him to overcome a great number of problems of varying complexity. Problems requiring considerable precision, and knowledge, in the use of the chemicals concerned - if they are to be used properly. Misuse due to ignorance can result in promising materials and techniques being quite wrongly considered a waste of money. One "eminent" failure in the district can offset the good of dozens of the unsung applications which did what was required of them.

I do not consider that anything but harm can come from advice on the use of herbicides being given by anyone insufficiently briefed to do so. A high degree of technical knowledge is also to my mind almost useless unless related to the practice of application: so that, if for no other reason than for the marriage of knowledge and practice within a merchant's organisation it is desirable to run at least one spraying unit on a contract basis for both routine and commercial work, and for trial or experimental work carried out with the co-operation of one's more progressive customers.

I mention this point here because it leads into my next one, namely that in this way over the years a fund of practical knowledge is obtained which is of invaluable service in fitting the solution to the problem, and sometimes not least in importance, the capability of the user who is faced with it. I doubt if anyone is in a better position to judge this very ability of the user, than the merchant, who has probably known him for many years, and is in constant touch with his farm, and his general farming methods. From another point of view, one of the greatest safeguards the farmer has when accepting his merchant's advice on the use of herbicides, as apposed to anyone else's, is that their business connections cover a wide field, and no merchant wishes to prejuduce his other trading interests by giving thoughtless advice on the use of herbicides.

At this point you may be beginning to wonder what I consider to be the manufacturer's role in all this in relation to the merchant's. It is my belief that many manufacturers are beginning to find that economics are forcing them to beam their selling effort to those merchants who offer a complete post sales technical service on the farm within their own organisations. These merchants can thus save the vast amount of time previously spent on the users' farms by the manufacturers' technical sales force. Particularly is this so in my own part of the country where farms are small and the potential from each individual call likewise small. The emphasis seems to be shifting to a pattern of manufacturers introducing new chemicals and techniques to the merchant, selling their known products as wholesalers, and letting the merchant do the actual retailing and most of the servicing at farm level. I am sure most manufacturers would consider it folly to try and carry a merchant who was merely a storekeeper by doing all his retail selling for him, particularly where that merchant was in competition with one who was prepared to do the job properly by providing his own after sales service. I would not leave this point without mention of the valauble and ever-increasingly efficient work of the N.A.A.S. in relation to advice on the use of herbicides. In my own county at any rate, we work in close and cordial co-operation with them.

From the foregoing remarks you will now have realised that I consider the merchant has in fact some small part to play in educating his customers as to the best use of the wares he has to offer. Having decided therefore to sell chemicals in this way, how can he go about obtaining the necessary knowledge, and how does he apply that knowledge for the benefit of his customers? There is probably no single ideal way of doing these things, as each merchant has different problems to face. There are vast differences in sizes of trading area, in the pattern of farming in various districts, and in the number of commodities in which your merchant already trades. I think there is one basic essential, however, and that is the presence in his organisation of at least one individual who is sufficiently well trained and practical to be capable of heading a special department dealing with herbicides, and at the same time probably fungicides and insecticides. The value of a contract service within this department I have already mentioned. You then have to strike a balance. Making all one's representatives highly technical in this field means their having less time to obtain the broader agricultural knowledge necessary to function properly within a selling organisation which probably includes farm seeds, fertilisers, feeding stuffs, and the hundred and one other things a merchant sells.

In our case my Company believes that as many representatives as possible should be briefed to a point when they can understand the broad principles involved assess the difficulty of a problem, and if necessary refer it back immediately to either myself or my deputy. To arrive at this stage they have probably availed themselves of the excellent technical courses for which the merchant is greatly indebted either to the major manufacturers, or to the efforts of their own Institute of Corn and Agricultural Merchants. As far as I am concerned, apart from such courses and such conferences as these, my technical knowledge, such as it is, has been gained through years of looking upon the search for information in this sphere as a hobby, irritating to my friends no doubt, and resulting in the consumption of huge quantities of midnight oil. Seriously though - it is extremely difficult to know how I would set about affording, for instance, my son a thorough knowledge of this vast subject if he were to decide he wanted to become technically qualified. Neither a degree in agriculture, nor a degree in chemistry would be what he was looking for.

Having obtained a nucleus of knowledgeable representatives we try, within our own organisation, to increase their knowledge under my guidance in the field and to keep them up-to-date by annual revisions, usually with the wholehearted assistance of our manufacturer friends.

Next is the problem of education of the user. Much can be done to impart basic principles by the many excellent films produced by the major manufacturers, which when shown to selected audiences, and with free rein given for discussion, can greatly assist, particularly if the actual sprayer operators can be present. We run many such business and pleasure evenings during the winter months. We have issued for the past two years, and I hope will continue to do so, an Annual Chemical Year Book, which gives simple basic facts relating to most of the chemicals on the market, including dosage rates, hints on maintenance and operation of equipment etc., even, sometimes, prices which are not out of date by the time we go to print. This is produced in a size which will go into the pocket, and we understand has done quite a lot to assist in a realisation of the main pitfalls which can trap the unwary.

I consider these methods help in fulfilling our role in a general basic education in the use of herbicides, but it is my firm belief that it is well-nigh impossible, and probably undesirable, to try to educate the majority of users to a high technical standard of knowledge of herbicides. You have got to advise them, write down your advice, and then hope the sprayer operator doesn't misread what you have written.

I am quite certain that many farmers have now decided that the whole business is much too complicated for them really to understand, or, to put it another way, the time required to be spent before such a state of understanding could arise would not be an economical proposition on a relatively small unit. Such units are in the majority in the West of England. As they often say "If I have a sick animal that is presenting a problem beyond the simple drench, I call in a vet - why, if I have a sick crop, presenting a problem beyond the simple application of say MCPA, not call in an expert in that particular sphere?" To solve this sort of problem we have developed a servicing scheme whereby farms are walked by appointment. A detailed written report on each field visited is sent to the farmer the following day. If a report is particularly urgent it is made out on the spot. The report gives a synopsis of the problem presented by the field with detailed recommendation of chemicals and techniques to be used where such a procedure is considered a paying proposition. One copy of the report goes to the Manager of our branch in whose area the farm is situated, and one copy to our files. Incidentally, we make a rule never to offer advice, or diagnose a problem over the telephone, This may sound obvious, but it is surprising how great the temptation to do so becomes in a busy period when the problem appears straight forward. We have learned from bitter experience, however, that rarely do things turn out to be exactly as described when we see the actual field.

To facilitate the best possible planning of work, which is necessarily hectic during the peak season, we cover most of the farms which avail themselves of this service on a regular annual or biannual basis. I feel that written reports after a visit are valuable because they imply an acceptance by the merchant of a measure of responsibility for the accuracy and calibre of the advice given. It also ensures against being told later that the grower was sure you said MCPA and not MCPB which in the absence of written confirmation of advice would be difficult to refute! The farm walk system does involve problems, however; such problems as the walking of crops too early to spot a late germination of Galium aparine for instance in a crop showing only Chenopodium album seedlings at the time of inspection. The adviser must have a considerable and accurate knowledge of the identification of weed species in the very early stages of growth - otherwise he cannot make a sufficiently early start on his inspections to enable him to see all the crops required of him in the time at his disposal.

All these problems, and the way the merchant tackles them raises the question of cost. If the farmer thinks it represents a really useful service he must be prepared to pay for it, at any rate to the extent of not expecting the merchant to cut his margins so that the whole business becomes uneconomical. In the majority of cases in my part of the country this is understood, but I sometimes get a little tired of haggling over perhaps a few shillings an acre, in chemical costs, when the advice one has given has been responsible for avoiding what would have been an almost complete lack of control of the weed concerned, with a consequent loss of several hundredweights per acre in crop yield, and several pounds per acre in cost of harvesting, not to mention the waste of the cost of chemical.

Perhaps I should mention just one other small problem - chemical names! Obviously it is unlikely that herbicides will ever be sold merely by reference to the name of the basic chemical or chemicals involved, but it would make things a little easier for merchant and farmer alike if some order could be brought to the sort of chaotic situation where the same basic chemical is given a different common name by, shall we say, commerce and the British Standards Institute.

To summarise briefly, I consider that the merchant has a very definite role to fulfil in the education of the user of herbicides, and that if he handles herbicides as part of his business it is incumbent upon him to play his part in this work. It seems to me, however, that it is not a realistic target to make of every farmer user a highly technical expert in relation to herbicides, but that every effort should be made to get him to that state of mind where he realises that a little knowledge is a dangerous thing. To carry out the merchant's part in the general effort to arrive at such a stage of education he has many problems to face. Probably his first problem is the assessment of the extent to which his Company is prepared to become involved in the handling of herbicides, bearing in mind factors such as the potential existing in his trading area, the competition he is going to have to face there, and the fact that the minimum requirements of a merchant so doing are going to involve him in considerable expense and effort.

I consider the main requirements, and probably the minimum requirements are as follows:

1) The setting up of a special department to deal with herbicides, and at the same time insectides and fungicides.

2) The employment of someone with sufficient technical and practical knowledge to manage the department and the advisory servicing of the chemicals sold.

3) A system whereby representatives can be briefed sufficiently to enable them to recognise the difference between an involved problem and a simple one, and to have a basic knowledge of weed identification and herbicide practice.

4) Means of keeping these representatives up-to-date with commercial developments as early as possible.

5) Probably essential is the provision of a contract spray service which should provide a constant source of learning how to turn theory into practice.

6) A system for answering questions on specific field problems by visits, confirmed in writing, which produce accurate advice, given early enough for it to be of practical use.

7) A set programme where groups of users can be kept informed in general terms of progress in this field by the printed word, visual means such as films and slides, and by general discussion.

If your merchant is thinking on these lines I am certain he will be able to rely for assistance in putting his thoughts into practice on those manufacturers who have already done such great work in the dissemination of technical information in this field.