CONTROL OF RHODODENDRON PONTICUM IN FOREST PLANTATIONS

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Summary

Experiments between 1964 and 1966 are described leading to provisional recommendations of a low-volatile ester of 2, 4, 5-T in oil or in water for control of *Rhododendron* in young forest plantations. Picloram at up to 8 lb, dicamba at up to 16 lb, and paraquat at up to 4 lb per 100 gallons of water were ineffective against *Rhododendron*; picloram caused serious malformations of the shoots of nearby planted trees, while dicamba caused slight damage.

INTRODUCTION

Rhododendron ponticum was introduced into Britain in the mid-18th century. It was planted extensively on many country estates, especially during the latter part of the 19th century, and since has become naturalised, spread and in many places forms dense thickets which can be penetrated only with difficulty. Often, the rhododendron thickets persist under light to moderately heavy shade from forest trees.

Where rhododendron exists without any over-crop, it prevents land being used for timber production; where an over-crop is present, it usually forms such an obstruction to access that the over-crop cannot be managed economically.

While some attempts have been made to kill full-grown rhododendron bushes, the dead wood is still left as a major obstruction. At present, there is no prospect of a treatment that will satisfactorily eliminate full-grown rhododendron thickets without clearing.

Rhododendron can be cut manually or mechanically, it can be crushed or it can be uprooted by bulldozer or similar heavy machine. However, neither cutting, crushing nor uprooting normally succeed in killing all parts of the plant; there is very often extensive regrowth, whether as sucker shoots from stumps or from layered branches. Also, following cutting, there is often germination of rhododendron seed so that in some localities, several thousands of seedlings can be found per acre of cleared ground.

Herbicides can be applied either to the stumps (stools) of cut rhododendron, to the young regrowth from untreated stumps or to seedlings. Ammonium sulphamate has been widely used in this way and is extremely effective if applied liberally to foliage, stump surfaces and the ground within a foot of the stump. This practice is based on work by Holmes (1956) who at the same time found that 2, 4, 5-T esters whether in water or oil killed the shoots of rhododendron but seldom killed the stumps.

The chief objection to the use of ammonium sulphamate has been the risk of damage to trees rooting in the treated area. Experience subsequent to Holmes' work has been that newly-planted conifers growing close to treated stumps are usually killed, while older trees up to 70 ft tall rooting in treated areas have also died. Also treatment with ammonium sulphamate is relatively expensive at £10 - 25 per acre (direct cost of materials and labour only).

The object of the e periments described here was to find an alternative to ammonium sulphamate which could be used to kill rhododendron seedling and sucker growth without damage to tree crops planted at 5 ft x 5 ft to 6 ft x 6 ft spacing, and also if possible to find a cheaper treatment.

1964/5 EXPERIMENTS

Sites Two areas were chosen. In Ringwood Forest, Corsican pine had been planted in 1962 on land previously carrying a dense thicket of rhododendron 12 - 18 ft tall. The rhododendron had been crushed in 1960 using a 'Holt' breaker. The site was then single-furrow ploughed at intervals of 5½ ft using a 'R.L.R.' plough. The soil is a loamy sand with abundant pebbles, derived from Bagshot beds.

At the time of first treatment the crop was 1½ - 4 ft tall. The weed flora included numerous clumps of rhododendron, up to 2½ ft high and 6 to 8 ft in diameter. The clumps were composed mainly of coppice shoots up to 4 years old, growing on a very much older woody stump. If left, it is almost certain that this area would develop into such an understorey of rhododendron under the pine that it would be impossible to thin or otherwise treat the crop economically.

At Sand Hutton, York Forest, rhododendron had been cleared by hand in 1958. Scots pines were planted in 1959. By 1964, there was a dense undergrowth of rhododendron 2 to 4 ft tall beneath pines 3 to 5 ft in height. There were also some older birch trees scattered sparsely over the area. The soil is a sand derived from glacial drift overlying Bunter sandstone.

METHODS and MATERIALS

Chemical Treatments: The following were applied -

Chemical	Diluent	Rate of Dilution
2, 4, 5-T (Unformulated ethyl-butyl ester)	Diesel oil	3, 6, 12 and 24 lb per 100 gallons
Ammonium sulphamate	Water	1, 2, 4 and 8 lb per gallon
Picloram (Potassium salt)	Water	1, 2, 4 and 8 lb per 100 gallons
Dicamba (diethylamine salt)	Water	2, 4, 8, 16 lb per 100 gallons
Paraquat	Water	½, 1, 2, 4 lb per 100 gallons

Volume applied: The spread of each clump of rhododendron was measured individually; the volume of spray applied related to the area of ground occupied by the clump, (hereafter referred to as the 'plan area') spraying at 400 ml/yd². In Ringwood Forest, clumps were measured along two diameters at right angles to each other across the woody stump; at Sand Hutton, clumps were measured along two diameters across the foliage and shoots.

Dates of Application: There were four dates of application at each site.

York Forest	Ringwood Forest
October 1964	September 1964
December 1964	December 1964
March 1965	March 1965
June 1965	June 1965

Experiment Design: Randomised block; the unit in each experiment was a clump of rhododendron; there were three replications of each treatment.

RESULTS

Response by Rhododendron

Table 1 shows the mean health scores of rhododendron on plots given the heaviest concentration of each herbicide. The assessments were made in July, 1965.

Table 1

Ringwood Forest	Health Scores; July 1965			
	Treatments applied in			
Chemical treatment	September 1964	December	March	June 1965
2, 4, 5-T	4.0	2.3	3.0	3.0
Ammonium sulphamate	3.0	2.3	2.3	2.7
Picloram	1.0	1.0	1.3	1.3
Dicamba	2.3	3.3	2.7	2.0
Paraquat	2.3	3.3	2.7	2.0
York Forest	**Health Scores; July 1965**			
2, 4, 5-T	5.0	5.0	5.0	5.0
Ammonium sulphamate	5.0	5.0	3.7	2.7
Picloram	2.0	3.7	2.3	1.7
Dicamba	3.0	4.0	3.7	2.7
Paraquat	2.7	3.7	4.3	3.7

Each figure represents the mean of three scores on the scale:

0 = Healthy, normal
1 = Leaves slightly mottled with a few light brown patches.
2 = Leaves mottled, some with large brown patches.
3 = Nearly all leaves partially or completely browned.
4 = Leaves nearly all dead, many stems dying back, many dead buds.
5 = Whole plant apparently dead.

The interval between dates of treatment and the assessments shown in Table 1 range from 1 month for treatments applied in June 1965 and assessed in July 1965 to 10 months for those applied in September or October 1964 and assessed in July. However, earlier assessments (where these were possible) differed very little from those made in July.

By the middle of 1965 ammonium sulphamate and 2, 4, 5-T had best controlled rhododendron regrowth. Paraquat had caused severe defoliation, though little kill of stems or stools. Picloram and dicamba had both damaged stools but there was less overall kill, and differed from other materials in being most effective when applied in December.

All treatments at York were more effective than those at Ringwood. This was due to a difference in the method of measuring clumps of rhododendron so that the York plants were sprayed more liberally than those at Ringwood.

Assessments made in late summer 1966 showed that at York most of the rhododendron treated with 2, 4, 5-T was dead; it had been killed quickly and there was little regrowth.

Plants treated with ammonium sulphamate at the heaviest rates had also been killed though these took longer to die than those treated with 2, 4, 5-T. Plants treated at the lower rates showed signs of recovery though much of the growth was somewhat malformed.

Both picloram and dicamba have been slow-acting. Many stumps though not dead had made very little growth in 1966.

Paraquat killed two bushes; the rest though damaged initially, recovered very quickly.

The rhododendron in Ringwood Forest has responded similarly though in every case there is more recovery than at York, as is to be expected from the poorer initial response illustrated in Table 1.

Regrowth of Rhododendron

New sprouts developed from existing or adventitious buds on most stools that were not completely killed. Stools sprayed with paraquat recovered quickly and looked similar to stools that had been cut back. There was extensive healthy regrowth by August 1966 on most of the bushes in the New Forest; only the stools treated with 2, 4, 5-T showed any consistent reduction in the vigour of regrowth. This recovery is consistent with the incomplete control of rhododendron shown by Table 1.

At York, more of the stools were killed outright and there was less regrowth.

Damage to the crop

Crop trees adjacent to plots treated with dicamba, picloram and ammonium sulphamate were in many instances killed or deformed. Ammonium sulphamate either caused partial defoliation or killed trees outright, but caused no malformation. Picloram, and to a lesser extent dicamba, caused acute malformation of the upper growing points, and in particular the leading shoot. The malformation took the form of gross thickening of the shoot, failure to elongate, thickening of the base of each pair of needles immediately below the point of needle attachment and failure of the needles to develop. A few trees were killed by picloram. Very slight damage was observed which could be attributed to the 2, 4, 5-T or paraquat, in both instances following treatments in June.

1965 EXPERIMENTS

METHODS and MATERIALS

At Bramshill Forest, an area of dense rhododendron on light gravelly sand derived from Bagshot beds was cut in 1962. The plan area of the stools and regrowth was measured. Sprays were applied overall to foliage, stem and stump in early May 1965 at 350 ml/yd^2 (plan area) with either 15, 30 or 60 lb of ethyl-butyl ester of 2, 4, 5-T per 100 gal of oil, or 4 lb of Ammonium sulphamate per gallon of water. Each plot was 8 to 10 yds^2 in area, and there were 3 replicates of each treatment.

R E S U L T S

When assessed in August, 1966, rhododendron was dead on all plots sprayed with 2, 4, 5-T, whatever the rate, and there was no sign of any regrowth from any of the stumps. Rhododendron sprayed with ammonium sulphamate was also dead, but the chemical had been slower to take effect than 2, 4, 5-T. There were no young trees in the area of this experiment at the time of treatment.

1965/66 EXPERIMENTS

The 1964/5 experiments in the New Forest and at York and the first indications from the 1965 experiment showed that of the materials tried, 2, 4, 5-T held the greatest promise of good control of rhododendron in planted crops.

METHODS and MATERIALS

1965/66 experiments compared:-

(a) Overall applications to foliage stem and stump of 2, 4, 5-T at 35 and 45 lb per 100 gallons of water.

(b) Basal-bark applications of 2, 4, 5-T at 20 and 30 lb per 100 gallons of diesel oil.

The water-borne treatments were duplicated, one set having water alone, and the other water + ½% sodium alginate, making a more viscous spray solution, which it was hoped would not run off foliage so readily as the water solution.

Sites: The experiment was repeated on three sites, at Bramshill, Hampshire, and Wareham, Dorset, both on sandy soils derived from the Bagshot beds, and at Bedgebury, Kent, on a silty sand derived from Hastings beds. On the first two sites, there were clumps of rhododendron with scattered birch. At Bedgebury, the rhododendron was in intimate mixture with chestnut coppice and young birch, willow and oak. On all sites, regrowth from the cut stools was 1 to 2 ft high. In addition at Bramshill, treatments were also applied to freshly cut stumps.

Method of Application: At each forest, the plan area of each rhododendron stool to be treated was measured, plants were then sprayed to run-off, and the volume of spray used recorded. Stools were sprayed either in October or November 1965 or March 1966. Stool areas varied from 15 to 84 ft^2.

The volume per yd^2 plan area of rhododendron to achieve run-off varied greatly from one site to another and appeared to be dependent largely on the man applying the spray. Most stools were sprayed at 250 - 400 ml/yd^2 but in several instances over 1000 ml/yd^2 were applied.

There were three replicates of each treatment except at Bedgebury where there was room only for two replicates.

R E S U L T S

Table 2 gives the health of the treated rhododendron assessed in July/August 1966 in the three experiments.

Table 2

Rhododendron Health Assessed late Summer 1966

Treatment Diluent	Concentration of 2,4,5-T (lb/100 galls. diluent)	Treated autumn 1965				Treated spring 1966			
		Bram.[1]		Ware.	Bedge.	Bram.		Ware.	Bedge.
		Stu.[2]	Regr.	Regr.	Regr.	Stu.	Regr.	Regr.	Regr.
Water, Overall	35	5.0	5.0	4.9	3.4	5.0	4.3	4.4	4.0
	45	5.0	5.0	5.0	5.0	5.0	4.3	4.6	3.0
Water + 0.5 Sod. alginate, Overall	35	5.0	4.7	5.0	4.0	5.0	4.0	4.7	2.8
	45	5.0	5.0	5.0	5.0	5.0	4.3	4.8	4.0
Oil, basal bark	20	5.0	4.0	3.9	4.4	4.0	4.0	3.2	2.8
	30	5.0	4.0	4.0	5.0	4.0	3.7	4.1	2.6

Health was scored using the convention as in Table 1. Each figure here represents the mean of 9 scores (6 for Bedgebury).

1. Bram. = Bramshill; Ware. = Wareham; Bedge. = Bedgebury.

2. Stu. = freshly cut stumps
Regr. = 2 - 3 year old regrowth from cut stools.

By late summer 1966, it was clear that the clumps of regrowth sprayed overall in autumn 1965 were mostly dead, while those sprayed overall in spring 1966 had been very severely damaged. The basal bark treatments generally were less successful. The freshly cut stumps sprayed at Bramshill had almost all been killed outright.

Regrowth

From a number of the larger stools sprayed overall and apparently killed, by late summer 1966, a few shoots had appeared from underground parts. In no case did these sprouts equal those on unaffected stools either in number or vigour. Usually there were two or three shoots per stool.

The stools given a basal bark spray had not produced sprouts from the base by late summer 1966. Almost all of them had a considerable part of their original foliage intact, but had made little shoot-growth in 1966.

Damage to the crop

The crops planted at each site were: at Bedgebury, Corsican pine; at Bramshill, Western hemlock; at Wareham, *Pinus radiata*.

At each site there was negligible damage to any crop tree. One or two trees at each site had lost a few needles where a lower branch had apparently got in the direct line of spray; needles on quite a number of plants were slightly distorted but in no case was this damage assessed as serious.

Effect of Volume of Spray Solution

While no critical comparisons can be made since most of the rhododendron sprayed overall was killed, for rhododendron stools with 2 to 4 years regrowth, sprays at 200 to 300 ml/yd^2 plan area (i.e. the lower end of the range of volumes used in these experiments) seemed adequate, wherever the foliage, stem and stump were all wetted.

Sodium alginate

Though shortly after spraying, foliage on stools sprayed with 2, 4, 5-T in water plus sodium alginate appeared to have been killed more quickly than those sprayed with 2, 4, 5-T in water alone, there was no measurable effect at later assessments.

DISCUSSION

The results of these experiments, while not conclusive, indicate firstly that 2, 4, 5-T in oil can effectively control rhododendron if applied at 15 to 30 lb/100/gal of diesel oil as an overall spray to foliage, stems and stumps. If the spray is applied only to the stumps and lower stems and not the foliage, the stools are not killed.

Overall sprays of 2, 4, 5-T in water have not been so consistent in achieving a complete kill of rhododendron stools, though it is clear that regrowth up to 3 - 4 years old can be killed right back to the stool with certainty and that the stump is sometimes completely killed. The fact that a better kill with 2, 4, 5-T was obtained in these experiments than those reported by Holmes, is probably due to placement. In Holmes' experiments, only foliage was sprayed; in these, foliage, stems and stumps.

The addition of sodium alginate to the 2, 4, 5-T in water has had little measurable effect on the control achieved, though shortly after treatment, it was clear that the sodium alginate had hastened kill of foliage.

Following treatments, even if there is no sprouting from concealed layered branches or roots, there is often germination and growth of seedlings and usually some patches are accidentally left unsprayed. Thus in most areas, it will probably be necessary to spray twice or even three times in the first ten years or so following planting forest trees in an old rhododendron area, if the development of an understorey of rhododendron is to be prevented. 2, 4, 5-T in water is probably effective enough for use in these circumstances and has the advantages of being cheaper, safer to the forest crop than Ammonium sulphamate, and less unpleasant to apply than 2, 4, 5-T in oil.

References

Holmes G. D. (1956) Experiments on the Chemical Control of Rhododendron ponticum. Proc. 3rd Brit. Weed Control Conf. 723-730. (Reprinted as For. Comm. Forest Record No: 34, H.M.S.O. London.)

CONTROL OF WEEDS IN CEREALS WITH NEW HERBICIDES

N.A.A.S. EXPERIMENTS 1964-66

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Summary   N.A.A.S. trials with ioxynil formulations both alone and in mixtures with mecoprop were conducted in 1964. Although results were variable the herbicide gave satisfactory control of Mayweed (Tripleurospermum maritimum ssp inodorum) and polygonum sp.

In 1965 morfamquat and picloram were tested in addition to ioxynil and mecoprop. Results were again variable but picloram was more variable than morfamquat.

Trials in 1966 were extended to include Chlorflurazole and MCPA mixtures. Morfamquat at medium and high doses, medium and high doses of the Chlorflurazole MCPA mixture and the ioxynil/mecoprop mixture gave good control of corn marigold, mayweed and spurrey at most centres.

INTRODUCTION

In 1964 ioxynil was tested alone and in mixtures with mecoprop. It was appreciated that ioxynil alone may kill only a few species of weeds and that for practical purposes it would be best to supplement its action by another herbicide.

Eight trials were laid down on spring barley.

In 1965 morfamquat and picloram were tested at seven sites in addition to ioxynil and mecoprop. Guidance on dose rates and mixtures was given by the commercial firms developing the herbicides and the W.R.O.

The future of morfamquat appeared to be as a single herbicide but picloram appeared more useful as an adjunct to existing herbicides.

In 1966 six trials were laid down including Chlorflurazole in mixtures with MCPA in addition to the same chemicals tested in 1965.

Experiments 1964

METHOD AND MATERIALS

The treatments applied at each site were as follows:-

Ioxynil at 4 ozs a.i. + mecoprop at 12 ozs a.i./ac	Supplied by A. H. Marks Ltd.
Ioxynil at 8 ozs a.i./ac	Applied at 30 gals/ac.
Ioxynil at 12 ozs a.i./ac	
Ioxynil at 16 ozs a.i./ac	
Ioxynil at 4 ozs a.i. + mecoprop at 16 ozs a.i./ac	Supplied by May and Baker Ltd.
Ioxynil at 4 ozs a.i./ac	Applied at 20 gals/ac.
Ioxynil at 6 ozs a.i./ac	
Ioxynil at 8 ozs a.i./ac	

Mecoprop at 12 ozs a.i./ac
Control.

Spraying was carried out when the crops had 3 to 5 leaves on the main stem of each plant in May or early June. The experiments were laid out as randomised blocks with three replicates.

Main assessments were of the kill of weeds and crop damage apparent three weeks after spraying; and the yield of grain.

RESULTS

(a) Weeds

Fifteen different weed species were present in the trials but only a few occurred at more than one or two sites. Where they did results were often at variance.

E.g. Tripleurospermum sp. where at three sites a satisfactory control was achieved with most ioxynil treatments, but at two other sites (South West and East) the effect of treatments was negligible or poor. The lack of effect at these two sites was difficult to explain, but there was generally poor weed control.

Excluding these two sites ioxynil gave a reasonable control of the following weeds (number of sites involved given in brackets):-

Tripleurospermum maritimum s.sp. inodorum (3), Polygonum convolvulus (2), Polygonum persicaria (3), Fumaria officinalis (1), Galium aparine (1), Sinapis arvensis (2) and Anagallis arvensis (1).

A fair control of the following was achieved:-

Chenopodium album (3), Polygonum aviculare (3), Stellaria media (4) and Veronica sp. (3).

The following were not well controlled by ioxynil:-

Chrysanthemum segetum (1), Spergula arvensis (1), Raphanus raphanistrum (2) and Galeopsis tetrahit (1).

Control of the following was improved by the addition of mecoprop:-

Stellaria media, Raphanus raphanistrum and Spergula arvensis.

Differences between formulations were not great and generally there was a flat dose/response curve.

The addition of mecoprop to ioxynil improved the control of most weeds, but except with the species particularly sensitive to mecoprop, e.g. Stellaria media, to no greater degree than was achieved by increasing the dose of ioxynil alone.

(b) Crop

Some scorch was noted at a few sites, but it was never considered serious. At one site in the South West, straw on the treated plots was slightly reduced.

Yields are shown in table 3.

TABLE 1. TRIPLEUROSPERMUM MARITIMUM s.sp. INODORUM

(0 = no effect; 10 = complete kill)

Site	West Midland	South West	East	South East	South East
Stage growth when sprayed (No. of true leaves)	young plant	.7	-	4-10	4-8
Ioxynil 4 oz + Mecoprop 12 oz a.i./ac	8.0	0	2.6	7.7	9.3
Ioxynil 8 oz a.i./ac	6.3	0	3.5	-	10.0
Ioxynil 12 oz a.i./ac	8.7	0	-	9.5	10.0
Ioxynil 16 oz a.i./ac	10.0	0	4.7	9.7	10.0
Ioxynil 4 oz + Mecoprop 16 oz a.i./ac	7.7	0.3	2.4	7.3	7.0
Ioxynil 4 oz a.i./ac	7.7	0	2.1	7.3	10.0
Ioxynil 6 oz a.i./ac	7.7	0	-	6.5	8.7
Ioxynil 8 oz a.i./ac	8.3	0	2.2	7.3	10.0
Mecoprop 12 oz a.i./ac	4.0	0	0≠	6.3/	3.7
Control	0	0	0	0	0

≠32 oz/ac

/12 oz MCPA + 4 oz 2, 3, 6-TBA

TABLE 2. CONTROL OF POLYGONUM SP.

(0 = no effect; 10 = complete kill)

Weed	Polygonum aviculare			Polygonum convolvulus		Polygonum persicaria		
Region	W.Mid.	S.East	W.Scot	S.West	East*	Y. & L.*	S.East	W.Scot
Stage of growth when sprayed (No. of true leaves)	Seed-ling	2-6	2-6	Young plant	3	1-2	1-3	1-2
Ioxynil 4 oz + Mecoprop 12 oz a.i./ac	8.0	8.0	6.3	9.7	8	9.0	8.7	8.0
Ioxynil 8 oz a.i./ac	5.7	7.7	4.0	8.0	9	-	-	8.7
Ioxynil 12 oz a.i./ac	7.7	8.3	3.5	8.7	10	9.0	9.7	9.5
Ioxynil 16 oz a.i./ac	8.3	9.0	4.5	10	10	9.0	9.2	10
Ioxynil 4 oz + Mecoprop 16 oz a.i./ac	8.3	6.0	6.3	8.3	9	8.5	8.6	6.5
Ioxynil 4 oz a.i./ac	7.3	5.3	2.3	7.7	9	-	8.6	4.3
Ioxynil 6 oz a.i./ac	8.0	5.0	2.5	9.7	8	8.5	9.5	7.0
Ioxynil 8 oz a.i./ac	6.3	5.0	5.5	8.7	10	9.0	9.0	8.5
Mecoprop 12 oz a.i./ac	5.3	2.3	5.5	6.0	6	2.5	5.6≠	3.8
Control	0	0	0	0	0	0	0	0

*based on weed counts
≠12 oz MCPA + 4 oz 2, 3, 6-TBA

TABLE 3. CROP YIELDS (AT 80% DRY MATTER)

Treatment	S.West	W.Mid.	Y. & Lancs	S.West	S.East	S.East	W.Scot.
Ioxynil 4 oz + Mecoprop 12 oz a.i./ac	114	108	95	96	109	190	101
Ioxynil 8 oz a.i./ac	115	105	-	94	111	-	100
Ioxynil 12 oz a.i./ac	114	116	92	95	109	184	96
Ioxynil 16 oz a.i./ac	110	113	107	98	113	190	98
Ioxynil 4 oz + Mecoprop 16 oz a.i./ac	118	118	100	92	116	172	108
Ioxynil 4 oz a.i./ac	105	117	-	95	111	193	101
Ioxynil 6 oz a.i./ac	110	124	107	95	109	168	100
Ioxynil 8 oz a.i./ac	122	107	101	94	107	180	101
Mecoprop 12 oz a.i./ac	113	108	85	95	123	172	106
Control	100	100	100	100	100	100	100
Yield in control plot (cwt./ac)	26.9	27.5	32.2	16.0	33.1	13.2	41.1

DISCUSSION

The results confirm that ioxynil causes insignificant damage to barley at quite high doses and early growth stages (between 3 and 5 leaves on the main stem).

The effect of ioxynil on weeds was not outstanding but the trials showed that a useful effect on Mayweed was possible. Polygonum persicaria and P. convolvulus and to some extent P. aviculare were also shown to be susceptible.

As dose ranges differed it was impossible to compare different formulations, but there appeared to be no great differences.

There was no evidence that ioxynil affected the action of mecoprop or vice versa. It seems that a low dose of ioxynil might be added to a growth regulator herbicide to add Mayweed and Polygonaceous weeds to the range of weeds controlled by the growth regulator.

Experiments 1965

Seven experiments were laid down to test the effects of morfamquat, picloram, ioxynil and mecoprop.

METHOD AND MATERIALS

Treatments applied at each site were:-

Morfamquat at 12 oz/ac
Morfamquat at 24 oz/ac
Morfamquat at 48 oz/ac
Picloram at $\frac{3}{8}$ oz/ac
Picloram at $\frac{3}{4}$ oz/ac
Picloram at $1\frac{1}{2}$ oz/ac
Picloram at $\frac{3}{4}$ oz + Mecoprop at 24 oz/ac
Ioxynil at 6 oz + Mecoprop at 24 oz/ac
Mecoprop at 24 oz/ac
Control

Layout - randomised block with three replicates.

Spraying was done when the crops had three to five leaves on the main stem of each plant.

RESULTS

(a) Weeds

Ten different weed species were present in the trials, "Mayweed" occurred in 5 different trials whilst others, e.g. P. convolvulus occurred only once. As in 1964 results were often at variance where a species occurred more than once. The evidence obtained was by no means consistent and it was impossible to decide from the scores the general susceptibility of species to the herbicides.

Other inconsistencies were found, e.g. Stellaria media was controlled well in two of three trials by morfamquat, although it is usually recorded as resistant. P. aviculare which is also regarded as resistant to morfamquat was controlled well in four trials at the highest dose.

Spergula arvensis, Chrysanthemum segetum, Polygonum convolvulus and Chenopodium album were all susceptible to morfamquat.

Results with picloram were more variable than with morfamquat. The addition of mecoprop tended to improve weed control. This was particularly the case with Stellaria media which appears to be rather resistant to picloram.

(b) Crop

Scorch from morfamquat only was reported in two trials.

Yields were taken in three trials, but these do not suggest that any herbicide was toxic to the crop. (See table I).

TABLE I. CROP YIELDS (AT 85% DRY MATTER)

(cwts/acre)

	Wiltshire	Shropshire	Staffordshire
Morfamquat at 12 oz	23.5	32.6	34.3
Morfamquat at 24 oz	24.1	34.9	34.9
Morfamquat at 48 oz	25.0	34.4	34.6
Picloram at $\frac{3}{8}$ oz	-	-	37.5
Picloram at $\frac{3}{4}$ oz	-	-	37.8
Picloram at $1\frac{1}{2}$ oz	-	-	38.2
Picloram at $\frac{3}{4}$ oz + Mecoprop 24 oz	-	35.2	37.5
Ioxynil 6 oz + Mecoprop 24 oz	26.3	33.5	34.6
Mecoprop 24 oz	24.2	32.7	37.2
Control	21.9	31.1	35.1

DISCUSSION

Morfamquat being a contact herbicide gave a quick kill of susceptible weeds, whilst Picloram is translocated and required a lapse of a week or two for it to become effective.

Comparisons of the two herbicides by scores taken at only one time could be misleading and of course the standard of the assessors varied. However, the degree of variation inherent in the method of assessment could not account for the wide differences between sites.

It appeared that the younger the weed growth at spraying the better the control and vigorous crop competition seemed to be an important factor.

Some of the variability in results may have been due to different patterns of distribution and retention of spray on the weed.

Experiments 1966

Trials were conducted at six centres, two in the S.W. Region, two in the Eastern Region and one each in the West Midlands and South East Regions.

METHOD AND MATERIALS

Treatments included at the various sites were:

Morfamquat at $\frac{3}{4}$ lb ion/ac
Morfamquat at $1\frac{1}{2}$ lb ion/ac
Morfamquat at 3 lb ion/ac

Picloram at $\frac{3}{8}$ oz/ac

Picloram at $\frac{3}{4}$ oz/ac

Picloram at $1\frac{1}{2}$ oz/ac

Picloram at $\frac{3}{8}$ oz/ac + dichlorprop at 36 oz/ac

Chlorflurazole at 8 oz/ac + MCPA at 12 oz/ac

Chlorflurazole at 12 oz + MCPA at 12 oz/ac

Chlorflurazole at 16 oz + MCPA at 12 oz/ac

"Actril C" at 4 pints per acre

Dichlorprop at 36 oz/acre

Control Wheelmarked

Control No wheelmarks

Picloram $\frac{3}{4}$ oz/ac + Mecoprop 24 oz/ac

Picloram $1\frac{1}{2}$ oz/ac + Mecoprop 36 oz/ac

Layout - randomised block with three replicates.

RESULTS

The main weed species occurring at most sites were Corn Marigold (Chrysanthemum Segetum), Mayweed and Spurrey (Spergula arvensis).

Observations were also made on Chickweed (Stellaria media), Black bindweed (Polygonum convolvulus) and Runch (Raphanus raphanistrum).

None of the treatments caused serious scorch and the control of Corn Marigold, Mayweed and Spurrey was good at most centres with medium and high doses of Morfamquat, medium and high doses of the Chlorflurazole/MCPA mixture and with "Actril C". Picloram both alone and in mixtures tended to give more variable results (see table 1).

Grain yields available for two centres show no correlation with weed control assessments (see table 2).

TABLE 1. CONTROL OF MAIN WEEDS

(0 = no effect: 10 = complete kill)

- = weed absent or treatment not applied

Weed	Corn Marigold *C. segetum*						Spurrey *Spergula arvensis*						Mayweed					
Region	Cornwall S.W.	Wilts. S.W.	W.Mid.	S.E.	E.	E.	Cornwall S.W.	Wilts. S.W.	W.Mid.	S.E.	E.	E.	Cornwall S.W.	Wilts. S.W.	W.Mid.	S.E.	E.	E.
Growth stage when sprayed (No. of true leaves)	3	4	2-6	4-8			1"-4"	4-6	8-10				-	seedling	seedling	2-8	4-5	
Morfamquat $\frac{3}{4}$ lb ion/ac	4.6	6	4.0	-	-	-	6.0	8	-	-	-	-	-	10	5.6	-	-	-
" $1\frac{1}{2}$ " "	7.3	-	5.3	9.0	-	-	8.0	-	-	9.0	-	-	-	-	9.3	7.0	-	-
" 3 " "	6.6	9	7.6	-	-	-	7.1	9	-	-	-	-	-	10	9.6	-	9.3	7.9
Picloram $\frac{3}{8}$ oz/ac	2.0	6	3.0	-	-	-	4.0	6	-	-	-	-	-	7	3.0	-	-	-
" $\frac{3}{4}$ "	3.3	7	7.0	-	-	-	4.6	7	-	-	-	-	-	10	2.0	-	-	-
" $1\frac{1}{2}$ "	4.6	-	8.0	-	-	-	5.3	-	-	-	-	-	-	-	8.0	-	-	-
Picloram $\frac{3}{8}$ oz/ac + dichlorprop 36 oz/ac	5.0	-	7.3	-	-	-	6.3	-	-	-	-	-	-	-	4.3	-	4.0	0
Chlorflurazole 8 oz/ac + MCPA 12 oz/ac	2.6	6	6.3	-	-	-	2.6	6	-	-	-	-	-	9	7.6	-	-	-
Chlorflurazole 12 oz/ac + MCPA 12 oz/ac	4.6	7	7.3	7.0	-	-	5.3	8	-	8.5	-	-	-	10	9.0	7.0	-	-
Chlorflurazole 16 oz/ac + MCPA 12 oz/ac	7.0	7	9.6	-	-	-	6.3	9	-	-	-	-	-	10	9.3	-	-	1.7
Actril 'C' 4 pints/acre	3.0	6	9.3	8.0	-	-	4.0	7	-	9.0	-	-	-	10	9.3	10	8.7	8.6
Dichlorprop 36 oz/ac	3.0	7	2.6	-	-	-	5.3	7	-	-	-	-	-	10	3.6	-	0	6.6
Control (Wheelmarked)	-	0	0	0	-	-	-	0	-	-	-	-	-	0	0	0	0	0
Control No wheelmarks	-	0	0	0	-	-	-	0	-	-	-	-	-	0	0	0	0	0
Picloram $\frac{3}{8}$ oz/ac + Mecoprop 24 oz/ac	-	-	7.6	-	-	-	-	-	-	-	-	-	-	-	4.6	-	-	-
Picloram $1\frac{1}{2}$ oz/ac + Mecoprop 36 oz/ac	-	-	-	9.0	-	-	-	-	-	9.0	-	-	-	-	-	10	-	-

TABLE 2. GRAIN YIELDS CWT./ACRE (15% MOISTURE)

Treatment	Surrey (Provisional)	Wiltshire	Cornwall
Morfamquat $\frac{3}{4}$ lb ion/ac	-	30.1	26.4
Morfamquat $1\frac{1}{2}$ lb ion/ac	31.5	-	26.5
Morfamquat 3 lb ion/ac	-	34.1	26.7
Picloram $\frac{3}{8}$ oz/ac	-	34.2	26.2
Picloram $\frac{3}{4}$ oz/ac	-	36.8	23.2
Picloram $1\frac{1}{2}$ oz/ac	-	-	26.9
Picloram $\frac{3}{8}$ + Dichlorprop at 36 oz/ac	30.7ø	-	21.5
Chlorflurazole at 8 oz + MCPA at 12 oz/ac	-	28.0	20.8
Chlorflurazole at 12 oz + MCPA at 12 oz/ac	33.0	30.3	23.4
Chlorflurazole at 16 oz + MCPA at 12 oz/ac	-	33.6	22.1
"Actril C" at 4 pints	31.8	36.0	29.2
Dichlorprop at 36 oz/ac	-	32.1	21.8
Control (wheelmarks)	-	24.8	23.6
Control (No wheelmarks)	26.0	23.2	26.7

øTordon $\frac{3}{8}$ oz + Mecoprop 36 oz a.i./ac

DISCUSSION

Assessments of weed control showed that in 1966 good control of Corn Marigold, Mayweed and Spurrey was obtained with Morfamquat, Chlorflurazole/MCPA mixtures and an Ioxynil mecoprop mixture (Actril C).

Unfortunately all the grain yield figures are not yet available but those from three centres (table 2) show that at two sites (Wiltshire and Surrey) all the treatments produced an increase in yield whereas at the other (Cornwall) yields were much more variable. This may have been due to lack of competition in the Cornish crop which was patchy and lacked vigour.

CONCLUSIONS

Results have tended to vary from site to site over the period reviewed and this cannot always be adequately explained. Any of the treatments tested appeared to be capable of giving good results under favourable conditions.

Whilst the susceptibility of weeds to the different herbicides clearly varies the vigour of the crop, stage of growth of the weeds, weather conditions and the patterns of distribution and retention of the spray on the weeds are equally important factors in determining the ultimate effect of the herbicide.

ACKNOWLEDGMENTS

Thanks are due to a large number of persons associated with this series of trials. Mention must be made of Messrs. A. H. Marks Ltd., Messrs. May and Baker Ltd., Messrs. Plant Protection Ltd., Messrs. Fisons Ltd., and Messrs. Dow Chemicals Ltd., who supplied the experimental materials.

Also the following N.A.A.S. Advisers: P. R. Scowcroft (Cornwall), G. L. Gladwell (Dorset), J. M. Proctor (Cambridge), K. R. Hubbard and K. E. Williamson (W. Midlands), T. J. Jones (Cardigan), G. A. Dowse (Wiltshire), J. M. Mackintosh (Warwickshire), J. O. Emms (Staffordshire) and H. A. Waterson (West of Scotland Agric. College) who were in charge of the individual experiments.

BROMOXYNIL AND IOXYNIL ESTERS AS SELECTIVE HERBICIDES IN CEREALS IN THE UNITED KINGDOM

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Summary Extensive field experiments by our colleagues principally in Western Canada and N. Western U.S.A have established the relative herbicidal activities of the alkali metal salts and octanoyl esters of ioxynil and bromoxynil and have led to the commercial use of bromoxynil ester formulations in these countries. This work has been extended to cover U.K. weeds and conditions and extensive trials have also been conducted to determine whether mixtures of the octanoyl esters of ioxynil or bromoxynil with 2,4-D or MCPA esters could be used under practical conditions of British farming.

Bromoxynil octanoate was confirmed to be markedly more active than bromoxynil salt and at a dose of 4 oz/ac gave good control of a number of important cereal weeds including Polygonum spp. and Tripleurospermum maritimum. Ioxynil salt or octanoyl ester is more active than bromoxynil salt or ester against Stellaria media and Veronica spp., although a minimum dose of 6 oz/ac would be necessary to give commercial control of these species as well as those that are more susceptible to bromoxynil. The addition of esters of MCPA or 2,4-D improved the reliability of control of susceptible weeds and checked other species normally resistant to ioxynil or bromoxynil. The addition of 2,4-D ester caused some risk of ear distortion at early growth stages, and both MCPA and 2,4-D ester could lead to some yield reduction when applied to wheat and barley after the fully tillered stage. Mixtures of bromoxynil octanoate or ioxynil octanoate with MCPA iso-octyl ester had no significant effect on wheat or barley yields when applied at the 3-5 leaf stages at doses effective for weed control. These mixtures could provide control of a number of important cereal weeds in the U.K. but their exact composition and use will depend largely on economic considerations.

INTRODUCTION

The differences in herbicidal properties between the alkali metal salts and octanoyl esters of ioxynil and bromoxynil were first described in a paper presented at this Conference in 1964, (Heywood et al 1964). The overall level of herbicidal activities is similar for the two compounds but there are some important differences. Ioxynil is markedly superior to bromoxynil against Stellaria media and Galium aparine, although there is little to choose between its salt and octanoate formulations. On the other hand bromoxynil octanoate is generally more active than bromoxynil salt on many species and is superior to both ioxynil formulations on certain Polygonaceae and Compositeae. These important differences have led to the use of ioxynil salt and bromoxynil octanoate in two widely differing areas of cereal production.

In the temperate areas of Central and N. Eastern Europe ioxynil is favoured because of its activity against a large number of the important annual weeds of cereals, in particular Stellaria media and Galium aparine. Although effective used alone, ioxynil is usually used as a salt in combination with a phenoxyalkanoic acid; MCPA to ensure suppression of perennial weeds; mecoprop or dichlorprop, to give more uniform control of the less susceptible species. Such mixtures are now widely used as medium priced broad spectrum herbicides.

In Western Canada, the limited weed spectrum and the importance of polygonaceous weeds in small grain cereals has favoured the development of bromoxynil octanoate. This compound has shown good activity used alone at 6 oz per acre against Amsinkia spp. in N. Western U.S.A. but in Western Canada a mixture of 4 oz bromoxynil + 4 oz MCPA as the octanoate and iso-octyl esters respectively is used as a broad spectrum herbicide to control such important species as wild buckwheat Polygonum convolvulus, tartary buckwheat Fagopyrum tartaricum, green smartweed Polygonum scabrum, and stinkweed Thlaspi arvense.

Research reports for 1964 and 1965 of the Canadian National Weed Committee contained numerous references to experiments carried out with this and similar mixtures by several workers, but in particular Friesen H. A., Friesen G., Molberg E. S. and our own colleagues Clarke F. C. and Cooke P. D.

Although mixtures containing salts of ioxynil with mecoprop or MCPA have been favoured in the U.K. as giving the widest range of weed control with the greatest crop tolerance, the effectiveness of bromoxynil/MCPA ester mixtures in Canada in low doses suggested that similar mixtures might find a use in the U.K. for the control of weeds susceptible to them in spring cereals. Preliminary experiments in this country had already shown that knotgrass and mayweed should be included in this category.

This report summarises the work carried out to confirm that bromoxynil and ioxynil ester formulations would be active at low doses in the U.K. and to choose the most useful hydroxybenzonitrile/phenoxyacetic mixture for our conditions.

METHODS

Materials and formulations

The following formulations were used throughout this series of experiments:

Common Name	Formulation
(hydroxybenzonitriles used alone)	
ioxynil (salt)	Aqueous solution of the sodium salt containing the equivalent of 5% w/v free phenol.
ioxynil octanoate	An emulsifiable concentrate of ioxynil octanoate, equivalent to 25% w/v ioxynil.
bromoxynil (salt)	Aqueous solution of the potassium salt containing the equivalent of 5% w/v free phenol.
bromoxynil octanoate	An emulsifiable concentrate of bromoxynil octanoate equivalent to 25% w/v bromoxynil.
(hydroxybenzonitrile/ phenoxyacetic ester mixtures)	
ioxynil or bromoxynil/MCPA or 2,4-D 1:1 and 1:1½ mixtures	Emulsifiable concentrates containing ioxynil or bromoxynil octanoates equivalent to 20% w/v free phenol + MCPA iso-octyl ester or 2,4-D iso-octyl ester to give either 20% or 30% a.e.
MCPA	Aqueous solution of the potassium salt containing 25% MCPA a.e.

Common name continued	Formulation
mecoprop	Aqueous solution of the potassium salt containing 30% mecoprop a.e.

Doses throughout this report are given in terms of 'phenol equivalent' for the hydroxybenzonitriles and 'acid equivalent' for phenoxyalkanoic acids.

Weed control experiments

Comparisons of the activity of ioxynil and bromoxynil salts or octanoate esters used alone were carried out at 21 sites in commercial crops. A small plot precision sprayer was used to apply fixed doses of 4 oz, 6 oz and 8 oz/ac at a volume of 15 gal/ac. All sites were simple randomised layouts, plot size 7 ft 6 in. x 25 ft, with three replicate plots per treatment.

The herbicidal activity of mixtures of the esters of the hydroxybenzonitriles with phenoxyacetic acids were compared on larger plots in 17 commercial crops.

Doses were:

ioxynil or bromoxynil 4 oz	phenol equivalent	+ MCPA 4 oz a.e./ac
"	"	+ MCPA 6 oz "
"	"	+ 2,4-D 4 oz a.e./ac
"	"	+ 2,4-D 6 oz "

Plot sizes were 9 ft x 120 ft sprayed with the small plot precision sprayer, or 18 ft x 120 ft with a Land Rover mounted machine. In both cases volume rate was 20 gal/ac with three replicate plots per treatment, in a simple randomised layout.

Cereal tolerance experiments

Two experiments were carried out to check the tolerance of 5 common varieties of spring wheat and 6 varieties of spring barley to the mixtures of ioxynil or bromoxynil with MCPA or 2,4-D esters sprayed at different growth stages. Doses were the same as those used in the weed control experiments and x $1\frac{1}{2}$ the 4 + 6 oz/ac dose. MCPA ester and 2,4-D ester at 6 and 12 oz/ac were included as reference compounds. Plot size 7 ft 6 in. x 12 ft per variety/treatment with two replicates per treatment in a randomised block layout split for times of application (3).

Two experiments in spring barley and 1 in spring wheat were designed to provide information on cereal yields of crops treated with the hydroxybenzonitrile/phenoxyacetic ester mixtures. Doses used were 4 + 6 oz/ac and 6 + 9 oz/ac hydroxybenzonitrile/phenoxyacetic a.e. i.e. the higher ratio used in the herbicide experiments and x $1\frac{1}{2}$ this dose. A randomised block layout was used, split for 2 times of application with 4 replicates. Individual plots were 9 ft x 160 ft.

Assessment methods

Weed control At all sites weed counts were made using 2 x $\frac{1}{2}$ sq yd quadrats on each plot, 4-6 weeks after spraying. Both plant numbers and bulk (number x mean height) were recorded.

Cereal tolerance The plots comparing the tolerances of wheat and barley varieties were inspected and recorded for leaf scorch 3 and 10 days after each spraying. Ten weeks after spraying the crop height and numbers of normal and abnormal ears per unit row length were recorded.

On the experiments designed to obtain information on yield the plots were harvested with a 6 ft forward drive combine harvester. Yields from each plot are expressed in cwt/ac at 15% moisture content.

RESULTS

Table 1.

<u>Control of weeds in cereals with salt and octanoyl ester formulations of ioxynil and bromoxynil</u>

Mean % control of plant numbers for species occurring at a minimum of 4 sites

Species and no. of sites at which each occurs		Compound and dose rate in oz/ac											
		bromoxynil potassium salt			bromoxynil octanoate			ioxynil sodium salt			ioxynil octanoate		
		4	6	8	4	6	8	4	6	8	4	6	8
Galeopsis spp. (g. tetrahit & g. speciosa)	4	25 ± 25	68 ± 36	84 ± 16	64 ± 27	74 ± 8.4	88 ± 12	49 ± 49	72 ± 18	64 ± 36	79 ± 21	96 ± 2.1	82 ± 18
Polygonum aviculare (in winter crops)	4	90 ± 1.8	96 ± 0.1	99 ± 1.0	94 ± 6.6	98 ± 1.0	97 ± 1.3	72 ± 5.6	81 ± 0.3	62 ± 7.4	75 ± 10.3	54 ± 20.6	64 ± 13.5
Polygonum aviculare (in spring crops)	8	41 ± 10.4	65 ± 8.1	75 ± 5.1	94 ± 1.4	91 ± 2.0	97 ± 1.2	31 ± 16.6	28 ± 6.0	41 ± 12.6	41 ± 14.2	40 ± 12.6	35 ± 12.2
Polygonum convolvulus	5	97 ± 0.5	99 ± 0.2	99 ± 0.6	98 ± 0.5	99 ± 0.8	99 ± 0.4	92 ± 1.0	98 ± 0.3	97 ± 2.0	86 ± 0.3	92 ± 1.0	98 ± 0.6
Polygonum persicaria + p. lapathifolium	7	93 ± 0.5	96 ± 1.5	98 ± 0.5	97 ± 0.5	99 ± 0.5	98 ± 0.5	89 ± 5.5	94 ± 1.7	96 ± 1.7	91 ± 2.5	95 ± 2.2	95 ± 1.7
Stellaria media	9	17 ± 9.5	20 ± 10.1	16 ± 9.5	10 ± 5.9	7 ± 3.3	23 ± 4.3	51 ± 5.1	63 ± 5.6	73 ± 11.3	59 ± 9.4	76 ± 3.7	70 ± 3.4
Tripleurospermum maritimum + M. recutita (mayweeds)	9	78 ± 1.2	87 ± 0.5	91 ± 0.6	93 ± 0.7	97 ± 0.6	97 ± 0.3	68 ± 3.4	75 ± 3.2	83 ± 2.2	79 ± 4.1	89 ± 3.8	87 ± 2.9
Veronica spp. (v. persica + v. arvensis)	5	66 ± 3.4	79 ± 10.0	80 ± 9.9	74 ± 9.4	84 ± 6.1	93 ± 3.3	88 ± 6.1	90 ± 7.2	89 ± 6.8	92 ± 5.6	96 ± 2.4	97 ± 2.1
Viola spp. (v. arvensis + v. tricolor)	7	18 ± 9.0	16 ± 6.1	8 ± 6.5	21 ± 7.7	21 ± 13.4	5 ± 3.5	17 ± 11.7	42 ± 21.7	29 ± 16.9	78 ± 4.2	82 ± 4.7	88 ± 2.6
Total weed populations numbers	21	60 ± 0.5	70 ± 0.5	72 ± 0.5	70 ± 0.2	74 ± 0.3	78 ± 0.2	59 ± 0.6	69 ± 0.7	76 ± 0.7	68 ± 0.7	77 ± 0.7	77 ± 0.7
Total weed populations, bulk (i.e nos & mean hts)	21	73 ± 0.5	78 ± 0.8	79 ± 0.9	81 ± 0.2	84 ± 0.3	86 ± 0.2	71 ± 0.9	75 ± 1.2	81 ± [illegible]	77 ± 0.7	84 ± 0.6	87 ± 0.6

Note: Percentages shown to 95% confidence limits.

Table 2.

Control of weeds in cereals with salt and octanoyl ester formulations of ioxynil and bromoxynil

Mean % control of plant numbers for species occurring on 3 sites or less

Species and no. of sites at which each occurs		Compound and dose (oz/ac)											
		bromoxynil potassium salt			bromoxynil octanoate			ioxynil sodium salt			ioxynil octanoate		
		4	6	8	4	6	8	4	6	8	4	6	8
Atriplex patula	3	99	100	99	97	100	100	76	88	67	95	92	98
Chenopodium album	2	82	94	98	94	98	99	65	78	80	77	94	91
Chrysanthemum segetum	3	68	80	83	93	96	98	39	49	65	73	90	95
Cirsium arvense	1	90	65	75	65	85	85	85	90	95	75	100	40
Fumaria officinalis	2	84	92	97	71	84	92	76	89	100	73	57	84
Galium aparine	2	37	73	70	58	81	81	58	80	90	53	60	82
Papaver rhoeas	3	67	94	94	79	89	85	68	66	80	80	72	81
Rhaphanus rhaphanistrum	2	87	91	99	96	91	94	97	94	97	70	96	100
Sonchus arvensis	1	49	31	38	21	79	26	62	85	79	31	79	67
Spergula arvensis	1	0	27	0	0	0	0	27	16	0	21	32	0

Table 3.

Effect of the addition of 2,4-D or MCPA iso-octyl esters on the herbicidal activity of ioxynil and bromoxynil esters

Mean % control of plant numbers for species occurring at a minimum of 5 sites

Weed sp.	Treatment and dose in oz/ac				
	bromoxynil octanoate	+ MCPA iso-octyl ester		+ 2,4-D iso-octyl ester	
	4 oz	4 oz	6 oz	4 oz	6 oz
T. maritimum subsp. inodorum	93 ± 0.7	99.5 ± 0.2	97 ± 0.2	99.2 ± 0.2	99 ± 0.2
P. aviculare (spring crops only)	94 ± 1.4	90 ± 1.6	93 ± 0.9	93 ± 2.3	94 ± 0.7
S. media	10 ± 5.9	23 ± 8.0	48 ± 5.8	3 ± 3.0	34 ± 5.6
Veronica spp.	74 ± 9.4	87 ± 1.7	85 ± 6.8	78 ± 2.6	84 ± 2.2
Viola spp.	21 ± 7.7	77 ± 2.5	81 ± 2.0	83 ± 1.5	91 ± 0.9
	ioxynil octanoate	+ MCPA iso-octyl ester		+ 2,4-D iso-octyl ester	
	4 oz	4 oz	6 oz	4 oz	6 oz
Tripleurospermum maritimum subsp. inodorum	79 ± 4.1	90 ± 1.1	91 ± 1.1	95 ± 0.5	96 ± 0.4
Polygonum aviculare (spring crops only)	41 ±14.2	67 ± 2.8	70 ± 3.6	75 ± 3.3	72 ± 1.5
Stellaria media	59 ± 9.4	71 ± 1.4	72 ± 1.3	70 ± 8.7	70 ± 4.0
Veronica spp.	92 ± 5.6	99 ± 0.8	99.5 ± 0.2	97 ± 1.8	96 ± 0.7
Viola spp.	78 ± 4.2	95 ± 0.7	98 ± 0.9	99 ± 0.6	99.9 ± 0.01

Note: Percentages are shown to 95% confidence limits

Table 4.

<u>Control of weeds in cereals with mixtures of the esters of hydroxybenzonitriles and phenoxyacetic acids</u>

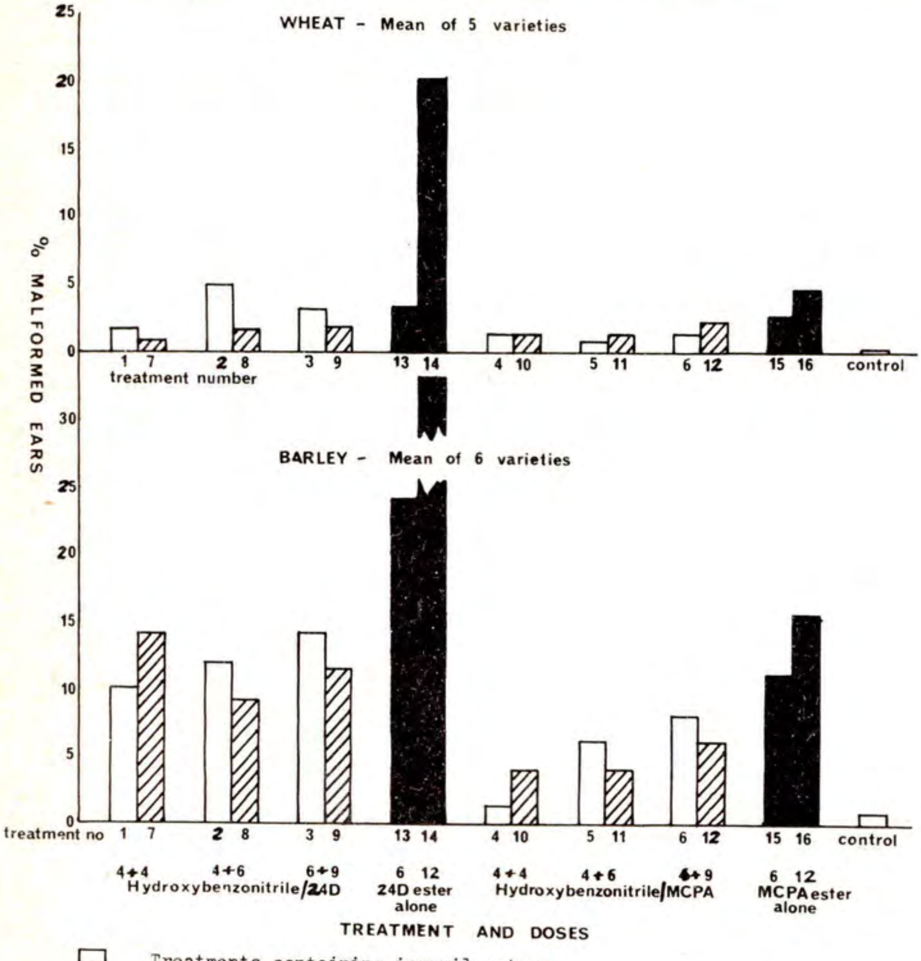
% control of plant numbers for species occurring at 4 sites or less

Species	Site no.	Growth stage at spraying	Treatment and dose oz/ac							
			bromoxynil + MCPA		bromoxynil + 2,4-D		ioxynil + MCPA		ioxynil + 2,4-D	
			4+4	4+6	4+4	4+6	4+4	4+6	4+4	4+6
Brassica nigra	11	6-8 leaves	all treatments 100% control							
Chrysanthemum segetum	2	5-6 leaves	31	19	50	66	28	43	50	55
	10	4 "	93	98	100	100	78	89	90	94
	16a	2 "	87	90	94	98	75	72	83	86
	16b	4-6 "	80	84	87	94	71	71	80	86
Fumaria officinalis	1	4-6 "	81	90	49	66	92	100	76	75
	8	4-6 "	65	92	17	45	91	94	78	91
Lapsana communis	1	4 "	100	99	88	98	98	98	99	97
	4	4-6 "	98	94	99	94	82	75	88	75
	6	4-6 "	55	73	45	55	55	53	42	55
Polygonum convolvulus	4 sites	2 "	all treatments 95-100% control							
Polygonum persicaria	12	3-4 "	87	93	91	96	83	88	87	93
	14	6-8 "	82	84	88	85	92	96	97	98
Rhaphanus rhaphanistrum	2	4 "	all treatments 97-100% control							
	16a	2 "								
	16b	4-8 "								
Sinapis arvensis	2	3-6 "	all treatments 100% control							
Sonchus arvensis		2"-3" rosettes	84	91	78	77	80	85	62	81
Spergula arvensis	4	4 whorls	85	80	64	88	72	89	81	3
	11	2 "	55	65	0	64	75	52	71	9
Urtica urens	2 sites	4 leaves	all treatments 100% control							

FIGURE 1.

MIXTURES OF ESTERS OF HYDROXYBENZONITRILES AND PHENOXYACETIC ACIDS 1966

% malformed ears of spring wheat and spring barley sprayed at 2-3 leaves



Treatments containing ioxynil ester

Treatments containing bromoxynil ester

2,4-D or MCPA esters alone

WHEAT Treatments 2, 14 and 16 have significantly more malformed ears than unsprayed control at 5% Probability level, and Treatment 2 significantly less than Treatment 14.

BARLEY All treatments have significantly more malformed ears than controls at 5% Probability level and Treatments 1-12 and 15-16 have significantly less than Treatment 14.

Table .

Effect on cereal yields of mixtures of the esters of hydroxybenzonitrile and phenoxyacetic acids

Yields - cwt/ac at 15% moisture

Crop and variety	Growth stage at application	Treatments and dose oz/ac								
		bromoxynil + MCPA		bromoxynil + 2,4-D		ioxynil + MCPA		ioxynil + 2,4-D		Standard
		4+6	6+9	4+6	6+9	4+6	6+9	4+6	6+9	
spring barley Europa	3-4 leaf	32.2	30.7	29.9	32.1	33.0	32.0	30.5	32.5	30.4 CMPP 24 oz/ac
				No significant differences						
spring barley Rika	4-5 leaf	19.7	21.3	16.4	19.5	20.7	19.7	20.7	18.6	19.9
	5-9 leaf tillering	20.1	18.7	18.2	16.7	17.4	19.0	19.3	19.4	17.3 MCPA 20 oz/ac
				No significant differences						
spring wheat Opal	4-5 leaf	33.6	34.8	35.0	35.4	35.9	35.6	36.8	35.5	37.3
	fully tillered nearly jointing	31.4	31.2*	30.8*	33.9	32.0	30.9*	33.4	32.2	34.2 CMPP 24 oz/ac
				*significant difference between these treatments and standard (P = 0.05)						
				LSD (P = 0.05) between treatments means = 2.8						

DISCUSSION

Weed Control

The weed counts in Tables 1. and 2. illustrate the relative activities of the salts and octanoates of ioxynil and bromoxynil used alone. These results confirm the earlier preliminary work (Heywood et al 1964) and the experiments carried out in Canada in 1964/65 (Clarke and Cooke 1964). Bromoxynil octanoate is as active or better than the other 3 compounds on many of the important species, and at 4 oz/ac will control Polygonum aviculare, P. convolvulus, P. persicaria, Tripleurospermum maritimum, Atriplex patula and Chenopodium album. Chrysanthemum segetum is also severely checked at the seedling stage, but doses higher than 4 oz/ac, with probably the addition of MCPA or 2,4-D, would be necessary to achieve reliable commercial control. There is less difference between the salt and octanoate formulations of ioxynil and both show an advantage over bromoxynil on Veronica spp. and Stellaria media. Even so, chickweed remains one of the more resistant weeds and a dose of at least 6 oz/ac ioxynil, either as salt or ester, is necessary to give effective control. The figures for total weed control illustrate the overall advantages of the octanoate formulations and also the slight but definite superiority of bromoxynil in this form.

As in previous work with mixtures of the salts of ioxynil, with MCPA or mecoprop (Carpenter et al 1964), the addition of MCPA and 2,4-D esters has improved the level and reliability of control given by ioxynil or bromoxynil esters used alone. Table 3. shows that even on very susceptible species e.g. P. aviculare and Tripleurospermum maritimum the addition of 2,4-D or MCPA leads to a greater reliability of control in the field.

The effect on other species largely depends on their relative resistance to ioxynil or bromoxynil. One of the most dramatic cases is with Stellaria media. This is virtually resistant to 4 oz bromoxynil octanoate but the addition of 6 oz MCPA ester, whilst not giving complete control, ensures a very satisfactory check of young plants. An even better control is achieved on Viola spp. with the addition of both MCPA and 2,4-D. Table 4. shows the general level of control achieved with the mixtures on other species.

The choice of hydroxybenzonitrile in a mixture depends on the range of weed species to be controlled. If Stellaria media or Galium aparine are present in significant numbers, one is bound to choose a mixture containing ioxynil, although it is doubtful whether even this, at the doses tested, would give adequate control under all commercial conditions. If the emphasis is to be on the control of Polygonaceous weeds and Compositae, mixtures containing the relatively lower doses of bromoxynil ester would be sufficient. The addition of 2,4-D is more effective on Tripleurospermum maritimum, Polygonum aviculare and Chrysanthemum segetum, whereas MCPA ester is better on Stellaria media and Fumaria officinalis. However in general the differences in effect between MCPA and 2,4-D are small and the choice in a mixture would depend more on their effect on crop tolerance than on activity.

Crop tolerance

We would have expected more crop damage with the esters of MCPA or 2,4-D than with the salts, but in fact crop reaction to the ester mixtures has been small and very similar to that of the ioxynil/MCPA or ioxynil/mecoprop salt mixtures reported previously (Carpenter et al 1964). There was no scorch on any of the wheat or barley varieties at any of the growth stages and no ear malformation occurred from applications made after the 3 leaf stage. All treatments caused some malformation at the 2-3 leaf stage and barley was more susceptible than wheat (Fig. 1.). 2,4-D ester caused more malformation than MCPA ester but the addition of ioxynil or bromoxynil ester considerably reduced the risk of malformation by the phenoxyacetic acids. Mixtures of ioxynil or bromoxynil ester at 6 oz/ac with MCPA ester at 9 oz/ac or mixtures containing 2,4-D ester at 6 oz caused some yield reduction to spring barley when applied at the fully tillered stage. Mixtures of ioxynil or bromoxynil esters with 2,4-D iso-octyl ester have insufficient margin between doses necessary for weed control and those likely to cause distortion or crop yield. At these early growth stages mixtures of 4 oz/ac ioxynil or bromoxynil ester + 4-6 oz MCPA could be safely used in spring wheat and barley between the 3 leaf stage and commencement of tillering without risk to crop yield. These results confirm those obtained in Canada in spring cereals with the same formulations (Friesen H. A. 1965, Hall B. and Friesen G 1965, Molberg E. S. 1965).

CONCLUSIONS

There is no practical difference between the levels of activity or weed spectra of ioxynil sodium salt and ioxynil octanoate. Ioxynil salt or octanoate are more active against a number of important weeds of cereals including Stellaria media and Galium aparine than bromoxynil salt or ester formulations. Bromoxynil octanoate is generally more active than an equivalent salt formulation and at 4 oz/ac is considerably more active on certain Polygonaceae and Compositeae than ioxynil salt or ester formulations.

The addition of MCPA or 2,4-D iso-octyl ester increases the reliability of control of a number of weeds susceptible to ioxynil or bromoxynil octanoates and gives a useful check to more resistant species including perennials.

The addition of ioxynil or bromoxynil octanoates reduces the likelihood of ear distortion to spring wheat and barley by application of 2,4-D ester or MCPA ester used alone.

The crop safety margin of mixtures of ioxynil or bromoxynil octanoates with 2,4-D iso-octyl ester is less than that with similar mixtures containing MCPA iso-octyl ester. Mixtures containing 4 oz/ac ioxynil or bromoxynil octanoates + 4-6 oz MCPA ester applied after the 3 leaf and before the jointing stages can be used safely to provide economic control of a number of important weeds in spring wheat and barley.

Acknowledgments

The authors would like to acknowledge the practical assistance of Mr G. B. Horsnail and other colleagues at Ongar during the course of these trials, and the statistical work on the results by Mr K. Ryan.

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FURTHER STUDIES WITH IOXYNIL FOR BROADLEAF WEED CONTROL IN CEREALS

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Summary Extensive trials in 1965 showed that three component mixtures comprising Ioxynil, a phenoxypropionic and a phenoxyacetic acid gave excellent control of a broad spectrum of weeds including Mayweed species, Polygonum species, Galeopsis tetrahit and Stellaria media. None of the mixtures caused any phytotoxic effects to the crop or had any effect on the yield of cereals. In 1966 commercial applications of an Ioxynil/Dichlorprop/MCPA mixture were observed and further field trials were carried out. Results confirmed that this mixture gives effective weed control for a broad spectrum of weeds and is particularly effective on Mayweed species, Polygonums and Galeopsis tetrahit.

Some field trials in 1965 and 1966 evaluated different formulations of Ioxynil and Bromoxynil. The oil soluble amine was discarded because of extensive scorch and poor weed control results. The ester formulations of Ioxynil gave some good weed control at dosage rates as low as 0.1 lb/ac. when mixed with Dichlorprop/MCPA.

INTRODUCTION

Experimental work with Ioxynil had indicated that mixtures with phenoxyacids were necessary to provide a broad spectrum weed control. Mixtures of Ioxynil and the phenoxypropionics in particular Ioxynil + Dichlorprop provided a more consistent and higher level of general weed control. Certain weeds were however only moderately susceptible to such mixtures, in particular Galeopsis tetrahit (Hemp nettle), (Joice and Norris 1964). The latter had been well controlled by an Ioxynil/MCPA combination and in consequence field evaluation of three component mixtures comprising Ioxynil, a phenoxypropionic and a phenoxyacetic acid were initiated in 1965 for weed control, crop phytotoxicity and effect on yield. As a result of the work an Ioxynil/Dichlorprop/MCPA mixture was selected for commercial use. In 1966 observations of commercial application confirmed the earlier experimental work. In both 1965 and 1966 other Ioxynil and Bromoxynil formulations were evaluated.

METHOD AND MATERIALS

In 1965 weed control trials were laid down at 15 sites. Plots of 1/400th or 1/200th acre were laid down in randomised blocks with 2 or 3 replications. Spraying was carried out with an Oxford Precision sprayer at a total volume of 30 gal. per acre. The stage of growth of the weeds ranged from seedling to young plant stage. Weed control was assessed by one of three methods:

(a) recording the fresh weight of individual species from random samples representing 10% of the plot area;

(b) counts of individual weeds; and

(c) visual assessments.

Crop phytotoxicity was measured by assessing leaf scorch, height depression and ear deformities. These effects were assessed on all weed control trials, the yield trials and in one additional trial laid down specifically for this purpose. In the latter trial dosage rates equal to twice those used in weed control trials were applied.

Yield plots were laid down in 1965 and 1966 as randomised blocks replicated 4 times and sprayed at a total volume of 30 gals. per acre. The yield was measured by cutting a single strip through each plot equivalent to 1/40th acre.

In 1966 the efficiencies of the commercial applications at the recommended rate of 4 pints/acre of the Ioxynil/ Dichlorprop/MCPA mixture (Certrol PA) were studied at numerous sites. Fixed quadrats were marked in the treated areas and these were observed throughout the season to assess the control of weeds.

During 1965 and 1966 different formulations of Ioxynil and Bromoxynil were evaluated in small fixed dosage plots and logarithmic plots. In the logarithmic experiments the Dichlorprop/MCPA component was kept constant at 1.5 + 0.5 lb/ac. and the Ioxynil or Bromoxynil diluted from a 10 to 1 concentration.

Formulation Data:

Ioxynil	- contains 1.0 lb. Ioxynil/Imp. gallon formulated as the potassium salt.
Ioxynil A	- contains 2.4 lb. Ioxynil/Imp. gallon formulated as an oil soluble amine.
Ioxynil E	- contains 2.4 lb. Ioxynil/Imp. gallon formulated as the octanoic acid ester.
Bromoxynil E	- contains 2.4 lb. Bromoxynil/Imp. gallon formulated as the octanoic acid ester.

RESULTS

Evaluation of Ioxynil/phenoxyacid mixtures for weed control 1965

The overall weed control and control of certain individual weed species for up to 15 sites are summarised in Table I.

TABLE I

% Overall weed control and % control of certain individual species

Treatment	Rate lb/ac.	% overall control	% control of weed species A	B	C	D	E	F
24DP	2.5	76(10)	85(4)	98(2)	41(3)	53(4)	0(1)	75(2)
24DP + Ioxynil	1.75 + 0.25	86(15)	90(8)	84(6)	84(3)	57(5)	71(1)	83(3)
	1.25 + 0.375	85(5)	99(2)	94(2)	73(3)	-	14(1)	98(2)
MCPA	1.25	74(5)	90(2)	83(2)	83(3)	-	91(1)	70(2)
MCPA + Ioxynil	1.0 + 0.25	92(5)	98(2)	93(2)	100(3)	79(1)	100(1)	84(2)
	0.75 + 0.375	87(5)	93(2)	91(2)	99(3)	82(1)	96(1)	71(2)
CMPP	2.25	83(5)	93(2)	99(2)	73(3)	17(1)	0(1)	60(2)
CMPP + Ioxynil	1.75 + 0.25	92(5)	95(2)	98(2)	91(3)	56(1)	77(1)	89(2)
	1.25 + 0.375	93(5)	96(2)	98(2)	92(3)	56(1)	6(1)	90(2)
24DP + MCPA	2.0 + 0.5	90(5)	95(2)	98(2)	97(3)	100(1)	81(1)	44(2)
24DP + MCPA + Ioxynil	1.5 + 0.5 + 0.25	89(10)	95(6)	76(6)	94(3)	100(2)	100(1)	94(3)
	1.0 + 0.5 + 0.375	85(10)	80(6)	77(6)	100(3)	67(2)	99(1)	98(3)
24DP + 24D	2.0 + 0.5	61(10)	71(6)	78(6)	50(3)	76(2)	18(1)	62(3)
24DP + 24D + Ioxynil	1.4 + 0.35 + 0.25	76(15)	85(8)	68(6)	97(3)	90(5)	91(1)	99(3)
	1.0 + 0.25 + 0.375	85(15)	90(8)	70(6)	73(3)	89(5)	84(1)	81(3)

Figures in parentheses denote number of sites at which weeds encountered.

Key to Table I

A - Tripleurospermum maritimum (Scentless Mayweed) ssp. inodorum

B - Stellaria media (Chickweed)

C - Galeopsis tetrahit (Hemp nettle)

D - Polygonum aviculare (Knotgrass)

E - Myosotis arvensis (Forget-me-not)

F - Lamium purpureum (Red Dead Nettle)

Evaluations were made of weeds other than those mentioned in Table I. These results are summarised as follows. All treatments effectively controlled Urtica urens (Annual nettle), Rumex species (Docks), Cirsium arvense (Thistle) together with those weeds normally controlled by MCPA. Polygonum persicaria (Redshank) and Polygonum convolvulus (Black Bindweed) were controlled by all mixtures containing Ioxynil, and where Dichlorprop was present in the mixture a higher level of control was achieved. Satisfactory control of Veronica species (Speedwells) was only obtained when Ioxynil was present in the mixture.

Observations of commercial applications 1966

During 1966 the observation of commercial sites confirmed that the selected Ioxynil/Dichlorprop/MCPA mixture controlled a broad spectrum of weeds including Mayweed species, Galeopsis tetrahit, Polygonum persicaria, Polygonum convolvulus, Stellaria media and Galium aparine. Two weeds, Polygonum aviculare and Viola arvensis were, however, only suppressed by the application.

Evaluation of other Ioxynil and Bromoxynil formulations

Ioxynil Oil Soluble Amine

The 1965 experiments indicated that the oil soluble amine of Ioxynil gave severe crop scorch and poor weed control. In consequence testing was discontinued.

Ioxynil ester and Bromoxynil esters

Experimental work in 1965 suggested that for an equivalent level of weed control a lower dosage of Ioxynil in the form of the octanoic acid ester was required than its potassium salt.

Table II shows the minimum dosage of Ioxynil or Bromoxynil with the fixed Dichlorprop/MCPA to give effective weed control (85% control).

TABLE II

Minimum dosage (lb./ac.) of Ioxynil or Bromoxynil to give 85% weed control

Formulation	Overall weed control	Galeopsis tetrahit	Tripleurospermum maritimum
Ioxynil	0.26	0.17	0.1
Ioxynil E	0.11	0.14	0.11
Bromoxynil E	0.27	0.11	0.11

Table III shows the % control of weeds with Ioxynil salt, Ioxynil ester and Bromoxynil ester when in mixture with Dichlorprop and MCPA.

TABLE III

Comparison of % weed control with Ioxynil, Ioxynil ester and Bromoxynil ester

Treatment	Rate lb/ac.	SITE 1 % overall control	SITE 1 % control weed spp. A	B	C	SITE 2 % overall control	SITE 2 % control weed spp. D	E
24DP + MCPA + Ioxynil	1.5 + 0.5 + 0.125	94	87	98	89	88	85	100
	1.5 + 0.5 + 0.25	98	90	100	99	72	70	100
24DP + MCPA + Ioxynil E	1.5 + 0.5 + 0.125	98	92	100	98	89	88	100
	1.5 + 0.5 + 0.25	97	87	100	99	92	93	100
24DP + MCPA + Bromoxynil E	1.5 + 0.5 + 0.125	96	84	100	100	99	100	100
	1.5 + 0.5 + 0.25	96	93	97	90	95	99	100

Key to Table III

A - Galeopsis tetrahit (Hemp nettle)

B - Stellaria media (Chickweed)

C - Polygonum convolvulus (Black Bindweed)

D - Polygonum aviculare (Knotgrass)

E - Polygonum persicaria (Redshank)

Crop Phytotoxicity

Several varieties of winter wheat, spring wheat and spring barley were examined for phytotoxic effects.

Leaf Scorch

None of the mixtures tested caused serious scorch at the dosage levels evaluated for weed control. Where the dosage was increased twofold some scorch was observed with all mixtures but was not significant. No varietal differences were observed. In 1966 observation of plots did not reveal any scorching of cereals by commercial applications of Ioxynil/Dichlorprop/MCPA and in yield trials where twice the recommended dosage was applied.

Height Depression

None of the treatments caused a depression in the height of the cereals.

Ear Deformities

At the normal dosage levels tested for weed control, mixtures containing MCPA or 24D caused severe deformities in spring wheat when applied at the 1-2 leaf stage. At the 3-4 leaf stage deformities were somewhat reduced and at the 6 leaf stage even twice the dosage caused negligible effects.

On barley the normal dosage levels caused insignificant ear deformities whereas twice the dosage rate caused severe distortions at the 3-4 leaf stage. At the later stage of growth viz. 6 leaf, none of the treatments caused deformities even at twice the dosage levels.

Effect on Yield of Cereals

All weights of cereals were corrected to 15% moisture content. These are shown in Table IV and Table V and are expressed as a % of untreated or standard treated control.

TABLE IV

Yield of Cereals as % of untreated or standard treated control 1965

Treatment	Rate lb/ac.	1 W.W. 2 Capelle 3 FT	W.W. Prof.M. FT	S.W. Opal	B. Vada	B. Camb.	B. Vada	B. Proc.	B. Rika 4-5L	B. Proc. FT	B. Freja FT
24DP	2.5	109.7	-	-	-	-	-	-	104.7	-	106.9
24DP + Ioxynil	1.75 + 0.25	99.6	99.6	94.0	110.3	100.6	107.2	100.0	103.1	111.8	102.4
	3.5 + 0.5	-	-	-	-	-	-	-	102.8	-	98.5
MCPA + Ioxynil	1.0 + 0.25	-	-	-	-	-	-	-	102.3	-	105.7
	2.0 + 0.5	-	-	-	-	-	-	-	100.4	-	98.5
24DP/ MCPA/ Ioxynil	1.5 + 0.5 + 0.25	102.1	-	-	-	-	-	-	-	109.7	104.5
	3.0 + 1.0 + 0.5	98.6	-	-	-	-	-	-	-	-	-
24DP/ 24D/ Ioxynil	1.4 + 0.35 + 0.25	103.6	127.3	104.9	100.9	108.2	110.8	105.8	-	112.4	105.4
	1.0 + 0.25 + 0.375	-	-	97.2	100.0	102.5	96.4	110.0	-	-	-
	2.8 + 0.7 + 0.5	89.2	126.9	-	-	-	-	-	-	-	107.5
24DP + 24D	2.0 + 0.5	100.0	100.0	-	-	-	-	-	-	100.0	-
Untreated control				100.0	100.0	100.0	100.0	100.0	100.0	-	100.0

TABLE V

Yield of Cereals as % of untreated control 1966

Treatment	Rate oz./ac.	1 2 3	B. Proc. 4L	B. Camb. 4L	B. 5L	B. Vada 4L	B. Rika 4L	S.W. Opal 4L
Untreated			100.0	100.0	100.0	100.0	100.0	100.0
24DP + MCPA	40		108.3	105.2	92.3	93.1	101.1	106.3
Ioxynil + 24DP + MCPA	36		105.5	101.2	95.2	95.2	105.7	102.4
	54		108.6	99.1	96.7	95.5	100.9	102.1
	72		109.2	100.0	93.4	93.6	102.0	106.9

Key to Tables IV and V

1. Crop

W.W. - Winter wheat
S.W. - Spring wheat
B. - Barley

2. Variety

Prof. M. - Prof. Marchall
Camb. - Cambrinus
Proc. - Proctor

3. Stage of growth at application

FT - fully tillered
L - number of leaves

DISCUSSION

Field trials and commercial applications have indicated and confirmed that the addition of Ioxynil to a phenoxypropionic/ phenoxyacetic mixture results in improved weed control.

General weed control was satisfactory with all the mixtures tested but certain species were not adequately controlled by the two component mixtures. Control of Tripleurospermum maritimum ssp. inodorum was at a reasonable level with all mixtures and was almost complete when Ioxynil was incorporated into the mixture. Stellaria media was effectively controlled by all treatments. Results in 1965 demonstrated that where Galeopsis tetrahit is present the addition of MCPA is beneficial. The three component mixture Ioxynil/Dichlorprop/MCPA gave better control of Galeopsis tetrahit than the Ioxynil/Dichlorprop mixtures or MCPA alone at the recommended rate. With Polygonum persicaria and Polygonum convolvulus control was satisfactory with all mixtures but mixtures containing dichlorprop tended to give better results. Polygonum aviculare proved to be difficult to control. However, mixtures containing Ioxynil/ Dichlorprop/24D were particularly promising giving a high level of control over 5 sites. Results with the Ioxynil/Dichlorprop/MCPA mixtures looked promising and indicated that effective suppression of the weed could be anticipated. Results on Myosotis arvensis were rather variable. MCPA alone gave good control but the addition of Ioxynil appeared beneficial. In all cases the inclusion of Ioxynil improved the control of Lamium purpureum and similar results were obtained on the control of Veronica species.

Ioxynil/phenoxyacid mixtures again proved to be very selective in cereals. In 1965 cereal scorch was observed only at the early growth stages. In 1966 it was not recorded with the commercial application of Ioxynil/Dichlorprop/MCPA or in any field trials.

Serious ear deformities were only caused by excessive dosages at an early time of application.

Yield experiments show that the mixtures will not cause any serious effects and the extensive trials in 1966 confirm that the Ioxynil/Dichlorprop/MCPA mixture is safe on cereals.

Ioxynil and Bromoxynil formulations

The oil soluble amine formulation of Ioxynil has now been discarded. The results with this formulation confirmed results of previous years with other oil soluble amine formulations. Their action appears to be more rapid producing extensive scorch which results in an inferior weed control.

No advantages could be seen with the ester formulation compared to Ioxynil on Mayweed species, Stellaria media, Polygonum convolvulus or Polygonum persicaria. The ester would appear to be more effective on Galeopsis tetrahit and Polygonum aviculare, requiring a lower dosage level than Ioxynil. The result with Bromoxynil ester on Polygonum aviculare was promising.

The advantages of ester formulations are somewhat marginal and are outweighed by the changes necessary in the formulation of mixtures.

Acknowledgments

The authors would like to express their thanks to J. W. Chafer Ltd., Shellstar Ltd., and Pan Britannica Industries Ltd., for their valuable assistance in the carrying out of these trials and also to all farmers who have willingly given their co-operation.

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Research Summary

FIELD EXPERIENCE WITH BENAZOLIN IN ADMIXTURE WITH OTHER HERBICIDES

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INTRODUCTION

Leafe[1], at the Seventh British Weed Control Conference 1964 described the properties of a new herbicide, 4-Chloro-2-oxobenzthiazolin-3-yl-acetic acid for which the common name "benazolin" has been proposed and confirmed by the British Standards Institute. At the European Weed Research Council Symposium on New Herbicides, Paris, 1965, Lush[2] et al reported field experience with the compound and made brief reference to overseas interest.

In the meantime further work has been carried out in the United Kingdom and abroad.

MATERIAL AND METHODS

A 30% potassium salt of benazolin coded as SN.3950 has been employed in most field evaluation work alone and in tank mixes with salts of phenoxyacetic and phenoxybutyric acids. A 10% dispersible powder of the ethyl ester coded as SN.5500 has also been used for combination with other herbicides. 25 detailed trials involving replicated treatments and 150 user trials where treatments were unreplicated have been carried out.

RESULTS AND DISCUSSION

Leafe[1] and Lush[2] et al demonstrated that in the United Kingdom the main role of benazolin was as an additive to a mixture of 24DB/MCPA to broaden the weed control spectrum to include Stellaria media (chickweed) and Galium aparine (cleavers) for use in undersown and direct sown grass/clover mixtures.

They showed that at a rate of 3 oz a.i. per acre, benazolin consistently gave a high standard of control of Stellaria media at seedling and young plant stages. Galium aparine, whilst not as susceptible as Stellaria media was always adequately suppressed by the same rate at similar growth stages and was prevented from being a problem at harvest time. At the 3 oz a.i. per acre rate, the effect on other weeds when used alone was found to be negligible but when combined with 24DB/MCPA, used at rates of approximately $1\frac{1}{2}$ and $\frac{1}{4}$ lb per acre respectively, benazolin at 3 oz was found to impart a slight increase in general broad leaved weed control particularly on polygonaceous weeds.

Benazolin used alone, was found not to have any deleterious effect on clovers nor did it increase the temporary leaf roll and suppression effects normally caused by 24DB/MCPA in red clovers at the trifoliate leaf stage. No effect on grasses from the 1st leaf stage has been observed. Benazolin was shown to possess a high safety margin in cereal crops. These findings have since been confirmed by a successful season of commercial use in the United Kingdom.

Brief reference was made by Lush[2] et al to the combination of benazolin with MCPB/MCPA. Work with this mixture has since been extended in Scotland and in those parts of England where mainly, Stellaria media, and less frequently Galium aparine occur in grass/clover mixtures in association with Galeopsis tetrahit, day or hemp nettle, a weed which is not adequately controlled by combinations of 24DB/MCPA.

Galeopsis tetrahit, traditionally a weed of great importance in Scottish cereal growing areas where it is known as day nettle also occurs in England as hemp nettle, particularly, though not exclusively, on highly organic soils but has never become such a serious weed problem as it is in Scotland. Of recent years, however, the weed has been observed to be an increasing problem in undersown and direct sown grass/clover mixtures, probably due to the extensive use of products based on 24DB/MCPA.

The work carried out with MCPB/MCPA/benazolin combinations has again demonstrated the ability of benazolin at a rate of 3 oz a.i. per acre, to broaden the spectrum of phenoxybutyric/phenoxyacetic acid mixtures to include Stellaria media and Galium aparine in the same manner as described above. An improvement in general broad leaved weed control was also found, but because of the reduced effectiveness of MCPB/MCPA against polygonaceous weeds, no significant improvement in their control was observed. Control of Galeopsis tetrahit was equivalent to that of MCPB/MCPA. The same high safety margin in clover/grass mixtures was confirmed in MCPB/MCPA combinations, where application to clovers at the spade leaf stage was found to be as safe as with MCPB/MCPA mixtures used alone. The addition of benazolin to MCPB/MCPA had no effect on yield of cereal crops.

The table summarises the herbicidal activities of the 24DB/MCPA and MCPB/MCPA mixtures with and without benazolin.

Weed control and crop response

Herbicide	Rate	Cereal	Clover	Stellaria media	Galium aparine	Polygonum persicaria	Galeopsis tetrahit
24DB/MCPA	i	0	0-3**	3-5	0	7-8	2-4
24DB/MCPA/ benazolin	ii	0	0-3**	8-9	6-8	7-9	2-4
MCPB/MCPA	iii	0	0-1*	0-3	0	2-5	6-9
MCPB/MCPA/ benazolin	iv	0	0-1*	8-9	6-8	2-5	6-9

Stage of treatment:	Cereals	-	3-4 leaf to just prior to jointing
	Clovers	-	spade to trifoliate leaf
	Weed	-	seedling to young plant stage

Assessment scale: 0 = no effect 10 = maximum effect

Scores refer to the effect of herbicide at the standard rate of use per acre:-

i	24DB	24 ozs	MCPA	4 ozs		
ii	24DB	24 ozs	MCPA	4 ozs	benazolin	3 ozs
iii	MCPB	24 ozs	MCPA	4 ozs		
iv	MCPB	24 ozs	MCPA	4 ozs	benazolin	3 ozs

(* 1 = slight temporary check of clovers)
(** 3 = temporary check with temporary leaf roll of clovers)

Cereal Yield	Rate	Number of results in cereals showing		
		Yield depression	Yield equal to untreated	Yield significantly greater than untreated
24DB/MCPA/benazolin	i	0	6	4
	ii	0	6	4
MCPB/MCPA/benazolin	iii	0	3	3
	iv	0	4	1

i	24DB	24 ozs	MCPA	4 ozs	benazolin	3 ozs per acre
ii	24DB	48 ozs	MCPA	8 ozs	benazolin	6 ozs per acre
iii	MCPB	24 ozs	MCPA	4 ozs	benazolin	3 ozs per acre
iv	MCPB	48 ozs	MCPA	8 ozs	benazolin	6 ozs per acre

Work has continued in a number of overseas countries. In New Zealand benazolin alone has been used commercially to control Stellaria media and Cerastium glomeratum in grass/clover associations where these weeds are dominant and there is increasing interest in combinations of benazolin with other herbicides to obtain a broader spectrum of weed control.

In Switzerland, mixtures of benazolin with phenoxybutyric/phenoxyacetic acids as used in the United Kingdom, have been evaluated with successful results against Stellaria media and Galium aparine on undersown and direct sown grass/clover mixtures. Other uses are also being investigated.

In Denmark, Sweden and Holland where use of phenoxybutyric herbicides is not customary, work is proceeding on the addition of benazolin to low dosages of MCPA, again to broaden the weed control spectrum to include Stellaria media and Galium aparine.

In Germany and France the use of benazolin in admixture with other compounds is under study while in North America an extensive field screening programme is proceeding in an attempt to find other susceptible weeds.

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PROJECT N.A.E. 30 "THE EFFICIENCY OF WEED CONTROL IN CEREALS ON COMMERCIAL FARMS"

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Summary A national survey carried out by the N.A.A.S. during 1965-66 aimed at measuring the direct benefits in grain yield obtained following the application of herbicides in commercial cereal crops. The results indicate that the removal of present day weed competition in many cereal crops seldom leads to any significant yield increase in the standing crop. The major benefits obtained from spraying for weed control in cereals today are often connected with ease of harvesting and grain conditioning. The report highlights some of the deficiencies in terms of application techniques and emphasises the need for greater attention to the correct choice of herbicides to meet specific weed and crop growth stage requirements.

INTRODUCTION

At least three surveys have been carried out in the United Kingdom in an attempt to assess herbicide usage - first a pilot survey in North Oxfordshire[1] in 1959 followed by two joint Rothamsted/N.A.A.S. surveys in arable districts[2](1959-60) and grassland areas[3](1961-62). The prime object of these surveys was to measure the extent of herbicide usage and to record the weed problems encountered. They made no attempt at measuring crop yield responses following the application of herbicides.

A review of some twenty five experiments involving commercial treatments carried out by the N.A.A.S. during the period 1958 to 1964 indicated that the response to the application of herbicides in cereals was seldom significant in terms of yield increase. Since many of these experiments were laid down under optimum conditions it was questionable whether growers, often spraying under adverse conditions, were in actual fact obtaining grain yield benefits following the application of herbicides for broad-leaved weeds in cereals. As a result N.A.A.S. project N.A.E. 30 was launched and during the last two years more than one hundred and fifty cereal crops have been surveyed on commercial holdings in districts as far afield as Yorkshire and Devon but concentrated in the south and east. Basically the survey is concerned with measuring the efficiency of herbicides used for broad-leaved weeds in cereals including the measurement of effect on grain yield. In addition the recording of details of field techniques adopted by operators together with an attempt at recording spray machine efficiency was carried out on 44 farms in the south east during 1965. Data collated in 1966 has not been analysed at the time of writing but some of the preliminary results are discussed. A continuation of the survey, with some modifications, is planned for 1967.

THE SPRAYER AND FIELD TECHNIQUES

(South East - 44 sites in 1965)

A total of 12,850 cereal acres were being sprayed by the 44 machines in 1965 - an average of 290 acres per machine generally in the ratio of 2:1 spring to winter sown cereals. The majority of the sprayers were aged between three and nine years of age - mean five years old. Hoses were in an unsatisfactory condition on six machines and on nine sprayers the pressure gauge was faulty. Pumps had been replaced on twelve machines these being mainly gear type. The condition of filters was generally good, replacements being frequently installed. Nozzles were being replaced annually on seven machines but in the majority of cases the same set of nozzles, except for one or two replacements, were in use since purchase of the spray machine.

Speed of travel, which was tested in the field, ranged from 3 to 7 m.p.h. with twenty two machines travelling at 4 to 5 m.p.h.. Height of boom above the main crop foliage density, when using fan nozzles, varied from 10 to 23 inches with the majority set at 17 to 20 inches. Static tests of overall boom outputs showed these to be generally within two gallons variation from the intended output per acre but tests carried out on individual nozzle output showed a percentage variation ranging from ± 5 to ± 22 per cent from the mean output per nozzle calculated from intended (overall) output. Most machines were operating at 30 to 40 p.s.i. but there were five instances of pressure exceeding 50 p.s.i. at work. Only in eight fields was a field marking system employed, the majority of operators relying on cereal drills for guidance to avoid overlap. Few of the machines had an efficient anti-drip device fitted. Many of the operators half filled the tank before adding chemical but only in six instances was any attempt made to stir the contents before proceeding with spray application. Pre-mixing of herbicide in water before adding to a larger volume of water in the tank was done by only two spray machine operators. Whilst surveyors had been warned not to influence the techniques adopted a follow-up advisory letter pinpointed faults and suggested means of improvement. Where sites were revisited in 1966 it is pleasing to record that many of the suggestions for improved techniques in spraying cereals had been adopted.

WEED CONTROL EFFICIENCY - 1965

From a total of seventy three cereal crops surveyed in five N.A.A.S. regions in 1965 fifty four were spring barley. A study of weed populations in these fifty four barley crops showed that only at three sites did the weed counts exceed 30 plants per square foot. Stellaria media (chickweed), Polygonum aviculare (knotgrass), Veronica spp. (speedwell) and Sinapis arvensis (yellow charlock) were the dominant species. Twenty barley crops were sprayed with either MCPA or 2,4-D amine, another eighteen with mecoprop or dichlorprop and the remaining sixteen with more complex herbicide mixtures. Forty nine of the crops were sprayed before the fifth leaf had emerged on the main tiller and thirty one of these before the fourth leaf stage. Weed control efficiency was recorded on a scale 0-10, where 0 = no weeds remaining and 10 = weed density equal to that of unsprayed areas, some six to eight weeks after spraying. In the majority of cases a score below 3 was recorded and none exceeded a score of 5.

Six of the other nineteen cereal crops were spring wheat and in these similar weed control efficiency to that obtained in barley was noted. The remaining thirteen crops were winter wheat or oats. In general weed populations in winter wheat were below 20 plants per square foot often composed of numerous species and weed control scores below 2 were recorded in these crops MCPA being the main herbicide used.

CEREAL YIELDS 1965

In thirty two crops combine harvested yields were obtained from sprayed and unsprayed areas of minimum size 1/50 acre. The remaining forty one crops were sampled for grain yield just prior to harvest using a technique involving the cutting of four random one yard length of two adjacent cereal drills in each sprayed and unsprayed area of the crop. There was a minimum of two replicates per treatment at these sites. The small samples were threshed on a small peg drum incorporating a cleaner.

The results can be briefly summarised as follows:-

CROP	Number of sites 1965	Mean yield - cwt per acre UNSPRAYED	SPRAYED
Spring Barley	54	32.7	32.6
Spring Wheat	7	37.0	35.6
Winter Wheat	7	42.5	46.5

The distribution of yields from sprayed areas, compared to those from unsprayed areas (100), in all crops and in the major crop, barley, is shown in the histograms - appendices 1 and 2. Statistical examination of the results on barley shows that about a third of the variation in yields was due to experimental error.

The preliminary results from twenty seven cereal sites (W. Midland, S. West and S. East) in 1966 show a mean yield index of 101 for sprayed areas compared to 100 control.

REPEAT SITES 1965-66

In some cases the same areas of a field, cropped cereals in both years, were left unsprayed for the second successive year. Contamination by weed seeds was avoided at harvest but other weed distribution factors were beyond control. There were seven repeat sites in the South East and the total weed populations in the sprayed and unsprayed areas, as noted in May, were remarkably similar in both years. There was however a difference in weed species dominance in the sprayed area particularly where MCPA was used in 1965 - e.g. Stellaria media having replaced other more MCPA susceptible weeds. In two instances Sonchus arvensis (perennial sowthistle) had become a dominant weed in 1966 when few plants had been observed in 1965.

DISCUSSION

There was no general correlation between weed species or population with yield response in the 73 sites surveyed in 1965 with the exception of two sites where weed population, chiefly Sinapis arvensis, exceeded 65 plants per square foot and a significant yield increase was obtained. In general however weed populations seldom exceeded 30 plants per square foot and there were at least three dominant weed species present at each site. A third of the crops were sprayed with MCPA and often at quite high rates - above 18 oz a.i. per acre considering that many of the spring barleys were being sprayed sometime ahead of the 5 leaf stage. There were also instances of 2,4-D used alone or in mixtures at dosage rates above 8 oz a.i. per acre when the cereal crop was in the 3 to 4 leaf stage. These practices generally led to loss of grain yield compared to that harvested from unsprayed areas.

The results of the survey in 1965 and 1966 indicate that many cereal crops are being sprayed before the development of five leaves on the main tiller. This is undoubtedly due to the extent of the cereal spray programme connected with an increased cereal acreage today on many farms but it is also fair to comment that modern varieties of spring cereals develop a canopy of foliage which restricts penetration of spray droplets to weeds if the crop is allowed to develop to the five leaf stage before spray application. The degree of weed control obtained at many of the survey sites, as observed a few weeks post-spraying, could be classed as very satisfactory. However, in two wet seasons, the recovery of one or two species by harvest was noted at many sites and Stellaria media (chickweed) was the worst culprit in this respect. It should be stressed that there was no attempt at a quantitative assessment of the effect of weeds on harvest efficiency. Comments recorded at this stage at some sites did indicate that the presence of some weeds retarded the operation of combine harvesting particularly in the unsprayed areas.

In the majority of cases however the only significant observation at harvest was that relating to an increase of weed seeds and other foreign matter in the grain produced from the unsprayed areas and this contamination increased grain moisture content and hindered the operation of grain conditioning at the barn. There is need therefore to give much more attention to weeds that can be troublesome at harvest when selecting herbicides for weed control in cereals.

It is becoming increasingly evident that direct benefits resulting from the removal of broad-leaved weed competition in many cereal crops today are of small magnitude. Failure to continue with weed control measures could however alter this situation although observations at repeat sites in 1966 indicate that provided there is a maximum crop vigour a return to high weed density is unlikely to be a rapid process despite the absence of spraying. Quite obviously the major benefits resulting from weed control in cereals today are related to the ease of harvesting and conditioning of grain and in a situation where labour, power and machinery costs approximate to one third of the total cost of cereal production these benefits are of some importance. Speedier, earlier harvesting can also significantly improve the conditions necessary for the control of perennial weeds in stubbles and allow for a more determined effort in destroying the remnants of previous cereal crops to reduce the incidence of soil-borne and foliage diseases.

The results obtained in the 1965 survey also indicate the need for improvements in field techniques coupled with greater attention to the maintenance and calibration of spray machinery. Familiarity with the use of herbicides can very easily breed contempt for the precision required if modern weed control techniques are to contribute towards increased financial returns from crop production.

Acknowledgements

Grateful acknowledgement is made to Dr. D. A. Boyd, Rothamsted Experimental Station, for guidance on the conduct of this project and for the statistical analyses of the crop yield figures.

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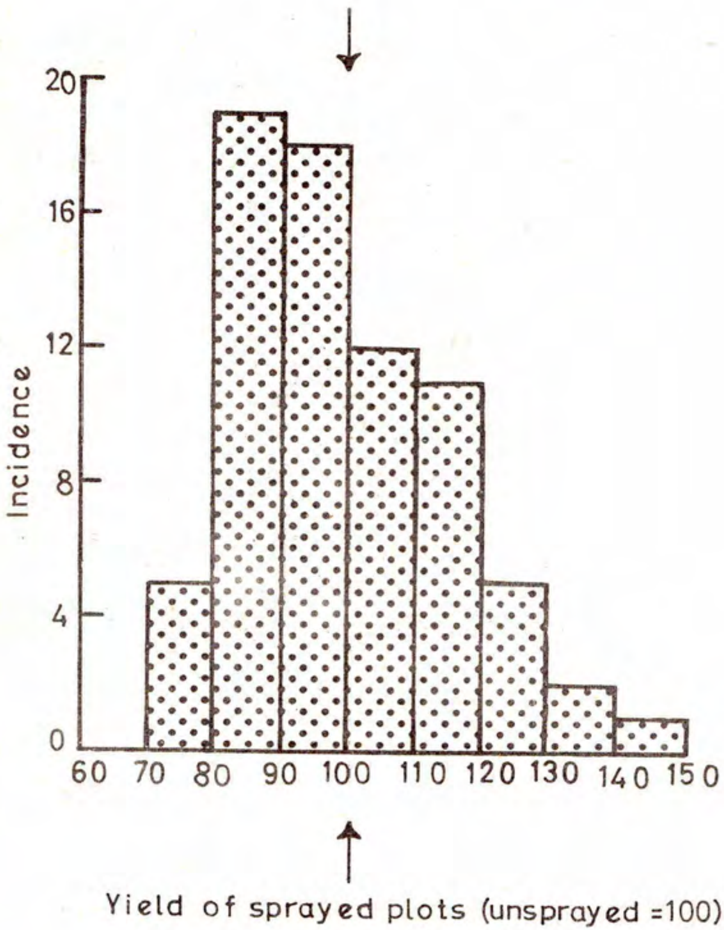
Appendix 1

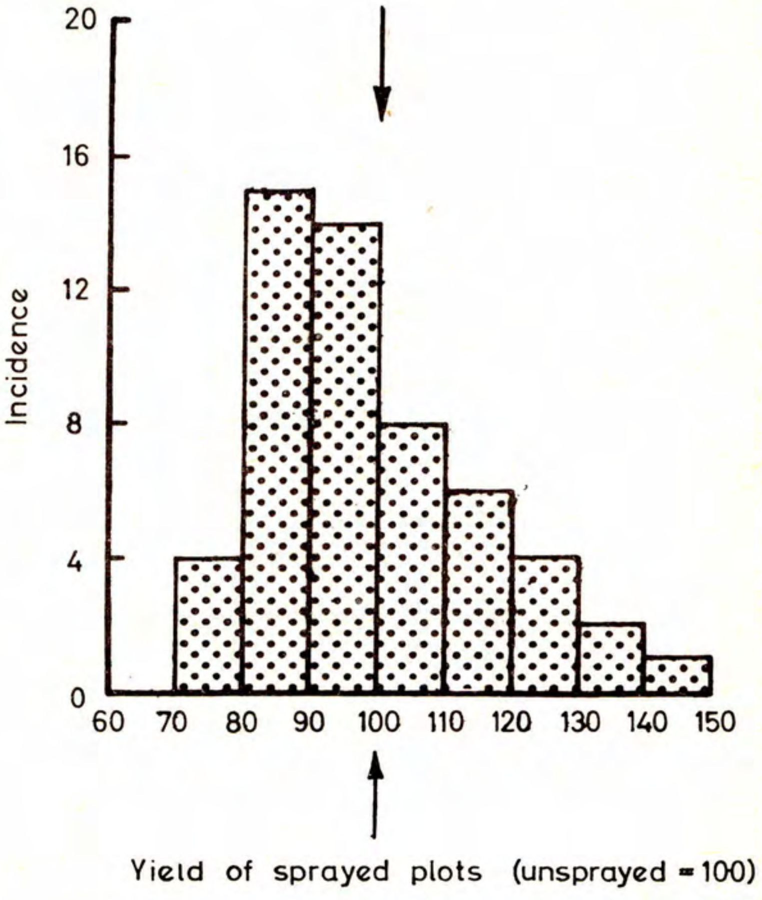
Distribution of variation of yield of sprayed plots compared with unsprayed plots

1965 all cereal crops - 73 sites



Distribution of variation of yield of sprayed plots compared with unsprayed plots.

1965 spring barley - 54 sites



THE CONTROL OF ALOPECURUS MYOSUROIDES (BLACKGRASS) IN WINTER WHEAT

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Summary In four experiments on winter wheat crops containing moderate to heavy infestations of *Alopecurus myosuroides* (blackgrass) and in one experiment on a relatively clean winter wheat crop, 15 different foliar or soil-acting herbicides were applied at logarithmically decreasing doses pre-drilling and incorporated, pre-emergence, early post-emergence or later post-emergence. Of the 30 different treatments, GS 14260 (4-ethylamino-2-methylthio-6-t-butylamino-1,3,5-triazine) applied pre-emergence was the most selective. No damage to the winter wheat was visible at doses below 6 lb a.i./ac and a dose of 2-3 lb/ac gave good control of blackgrass. A number of other herbicides seemed to merit further investigation.

INTRODUCTION

Barban, dichlobenil and tri-allate are herbicides which can be used for the control of *Alopecurus myosuroides* (blackgrass) in winter wheat but there are problems in the use of all these chemicals. For maximum selectivity, barban should be applied in mid-winter: at which time much winter wheat land is unsuitable for the use of tractor mounted sprayers; dichlobenil has proved unreliable in this country; and tri-allate needs incorporation, often a difficult operation on a typical winter wheat seed bed.

In Europe simazine has also been used on a fairly wide scale with some success but its selectivity is not adequate under all conditions.

Information from manufacturers (e.g. Fisons Pest Control in respect of methoprotryne and GS 14260) and greenhouse experiments at W.R.O. in 1965 had indicated a number of herbicides which might be used selectively for this problem. Therefore in the autumn of 1965 experiments were laid down to examine a total of fifteen herbicides on five different sites.

METHODS AND MATERIALS

Four of the experiments were on winter wheat crops at outside farms where infestations of blackgrass were expected. The soil at these four sites was heavy and 'cloddy' typical of that on which much of the winter wheat is grown in this country. The fifth site, used to check crop tolerance, was at W.R.O. Begbroke on a relatively clean crop with no blackgrass present. The soil was a light sandy loam and thus the effects of herbicides acting through the soil were expected to be at their most severe.

Applications were made at any of four different times:

(1) Immediately pre-drilling and incorporated with the soil by rotary cultivation,

(2) pre-emergence to soil surface (no crop or weed plants visible),

(3) early post-emergence (all crop plants visible, some of weed plants visible),

(4) later post-emergence (all crop and weed plants visible).

The equipment used was a Fisons Mini Logarithmic Sprayer, applying a volume rate of 28 gal/ac, using a matched pair of Bray fan jets size '0'. The half-dose distance was 5.5 yd and each plot was 22 yd x 1 yd. The experimental design was a randomised block, replicated twice, with a yard discard between each plot.

Incorporation of the pre-drilling treatments was by one pass of a small tined rotary cultivator, mounted on a Ransom's MG 40 tractor and working to a depth of approximately 4 in. The implement always worked up the logarithmic dose from the lighter to the more heavily treated end of the plot.

The herbicides used in these experiments and their formulation are listed below. All doses quoted in this paper are in terms of active ingredient.

Triazines

simazine	50% w.p.
methoprotryne (4-isopropylamino-6-(3-methoxypropylamino)-2-methylthio-1,3,5-triazine)	25% w.p.
GS 13528 (2-chloro-4-ethylamino-6-sec-butylamino-1,3,5-triazine)	50% w.p.
GS 14260 (4-ethylamino-2-methylthio-6-t-butylamino-1,3,5-triazine)	50% w.p.
GS 16065 (4-ethylamino-2-ethylthio-6-isopropylamino-1,3,5-triazine)	25% w.p.

Ureas

diuron	80% w.p.
norea (N'-(hexahydro-4,7-methanoindan-5-yl)-NN-dimethylurea)	80% w.p.
siduron (N-(2-methylcyclohexyl)-N'-phenylurea)	50% w.p.

Carbamates

barban	12% e.c.

Thiolcarbamates

tri-allate	40% e.c.
R 4572 (S-ethyl,NN-hexamethylene(thiolcarbamate))	72.28% e.c.

Benzonitriles

dichlobenil	50% w.p.
chlorthiamid (2,6-dichlorothiobenzamide)	75% w.p.

Miscellaneous

CP 31675 (α-chloro-6-t-butyl-o-acetotoluidide)	75% w.p.
D-263 (4,6-diisopropyl-1,1-dimethyl-5-indanylethylketone + 4,6-diisopropyl-1,1-dimethyl-7-indanylethylketone)	25% e.c.

The details of the site, date of treatment, stage of growth of the crop and weed, and the weed density are given in the Table 1. The figures for stage of growth and density are given as an average, with the range in brackets. Assessments were made after the blackgrass had set seed, by scoring on a scale of 0-10 (0 = No inflorescences present, 10 = indistinguishable from the adjacent paths) every 2.75 yd along each plot. At the four outside experiments, only the distances at which the crops appeared to be normal were noted, but at Begbroke the crop was scored for vigour on a scale of 0-10 (0 = complete kill, 10 = as untreated strip) at every 1 yd interval along each plot.

Table 1.
Details of sites, and stages of growth of A. myosuroides (blackgrass) and the crop at the time of treatment

			Stage of growth				
			Crop		Weed		
Site	No.	Date of spraying	No. leaves (main stem)	Height (in.)	No.leaves	Height (in.)	Density (No./ft^2)
Bishopstone	I	26.10.65	Pre-sowing	-	-	-	none
Bucks	II	5.11.65	Pre-em.	-	1-1.5	-	a few
Var. Capelle							
Sown-26.10.65	III	20.12.65	1-1.5	2.5-3	1-1.5	1-1.5	variable
	IV	17. 3.66	4.8(3.5-6)	-	3.5(2.5-6.5)	-	10(3-40)
Bucknell	I	20.10.65	Pre-sowing	-	-	-	-
Oxon	II	28.10.65	Pre-em.	-	-	-	-
Var.Marris Widgeon	III	14.12.65	1.5-2	-	1-1.5	-	numerous
Sown-21.10.65	IV	15. 3.66	4.5(4-5)	4	3.6(3-4.5)	2.5	Block I 13(3-27) Block II 41(25-72)
Northmoor	I	22.10.65	Pre-sowing	-	-	-	none
Oxon	II	29.10.65	Pre-em.	-	-	-	-
Var. Cappelle	III	15. 2.66	2	2.5-3	1	-	numerous
Sown-23.10.65	IV	18. 3.66	5(4.5-5.5)	-	4(3-5.5)	-	11(5-32)
Worminghall	I	-	-	-	-	-	-
Bucks	II	5.10.65	Pre-em. 10% em. at 0.5	-	-	-	-
Var. Capelle	III	15.10.65	1.5	3.4	1	-	a few
Sown-25.9.65	IV	14. 3.66	4.5(4-5)	-	v.uneven	-	v.uneven
W.R.O. Begbroke	I	25.10.65	Pre-sowing	-	-	-	-
	II	4.11.65	Pre-em.	-	-	-	-
Var. Capelle	III	21.12.65	1.5-2	-	-	-	none
Sown-25.10.65	IV	15. 3.66	4-6.5	5	-	-	none

RESULTS

Fig. 1, 2, 3 and 4 show the scores for the densities of blackgrass at each of the selected doses along the logarithmic plots at the four outside experiments. The dose below which the crop was apparently unaffected is shown as a single vertical line on each small graph. Each graph is a mean of two replicates. The figures for crop response obtained at Begbroke are shown in Fig. 5.

The treatment which consistently showed the highest degree of selectivity was the pre-emergence application of the triazine GS 14260. A dose of 2 lb/ac generally gave a 75-80% control of blackgrass but at no site was crop damage visible below a dose of 6 lb/ac. The treatments applied after crop emergence did not show the same degree of selectivity due to their greater effect on the crop but even so no damage was visible below a dose of 2 lb/ac on any of the experiments.

Among the other triazines methoprotryne was not as effective as GS 14260 pre-emergence but showed a greater degree of selectivity as a post-emergence treatment particularly when applied in March. The control of blackgrass by methoprotryne at this time was however more variable than the pre-emergence treatment with GS 14260. GS 16065 applied in March gave good control of blackgrass at 1.5 to 2 lb/ac but as the maximum dose applied was only 2 lb/ac there was little indication of the crop tolerance. Simazine and GS 13528 were very variable in their effects on the wheat and did not show sufficiently consistent selectivity. The selectivity of the two ureas, diuron and norea was also inconsistent. Siduron although safe on the crop was variable in its effect on blackgrass; unfortunately it was not received until rather late in the season and its most effective period may have been missed.

The benzonitrile herbicides dichlobenil and chlorthiamid did not show sufficient selectivity. Chlorthiamid was generally the more damaging to the crop.

CP 31675 applied pre-emergence was promising at first but the 1.5-2.0 lb/ac required for satisfactory control of blackgrass was marginal on the crop at Begbroke although on the other sites up to 3 lb/ac was tolerated. Barban gave a reasonably selective control at the two sites (Bucknell and Bishopstone) where it was applied in mid-December as is recommended. Elsewhere and at other times it was either ineffective or damaging to the crop. None of the other herbicides gave satisfactory control of the blackgrass.

DISCUSSION

Applied pre-emergence, the triazine GS 14260 was remarkable for the consistency of its activity on both blackgrass and winter wheat. Although all the 'outside' experiments were on so-called 'heavy' soils they varied from a heavy clay at Worminghall, where parts of the remainder of the field were waterlogged for considerable periods during the winter, to a clay over limestone brash at Bucknell and a heavy silt at Northmoor (soil samples were taken for analysis but unfortunately the data are not yet available). The selectivity of this herbicide was consistently high even in the crop tolerance experiment on the light sandy soil at Begbroke where no damage was visible at doses below 7 lb/ac. Simazine caused visible damage at 0.7 lb/ac and diuron at 1 lb/ac in this same experiment. The dose required to give good control of blackgrass was between 2 and 3 lb/ac, the slightly higher dose being required at Bishopstone. This may have been because a number of blackgrass seedlings had already emerged at the time the pre-emergence application was made.

The almost negligible effect of the pre-sowing applications of tri-allate and R 4572 is surprising particularly as tri-allate is being used successfully on a commercial scale, but may have been due to excessive incorporation. A rotary cultivator was used and this may have reduced the herbicide in the surface layers of the soil below the effective concentration level. Blackgrass plants generally arise from seed which is at or very near the soil surface.

On the other hand D-263 which was also relatively inactive may have been more effective if it had been mixed with the surface layers of the soil, as it is a relatively incoluble compound.

The treatments used in these experiments which would appear to merit further investigation are GS 14260 pre-emergence, methoprotryne post-emergence, siduron and CP 31675 pre-emergence and GS 16065 and GS 13528 applied either pre- or early post-emergence.

Acknowledgments

Thanks are due to Messrs. M.E. Thornton, J.A. Bailey and P.R. Collier for carrying out most of the experimental work, and the commercial firms for supplying the herbicides.

FIG.1. <u>Control of Alopecurus myosuroides in Winter Wheat (Cappelle) on plots sprayed logarithmically at various times of application</u>

<u>Site</u> - Bishopstone

(Scores for no. of inflorescences - 0=none, 10=as control)

<u>Dates of Application</u> I 26.10.65 II 5.11.65 III 20.12.65 IV 17. 3.66

<u>Vertical bar</u> Dose below which crop is normal

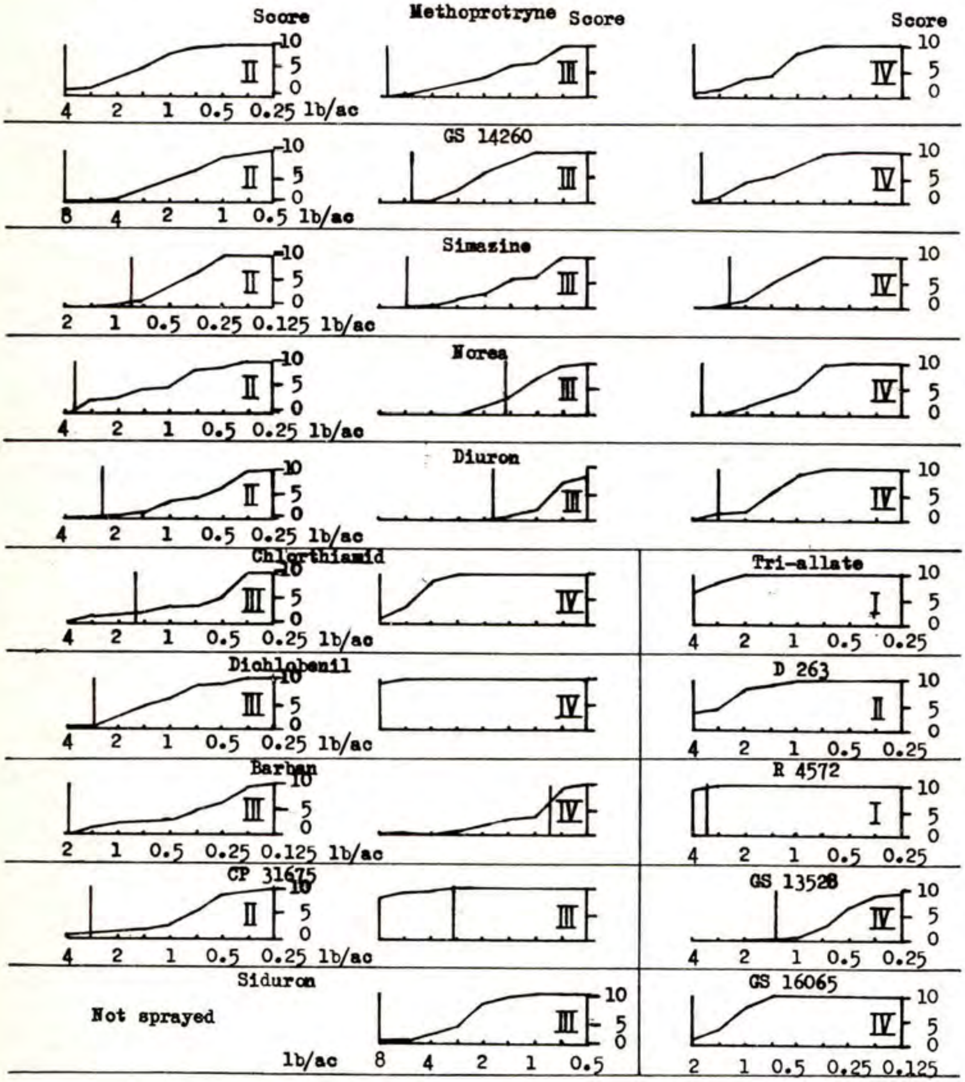


FIG. 2. Control of Alopecurus myosuroides in Winter Wheat (Marris Widgeon) on plots sprayed logarithmically at various times of application

Site - Bucknell

(Scores for no. of inflorescences - 0=none, 10=as control)

Dates of Application I 20.10.65 II 28.10.65 III 14.12.65 IV 15. 3.66

Vertical bar Dose below which crop is normal

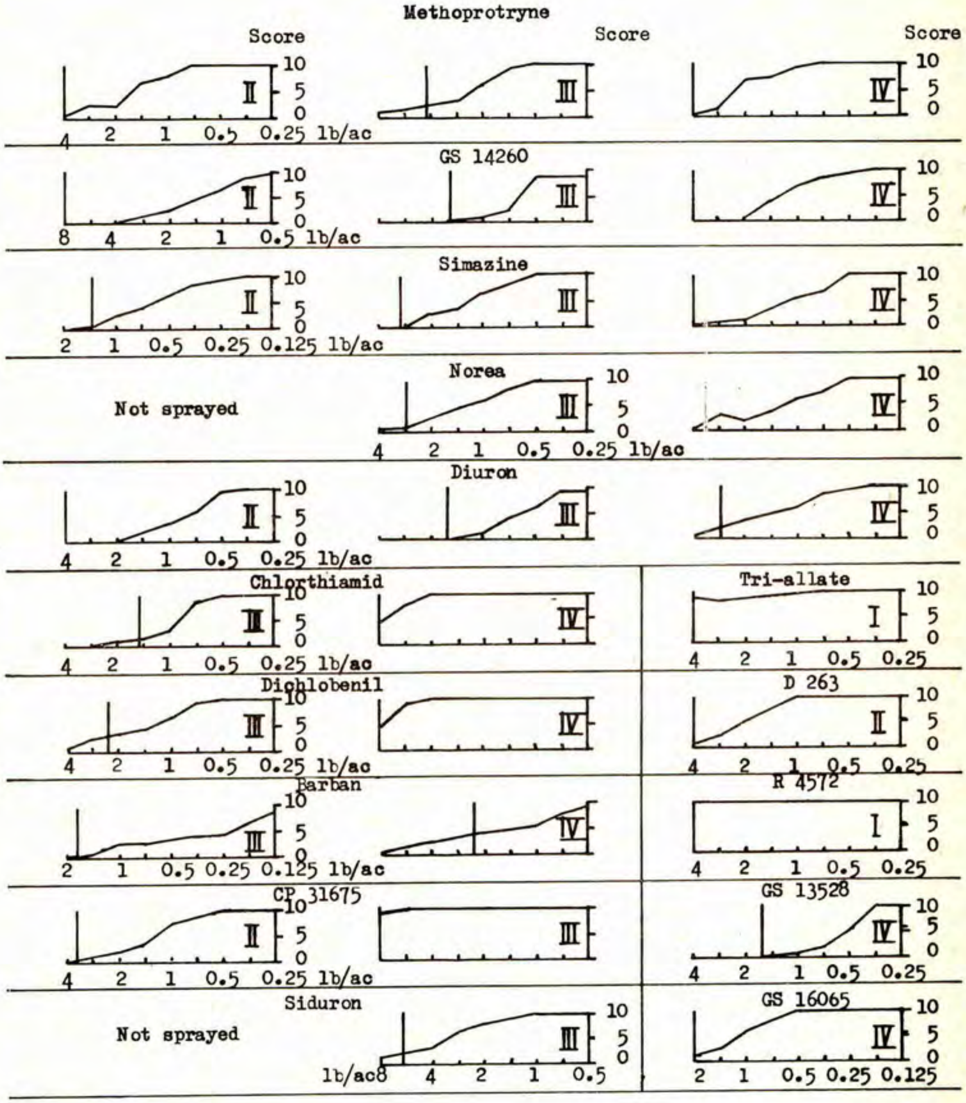


FIG. 3. Control of Alopecurus myosuroides in Winter Wheat (Cappelle) on plots sprayed logarithmically at various times of application

Site - Northmoor

(Scores for no. of inflorescences - 0=none, 10=as control)

Dates of Application I 22.10.65 II 29.10.65 III 15. 2.66 IV 18. 3.66

Vertical bar Dose below which crop is normal

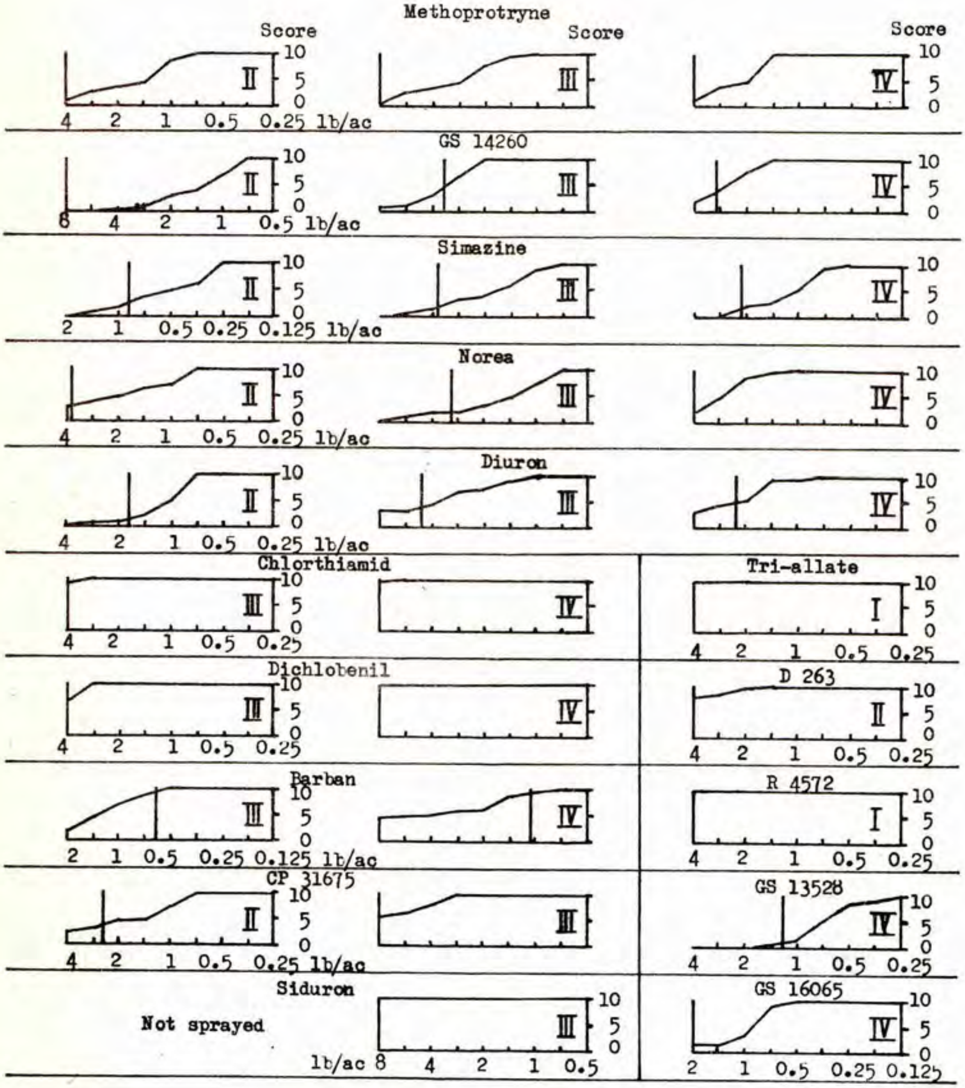


FIG. 4. Control of Alopecurus myosuroides in Winter Wheat (Cappelle) on plots sprayed logarithmically at various times of application

Site - Worminghall

(Scores for no. of inflorescences - 0=none, 10=as control)

Dates of Application: I not sprayed II 5.10.65 III 15.10.65 IV 14. 3.66

Vertical bar Dose below which crop is normal

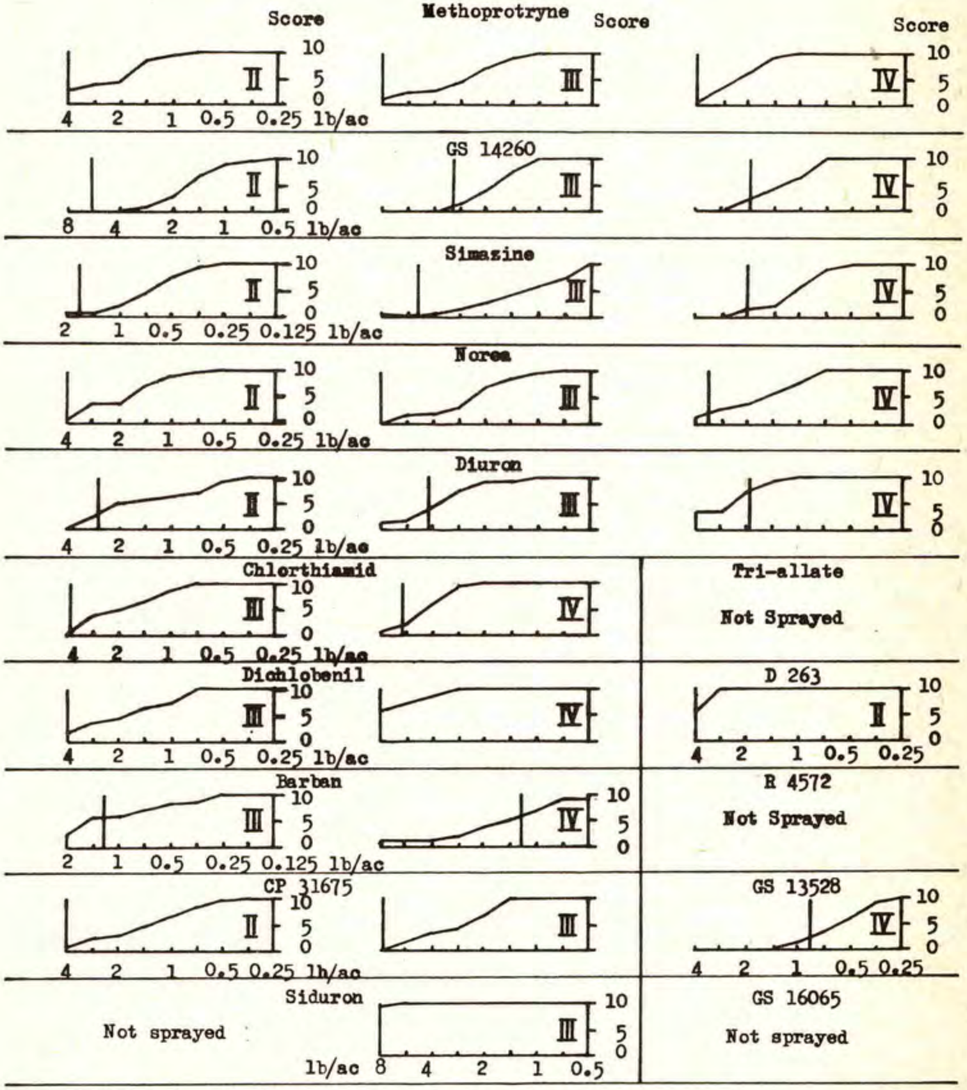


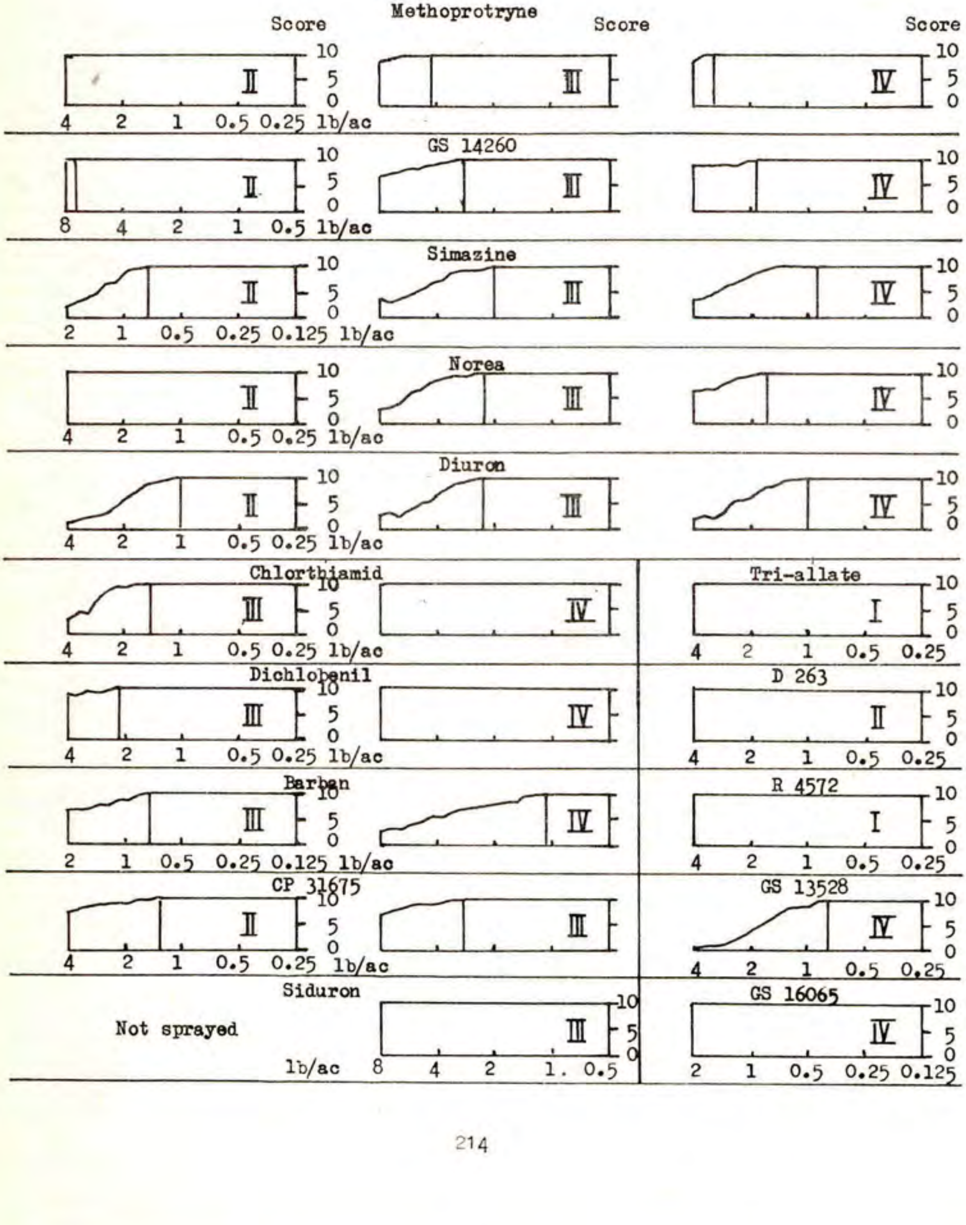
FIG.5. Susceptibility of Winter Wheat (Cappelle) to logarithmic doses of various herbicides applied at various times

Site - Begbroke

(Scores for no. of inflorescences - 0=none, 10=as control)

Dates of Application I 25.10.65 II 14.11.65 III 21.12.65 IV 15. 3.66

Vertical bar Dose below which crop is normal



ACTION OF SEVERAL HERBICIDES APPLIED PRE-EMERGENCE FOR CONTROL OF BLACKGRASS (*Alopecurus myosuroides* Huds.) IN WINTER WHEAT

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Summary Neburon and FW 925 (2,4-dichlorophenyl-4-nitrophenylether), used pre-emergence, have resulted in the destruction of blackgrass in winter wheat with a considerable safety margin, shown up by yield trials. However, the resistance of wheat was inferior on cloddy and capping soils. The efficiency of neburon was influenced more by the clay content of the soil than was the efficiency of FW 925.
BV 201 : 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone, has shown a more irregular behaviour, especially with regard to the crop.
The performance of triazine GS 14260 (2-methylthio-4-ethylamino-6 tert. butylamino-s-triazine) was satisfactory at rather high doses, which were not always absolutely selective.
The following is a consideration of the interest of pre-emergence treatments.

INTRODUCTION

In France, blackgrass occurs more and more frequently in winter wheat crops, which it infests either in autumn or at the beginning of spring. The weedkillers used for controlling it : dichlobenil and methoprotryne (1), are not well tolerated by the crops except after the beginning of tillering, in February or March, when soil moisture is sometimes too high to allow for efficient control.

Pre-emergence treatments on the other hand are more easily carried out and would have the advantage of limiting the weed competition at the earliest moment.

Actually several publications note the encouraging results obtained by preventive treatments (P. POIGNANT et al. ; D.H. MAC RAE and P. de SARJAS ; J. ROGNON and M. BALLACEY ; A. GAST et al. ; H. de VROEY ; 1965).

METHODS AND MATERIALS

The following products have been studied in 1966 :

- neburon : N-butyl-N'-(3,4-dichlorophenyl)-N-methylurea. Wettable powder, 50 % a.i.
- FW 925 : 2,4-dichlorophenyl-4-nitrophenylether. Emulsifiable solution, 25 % a.i.
- BV 201 : 1-(3,4-dichlorophenyl)3-methyl-2-pyrrolidinone. Emulsifiable solution, 25 or 18.75 % a.i.
- Triazine GS 14260 : 2-methylthio-4-ethylamino-6-tert. butylamino-s-triazine. Wettable powder, 50 % a.i.

Weed control trials :

Neburon and triazine GS 14260 were the subject of 22 weed control trials, and FW 925 of 24. Two trials, where the three products figured, were not infested by blackgrass but by *Lolium rigidum*. BV 201 was tested in 11 trials. Furthermore, FW 925 was associated with BV 201 in 5 trials.

Doses, in kg/ha a.i. :
Neburon : 2 - 2.5 - 3.75 - 5.
FW 925 : 1.5 - 2 - 3 - 4.
BV 201 : 3.75 - 5 - 7.5 - 10.
GS 14260 : 1 - 1.5 - 2.25 - 3.
FW 925 + BV 201 : 1.5 + 2 - 1.5 + 3 - 1.5 + 4 - 1.5 + 5.

Plot size : 30 m^2.

(1) called in France : méthotryne

The efficiency of treatments and the damage to the cereal have been estimated only visually.

Yield trials (table 1) :

Only neburon and FW 925 have been studied in yield trials : 8 for the first and 9 for the second product. The plot size was 75 or 80 m^2, and there were 6 replicates. One unsprayed plot was included per replicate.

Doses, in kg/ha a.i. :
FW 925 : 2 - 4 - 6.
Neburon : 2.5 - 5 - 7.5.

Three trials were more or less seriously infested by graminaceous weeds. As a matter of fact it is impossible to be sure, at sowing time, that the soil will remain clean.

All treatments were carried out with knapsack sprayers with constant pressure functioning with propane gas and equipped with a 2 m sprayboom. The spray volume was 500 l/ha. The treatments took place before the emergence of wheat and blackgrass, as soon as possible after sowing, that is, between 0 and 7 days in the majority of trials.

The trials have been conducted in the Paris Basin, central-eastern and south-western France.

Table 1.

Conditions under which yield trials were conducted

No.	Site	Soil type	Dates of sowing and spraying	Products	Observations
1	Essonne	loamy sand	26 and 28/10	FW 925-neb.	
2	Eure-et-Loir	sandy clay	23 and 23/11	" "	roughly prepared soil
3	Allier	calcareous clay	7 and 9/12	neburon	cloddy, moist soil
4	"	"	7 and 13/12	FW 925	" " "
5	Isère	silt	22 and 25/10	FW 925	
6	Tarn-et-Gar.	silty sand	28 and 29/10	neburon	some Apera s.v.
7	"	"	28 and 29/10	FW 925	many Apera s.v.
8	Loir-et-Cher	sandy clay	17 and 22/11	FW 925-neb.	
9	Eure	capping silt	13 and 26/11	" "	
10	Cher	stony calcareous clay	14 and 20/10	" "	Alopecurus 200 ears/m^2
11	Oise	silt	6 and 18/11	neburon	
12	Oise	humic silt	5 and 5/1/66	FW 925	

RESULTS

The germination of blackgrass was rather late, especially in the Paris Basin. The autumn emergence occurred frequently in December ; further emergences were spread over February to mid April.

The abundant rainfall in autumn and winter (69 mm above the average in Paris and 131 mm in Toulouse, from October to March) has probably facilitated the diffusion of the products in the soil. On the other hand, it is possible that the persistance of a concentration sufficient for destroying the latest emergence has been shortened by the rain.

Neburon :

Effect on blackgrass :

The effect of neburon on blackgrass appeared very slowly. Following some October and November treatments the control of weeds was not accomplished until the end of May.

However if the action of neburon, slowed down during the winter, is accelerated in higher temperature, it also seems to depend on soil moisture immediately after the germination of blackgrass. Indeed, the treatments were less efficient in winter barley crops sown 1-2 months before the wheat, and it was therefore about 6 weeks before they could benefit from the first important rainfall. It would seem that absorption of the chemical soon starts, but that the control of susceptible weeds is progressive thereafter.

The weed control was satisfactory ($\geqslant$ 90 %) in all trials except one in a very cloddy soil where the emergence of blackgrass occurred only in April ; but the dose required was much influenced by the clay content of the soil. This shows that the dose of 2 - 2.5 kg/ha of neburon has been sufficient on loamy sand, silty or chalky soils, while 3.75 kg/ha have been generally necessary on sandy clay or calcareous clay soils, and 5 kg/ha on one calcareous clay soil in the south-west.

Effect on other weeds :

The action of neburon on Lolium rigidum, L. temulentum and L. multiflorum was both faster and more complete than on Alopecurus. A very early emergence of L. rigidum was completely controlled before winter by the treatment. These grasses were sensitive to only 2 kg/ha of neburon ; however, few observations have been carried out in 1966. Apera spica-venti has been eliminated by 2 - 2.5 kg/ha, except on calcareous clay soil.

A great number of dicotyledons were controlled : Sinapis arvensis, Raphanus raphanistrum, Stellaria media, Papaver rhoeas, Ranunculus arvensis, Matricaria sp., Centaurea cyanus, Capsella bursa-pastoris, Cerastium arvense, Polygonum aviculare, Adonis sp., by 2 - 2.5 kg/ha ; Aphanes arvensis, Polygonum convolvulus, Viola tricolor and arvensis by 3.75 kg/ha. Their rapid decay contrasted noticeably with the slow reaction of blackgrass.

Resistant weeds : Veronica sp., Fumaria officinalis, Lamium purpureum, Galium aparine, as well as perennial species.

Effect on wheat :

In one weed control trial, the dose of 5 kg/ha had a slightly phytotoxic action, on capping silt with excessive moisture.

The results of yield trials are shown in table 2. On hastily prepared soils, cloddy and moist at sowing time, the treatment retarded the emergence of wheat seedlings and brought about an appreciable thinning at the highest rate. This effect has lessened afterwards ; it can be presumed that a more severe winter, on the contrary, would have aggravated it.

It must be said that wherever cultivation of the soil had been carried out carefully, even the rate of 7.5 kg/ha has not diminished the cereal yield.

In trial No. 10, which was weedy, the dose of 2.5 kg/ha destroyed the dicotyledons but only 50 % of the blackgrass ; the yield improvements registered with higher doses are noticeably proportional to the increase in herbicidal efficiency.

Furthermore, 2 trials concerning winter barley have not shown up any yield decrease from 7.5 kg/ha.

FW 925 :

Effect on blackgrass :

FW 925 had a much faster effect than neburon. However, the emergence of blackgrass was not always prevented ; in some of the trials, the seedlings started to grow before dying.

The dose of 2 kg/ha assured a sufficient weed control ($\geq$ 90 %) in 18 trials out of 22 infested by blackgrass. The result has been satisfactory in almost all cases with 4 kg/ha. FW 925 was a little less active on calcareous clay humic soils, on sandy clay soils and generally when the ground was very cloddy. However the texture of the soil does not seem to play the leading part.

Besides, the efficiency of the product has not lasted longer than March 15th for autumn applications ; this observation is valid only for climatic conditions of the year considered : heavy rainfall in winter and a temporary increase in temperature before the last emergence of blackgrass (mild February, high temperatures in the beginning of April).

Except in cases where the seed bed preparation left much to be desired and cases where blackgrass has appeared exceptionally late, FW 925 has shown a remarkably constant efficiency.

Effect on other weeds :

Lolium sp. and Apera spica-venti were destroyed by 1.5 to 2 kg/ha. Avena fatua was sensitive to the dose of 3 kg/ha when its germination did not occur for more than 6 - 8 weeks after the spraying.

Among the dicotyledons, only speedwell was eliminated, by 2 kg/ha of FW 925. A fairly satisfactory effect has been noticed on the one hand on Papaver rhoeas and on the other hand on Viola sp., but only following a very early germination of these species.

Effect on wheat :

In weed control trials, wheat tolerated well the dose of 3 kg/ha. At 4 kg/ha a thinning of the crop was observed in 8 trials out of 24, mainly on capping silty soils and on very cloddy soils. A comparable observation was made in certain yield trials (No. 2 and 4) ; but the disappearance of some seedlings has been compensated for by a better tillering, and the yield has been significantly diminished only by a dose of 6 kg/ha (table 2).

Trial No. 7 was infested by Apera spica-venti. Weed control was already satisfactory at the first rate and, since no difference has been observed between the yields, it can be concluded that the treatment is harmless to the crop. In the same way, in No. 10 trial, the yield increase achieved with 2 and 4 kg/ha does not seem impaired by the application of a higher dose.

On the other hand, the resistance of winter barley to FW 925 has proved very inferior to that of the wheat.

BV 201 :

Effect on blackgrass :

The dose of 10 kg/ha was always satisfactory, even with a very late spring germination. The dose of 5 kg/ha gave satisfactory results in 8 trials and the dose of 7.5 kg/ha in 10 trials out of 11.

Table 2.

Yield trials results

The yields are expressed in % of the yields of untreated controls.
Underlined figures differ significantly (P = 0·05) from control yields.

No.	FW 925			neburon			CV	l.s.d.	Control yield
	2	4	6	2.5	5	7.5	%	(0·05)	(q/ha)
1	103.6	103.3	103.4	104.9	103.2	102.8	3.07	NS	58.4
2	105.4	94.8	84.4	102.3	95.8	74.8	7.74	8.56	38.8
3				96.5	96.1	87.8	3.75	4.38	53.2
4	99.8	98.4	89.2				4.09	4.84	51.5
5	111.7	103.7	95.7				8.00	10.13	49.0
6				104.7	110.4	107.2	5.90	NS	39.9
7	122.2	121.9	121.6				6.00	8.60	37.5
8	101.5	103.5	101.5	99.0	101.0	96.1	5.17	NS	50.7
9	103.6	100.5	102.0	104.4	110.6	94.6	9.74	NS	28.8
10	125.3	134.7	130.0	148.2	162.5	180.3	8.89	14.70	23.2
11				103.5	102.7	99.9	2.00	2.50	47.4
12	104.6	101.7	100.0				5.66	NS	42.8

Effect on other weeds :

Effects of BV 201 on other graminaceous weeds have not been studied. The control of Sinapis arvensis, Stellaria media, Chenopodium sp., Centaurea cyanus, Aphanes arvensis was generally obtained with 5 kg/ha ; that of Ranunculus arvensis and Matricaria sp. with 7.5 kg/ha. The behaviour of Polygonum sp. can be linked with their particularly late germination.

Effect on wheat :

Yield experiments have not been carried out with BV 201. The first sign of toxicity to cereals has occurred at a dose of 7.5 kg/ha on cloddy and on chalky soils. Quite significant crop toxicity has occurred with 10 kg/ha in 4 out of 11 trials ; the yield loss has been estimated at 35 % on a sandy clay soil where other products have been tolerated much better.

Triazine GS 14260 :

Effect on blackgrass :

The doses of 1 and 1.5 kg/ha were insufficient. With 2.25 kg/ha, the efficiency was satisfactory in 15 trials, and with 3 kg/ha in 18 trials out of 20. It was lower on a very cloddy soil and in cases of late appearance of blackgrass. A high clay content has also been unfavourable.

Effect on other weeds :

Lolium rigidum was controlled by 1.5 kg/ha in one trial. The elimination of L. multiflorum required 2.25 kg/ha after an early germination, while it was still incomplete with 3 kg/ha after a spring emergence.

Apera spica-venti was susceptible to doses ranging from 1 to 2.25 kg/ha.

The persistence of the product was not always sufficient to hinder the germination of dicotyledons. Sinapis arvensis, Raphanus raphanistrum, Stellaria media, Papaver rhoeas, Capsella bursa-pastoris, Centaurea cyanus were destroyed. Irregular results were obtained with Veronica sp., Matricaria sp., Viola sp., Ranunculus arvensis and Fumaria officinalis. Galium aparine, Polygonum aviculare and P. convolvulus were resistant in all cases.

Effect on wheat :

Triazine GS 14260 was not the subject of yield trials. A distinct toxicity was observed in one trial with 2.25 kg/ha and in 5 trials out of 22 with 3 kg/ha. In question were capping soils and one chalky soil. The damage suffered by the crop seemed to depend more on soil structure than on its physical composition.

The minimum dose necessary for the destruction of blackgrass having been 2.25 kg/ha, it would be instructive to know the reaction of wheat to doses ranging from 4 to 4.5 kg/ha. As a matter of fact, the range of efficient doses is reduced more here than for the other compounds and it is difficult to assess the margin of safety.

DISCUSSION

In the different trials, pre-emergence applications have been followed up by applications at the 1 - 3 leaf stage of blackgrass. It has been confirmed for the four products tested, that the first technique was the best. For neburon, because of its lower efficacy in post-emergence ; for BV 201 and triazine GS 14260, because of the lower resistance of wheat ; for FW 925, because of both of these disadvantages.

Flexibility of employment :

Blackgrass occurs in almost all wheat growing areas in France, under different soil types and under different climatic conditions. It would therefore be desirable for weedkillers efficient against blackgrass to be used under as many different conditions as possible.

By adapting the dose to the clay content, and probably to organic matter content of soil, neburon can satisfy this requirement to the extent where the cost of treatment is not concerned. It is however important that a protracted draught should not follow the sowing, especially in the mediterranean area.

With FW 925, the dose of 2 kg/ha can be retained in most situations. However, very late germinations of blackgrass may not be controlled by this treatment.

These two herbicides show a very satisfactory selectivity with regard to winter wheat. Nevertheless it is convenient not to use them on very cloddy, roughly prepared soils and also not on capping soils. Compaction of the soil and excessive moisture interfere with germination of seeds and with growth of seedlings ; the effect of the products, whose absorption is made easier by the moisture of the soil, is then injurious and a thinning of the crop is to be expected. If the winter is not very severe, the wheat quickly regains normal vigour and the yield is not affected after all.

The use of triazine GS 14260 presupposes the adjustment of the dose to the nature of soil, as for the other triazines. Its persistence has sometimes been insufficient to control blackgrass emergence in spring. The destruction of blackgrass has been obtained with doses higher than the dose which had been presumed efficient ; it would therefore be premature to make a conclusion as to its selectivity, which seems to be a limited one with regard to winter wheat under French conditions.

Table 3, drawn up from results of 20 weed control trials, comparing neburon, FW 925 and triazine GS 14260, shows that visible toxicity of this last product has been noted nearer the herbicidal dose than for the other two products. It must be pointed out that the symptoms observed would not necessarily have brought about a yield reduction ; only their frequency should be considered.

As to BV 201, it has proved more irregular in behaviour than the other products. Its efficiency has been fairly constant but it has sometimes shown a sudden and unexplained phytotoxicity.

Advantages and disadvantages of pre-emergence treatments :

Preventive treatments are not used in France as yet for weed control in wheat crops. Now, in areas infested by blackgrass the probability of autumn or spring emergence is high. For example, of all weed control trials carried out in pre-emergence only one had to be eliminated because of total absence of graminaceous weeds, while 3 yield trials on soils reputdly non-infested have been overgrown either by Apera or by blackgrass. Some products however may remain without effect on April germinations.

Table 3.

Frequency of successes and failures registered with the 4 weedkillers.

Remark : Only trials where all products have been employed under same conditions were taken into account.
Treatments having an efficiency ⩾ 90 % have been noted as efficient ; those that have caused a visible depressive effect > 10 % have been considered as toxic.
The proportion of doses is 1/1.5/2.

Products and doses (kg/ha)	1st dose		2nd dose		3rd dose		Number of trials
	Eff.	Tox.	Eff.	Tox.	Eff.	Tox.	
neburon (2.5 - 3.75 - 5)	12	0	18	0	19	1	20
FW 925 (2 - 3 - 4)	17	0	18	0	18	7	20
GS 14260 (1.5 - 2.25 - 3)	3	0	15	1	18	4	20
BV 201 (5 - 7.5 - 10)	4	0	7	2	8	3	8

Owing to their extended and durable effect on many broad-leaved weeds, treatments with neburon are never useless, even if the graminaceae are less abundant. Triazine GS 14260 and BV 201, applied in autumn, have had a much more aleatory effect on dicotyledons.

FW 925 is much more specific. Besides annual grasses it destroys only speedwell. Possibly owing to the short persistence of the chemical, the control of speedwell is perhaps due to its very early appearance before winter as compared with other weeds ; the more so since FW 925 applied post-emergence has a less restricted herbicidal activity.

Therefore the elimination of blackgrass in autumn could result in a denser stand of dicotyledons in the crop in spring. The cereal, free from blackgrass competition, will prove stronger, but a treatment against the dicotyledons should complete the pre-emergence application.

The association of FW 925 either with neburon or with BV 201 can be considered. The first formula, provided a compatibility exists between the two chemicals, would fill in the gap left by neburon in the control of speedwell. The second formula has been tried ; with respectively 1.5 and 3 kg/ha of FW 925 and of BV 201 the result was satisfactory.

FW 925 and neburon differ furthermore by their speed of action. It would be useful to ascertain whether the early disappearance of blackgrass, as assured by FW 925, is economically more advantageous than its elimination only after the winter. Trials will be conducted in 1967 for this purpose.

Acknowledgements

We express our gratitude to P. Albrespy, M. Ballacey, A. de Butler, J. Garon, J. Maumené and M. Maynadier, who have actively participated in carrying out these experiments.

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Research Summary

PRE-EMERGENCE CONTROL OF BLACKGRASS AND BROAD-LEAVED WEEDS IN WINTER WHEAT WITH 2-METHYLMERCAPTO-4-ETHYLAMINO-6 TERT. BUTYLAMINO-S-TRIAZINE (GS 14260)

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INTRODUCTION

The possibility of using triazines for pre-emergence weed control in cereals, particularly for the control of blackgrass (Alopecurus myosuroides) has been explored for several years. The results indicated that only a triazine of exceptional selectivity would prove reliable enough for practical use.

In 1964, while testing new triazines synthesised by J.R. Geigy S.A., the authors found that 2-methylmercapto-4-ethylamino-6 tert. butylamino-s-triazine (coded GS 14260) was markedly more selective to wheat pre-emergence than other closely related 2-methylmercapto-triazines (for instance, prometryne or ametryne).

Research on GS 14260 was therefore intensified with the following objectives:

a) to confirm in repeated and more detailed experiments the finding of the superior selectivity of GS 14260

b) to assess the optimum dose and the reliability of performance in relation to environmental factors as well as the effect of GS 14260 on crop yield.

Details of the results of three years' research work (some 150 greenhouse and field experiments) will be published in Weed Research. Only a brief outline is presented in this Research Summary.

I SELECTIVITY OF GS 14260

Repeated experiments under a range of conditions (greenhouse and field) conclusively confirmed that GS 14260 in pre-emergence applications was safer to wheat than related triazines while being only slightly less active on broad-leaved and annual grass weeds including blackgrass. For GS 14260 the selectivity index (ratio of maximum tolerated to minimum effective dose) for the control of blackgrass in wheat was at least twice the corresponding values for ametryne, prometryne and methoprotryne (G 36393).

The selectivity of GS 14260 between winter wheat and several broad-leaved weeds (for instance Stellaria media, Tripleurospermum maritimum, Veronica persica) was even higher and such weeds were well controlled by much lower rates than were needed for blackgrass control. Galium aparine and Veronica hederifolia were found to be resistant.

Experiments on soil incorporation of different formulations of GS 14260 showed no advantage of incorporation over surface application. With granular formulations selectivity was not reduced but a higher dose was needed for the same level of activity. No differences in tolerance to GS 14260 were found in wheat variety experiments.

II OPTIMUM DOSE, RELIABILITY OF PERFORMANCE AND EFFECT ON YIELD

100 winter wheat experiments were sprayed in the autumn of 1965 in blackgrass infested areas in 14 counties. GS 14260 was applied at 6 doses ($\frac{1}{2}$ to 8 lb a.i./ac) in 2 replications on plots measuring 10 yd x 2 yd. Blackgrass infestations occurred on 53 sites. Blackgrass control and crop response were assessed visually. The 26 most even experiments were harvested.

The <u>optimum dose</u> was found to be approximately 2 lb a.i./ac with no crop damage occurring in any of the 100 experiments at this rate.

The <u>reliability of blackgrass control</u> at 2 lb/ac is shown in the following frequency distribution.

% blackgrass reduction	Number of experiments Assessment - March 1966
90 - 100	44
80 - 89	5
70 - 79	3
60 - 69	0
50 - 59	1
below 50	0
	53

The relative activity of GS 14260 in the 100 soils was estimated in a greenhouse experiment (6 doses, 3 replications per soil) on 2 test species (mustard and barley). The data on the relative 'greenhouse activity' as well as the corresponding data on 'field activity' were subjected to computer analysis in an attempt to find a possible relationship between activity and soil properties (for instance clay, silt, sand, organic carbon) or other environmental factors (for instance sowing and spraying dates, moisture status in the field and clod size).

A negative correlation was found between clay content and 'greenhouse activity' but no significant correlation occurred with 'field activity'. This lack of correlation under field conditions may be due to a compensating effect of adsorption (increasing with clay and humus content) and leaching under prolonged winter rainfall conditions (decreasing with higher clay content). No clear correlation was found between greenhouse or field activity and any other single environmental factor. However, field observations showed a reduction of activity on blackgrass in heavily waterlogged soil.

The <u>residual activity</u> of GS 14260 is short and at the suggested rate is unlikely to exceed 2 - 3 months. There is therefore no risk of damage to succeeding crops but on the other hand spring-germinating blackgrass or broad-leaved weeds are not controlled. When winter wheat is drilled after mid-November, both crop and blackgrass may be very slow to emerge. Under these conditions much of the GS 14260 may have become inactive by the time it is needed.

<u>Yield data</u> were obtained from 4 replicated experiments in 1964/65 and from 26 experiments in 1965/66. The latter experiments were selected from 53 blackgrass infested experiments solely on the basis of evenness of blackgrass and crop. The following table summarises the results obtained.

GS 14260 lb/acre a.i.	% of untreated		Yield difference from untreated - cwt/acre	
	1965 Mean of 4 experiments	1966 Mean of 26 experiments	1965 Mean of 4 experiments	1966 Mean of 26 experiments
½	110	100	+ 2.1	0.0
1	117	111	+ 4.0	+ 2.9
2	131	123	+ 7.3	+ 6.1
4	130	122	+ 5.7	+ 6.1
8	-	91	-	- [illegible].3

Research Summary

EFFECT OF SEED-BED PREPARATION ON THE WEED FLORA OF SPRING BARLEY

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Blackett (1965) showed that the method of seed-bed preparation affected the weed flora of Spring and Autumn cereals. As part of an experiment on minimum cultivation techniques for Spring Barley, started in 1964, the effect of 3 different cultivation treatments on the weed flora was studied.

METHODS AND MATERIALS

The experiment is on two sites. Site 1 ("Grassland") was in ley 1958-1964; Site 2 ("Arable") was in Barley 1956-1964. Three methods of seed-bed preparation are compared: (a) Normal cultivation (herbicides for weed control in crop only); (b) No cultivation (herbicides for control of surface vegetation and weeds); (c) Minimal cultivation (herbicides as (b), but rotovated to create shallow tilth). There are two levels of nitrogen application and 3 replicates.

The Grassland site was sprayed with Paraquat at $1\frac{1}{2}$ lb a.i./ac. in October 1964 and at $\frac{1}{4}$ lb a.i./ac. in February 1965. The Arable site was sprayed in March 1965 with a 50/50 mixture of Diquat and Paraquat at $1\frac{1}{2}$ lb a.i./ac. Normal cultivation plots were ploughed in February and minimal cultivation plots were rotovated in March. Rika Barley at 140 lb/ac. was drilled by unmodified corn drill on 1st April. Fertilizer at rates of 50 units P_2O_5 and K_2O and either 20 or 60 units N/ac. was applied.

Weed counts or botanical analyses were made using randomly placed 1' square quadrats: (a) Before spraying; (b) 5 weeks after drilling; and (c) At harvest.

The Barley was sprayed with either 2.4.D (0.44 lb a.e./ac.) or Mecoprop (2.4 lb a.e./ac.) in May on the Grassland and Arable sites, respectively.

RESULTS AND DISCUSSION

Grassland Site

Original sward was Ryegrass/Agrostis with large amounts of Cocksfoot and Brome. Autumn application of Paraquat gave a good kill, but recovery of Cocksfoot and clover occurred. The Spring application was slow-acting but gave good kill of all species.

Five weeks after drilling, *Agropyron repens* and *Agrostis stolonifera* were the dominant grasses and *Sinapis arvensis* the dominant broad-leaved weed. Cultivations, either by ploughing or rotovation, increased the number of broad-leaved weeds (Table 1). Ploughing decreased grass infestation. Nitrogen level did not affect the density of broad-leaved or grass weeds. Grass weeds common to all treatments included: *A. repens*, *A. stolonifera* and *Phleum pratensis*. Broad-leaved weeds common to all treatments included: *S. arvensis*, *Fumaria officinalis*, *Trifolium repens*, and *Stellaria media*. *Urtica dioica*, *Cirsium arvense*, *Vicia sativa* and *Potentilla anserina* were confined to no cultivation plots, and *Veronica chamaedrys*, *Polygonum aviculare* and *P. persicaria* to cultivated plots.

At harvest, *A. stolonifera* and *Alchemilla arvensis* were the dominant weeds, *S. arvensis* having been almost completely checked by 2.4.D. The density of grass weeds was lowest on cultivated plots, with no significant difference in broad-leaved weeds. Nitrogen decreased weed densities, presumably by increasing competition from the Barley.

Arable Site

The original stubble contained S. media, V. chamaedrys, A. stolonifera and A. repens. Spring application of Diquat/Paraquat mix gave good kill of all species.

Five weeks after drilling, S. media and V. chamaedrys were dominant. A. stolonifera and A. repens were the commonest grass weeds. Broad-leaved weeds common to all treatments included S. media, V. chamaedrys, P. persicaria, P. aviculare, Chenopodium album, Mentha arvensis, Anthemis cotula and V. dioica. Sonchus oleraceus and Galeopsis tetrahit were only present on cultivated plots. Cultivation increased broad-leaved weed numbers but ploughing decreased grass infestation. Nitrogen had no effect on weed densities.

At harvest, A. repens and A. stolonifera were the dominant weeds. Spraying with Mecoprop had almost completely checked S. media and V. chamaedrys. Broad-leaved weeds were most numerous on cultivated plots, grass weed populations were unaffected by cultivation. Nitrogen decreased populations of both broad-leaved and grass weeds.

Five weeks after drilling, the Grassland site had significantly higher population of grass weeds but lower population of broad-leaved weeds than the Arable site. At harvest, however, no differences between sites in grass weed populations could be found, although broad-leaved weed populations remained significantly higher on the Arable site.

References

BLACKETT, G.A. (1965) 2nd Paraquat Symposium (Plant Protection Ltd.), Cranfield Bedfordshire. Dec. 14th & 15th, 1965.

Table 1.

Weed counts 5 weeks after drilling (1) and at harvest (2).

Number/ft.^{2} transformed to log (x+1).

	Broad-leaved weeds			Grass weeds		
	No cult.	Minimal cult.	Normal cult.	No cult.	Minimal cult.	Normal cult.
(1) Mean of sites	1.06	1.47	1.61	0.85	0.82	0.34
	S.E. = ± 0.028 (d.f. = 8)			S.E. = ± 0.025 (d.f. = 8)		
(2) Grassland site	0.70	0.58	0.59	32.16*	23.55	15.28
Arable site	0.80	1.16	1.12	24.86	28.82	23.28
	S.E. = ± 0.031 (d.f. = 8)			S.E. = ± 1.906 (d.f. = 8)		

* % cover, arc-sine transformation.

THE INTERACTION OF CYCOCEL* 2-CHLOROETHYLTRIMETHYLAMMONIUM CHLORIDE AND NITROGEN TOP DRESSING ON THE GROWTH, LODGING AND YIELD OF WHEAT

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Summary Further experimental work is described with CYCOCEL 2-chloroethyltrimethylammonium chloride, a plant growth regulant, a product used to prevent lodging in wheat. Twelve trials were carried out in 1965 and 1966 to examine the effects of different levels of CYCOCEL sprayed at growth stage 6 in conjunction with different levels of nitrogen top dressing on the stem and internode length, lodging and grain yield in spring and winter wheat varieties. The best results were obtained using a dose of 1.0 lb a.i. per acre on spring wheat and 1.5 lb a.i. per acre on winter wheat. Where lodging occurred in June and to a lesser extent in July and August treatment with CYCOCEL was associated with yield increases as a result of prevention or reduction of lodging. When no lodging occurred there was no effect of CYCOCEL on yield except at one site where a significant reduction occurred. These trials did not demonstrate any increase in yield when nitrogen top dressing was increased above the normal level.

INTRODUCTION

One of the factors which has prevented the application of high levels of nitrogenous fertiliser to wheat is the increased tendency to lodge of crops so treated, thus losing the potential yield increase that the higher levels of nitrogen might bring. Although lodging is not the only limiting factor to the utilisation of an increased nitrogen application, it seemed likely that if lodging could be reduced or eliminated, then levels of nitrogen top dressing could be increased above normal and an increased grain yield resulting from the application could be harvested. The properties of CYCOCEL 2-chloroethyltrimethylammonium chloride (also referred to as chlormequat, CCC and chlorocholine chloride) as an agent for shortening and strengthening the stem of wheat have already been widely reported. Sturm and Jung (1964) applied CYCOCEL plant growth regulant with nitrogen top dressing at rates up to 20 to 30 kg N/ha. Where lodging occurred on plots without CYCOCEL, treatment with the growth regulant resulted in an increase of 12.1 - 13.7 kg of wheat grain per kg of extra N compared with 7.1 kg for plots without CYCOCEL. Geering (1965) stated that the improved resistance to lodging produced by treatment with CYCOCEL allowed a higher nitrogen application rate to be used than was formerly practicable. This combination of treatments lead to an increased plant density in eight field trials and increased grain yields by an average of 15%.

Trials in the United Kingdom in 1964 demonstrated the advantages of using CYCOCEL on the winter wheat variety Cappelle Desprez (Caldicott and Lindley, 1964). Depressions in yield due to lodging were avoided. Where higher than normal levels of nitrogenous fertiliser were applied yield increases were recorded on plots treated with CYCOCEL and lodging was reduced or eliminated. Further work was required to establish the response of selected winter and spring wheats to different rates of CYCOCEL in relation to different levels of nitrogenous fertiliser as a top dressing. Trials were laid down in 1965 and 1966 adopting a 3 x 3 factorial design with three levels of CYCOCEL and three levels of nitrogenous top dressing to observe possible interactions between CYCOCEL plant growth regulant and nitrogen on stem and internode length, lodging and yield.

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METHODS AND MATERIALS

In 1965 eight trials were laid down by Cyanamid of Great Britain Limited on one spring (Opal) and three winter wheat varieties (Cappelle Desprez, Rothwell Perdix and Professeur Marchal); an identical trial (65/4) was carried out on Cappelle Desprez winter wheat by J. W. Chafer Ltd. and the result of this trial is reported here. The size of plots in all trials was eight yards wide and twenty-five yards long. The lay-out was two replicates of nine plots lying alongside each other but with a ten-yard wide strip of untreated crop between them. The plots within each replicate were separated from each other by a two-yard wide strip of untreated crop.

The levels of CYCOCEL applied to the winter varieties were 0, 1.5 and 2.5 lb a.i. per acre. On the spring variety Opal, lower doses of 0, 1.0 and 2.0 lb a.i. per acre were applied.

The CYCOCEL plant growth regulant used in these trials was a 50% aqueous solution of 2-chloroethyltrimethylammonium chloride and was applied in 50 gallons of water per acre with the addition of AGRAL* 90 wetting agent at 0.1%. A small boom sprayer was used in eight trials and a tractor mounted sprayer was used in trial 65/4. The top-dressed nitrogen doses applied on mineral soils were 0, 80 and 160 units per acre. On peat soils with a high natural nitrogen content the levels were 0, 80 and 120 units per acre. On two mineral soil sites due to accidental dressing with nitrogen by farm staff, the N_0 and N_1 rates had to be adjusted. Thus on trial 65/3 the nitrogen levels were N_0 = 60 units, N_1 = 120 units and N_2 = 160 units, and on trial 65/6 the nitrogen levels were N_0 = 80 units, N_1 = 120 units and N_2 = 160 units. The type of nitrogenous fertiliser used in eight trials was a granular preparation containing 21% nitrogen and was applied to the plots by means of a tractor drawn "New Idea" fertiliser distributor covering an eight-foot swath. Applications were made in early April at sites 65/1, 2, 3, 5, 7 and 8 but was delayed by bad weather until late April or early May at sites 65/6 and 65/9. At trial 65/4 a liquid nitrogen fertiliser containing 24% nitrogen was applied on 1st April.

In 1966 three trials were laid down identical in design and layout to those carried out in 1965. These trials covered two winter varieties, Cappelle Desprez and Champlein, and one spring variety Opal. Nitrogen applications were similar in terms of type, dose and method of application. The method of application of CYCOCEL was the same as in 1965, but a 40% aqueous formulation was used and no wetting agent was added. The treatments differed from the previous year in that CYCOCEL doses were reduced. The doses for winter wheat were C_0 = 0 lb, C_1 = 0.75 lb and C_2 = 1.5 lb a.i. per acre and for spring wheat C_0 = 0 lb, C_1 = 0.5 lb and C_2 = 1.0 lb a.i. per acre.

Crops were sprayed at the commencement of stem elongation at growth stage 6 on the Feekes Large Scale as modified by Large (1954). Details of each trial are given in table 1.

Lodging was assessed by eye by two observers taking into account both extent and severity of lodging. Lodging index values were calculated on a scale running from 0 = no lodging to 100 = whole plot completely flat.

Straw and ear samples were taken immediately prior to harvest by pulling handfuls of plants, including roots, at twenty random points in each plot. From each sample, ten complete plants were taken at random. From each of these the longest stem was selected. For each of these stems individual internode lengths were recorded together with the total length of stem. The ear was detached and a count was made of the number of fertile spikelets, number of grains per fertile spikelet and numbers of grain per ear.

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* Agral is the registered trademark of Plant Protection Ltd.

The trials were harvested by combine. Due to exceptionally bad weather the 1965 trials were not harvested until late September to mid-October. In 1966 trials were harvested in late August and early September. In all cases the complete plot was cut. Yields of grain were recorded and adjusted to 15% moisture content. Sub-samples of grain were oven dried for 1000-grain weight estimations.

Table 1

Trial Details

Trial no.	Wheat variety	Previous crop	Soil type	Date of nitrogen application	Cycocel application		
					Date	Stage of plant growth	Height of primordium above base (cm)
1965							
65/1	Cappelle Desprez	wheat	loam	9/4	7/5	6	3.0
65/2	Cappelle Desprez	wheat	clay loam	12/4	6/5	6	-
65/3	Cappelle Desprez	long ley	coarse sand	12/4	5/5	6	5.3
65/4	Cappelle Desprez	lucerne	clay + flints	1/4	19/5	5-6	-
65/5	Rothwell Perdix	potatoes	mere peat	8/4	27/4	6	5.5
65/6	Rothwell Perdix	broad beans	clay	30/4	30/4	6	4.4
65/7	Professeur Marchal	barley	clay + flints	6/4	12/5	6	5.7
65/8	Opal	cabbage	moss peat	14/4	25/5	7	11.2
65/9	Opal	potatoes	moss peat	11/5	26/5	6	4.9
1966							
66/1	Cappelle Desprez	potatoes	clay loam	7/4	26/4	6-7	6.56
66/2	Champlein	lay	clay loam	12/4	27/4	6	2.46
66/3	Opal	cabbage	silt	24/5	7/6	6	3.5

According to Feekes Large Scale as modified by Large (1954)

RESULTS

Effects on stem and internode length

The effects of treatment on stem length are given in table 2 where the lengths are expressed as percentages of the lengths of stem on the plots which had received neither CYCOCEL plant growth regulant nor nitrogen. The mean effects are given in tables 3 and 4 respectively.

The results were very consistent and the coefficients of variation were all low.

At each of the eight sites examined in 1965, CYCOCEL decreased straw length significantly. At no site were the effects of C1 and C2 significantly different. At three of the sites (65/1, 8 and 4) nitrogen increased stem length significantly with the N2 level having slightly more effect than the N1. At site 65/9, N2 significantly increased stem length while N1 did not. At site 65/7 it was only the N1 level which significantly increased stem length. At three sites there was a significant interaction between nitrogen and CYCOCEL. The stem shortening effect of CYCOCEL was reduced in the presence of increasing levels of nitrogen. In trial 65/3 no detailed stem measurements were made. Field observations on this trial indicated that both levels of CYCOCEL had decreased stem length equally.

Table 2

Effects of treatment on stem length of wheat plants *

(Stem length of C_oN_o expressed in inches. Other straw lengths expressed as % of C_oN_o)

	65/1	65/2	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
Stem lengths of C_oN_o in in.	35.5	37.0	33.5	46.5	46.0	43.5	45.0	40.0	38.8	36.1	41.6
Stem lengths as % of C_oN_o	100	100	100	100	100	100	100	100	100	100	100
C_oN_1	101.7	100.8	113.7	97.0	101.3	96.0	95.6	93.0	101.0	96.1	99.6
C_oN_2	100.5	99.2	107.2	99.5	96.6	91.1	95.9	100.0	101.8	105.2	96.2
C_1N_o	82.9	87.3	77.0	93.3	80.3	86.5	55.6	65.8	86.2	86.8	78.9
C_1N_1	90.6	86.7	85.4	91.2	81.3	93.0	60.5	72.0	90.0	93.7	77.4
C_1N_2	96.8	88.8	95.9	96.6	84.0	87.1	74.7	73.5	91.5	91.6	79.2
C_2N_o	85.5	86.7	72.2	93.3	80.9	84.4	50.5	66.0	88.4	84.2	66.8
C_2N_1	92.6	87.0	89.5	90.0	83.6	91.5	65.1	71.5	80.6	89.0	71.4
C_2N_2	94.0	88.6	97.0	96.3	77.6	90.2	72.0	72.7	83.3	97.5	66.9
L.S.D: $P = 0.05$	5.3	11.0	7.1	7.9	8.7	3.9	4.2	8.1	★	10.0	6.6
$P = 0.01$	7.8	14.6	10.3	11.4	12.6	6.3	6.0	11.7	★	14.5	9.6
Coefficient of variation %	2.7	5.2	3.3	3.6	4.3	2.1	2.4	4.4	★	4.6	3.5

* No measurements were made at site 65/3

★ It was not possible to analyse the results of trial 66/1

Table 3

Mean effects of nitrogen on stem length of wheat plants *

(Lengths are expressed as % of N_o)

Treatment	65/1	65/2	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
N_o	100	100	100	100	100	100	100	100	100	100	100
N_1	106.0	100.3	114.9	97.2	102.3	103.8	107.5	102.2	99.0	102.8	101.2
N_2	108.6	101.2	120.2	102.1	99.1	99.0	118.0	106.5	100.7	108.9	98.6
L.S.D: $P = 0.05$	3.5	6.9	4.9	4.8	5.8	2.5	3.5	6.0	★	6.4	4.6
$P = 0.01$	5.0	10.2	7.1	6.9	8.4	4.0	5.1	8.7	★	9.3	6.8

* No measurements were made at site 65/3

★ It was not possible to analyse the results of trial 66/1

Table 4

Mean effects of CYCOCEL on stem lengths of wheat plants *

(Lengths are expressed as % of C_o)

Treatment	65/1	65/2	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
C_o	100	100	100	100	100	100	100	100	100	100	100
C_1	89.5	88.5	80.9	94.8	82.5	92.7	65.5	72.1	88.4	90.4	79.6
C_2	90.4	88.5	81.0	94.4	81.2	92.6	64.3	71.6	83.3	89.8	69.3
L.S.D: P = 0.05	3.1	6.3	3.9	4.6	5.0	2.3	2.1	4.8	☆	5.8	3.8
P = 0.01	4.5	9.3	5.6	6.6	7.5	3.8	3.6	6.9	☆	8.4	5.6

* No measurements were made at site 65/3

☆ It was not possible to analyse the results of trial 66/1

In 1966 stem length was not affected by nitrogen treatment except in trial 66/2 where stem length was significantly increased by 160 units of nitrogen. In this trial both levels of CYCOCEL reduced stem length significantly and equally. In trial 66/1 several plots were accidentally cut out by farm staff leaving only one plot of each of several treatments; the results could not therefore be analysed. In this trial both levels of CYCOCEL reduced stem length; by 12% at the 0.75 level and by 17% at 1.5 lb a.i. per acre. There was no significant interaction between nitrogen and CYCOCEL plant growth regulant at this site. At the spring wheat site 66/3 both levels of CYCOCEL reduced stem length significantly but there was also a significant difference (at P = 0.01) in the stem length reductions between the levels of 0.5 lb and 1.0 lb a.i. per acre.

In both the 1965 and 1966 trials the greatest proportional decrease of internode length took place in the second, third and fourth internodes from the base of the stem in winter varieties, and in the third, fourth, fifth and sixth internodes in the spring variety Opal. A greater proportional shortening of the whole stem occurred on Opal than on the winter varieties. The one exception was on the winter variety Cappelle Desprez in trial 66/1 where the greatest proportional decrease of internode length took place in the third, fourth and fifth internode from the base of the stem. The plants at this site were sprayed at a later stage than the other winter varieties; i.e. stage 6-7 as compared to stage 6.

Effects of Lodging

In 1965 lodging occurred in six trials at varying degrees of severity from mid-June onwards. The progress of lodging on each treatment in these trials is shown in table 5. Lodging occurred in June on plots which had received no CYCOCEL and, of these, the plots with the highest level of nitrogen lodged most severely. In only one trial (65/7) did lodging occur on plots treated with CYCOCEL in June and this was on the weak-strawed variety Professeur Marchal; even so, lodging was largely confined to the high nitrogen plots. The position changed little until 19th September on which day very high winds and heavy rain occurred throughout the country. Heavy lodging occurred on nearly all trials not harvested by that date, including 65/4 on which no lodging had hitherto occurred. Thus on the day of harvest many CYCOCEL treated plots had lodged badly. Both levels of CYCOCEL reduced the incidence of lodging equally.

In 1966 lodging was not as severe as in 1965 and in particular, no lodging occurred in June. In trial 66/1 the C_2 level of CYCOCEL plant growth regulant was more effective than C_1 but in trial 66/2 only a slight difference between the levels could

Table 5

Effects of treatment on lodging

(Lodging Index: 0 = all upright; 100 = all flat)

Trial *	65/2	65/3	65/4	65/6	65/7	65/8	65/9	66/1	66/2
Treatment	June Aug. Sep.	June Aug. Sep.	Aug. Sep.	June Aug. Sep.	June Aug. Sep.	June Aug. Sep.	June Sep.	July Aug.	July Aug.
C_oN_o	53 62 81	0 0 22	0 2	25 25 93	39 95 99	7 63 80	1 5	8 48	0 13
C_oN_1	41 63 75	0 13 76	0 39	42 42 92	56 95 97	73 96 100	10 38	26 66	0 25
C_oN_2	91 92 100	10 40 95	0 65	45 45 97	68 97 100	82 81 94	79 80	55 90	0 31
C_1N_o	0 0 50	0 0 10	0 0	0 0 90	0 23 39	0 20 87	0 0	0 11	0 2
C_1N_1	0 0 44	0 0 73	0 2	0 0 86	0 6 67	21 72 52	0 0	1 36	0 9
C_1N_2	0 0 44	0 10 88	0 44	1 2 87	0 1 57	46 81 100	0 0	5 40	0 16
C_2N_o	0 0 44	0 0 21	0 0	0 0 86	0 13 54	0 24 53	0 0	0 7	0 1
C_2N_1	0 0 50	0 0 73	0 1	0 0 85	0 0 40	10 75 96	0 0	1 11	0 7
C_2N_2	0 0 50	0 14 87	0 20	0 0 84	0 1 66	25 77 100	0 0	0 31	0 20

* No lodging occurred at sites 65/1, 65/5 and 66/3

be discerned. No lodging occurred on trial 66/3.

Effects on Yield

The effects of treatment on yield are given in table 6 where yields are expressed as percentages of the yield on the plots which received neither CYCOCEL plant growth regulant nor nitrogen. The direct effects of treatment on yield are masked by the effects of treatment on yield through lodging or its prevention. No attempt has been made to separate these effects. In the 1965 trials no lodging occurred at two sites (65/1 and 9). At neither of these sites did treatment with nitrogen or CYCOCEL plant growth regulant have significant effects on yield nor was there any interaction between them. As shown in table 7, at only one site (65/1) did nitrogen significantly

Table 6

Effects of treatment on yield of wheat plants

(Yield of C_oN_o expressed as cwt per acre at 15% moisture content. Other yields expressed as % of C_oN_o)

	65/1	65/2	65/3	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
Yield of C_oN_o (cwt/ac.)	29.9	23.9	35.1	38.8	20.5	33.2	18.8	46.7	44.4	50.3	47.0	32.3
Yields as % of C_oN_o	100	100	100	100	100	100	100	100	100	100	100	100
C_oN_1	105	100	92.0	111.3	68.5	92.2	115.8	95.9	107.4	91.0	92.0	88.2
C_oN_2	110.5	69.0	56.8	116.6	67.0	82.6	111.3	68.1	108.8	112.0	78.0	83.2
C_1N_o	103.7	130.0	105.3	97.9	104.0	128.0	171.5	109.9	97.5	96.0	114.0	97.5
C_1N_1	100	110.0	102.6	113.1	84.0	158.5	146.2	110.7	111.0	114.0	95.5	83.9
C_1N_2	106.8	117.0	85.3	104.1	67.0	124.5	136.5	83.5	105.9	110.0	81.0	74.6
C_2N_o	101.8	129.5	100.5	103.9	100	140.5	169.5	106.0	109.2	103.0	97.0	98.6
C_2N_1	102.5	119.3	99.5	113.7	89.0	139.0	146.0	111.8	102.0	104.0	91.5	81.7
C_2N_2	112.0	108.0	78.8	116.0	75.0	151.8	142.5	88.2	110.1	120.0	77.0	64.0
L.S.D. $P = 0.05$	18.1	25.6	18.8	9.4	32.2	42.1	50.8	13.2	14.2	★	14.0	7.2
$P = 0.01$	26.1	37.2	27.2	13.7	46.4	63.8	76.0	19.3	20.7	★	20.4	10.5
Coefficient of variation %	7.5	10.2	8.8	3.8	16.5	13.8	16.5	5.9	5.8	★	6.1	3.6

★ It was not possible to analyse the results of trial 66/1

Table 7

Mean effects of nitrogen treatment on yield of wheat plants

(Yield expressed as % of N_o)

Treatment	65/1	65/2	65/3	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
N_o	100	100	100	100	100	100	100	100	100	100	100	100
N_1	101.2	91.7	95.7	112.1	79.5	105.5	92.6	100.7	104.4	103.0	93.0	85.7
N_2	108.7	81.8	72.6	110.0	68.8	97.0	88.5	75.9	105.9	114.0	78.5	75.0
L.S.D. $P = 0.05$	9.9	12.2	10.4	5.4	18.2	19.8	20.6	7.3	8.0	★	7.3	5.2
$P = 0.01$	14.5	17.8	15.2	7.8	26.5	30.0	30.0	10.3	11.7	★	10.7	7.5

★ It was not possible to analyse the results of trial 66/1 increase yield. Small increases were associated with nitrogen treatment in trials 65/1 and 65/9 but these were not significant. Nitrogen treatment had no effect in trial 65/6 whilst in the other five trials it was associated with decreases in yield. Of these the N_1 level caused a significant yield decrease in one trial and the N_2 level caused a significant decrease in four.

The mean effects of CYCOCEL on yield are given in table 8. At six of the seven sites where lodging occurred in 1965, the CYCOCEL treatments were associated with increases in yield; at four of these the increases were significant at 1% and at one at 5%. At the seventh site 65/4, CYCOCEL had no effect on yield. There was no significant interaction on yield between nitrogen and CYCOCEL plant growth regulant at any of the 1965 sites.

Table 8

Mean effects of CYCOCEL treatment on yield of wheat plants

(Yield expressed as % of C_0)

Treatment	65/1	65/2	65/3	65/4	65/5	65/6	65/7	65/8	65/9	66/1	66/2	66/3
C_0	100	100	100	100	100	100	100	100	100	100	100	100
C_1	97.0	132.7	119.0	97.4	108.6	149.5	138.8	115.1	99.4	106.0	103.0	94.5
C_2	100.2	132.7	112.3	103.3	112.0	156.8	139.9	115.8	101.7	109.0	98.0	90.0
L.S.D.												
P = 0.05	9.5	16.3	12.9	5.0	23.5	26.3	27.8	8.7	7.7	*	8.11	5.6
P = 0.01	13.9	23.8	18.8	7.3	34.2	40.2	40.5	12.9	11.3	*	11.8	8.2

* It was not possible to analyse the results of trial 66/1

There was a close correlation between the application of high levels of nitrogen and the incidence of heavy lodging and between the application of CYCOCEL and the absence of lodging or incidence of only slight lodging. There was a close correlation between incidence of lodging in June and loss of yield, whilst heavy lodging just before harvest had little effect on yield as in these cases all the crop could be harvested.

In 1966 in trial 66/1 there was an increase in grain yield from both CYCOCEL and nitrogen; lodging occurred on plots without CYCOCEL in July. In trial 66/2 lodging occurred only just prior to harvest. CYCOCEL had no effect on yield in this trial whilst both levels of nitrogen caused yield reductions; N_2 caused a significantly greater reduction (at P = 0.01) than N_1. In trial 66/3 both levels of nitrogen significantly reduced yield; 80 units caused a 15% reduction and 160 units a 25% reduction. Both levels of CYCOCEL reduced yield. The 10% yield reduction on the 1.0 lb a.i. rate was significant at P = 0.01. There was in this trial a significant interaction (P = 0.01) between the linear effects of nitrogen and CYCOCEL plant growth regulant; the reductions due to CYCOCEL were greater at high nitrogen levels and vice versa.

No clear pattern emerged between effects of treatment on yield and effects of treatment on the components of yield examined in these trials. Yield increases due to CYCOCEL were associated with small increases in numbers of grain per ear in three trials (65/6, 65/7, 65/8) and in one of these (65/7) small increases in heads per yard of row and 1000 grain weight were also recorded. Yield increases due to nitrogen were associated with small increases in heads per yard of row in two trials (65/1, 65/9).

Yield increases due to CYCOCEL in trials 65/2 and 65/5 could not be associated with any yield component, so it must be assumed that yield differences were largely due to the impossibility of retreiving with the combine all the heads from heavily lodged plots. This will also be true of some of the other sites, notably 65/6. Detailed observations on components of yield were not made at trials 65/3 and 65/4. The results of the effects of treatments in the 1966 trials on the components of yield could not be presented in this paper as there was not time to carry out examinations before publication.

DISCUSSION

The results of these trials must be viewed from two standpoints. The first of these is the effect of CYCOCEL in strengthening wheat stems, even in the presence of high levels of nitrogen, and its value thereby in preventing yield loss due to lodging. The second is the value of CYCOCEL in allowing the beneficial effects of increased nitrogen dosage to be realised.

The 1965 results showed that on winter wheat CYCOCEL at 1.5 lb a.i. per acre was as effective as the 2.5 lb rate in reducing stem length and lodging. Similarly, on the spring variety Opal, the 1.0 lb a.i. per acre rate was as effective as the 2.0 lb rate. Nitrogen significantly increased stem length at three sites only. At these three there was a significant interaction between CYCOCEL plant growth regulant and nitrogen on stem length effect; the actual shortening effect of CYCOCEL being reduced in the presence of increasing levels of nitrogen. CYCOCEL significantly reduced stem length in all trials. In the 1966 trials both levels of CYCOCEL significantly reduced stem length in the two trials from which the results could be analysed. The C_1 and C_2 values were lower than in 1965. On the winter variety Champlein both 0.75 lb and 1.5 lb a.i. per acre reduced stem length equally, but on the spring variety Opal there was a significant difference between the shortening due to 0.5 lb and 1.0 lb a.i. per acre. There were no interactions between the effects on stem length of nitrogen and CYCOCEL plant growth regulant at these two sites.

The results showed that where lodging occurred, and particularly if it occurred early in the season, yield reductions were prevented by CYCOCEL. The mean yield increases due to CYCOCEL varied from 1.5 cwt per acre (10%) in trial 65/7 where the mean yield was low to 16 cwt per acre (53.5%) in trial 65/6 where the mean yield was high. When occurring just before harvest lodging was, in many cases, not prevented by treatment with CYCOCEL but neither did it affect yield. Mid season lodging (July) had a detrimental effect on yield in trial 65/7 and this was avoided on plots treated with CYCOCEL. The reduction in yield caused by lodging in early August had been demonstrated by Barrett, Means and Mees (1966).

This series of trials was relatively unsuccessful in demonstrating that CYCOCEL could be used to realise the beneficial effects on yield of top dressings of nitrogen above the normal level. The subject of optimum nitrogen levels for wheat crops has been under investigation for many years without final conclusion. This level must vary with soil type, previous crop and weather conditions. It has been suggested that for spring wheat 40 units nitrogen per acre should be applied to crops sown late or following grazed kale or ploughed up grass, and 60 units per acre to crops following a series of arable crops (Lessells and Webber 1965a). For winter wheat 40 - 60 units per acre in May are suggested for sites recently ploughed from grass; after arable cropping 60 units per acre in April are suggested on heavy clay soils, 80 - 90 units per acre on other soils and 40 units per acre in May on peaty fen soils (Lessells and Webber 1965b).

In the trials described in this paper the aim was to apply, in comparison to no nitrogen, a "normal" level of 80 units to all crops and an upper level of 180 units on mineral soils and 120 units on peaty fen soils. It was expected that 80 units would give a reasonable increase in yield over the plots which received no nitrogen.

The high level of nitrogen was included to ensure that some lodging occurred, it was also hoped that some beneficial effect on yield above the 80 unit level would result. However, it was disappointing to observe that in only one trial (65/4) did a significant yield increase occur as a result of even the 80 unit level. The summers of both 1965 and 1966 were both very wet and this fact may be associated with the lack of response to nitrogen. Alternatively, the lack of attention to giving complementary increases of potassium and phosphate fertilisers may be an aggravating factor. The fact that significant yield reductions due to nitrogen occurred at five sites suggests that in these cases even 80 units of top dressed nitrogen was so excessive that it exercised a depressive effect on yield. The decision to use 0, 80 and 160 (or 120) units of nitrogen at all sites was taken to give conformity to the series of trials. In the light of the results it might have been better to take into account residual nitrogen in the soil of each field and any additional nitrogen applied in the seed bed. Eagle (1966) has suggested that if rainfall the previous winter was low, then the response to top dressed nitrogen will be poor due to the absence of leaching of residual nitrogen. The previous winters rainfall appropriate to each site has not been established.

Lessells and Webber report that in trials between 1959 and 1962, the response on spring wheat sown before mid-April was for 60 units nitrogen per acre to increase the average grain yield by 9.0 cwt per acre (1965a) and in trials between 1957 and 1963 the response on winter wheat was for 60 units nitrogen per acre to increase the average grain yield by 6 cwt per acre (1965b). If the poor response of wheat crops to nitrogen in 1965 and 1966 was was due to unusual climatic conditions, it would be reasonable to suppose that in the majority of seasons there will be a benefit from some extra nitrogen top dressing over the level normally used by the farmer. If a farmer has previously decided not to increase above his normal nitrogen level because of the danger of lodging, then treatments with CYCOCEL will prevent or reduce that lodging and particularly it will reduce the early lodging which is most harmful to yield. This has been previously demonstrated by Sturm and Jung (1964), Caldicott and Lindley (1964) and Geering (1965). Because treated plants are shorter and upright, the use of CYCOCEL will also prevent increased costs that are involved in harvesting a lodged crop. In a dry year the danger of lodging is considerably less, but some workers (Caldicott and Lindley, 1964; Humphries, Welbank and Witts, 1965) reported increases in yield after application of CYCOCEL in a dry season when no lodging occurred. These yield increases have been associated with an increase in head-bearing tillers (Humphries, Welbank and Witts, 1965), but the reasons for this are not yet fully understood.

It is concluded that CYCOCEL has been shown in these trials to be of value in preventing or reducing lodging where weather conditions have caused considerable loss of yield due to lodging in untreated wheat. Lodging was also prevented or reduced when up to 160 units of nitrogen top dressing were applied. For winter wheat the 1.5 lb a.i. per acre rate of CYCOCEL appeared slightly better than 0.75 lb rate, but there was no advantage in using 2.5 lb a.i. per acre. Similarly for spring wheat 1.0 lb a.i. per acre of CYCOCEL has given a significantly greater straw length reduction than 0.5 lb, but there was no advantage in increasing the rate to 2.0 lb a.i. per acre. These trials have not been successful in demonstrating that increases of nitrogen top dressing over levels normally used have produced increases in yield. In fact, in many cases, these increased doses of nitrogen resulted in yield reductions.

Acknowledgements

The author is in debted to Mr. J. Palmer of J.W. Chafer Ltd. for carrying out trial 65/4 in 1965, to Mr. A. H. Nuttall for his assistance in the field and to Mr. R. J. Isherwood for help with the statistical analyses. Thanks are also due to the farmers who allowed work to be carried out on their crops.

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THE EFFECT OF CYCOCEL (2-CHLOROETHYL) TRIMETHYLAMMONIUM CHLORIDE ON THE GROWTH AND PHYSIOLOGY OF WHEAT AND BARLEY

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Summary. Field and glasshouse experiments are described in which the effect of cycocel on spring wheat and barley was investigated. In one field experiment cycocel effectively controlled lodging and increased grain yield. Glasshouse experiments, in which rate, time of application and varietal differences were examined indicated that responses obtained in barley are not as pronounced as found in wheat, although varietal differences existed in this respect. The translocation of C^{14} labelled cycocel was found to be restricted in Proctor barley but not in Opal wheat which may explain the poor morphological responses obtained in barley.

INTRODUCTION

Numerous experiments have demonstrated that lodging in wheat can be controlled by the application of cycocel - see review by Caldicott (1966). Barley, on the other hand, has generally shown poor responses with considerable varietal variation. Barrett et al (1966), Goodin et al (1966), Larter et al (1965). In view of the importance of barley in the United Kingdom and its susceptibility to lodging, a programme of investigation was commenced in 1965 to examine the reaction of barley to cycocel, particularly in comparison with wheat. This paper summarises these investigations, all of which will be reported elsewhere in greater detail.

MATERIALS AND METHODS

Experiment I

Proctor spring barley was sown on the 16th March 1965 at the rate of 160 lb/ac. A blanket dressing of a phosphate-potash fertiliser was applied at seeding. Treatments consisted of three levels of nitrogen application (63, 126 and 252 Units/ac. at seedling emergence) and two levels of cycocel (nil and 4 lb a.i. in aqueous solution containing 'Agral' 90 wetting agent/ac.) sprayed on the 10th May at growth stage 5 (Feekes scale). Each plot consisted of 1/48 ac. from which grain and straw yields were measured and 1/96 ac. from which samples were obtained for Growth Analysis. Full descriptions of the techniques used are described by Alcock (1963). The experiment was in the form of a randomised block design with four replicates.

Experiment II

Plants of Opal spring wheat and Proctor spring barley were grown 2 per 6" pot in the glasshouse in the winter of 1965-66. Supplementary illumination from 400-watt mercury vapour lamps was given with a 16hr photoperiod. All plants received adequate mineral nutrition and water. Two experiments were performed:-

(a) Four rates of application to the soil of an aqueous solution of cycocel at growth stage 1 (Feekes scale). (Nil, 75 ml, 150 ml and 300 ml. 10^{-2} Molar concentration.

(b) 200 ml 10^{-2} Molar concentration of aqueous cycocel applied to the soil at growth stages 1, 6 and 9.

Both experiments were arranged in randomised block designs. Detailed measurements were made on internode length at harvest.

Experiment III

Six varieties of spring wheat and six varieties of spring barley were grown as single plants in 6" pots in the glasshouse during Spring 1966.

Varieties

Spring Wheat	Spring Barley
Svenno	Union
Atle	Proctor
Koga II	Impala
Opal	Europa
Jufy I	Pallas
Kloka	Deba Abed

Lighting and nutrition was as given in Experiment II. Treatment consisted of 75 ml 10^{-2} Molar aqueous cycocel applied to the soil at growth stage 5. Individual internode lengths were recorded at harvest.

Experiment IV

Single plants of Opal spring wheat and Proctor spring barley were grown in 6" pots in the glasshouse during summer 1966. When the 5th leaf on the main shoot was fully expanded an application was made to this leaf of either 1 or 4 μc of aqueous chlorochline - $1_{1}2\text{-}C^{14}$ chloride (specific activity 4.8 millicuries per millimole - 30.5 μc/mg). The application was made as a droplet of 0.01 ml or 0.04 ml. Plants were harvested with three replications per variety at frequent intervals until plant maturity. The harvested plants were freeze-dried, mounted on paper and autoradiographs prepared using the techniques described by Crafts et al (1964).

The distribution of radioactivity in the plants was assessed visually.

RESULTS

Experiment I

Lodging occurred as early as the 24th May and by harvest the high nitrogen plots were completely flat. The medium nitrogen plots were 50% lodged and the low nitrogen plots 15% lodged. Cycocel controlled lodging at low levels of nitrogen, halved lodging at the medium level but had no effect at the high level of nitrogen application. There was no delay in time of heading or harvest due to cycocel. Cycocel increased yield at all levels of nitrogen mainly be increasing the number of fertile shoots.

Table 1.

The effect of cycocel in the presence of three levels of nitrogen on the yield and components of grain yield of Proctor barley

Units of Nitrogen per ac.	Cycocel	Grain 15% moisture cwt/ac.	1,000 grain wt. g.	Number of grains/ear	No. ears/ 18" row
63	Nil	37.9	34.30	18.5	68.5
	4 lb ai/ac	42.6	33.86	18.4	73.5
126	Nil	36.2	33.22	14.6	71.0
	4 lb ai/ac	41.8	33.34	13.9	81.8
252	Nil	32.5	29.96	17.9	68.8
	4 lb ai/ac	35.2	29.99	16.9	76.0
	S.E. ±	1.4	C.49	0.66	3.4

This increase in fertile shoots was a result of more shoots surviving to produce ears rather than more shoots being produced. Cycocel had little effect on the leaf area index (L.A.I.) or net assimilation rate (N.A.R.) during the early part of growth but increased L.A.I. after ear emergence mainly as a result of an increase in fertile shoots. Plant height was not affected to a large extent by cycocel although lower internodes were shortened (Table 2).

Table 2.

The effect of cycocel at three levels of nitrogen on internode length of Proctor barley
(expressed as % of non treated barley 1 = basal internode)

Units of Nitrogen per ac.	Internode 1	2	3	4	5	6	7	Total length
63	72	105	105	106	115	121	107	108
126	58	92	108	102	103	100	108	99
252	51	84	111	105	104	94	88	94

Proximate analysis of the grain revealed no change in chemical composition as a result of the application of cycocel.

Experiment II

(a) All rates of application markedly decreased internode length in Opal wheat with the first (basal) internode being shortened the most. An optimum appeared to be reached at 150 ml 10^{-2} M./pot. With Proctor barley the 2 lowest rates of application increased total length of straw mainly by increasing the second internode. The highest level of application shortened internodes 1, 4, 5 and 6 and total plant height.

(b) All times of application reduced internode length in Opal wheat. The most uniform shortening of all internodes followed application at stage 9. With Proctor barley large increases in internode length (1, 2, 3, 4 and 5) followed application at stage 1. Smaller increases in the length of the first three internodes occurred after stage 6 application. Only stage 9 application was effective in reducing internode length (1, 2 and 3).

Experiment III

Wheat varieties all showed considerable reductions in internode lengths. The most responsive varieties were Jufy I and Opal. Kloka was the least responsive. Greater variations occurred in barley. Proctor, Impala and Deba Abed responded mainly with increased internode length. Union and Pallas had shortened basal internodes. Europa, on the other hand, behaved more like wheat in that all internodes were reduced in length.

Experiment IV

The pattern of distribution of radioactivity was fairly constant between replicates. After one day in Opal wheat activity was found mainly in the treated leaf and sheath, leaf below the treated leaf and some activity in roots and tillers. There was a general increase in distribution and level of activity in the various plant parts over days 2, 3, 4 and 7. In Proctor barley activity was found mainly in the treated leaf and a little in the treated leaf sheaths. No activity was found in the roots but by day 4 slight activity could be detected in some tillers. There was no change in the picture by day 7. On day 14 the emerging ears of wheat showed considerable activity and there was generally high activity in the tillers and roots. In barley at this time activity was still mainly in the treated leaf with a little in tillers but none in the roots. After 1 month when grain was developing in both cereals a similar pattern was still evident. A considerable amount of activity was found in the wheat ear with a low level of activity throughout the plant. In barley the treated leaf still retained most of the activity although a low level was present throughout the plant. Chemical identification of the active fractions has not yet been performed.

DISCUSSION

It is evident from this and other work reported in the literature that barley is in no way as responsive as wheat to the shortening action of cycocel. Part of the explanation for this may be found in the limited translocation of cycocel from the leaves in barley. Restricted translocation may be partly concerned, for example, in the resistance mechanism of various plant species to auxin-type herbicides, Marinos et al (1964). Whether translocation is limited from root uptake has not yet been demonstrated or whether metabolic breakdown occurs in barley is not yet known. There is no evidence of such breakdown, however, in wheat - Cycocel Manual (1966).

Under certain ill-defined conditions as found in Experiment I cycocel can control lodging to a considerable extent. The increase in grain yield that is also brought about is as large as that found in experiments with wheat, Caldicott (1966). Likewise the reason for this increase which is a greater number of shoots surviving to form ears is similar, Humphries (1965). There is evidence that survival is influenced by the degree of self-shading in the canopy, Lovett (1963). Since light penetration is greater in cereals treated with cycocel this may result in the increase in shoots surviving to produce ears. Glasshouse experiments (Experiment II a+b) suggest that a larger application of cycocel is required for barley than wheat to obtain a shortening of the internodes. The finding that the greatest shortening in Proctor barley occurred from an application made just prior to ear emergence may, unfortunately, be of little practical significance.

The demonstration of varietal differences in morphological response particularly in barley is now being followed up with an examination of translocation of C^{14} cycocel. Factors influencing uptake and translocation with the object of attempting to increase this in barley are also being investigated.

Acknowledgments

We are grateful to Cyanamid of Great Britain Ltd. for gifts of cycocel and to the American Cyanamid Company for a gift of C^{14} labelled cycocel.

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CCC: ITS COMBINATION WITH CERTAIN HERBICIDES AND SPECIAL CONSIDERATIONS OF DOSAGE RATE AS RELATED TO DISEASE INCIDENCE IN CEREALS

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Summary

1. Combinations of CCC with certain herbicides of the hormone type enables dosage reductions by 0.25 kg to 0.5 kg over normal field rates.

2. The degree of effectiveness of CCC is found to depend on:

   quantity applied and method of application,
   crop variety,
   climatic conditions which precede and follow treatment.

   Surprisingly, CCC dosage can be reduced in wet seasons, or in high rainfall region crops, compared with the dosages required in dryer regions.

   Under West German conditions rates of from 0.4 kg a.i./hectare to 1.3 kg a.i./hectare are found to be the effective range of dosage.

3. Where excessive rainfall or high humidity follows shooting of CCC treated wheat, there may be shown an increased susceptibility towards ear diseases. viz. Septoria nodorum, Fusarium culmorum, also Alernaria, Cladosporium and Cercospora spp.

   Infection has been found to increase with ascending rates of CCC. Offsetting this, however, is the increase in stem rigidity often found.

   In normal, moderate rainfall years, there is no correlation between incidence of ear disease and CCC treatment.

4. In pot experiments and field micro-plot trials, CCC produced certain modifications to crop micro-climate. This led to a slight increase in Erysiphe infection.

5. CCC is known to increase wheat stem diameter, also to increase the thickness of stem-wall, particularly at the stem base. As a result, wheat is more resistant to lodging, even where infected with Cercosporella.

INTRODUCTION

Tolbert 1960 had found that Chlorcholinchloride (CCC) inhibits cell elongation in numerous plants, and particularly in wheat (1:2). Its findings indicated that CCC is active in reducing or preventing the natural lodging of this crop and stimulated considerable interest in this material.

Over the past six years, more than 100 scientific papers on this subject have been published from Western European countries alone. A review volume on the "CCC Symposium" December 1965: Agricultural Experimental Station Limburgerhof, has been prepared and will become available later this year.

Combination of CCC with Herbicides

Interest in the possible uses of CCC as a component of herbicide mixtures led to work by Frohner (12a) and Sturm (13). This has shown that CCC can be applied in a practical way, in combination with plant phytohormone materials. Such mixtures are reviewed in some detail. They have been found to be economical to use and simple to apply under Continental conditions.

Further experimental work during the past three years was undertaken to investigate (a) optimum dosage rates, where CCC used alone, (b) further combinations with herbicides and (c) the effects of Cercosporella attack under practical conditions.

It should be noted however, that combined application of CCC with KNOC is not practical due to chemical antagonism producing severe flocculation at spray volume dilutions.

Effects of CCC on stem strength of wheat.

The work of Bockman (9) Diercks (10) Mayer et al (11) and Sturm (12) has shown that CCC acts indirectly to cause strengthening of the wheat stem base. In this way, lodging due to Cercosporella herpotrichoides is kept at a reduced level.

Diercks found some indication of a fungistatic effect from this treatment (10) Jung and Riehle (13) were able to show in pot experiments that CCC had the effect of (a) shortening of lower internodes on plant (b) an increase in stem diameter at these nodes.

Yield Depression due to crop lodging

It has been shown that yield losses or yield depressions attributed directly to lodging, can be reduced or prevented by CCC treatment. This applies particularly where advanced high potential wheat varieties are grown with large nitrogen dressings. (Mayer et al (3), Linser et al (4), Jung and Sturm (5,6)).

Timing of CCC application

The most favourable time of application has been shown to occur from 5-leaf-stage to the early shooting stage. (Sturm and Jung (7)). Applications made later than this have a reduced performance in strengthening of the stem base of wheat.

Optimum Dosage Rates of CCC

There has been some disagreement of findings regarding optimum dosages of CCC. Linser et al (8) and Mayer et al in their early experiments applied 4-16 kg/ha CCC active. Jung and Sturm (5) used from 2.5 kg to 7.5 kg/ha.

In all recent experimental work it has been the authors' experience that reduced dosage rates of CCC were adequate to ensure nil-lodging of wheat, even where a high nitrogen status prevails, and wet conditions predominate.

Further experimental work with CCC

This sets out to investigate the following:-

(a) optimum dosage rates for CCC in wheat,
(b) application in herbicide mixtures,
(c) influence of Cercosporella on wheat under practical conditions,
(d) correlation between CCC treatments and fungal infection (post experiments.

A report is given below on all these experiments.

METHODS AND MATERIALS

a) Field Experiments

Plot size: 20 - 25 m^2
Number of replicates: 4.

Fertilizer Applications: Adequate P_2O_5 and K 20 was supplied. A spring dressing of from 100 kg to 120 kg/ha was also applied.

Application of CCC: This was applied as an aqueous solution containing 460 g/l CCC and approx. 320 g/l Cholinchloride. All data presented refers to active material CCC.

Spraying was commenced when the wheat had reached 20 cms in height, and a spray volume of 400 litres water per Hectare, employed.

b) Pot Experiments

Mitscherlich - standard pots, holding 6 kg of a sandy-loam soil were used. Soil PH was 7.2.

CCC application was based on 0-3 kg/ha active material-equivalent.

Visual Estimation of Lodging

A linear scale 1 - 9 was used where 1 = no lodging and 9 = complete lodging.

Estimation of Cercosporella-Infection

After the method of Bockmann, whereby the number of strongly infected stems X 2 added to number of slightly infected stems X 1; the sum of 100 readings devided by 2 = Value of infection.

Estimation of Septoria & Erysiphe Infections

Based on scheme of "Biologische Bundesanstalt Braunschweig", whereby 1 = no infection; 9 = very strong infection.

RESULTS

a) combined application of CCC with hormone herbicides: effect on dosage rate

In 1965 (a wet year) it was observed in many cases that a combination of CCC plus hormone-type herbicides had a stronger effect compared to CCC used alone. To examine this further, straw lengths were measured in 5 experiments.

TABLE 1
Influence of CCC, phytohormones, and their joint effect on wheat straw length and lodging (means of 5 readings).

Treatment	2,4-D	MCPA	2,4-D+ MCPA	Mecoprop	2,4-D+ Mecoprop	Mecoprop +2,4,5-T	Dichlor-prop
a) strawlength in cm							
Phytohormone only	114	115	114	114	111	114	112
CCC only (99)							
CCC + phytohormone in combination	95	98	96	97	97	97	96
b) lodging							
phytohormone only	3,8	3,0	2,4	4,2	3,4	3,6	4,6
CCC only (1,0)							
CCC phytohormone in combination	1,2	1,0	1,0	1,4	1,2	1,0	1,2

It can be seen that combination of CCC with phytohormones had resulted in a most pronounced shortening effect on wheat straw length. However it was also noted that in those fields where Septoria infection was serious there was generally some increase in the degree of crop attack by this pathogen.

b) Influence of CCC dosage rate on wheat stem-strength and crop yield.

Initial field experiments were conducted using high CCC doseage rates and followed earlier data by Tolbert (2).

It was soon established that rates as low as 2.5 kg/ha CCC were adequate to produce crop straw-strength and yield responses.

For this reason, experiments in 1963 had been based on using low to moderately high rates viz: 1.5 - 3.0 kg up to 4.5 kg/ha CCC.

Findings showed that the lowest rate of 1.5 kg/ha CCC gave the greatest response in terms of straw strength, and as a result of early spraying, produced an optimum yield.

These results encouraged further examination of response shown to greater reductions of dosage rate.

TABLE 2
Influence of increasing CCC dosage rates on stemlength, lodging and yield of winter-and spring-wheat during the dry year 1964

Winterwheat (Mean of 11 trials)				Springwheat (Mean of 11 trials)			
Rate of CCC kg/ha	stemlength in cm	lodging	yield dz/ha*	Rate of CCC kg/ha	stemlength in cm	lodging	yield dz/ha
-	107	3	44,0	-	105	2,7	40,4
1,0	92	2	44,1	0,5	90	1,7	41,3
1,5	91	1,6	45,4	1,0	86	1,7	41,3
2,0	89	1,3	46,3	1,5	82	1,5	40,8
2,5	87	1,3	45,9	2,0	80	1,5	41,1
3,0	86	1,3	44,7	2,5	77	1,5	39,7

* 1 dz = 100 kg

Stemlength was already shortened on average by 15 cm with all lower dosage rates. Higher CCC rates in winter-wheat resulted in further stem shortening of only 1-2 cm per 0,5 kg/ha CCC applied. In spring-wheat however the figure was 3-4 cm. From this it can be seen that spring-wheat reacted more strongly to CCC than winter-wheat, and confirmed earlier findings in this respect.

Lodging of wheat was not severe in the dry year 1964. However the best strengthening response was found with winter-wheat from 2,0 kg/ha and in spring-wheat from 1,5 kg/ha CCC.

In 1964 winterwheat-yield had reached an optimum with a dosage rate of 2,0 kg/ha CCC. Spring-wheat responded positively to lower rates. Increasing the CCC-rates resulted in some yield depression, mainly with short strawed varieties.

In comparison to this, the following experimental results from the wet years 1965 and 1966 are noteworthy.

TABLE 3

The influence of increasing CCC-dosage-rates on the stemlength, lodging and yield of wheat in 1965 and 1966

Rate of CCC kg/ha	(Mean of 15 trials) 1965 stem length cm	degree of lodging	yield dz/ha	(Mean of 9 trials) 1966 stem length cm	degree of lodging	yield dz/ha
0	113	5,2	42,1	112	6,1	33,5
0,45	-	-	-	100	3,5	40,1
0,9	99	1,8	47,8	94	2,8	40,0
1,35	96	1,2	48,2	-	-	-
1,8	94	1,2	48,5	90	2,1	40,5
2,25	93	1,2	47,3	-	-	-

Contrasting with results from the dry year 1964, in 1965 and 1966 1,35 kg/ha CCC gave the best response. Lower rates also performed well. Optimum yields were obtained with lower rates; rates above 2 kg/ha CCC resulted in some degree of yield depression. It can therefore be concluded that in wet years 1 - 1,5 kg/ha CCC was an adequate dosage range.

c) Influence of CCC-dosage-rate on wheat infection by Septoria nodorum.

In dry years or regions of low rainfall attack of ear-diseases in wheat is of minor importance. Estimations have shown that under dry climatic conditions Septoria-infection is neither positively nor negatively influenced by CCC treatment. On the other hand it was found that in regions with high humidity during June/July (e.g. the region at the edge of the Alps) and where Septoria occurs almost each year, CCC treated crops frequently exhibited increased Septoria-infection or increased attack by other ear-disease pathogens. This is confirmed by experimental results from 1966 (a very wet year).

TABLE 4

Influence of increasing rates of CCC on the infection with Septoria nodorum

Rate of CCC kg/ha	Degree of lodging	Septoria-estimation	Yield dz/ha
-	9	7,2	28,0
0,4	6,2	4,7	35,0
0,8	5,1	4,8	35,4
1,6	3,6	4,9	36,2
2,4	2,4	5,5	35,8

Lodging scores decreased as CCC-dosage-rates increased. This was reflected by the grain-yields obtained. The intraction of lodging and infection by Septoria thus becomes of particular interest. The heaviest infection was noted in untreated plots, i.e. on those plots with the greatest degree of lodging. Where reduced lodging was seen at later stages, Septoria-infection at the lower CCC-rates was considerably lessened. However with the highest CCC-rate a further increase was noted. Considering the influence of CCC upon Septoria-infection the degree of lodging must also be taken into account.

In this connection a review of the low yields of wheat in 1966 obtained in many countries of Western Europe is relevant. Schwerdt (14) demonstrated that widespread incidence of Septoria and other ear diseases had been in main due to climatic conditions in June/July of that year.

Those years with high rainfall and in these months (1955 and 1956 were examples) all show a high degree of infection of wheat by ear-diseases. These findings have been confirmed in 1966.

TABLE 5
Precipitation, number of wet days and hours of sunshine
Western Germany July 1966

Location	Precipitation as % of long term means (= 100)	Number of rainy days	Periods of sunshine as % of long term means (= 100)
Braunschweig-Voelkenrode	131	20	79
Goettingen	177	19	77
Giessen	211	20	72
Alzey (Palatine)	147	20	74
Wuerzburg	145	18	65
Deggendorf	143	19	-

Thus on average precipitation in Western Germany in July 1966 was 40% to 100% above "Normal" (based on means of many years); periods of sunshine were some 25% lower; 19-24 days showed overcast skies and produced at least o,1 mm precipitation. As a result regionally heavy infections with ear diseases were noted. These ear diseases met favourable microclimatic conditions in vigorous wheat crops and developed exceptionally well. Yield-reductions up to 20 dz/ha were subsequently recorded.

d) Influence of CCC on wheat infection by Erysiphe graminis

In field experiments a more pronounced infection of Erysiphe graminis was sometimes observed after CCC-application. For this reason two experiments in Bavaria in 1965 were analysed in respect of Erysiphe-infection.

TABLE 6
Influence of increasing dosage rate on wheat infection by Erysiphe graminis in 1965

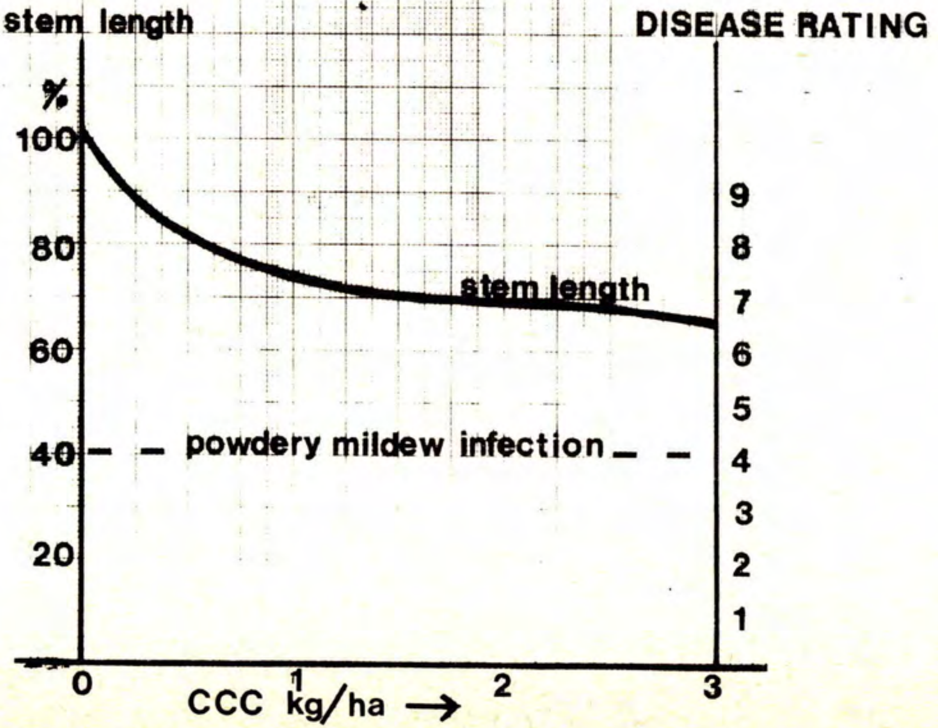
Rate of CCC kg/ha	Erysiphe-estimation variety Florian	variety Schernauer	means
-	4,0	5,8	4,9
0,9	4,3	6,0	5,1
1,35	4,5	6,3	5,4
1,8	4,8	6,3	5,5
2,25	4,5	6,3	5,4

Findings reflect a very slight increase in the Erysiphe-infection obtained. However higher rates of CCC did not intensify this infection. Therefore, it can be concluded that slight increases of infection were due to variable micro-

FIG:I

STEM LENGTH AND INFECTION WITH POWDERY MILDEW – INCREASING RATES OF CCC

pot trial : spring wheat



climatic conditions in the crop. CCC itself does not seem to influence the disposition of the plant towards Erysiphe graminis.

To study this question independent of the field climatic factors, two pot experiments were conducted; here a spring wheat-variety "Opal" was placed under test. In this rate-of-dosage trial CCC was applied as foliar sprays at the rates of 0,1; 0,25; 0,5; 1,0; 2,0 and 3,0 kg/ha a.i. As can be seen from figure 1, stem length was reduced by approx. 37% with rising CCC-dosage-rates. Surprisingly this extreme morphological alteration to the wheat under pot experiment conditions had no significant influence on plant infection by Erysiphe graminis.

In a further experiment 0,5 and 2,5 kg/ha CCC was applied by foliar spray: (a) as CCC only, and: (b) in combination with a fungicide (Maneb). Intervals chosen were 12, 19 and 44 days and estimated infection values are given in Fig.2.

At the high rate of 2,5 kg/ha CCC only, was a tendency towards increased Erysiphe infection observed (with and without fungicide treatment); this was observed only at a later growing-stage (microclimate effect?). Effects of fungicide applied at time of CCC application was very pronounced after 12 days, and remained effective for more than 20 days.

e) <u>The influence of CCC on infection of wheat with Cercosporella herpotrichoides</u>

Investigations were made under practical conditions to check the validity of positive findings which indicated reduced disease attack and crop lodging where CCC had been applied.

It is well established that Cercosporella herpotrichoides destroys cellular tissues at the stem-base of wheat.

TABLE 7

Influence of CCC and Maneb on the infection of Cercosporella herpotrichoides, lodging and yield

(means of 9 trials in 1965)

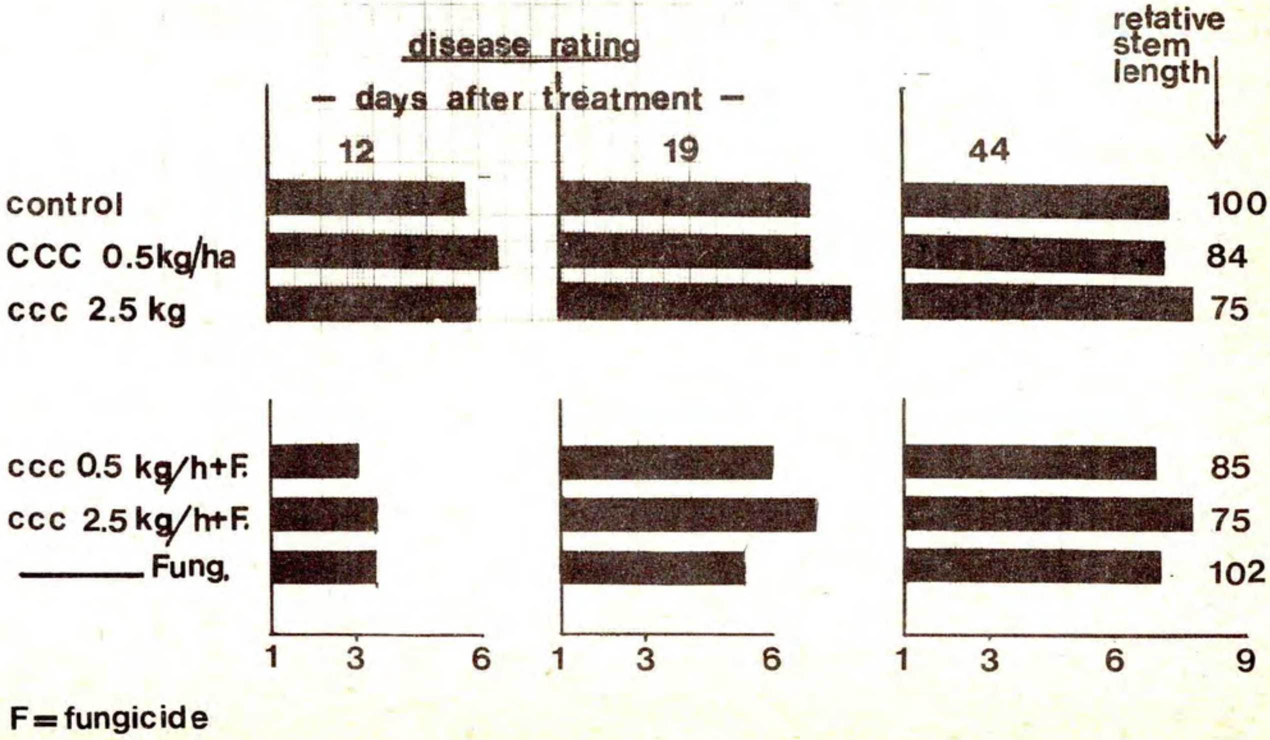
Rate of CCC kg/ha	Maneb kg/ha	Disease Rating on 100 Stems non	slight	strong	degree of infection	lodging	yield dz/ha
-	-	4	25	71	84	6,9	45,4
1,8	-	9	37	54	73	1,6	51,1
1,8	2	13	35	52	70	1,1	52,1
0,9	2	15	32	53	69	1,3	51,7

From this it is seen that CCC did not prevent Cercosporella-infection but the degree of infection was reduced. Consequently the damage caused by Cercosporella was considerably reduced. Thus in the means of 9 trials, CCC was found to obviate yield reductions of the order of 6 dz/ha caused by lodging.

In 2 out of these 9 trials the maneb-applied at the same time as CCC significantly reduced Cercosporella-infection. Obviously in such cases maneb was applied just at the time when the main infection was starting. With earlier or later infective periods application of maneb does not produce any lessening of the ultimate infection.

FIG:2

INFECTION WITH POWDERY MILDEW — ON SPRING WHEAT
after treatment with CCC and fungicide



DISCUSSION

During 1964 results from CCC rate-of-dosage trials showed that in regions with rainy spring and summer climates the CCC rate could be reduced as compared to rates required under dryer climatic conditions. A comparison of the results confirms these rather unexpected findings.

In practical applications during the rainy years of 1965 and 1966 straw length reductions of up to 40% were observed. In those years the dose rate used was only 1 - 1,5 kg/ha.

In the dry year 1964 the shortening effect at higher CCC rates, i.e. (2-3 kg/ha) was only 10-20%.

These findings are also confirmed by the results from Lovato (15), Lhoste and Vernie (16), who were working with higher CCC rates in the dryer climatic regions of Italy and France.

Regions with a rainy climate suffer from some degree of increased incidence of ear diseases, mainly Septoria nodorum. It has been shown that CCC rates in these regions are best kept at the lower levels of: from 1,5 - 1,0 kg/ha CCC. In regions where ear diseases occur regularly we do not recommend CCC application due to the possible risk involved. Under such circumstances farmers must decide whether they are prepared to accept the benefit of improved wheat straw strength and accept the chance of increased infections by wheat ear disease. It must be emphasised here that Septoria infection in lodged crops is always of a very high order.

There is no direct correlation between CCC treatment and Erysiphe infection. However it is shown that CCC encourages development of a broader leaf and also shortens straw.

Fungal diseases may increase slightly by a factor of: 0,5 on the scale: 1 to 9 due to favourable microclimatic conditions. Field experiments have shown that high rates of CCC do not result in stronger infections.

Experiments in wheatcrops with a high degree of Cercosporella herpotrichoides confirmed the results of Bockmann (9), Diercks (10), Mayr (11) and Sturm (12).

It was shown that CCC reduces the degree of damage caused by this disease which attacks the lower portion of wheat stems. The fungus apparently requires more time to destroy the thicker tissues produced at the crop stem base. For this reason the degree of infection is lessened.

ACKNOWLEDGEMENTS

The authors acknowledge the help of Messrs. BASF United Kingdom Limited, London and Mr. Schneider, BASF Agricultural Experimental Station, Limburgerhof in the translation and final preparation of this paper.

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CCC AND NITROGEN IN WINTER WHEAT

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Summary - The relations between CCC and nitrogenous fertilization were studied by the Syndicat Professionnel de l'Industrie des Engrais Azotés in 76 experiments located in numerous areas of France. CCC action varies from a decrease of 6.7 q/ha to an increase of 11.7 q/ha, the average action being an increase of 0.6 q/ha. No clear explanation has been found to the CCC depressive action. As a rule there is a positive action of CCC when lodging is recorded but there is sometimes such a positive effect when no lodging is recorded. The CCC action increases with the amount of nitrogen, but it often only neutralizes the depressive action of too high levels of nitrogen. CCC has a better action when nitrogen is used during tillering than during stem growth. There is no interaction between weed control, studied in 6 experiments, and nitrogen, nor between weed control and CCC.

INTRODUCTION

As nitrogen and CCC have opposite effects on the length of wheat straw and on the lodging resistance, it was of interest to examine the influence of CCC on the optimum nitrogenous fertilization. Therefore 91 experiments were made on winter wheat by the Syndicat Professionnel de L'Industrie des Engrais Azotés (S.P.I.E.A.). 8 experiments have been cancelled during the growing season or just at harvest time. The experiments have been drawn together in 5 series according to their experimental procedure. 7 experiments of which the experimental procedure could not be incorporated in a series of at least 5 experiments are not mentioned in this report which finally contains only 76 experiments (fig.1). Yields of wheat, in quintal of grain per hectare (q/ha) have only been studied up to now in this report.

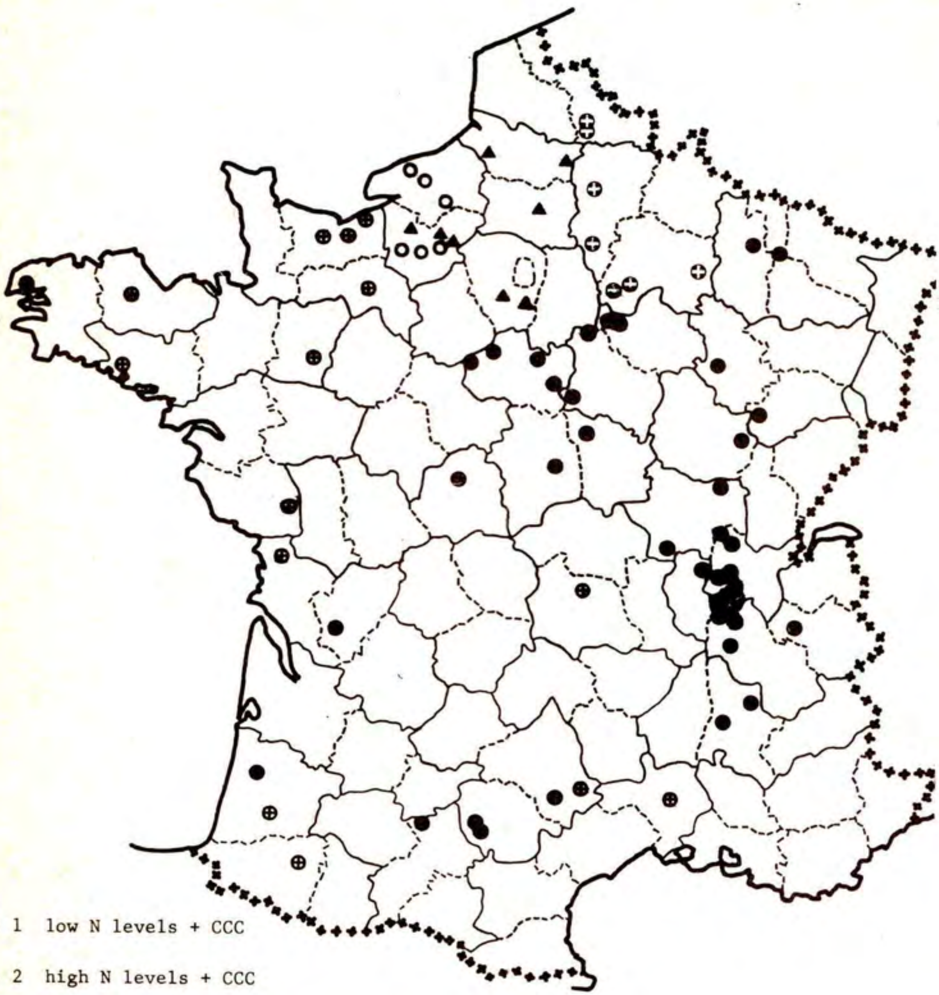
METHOD AND MATERIALS

There was a total of 2495 experimental plots of 150 to 200 m^2 each, belonging to different farmers and an average of 33 plots per experiment. The experimental layouts used were randomized blocks, split-plot or confounding according to the experimental procedure.

The general method used to study the results is a comparison between 2 production functions, relating to wheat, with and without CCC. The production functions have been calculated when there are, at least, 4 nitrogen levels by fitting successively a polynomial of the first, second or third degree. The most frequent polynomials were parabolas. The economial optimums for nitrogen are calculated on the bases of 5 kg of wheat to pay 1 kg of nitrogen. The farmer's profit is the highest when he uses such an optimum fertilization. For all statistical operations an I.C.T 1301 computer has been used.

Figure 1

Experimental sites in 1966



⊕ 1 low N levels + CCC

● 2 high N levels + CCC

▲ 3 low N levels + times of N application + CCC

✪ 4 medium N levels + times of N application + CCC

○ 5 medium N levels + times of N application + weed killer + CCC

CCC was generaly used at a level of 1.6 to 2 kg/ha pure CCC, the time of application varying from the end of the tillering to the beginning of the stem growth.

In the experiments where the time of nitrogen application was not a variable, nitrogen has been applied either in a single dressing during tillering or in two dressings during tillering and the beginning of stem growth. Nitrogen was usually applied as highly concentrated ammonium nitrate.

RESULTS

There are 5 experimental series which we shall examine successively. 4 factors have been studied :

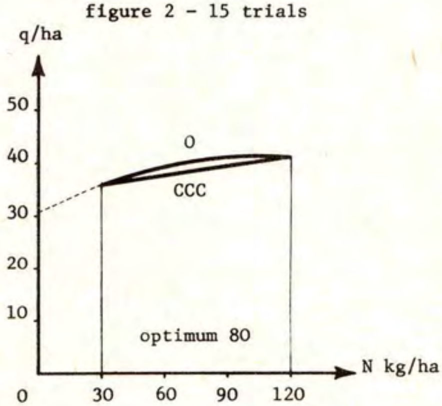
- Levels of nitrogen
- CCC
- Times of nitrogen application
- Weed control

The 2 first series include the 2 first factors only. The 2 others include the 3 first factors and the last one the 4 factors.

1 - The first series is a 15 trial one. There are 9 treatments : 4 rates of nitrogen (30-60-90-120 kg/ha) without CCC, the same rates of nitrogen with CCC and a control without nitrogen and CCC.

This rather low nitrogen level series was primarily designed for soil rich in available nitrogen (the preceding crop was a legume 7 times out of 15). The average optimum rate of nitrogen is rather low (80 kg/ha) when compared with the national 1966 average, based on 268 trials (110 kg/ha).

figure 2 - 15 trials

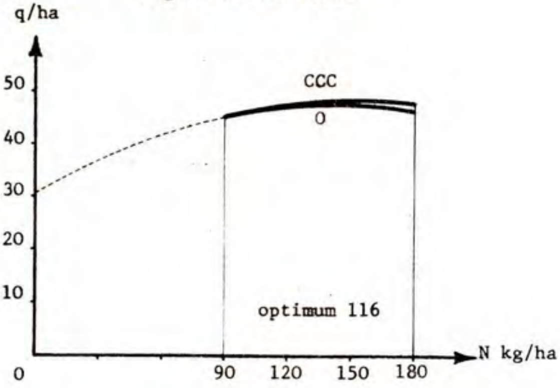


In this series CCC has a depressive effect whose average value is 0.8 q/ha (fig.2). This small difference is not significant. There is no interaction CCC x nitrogen.

2 - The second series includes 40 trials. The experimental procedure is similar to the first one but with higher levels of nitrogen : 90-120-150-180 kg/ha.

The sites on which these experiments have been settled down represent probably an average French agricultural situation, for the average optimum of this series is 116 kg/ha.

figure 3 - 40 trials

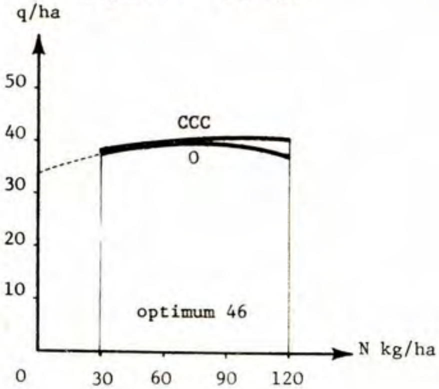


CCC has here a positive and non significant effect of 0.5 q/ha (fig.3). This effect is pratically null at the lower rates of N and is more perceptible at the higher rates (1.6 q/ha at the 180 N level). In this case CCC reduces the depressive effect of the highest nitrogen rates.

3 - The third series includes 8 trials with a more complex experimental procedure : 32 treatments factorially combined (4 rates of nitrogen x 4 times of nitrogen application x 2 rates of CCC). There are, in addition, controls without N. The experimental design is an unreplicated confounding. The 4 rates of nitrogen are : 30-60-90-120 kg/ha. The 4 times of application are : sowing, beginning of tillering, end of tillering, beginning of stem growth. The 2 levels of CCC are presence or absence.

The nitrogen optimum is low (46 kg/ha) because the soils were probably rich in available nitrogen.

figure 4 - 8 trials



There is an average positive and significant effect of CCC (1.5 q/ha). This effect increases with the rates of nitrogen (fig.4). Once more, CCC chiefly prevents the depressive action of nitrogen. The "times of application" effect is very low on the average. Nevertheless, CCC has a greater action when nitrogen is applied early (sowing or beginning of tillering). This means a rather significant "times of application x CCC" interaction (table 1).

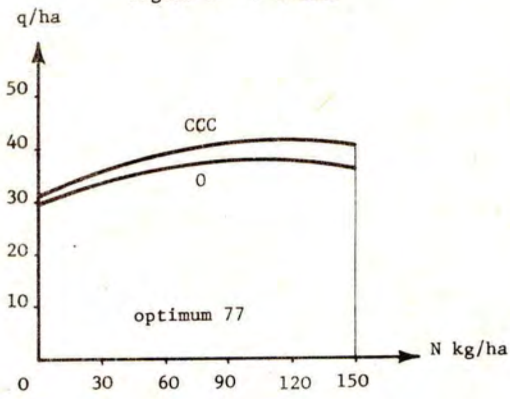
Table 1

CCC x times of N application interaction (8 trials)

	without CCC	with CCC	average
Sowing	38.3	41.4	39.8
Beginning of tillering	36.8	40.0	38.4
End of tillering	38.9	39.6	39.3
Stem growth	39.4	38.6	39.0
Average	38.4	39.9	

4 - The fourth series includes 7 trials. Its experimental procedure is very similar to the third one : the only difference is that the rates of nitrogen are slightly higher : 60-90-120-150 kg/ha. The average nitrogen optimum is 77 kg/ha. It is lower than the average national optimum. But it is higher than the optimum of the third series.

figure 5 - 7 trials



The average CCC effect is here positive, significant and really larger than in the other series : 3.7 q/ha (fig.5).

This effect increases with increasing rates of nitrogen applied. Consequently the nitrogen optimum is higher with CCC since the effect of CCC is here not limited only to an anti-lodging action (71 kg/ha without CCC, 84 kg/ha with CCC, although this difference is not significant).

Table 2

CCC x times of N application interaction (7 trials)

	without CCC	with CCC	average
Sowing	34.5	36.5	35.5
Beginning of tillering	35.8	43.0	39.4
End of tillering	37.3	41.9	39.6
Stem growth	39.1	40.1	39.6
Average	36.7	40.4	

The applications at sowing time were effectively inferior, compared to the other times of application (table 2). But there are little differences between the three other times of application. These results agree with those found in another 48 trial series studying the problem of timing. Last winter heavy rainfall was not favourable to autumn nitrogen applications, probably because of an important leaching. There is a significant interaction between CCC and timing. CCC has a more perceptible effect when nitrogen is applied during tillering (either beginning or end of tillering).

5 - The fifth series includes 6 trials. In addition to the previous factors studied in the third and fourth series (rates of application, timing, CCC) a last factor, weed control, is introduced.

However, rates and times are different :

- only 2 rates of N : 60 and 90 kg/ha
- 4 dates which are here beginning of tillering, end of tillering, beginning of stem growth, full stem growth
- 2 weed killers were used at 2 levels (presence or absence) :

  gesaran 25 (Triazine) 6 kg/ha
  Certrol P (Ioxinyl + MCPP) 3.5 l/ha

This experimental procedure includes 32 treatments and the layout is an unrepeated confounding (4X2X2X2). Furthermore, there are 4 controls without nitrogen, CCC or weed killer.

The average nitrogen optimum cannot be found as in the previous series for there are only 3 levels of nitrogen (0-60-90 kg/ha). But this optimum is probably not very far from 90 kg/ha since there is a positive difference of 1.6 q/ha between 60 and 90 kg N/ha (table 3).

Table 3

CCC x times of N application x N levels interaction (6 trials)

	C C C		N kg/ha		Average
	without	with	60	90	
Beginning of tillering	40.3	42.2	41.0	41.5	41.3
End of tillering	40.8	42.6	40.3	43.1	41.7
Beginning of stem growth	40.2	39.0	38.4	40.8	39.6
Full stem growth	38.3	36.3	36.9	37.7	37.3
Average	39.9	40.0	39.2	40.8	

There is no CCC effect, on the average (table 3). But there is probably a CCC x times of application interaction. As a matter of fact, according to the previous results, the CCC effect decreases in so far as the time of application is delayed.

Table 4

CCC x weed killer x N levels interaction (6 trials)

	C C C		N kg/ha		Average
	without	with	60	90	
No weed killer	37.7	37.8	36.9	38.7	37.8
Weed killer	42.1	42.2	41.4	42.9	42.2

The average effect of the weed killer is important : 4.4 q/ha (table 4) but there is no interaction weed killer x CCC nor interaction weed killer x nitrogen.

DISCUSSION

CCC has an average and positive effect of 0.6 q/ha in the 76 experiments studied. As the price of the CCC treatment is worth about 2 q of wheat, the use of CCC is not profitable,on the average. Such is the average result but the individual results are extremly variable, ranging from - 6.7 to + 11.7 q/ha.

Occasional yield decreases due to CCC are surprising and their causes are not yet cleared up. CCC might have brought a few day delay in the ripening of the wheat and consequently drought damages. A similar reason can probably explain less effectiveness of the late nitrogen dressings this year, as compared with the results of the last years. Increases of yield, due to CCC, were generally recorded in experiments in which lodging occured, but some noticeable increases were also observed in experiments without any lodging.

It is early to interpret correctly these first results. Yields only are discussed in this paper but a further study will be done on the other figures : straw heights, number of ears per square metre, thousand grain weight, etc... and will probably give a better understanding of so wide variations of yield.

Relations between nitrogen and CCC are not yet brought out very clearly. There is probably no correlation between the N economical optimum and the effect of CCC. However the effect of CCC seems to increase with the levels of nitrogen. More often, CCC acts on wheat as a neutralizer of the depressive effect of excessive amounts of nitrogen. If the nitrogenous fertilization is not above the economical optimum, the effect of CCC is negligible, on an average, although being important in some particular cases.

The time of nitrogen application is an important factor to clear up the effect of CCC. The better time of nitrogen application as far as CCC is used, is probably during tillering. CCC gives rather inferior results when nitrogen is used during stem growth. This reaction is logical in fact, because nitrogen and CCC have opposite effects on the height of the wheat stem. Nitrogen lengthens the stems of wheat but the later is the time of application the lower the elongation of the stems. Nitrogen applied during stem growth acts only on the last upper internode.

In conclusion : in 1966, a very particular year for N and CCC, the economical optimum of nitrogen was not apparently modified by CCC. However it seems that in order to get a chance of utilizing profitably CCC, it is necessary to use it with a high level of nitrogen.

DICAMBA - DISSIPATION IN AND ON LIVING PLANTS

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Velsicol Chemical Corporation
Chicago, (USA)

Dicamba* (3,6-dichloro-o-anisic acid) has proven to be an effective broad-spectrum herbicide. It is probably the most diversified herbicide commercially available to the farmer throughout the world today. The extensive use of dicamba has encouraged a search for knowledge regarding its fundamental aspects. Dissipation of dicamba in plants and soils, its safety to invertebrates, domestic animals and wildlife, and the influence of its physical and chemical properties in biological systems has been and is being studied extensively.

We are limiting our discussion here to a review of the current research being undertaken on uptake, movement, elimination, and dissipation of dicamba in or on plants. Some research relative to the dissipation of dicamba in soils is being presented in another section of this conference by Dr. T. J. Sheets, North Carolina State University, Raleigh, North Carolina. Additional soil studies have been conducted or are in progress by Burnside et al (1966), Corbin (1965, 1966), Cain (1966), Harris (1964) and others. Under normal conditions, dissipation in soils is relatively rapid. The important contributing factors are biological and/or chemical conversion and leaching.

With regard to the toxicity of dicamba, acute, subacute and chronic studies show that exposure by ingestion or by contamination of skin, mucous membranes or eyes, even at high levels, will produce no serious health hazard to animals or fish. It is therefore concluded that dicamba presents no hazard to man or animals under normal conditions of use.

Dissipation of dicamba in plants can occur on the surface of the plants, in leaf tissue, or in root tissue. On the leaf surface, dicamba may be dissipated by photodecomposition or volatilization. Gentner (1964) studied volatilization using Pinto beans as an indicator plant in a closed system. The plants showed symptoms from vapors of the dimethylamine salt formulation of dicamba which were rated slightly higher than those resulting from the low-volatile propylene glycol butyl ether ester of 2,4-D. However, the symptoms were considerably less than those given by vapors from the potassium salt of 4-amino-3,5,6-trichloropicolinic acid.

*BANVEL® D - Velsicol Chemical Corporation

Using dicamba-7-C^{14} on bare planchets at 0 to 100% relative humidity, Burnside et al (1966) found that it took 11 weeks incubation at 35°C to reduce the dicamba on the planchets to about 50% of the original amount. He compares this to the work of Kearney et al (1964), who reported more than 90% loss of atrazine from bare planchets within a twenty-four hour period at 35°C.

Numerous experiments using dicamba in preemergence and post-emergence applications for weed control have shown that dicamba is readily taken up by plants through both the roots and leaves.

Linder et al (1964), Hurtt & Foy (1965a, 1965b), Sand (1963), Egley (1963), Montgomery et al (1965), and Quinn & Bingham (1965) found that many plants have the ability to absorb dicamba through the leaves, translocate it both basipetally and acropetally, and exudate it through the roots. The amount of root exudation varies from one plant species to another. Cain (1966), using autoradiography techniques described by Crafts & Yamaguchi (1964), also found dicamba to be quite mobile through both the xylem and phloem with the added ability to transfer from one to the other. In the parasitic plant, witchweed (*Striga asiatica*), Egley (1963) found the movement of dicamba, as well as 2,3,6-TBA, to be primarily acropetal.

Using autoradiographic techniques in grapes, Leonard et al (1965) found no accumulation of dicamba in the roots, but there was accumulation at the margin of the leaves with concentration in areas corresponding to the location of the hydathodes. This could be attributed to the exudation of dicamba through the process of guttation.

Working with purple nutsedge, (*Cyperus rotundus* L.), and using autoradiography techniques, Magalhaes & Foy (1966) found that dicamba-7-C^{14} was moved readily via the connecting rhizomes from one nutlet to another.

Hurtt & Foy (1965a, 1965b) found dicamba excreted in detectable amounts from roots of Black Valentine beans (*Phaseolus vulgaris* L.) following application to the foliage of amounts as low as 0.02 ug/plant. Transfer of dicamba in an apparently unchanged form occurred from roots of donar (treated) plants to soil, sand, and various concentrations of nutrient solution. Nonmetabolized dicamba excreted into nutrient solutions was identified by autoradiography (dicamba-7-C^{14} only), bioassay (recipient control plants) and various chromatographic procedures.

Using dicamba-7-C^{14} in "balance-sheet" type studies still in progress, Hurtt & Foy (1966) found that a slight loss of C^{14} from bean roots occurred as early as two hours after foliar treatment. The quantity of C^{14} labelled material appearing in the external medium bathing the roots continued to increase until three to five days following treatment, after which it diminished steadily over a two week period.

Broadhurst et al (1966a), using tracer techniques, studied the metabolism of dicamba in treated bluegrass. They identified the major derivative by paper and gas chromatography as 5-hydroxy-3,6-dichloro-o-anisic acid (5-OH dicamba). The only other derivative, found in minor quantity, was 3,6-dichlorosalicylic acid.

Smith et al (1965, 1966) were also able to isolate 5-OH dicamba from bluegrass by a simplified technique. They established identity with the compound isolated by Broadhurst et al, and also to 5-OH dicamba synthesized by Velsicol Research Department, using gas chromatography, thin-layer chromatography, and infrared spectroscopy. Subsequent studies revealed that this derivative could be extracted from plant tissue by acidified ether and quantitatively measured without a hydrolysis step using gas chromatography with an electron capture detection system.

The conversion product, 5-OH dicamba, interpreted by Broadhurst et al as a metabolite, is formed from dicamba in sterile water in the presence of sunlight (Chirchirillo, 1966). Neither pure dicamba nor the technical product (BANVEL® D) was converted under similar conditions in the dark.

In the major agronomic uses of dicamba, such as in small grains, residues of dicamba or its derivatives are not significant. Both 5-OH dicamba and 3,6-dichlorosalicylic acid are of a very low order of toxicity. For example, their $LD_{50's}$ to rats, respectively, are 4200 mg/Kg and 1440 mg/Kg. These correspond to the LD_{50} for dicamba which is 2900 ± 800 mg/Kg. Both derivatives are also herbicidally inactive.

Additional work by Broadhurst et al (1966b) showed that dicamba was converted in wheat and bluegrass in the presence of DDT, 2,4-D, sevin, malathion, or mylone by the same route as if no other pesticide were present. Evidence indicated that some of the pesticides may slightly inhibit the rate of conversion of dicamba.

Using thin-layer chromatographic and autoradiographic analysis of the extracts of purple nutsedge plants treated with dicamba-7-C^{14}, Magalhaes & Foy (1966) found no C^{14} labelled metabolites regardless of the age or part of the plant analyzed. All labelled material found was dicamba.

Working with excised root cultures and using thin-layer chromatography, Ray & Wilcox (1966) found some dicamba converted to 5-OH dicamba by excised corn roots, and to 3,6-dichlorosalicylic acid by excised barley roots.

Using unlabelled dicamba and $C^{14}O_2$ autoradiography and scintillation counting techniques, Magalhaes & Foy (1966) found dicamba to have little, if any, effect on the translocation or concentration of assimilates in purple nutsedge. On the other hand, using similar techniques, Leonard & van der Zweep (1966) report marked accumulation of assimilate in the roots of soybeans after treatment with dicamba.

Using excised portions of leaves and tuber slices from purple nutsedge immersed and infiltered by vacuum for five hours in various concentrations of dicamba, Magalhaes & Foy (1966) found the permeability of leaf tissue increased but the permeability of tuber tissue decreased as the concentration of dicamba increased, as measured by a conductivity method.

Hilton (1965) found evidence that dicamba acts as a direct inhibitor of ketopantoate utilization for pantoate biosynthesis. However, he concludes that this action is of little significance in the herbicidal activity of dicamba. Quimby (1966) found that dicamba, applied to wheat and buckwheat, gave a temporary increase in peroxidase activity. Foy & Penner (1965) found dicamba, in concentrations of 1 x 10-3 molar, effective in inhibiting tricarboxylic acid cycle substrate oxidation by mitochondrial fractionsfrom etiolated cucumber cotyledons when succinate was used as the substrate. However, no inhibition occurred when α-ketogluterate was used as a substrate.

Pate et al (1965), working with nodal tissue of alligatorweed, found that an application of 2 lbs/A of dicamba resulted in destruction of phloem, cambium and associated parenchyma tissue above and within the nodes.

Much work is still in progress on various phases of dicamba including the scope of its activity and mode of action. While a great deal is already known, it is expected that more will appear in the literature in the next few years. In the meantime, any questions concerning the subject matter of this paper are most welcome.

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THE UPTAKE, TRANSLOCATION AND METABOLISM OF FLUOMETURON AND METOBROMURON IN PLANTS[1)]

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The fateof fluometuron (N'-[3-trifluoromethyl]-phenyl-N,N-dimethylurea) and metobromuron (N-methyl-N-methoxy-N'-[4-bromophenyl]-urea) in plants, including uptake, translocation and metabolism is investigated with the radiolabelled compounds. The present note summarizes some of the main results which so far have emerged from this study.

UPTAKE AND TRANSLOCATION. French dwarf bean and corn seedlings were cultured in Knop nutrient solution containing equal concentrations (2.5 ppm) and radioactivity (10.05 mμc/ml) of ^{14}C-fluometuron, ^{14}C-metobromuron and ^{14}C-chloroxuron respectively. Uptake by the root systems and translocation into stems and leaves were followed in short-term experiments by autoradiography (Crafts & Yamaguchi 1964) and total radioactivity determinations.

A typical series of autoradiographs is presented in Fig. 1.

Fig. 1 Autoradiograph of French dwarf bean seedlings cultured for 24 hours in nutrient solution containing 2.5 ppm (10.05 mμc/ml) of ^{14}C-labelled chloroxuron, metobromuron and fluometuron.

1) Fluometuron and metobromuron are the active ingredients of CIBA Ltd's COTORAN® and PATORAN® herbicide formulations respectively.

Results obtained with both plant species demonstrate that the ability to be translocated decreases in the following order : fluometuron > metobromuron ≫ chloroxuron. The difference in mobility between fluometuron and metobromuron is particularly noteworthy when comparing the distribution pattern of their radioactivity in leaves.

Uptake of the herbicides by the hypocotyls of bean seedlings was determined by exposing these plant parts to the nutrient solution described above. Entry of all three compounds into the xylem system was observed to be limited and does not appear to be a major contributing factor under field conditions.

METABOLISM. Metabolism studies were carried out with fluometuron (trifluormethyl-^{14}C) on cotton and wheat and with metobromuron (ring-^{14}C) on potatoes. Large numbers of plants were cultured in aerated 10 l. tanks for periods of 7-17 days. Extraction with acetonitrile and further clean-up by partitioning between different solvents gave the following three main fractions : residue, organic phase, aqueous phase. The bulk of radioactivity was recovered in the organic phase, which was further fractionated by thin layer and column chromatography. (Fig. 2 and 3). The identity of several metabolites was verified by IR-spectroscopy.

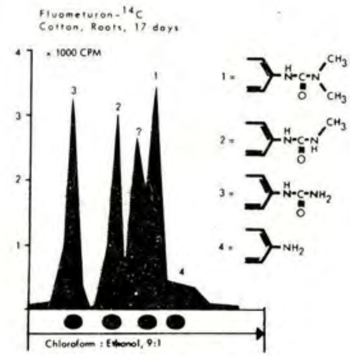

Fig. 2 Thin layer autoradiograph of organic phase derived from cotton roots which were exposed to ^{14}C-fluometuron for 17 days.

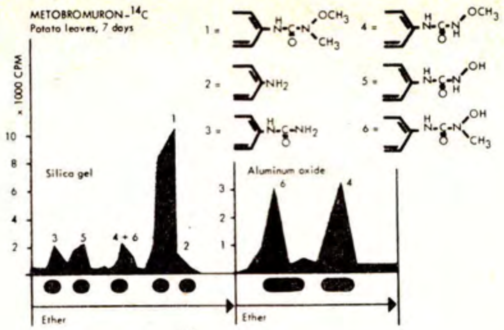

Fig. 3 Thin layer autoradiographs of organic phase derived from leaves of potato plants exposed to ^{14}C-metobromuron for 7 days.

The results demonstrate that stepwise demethylation represents a major metabolic pathway for fluometuron as well as metobromuron. Further degradation to the corresponding free aromatic amines is non-existent or at best very limited. So far, neither ring-splitting nor dehalogenation of the two substances have been observed. However, there appears to be some formation of conjugates which have not yet been identified.

Reference

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DIFFERENTIAL UPTAKE AND MOVEMENT AS A FACTOR INFLUENCING SELECTIVE TOXICITY OF MCPA AND MCPB

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Summary (1) The results presented confirm earlier findings that in the bean plant, MCPA susceptibility is related to extensive movement throughout the plant, whereas resistance to MCPB coincides with virtual localisation within the treated leaves.
(2) Whilst differential cuticle penetration does initially favour entry of MCPA, in the long-term this difference is apparently nullified. It would appear that the vital factor determining selectivity of these two compounds lies in the fate of the herbicide once inside the leaf.
(3) It may be that selective adsorption of MCPB at protein or vacuolar sites in the leaf renders a degree of resistance to the plant, possibly by minimizing the amount of MCPB reaching potential sites of B-oxidation.

INTRODUCTION

A chemical may in theory be an efficient metabolic inhibitor, but in practise its effectiveness may be influenced by the efficiency with which it traverses various membrane barriers and moves along tissue pathways en route to the sites of action. Thus a foliar-applied translocated herbicide must first penetrate the leaf cuticle, either by direct penetration or by movement through stomata, cracks, punctures and pectinaceous channels (Silva Fernandes 1965). The efficiency of cuticle penetration is influenced by many factors such as cuticle thickness, plant water relations, temperature, pH and formulation of the herbicide solution (van Overbeek 1956). The rate of movement of the herbicide away from the site of entry is also believed to influence penetration (Sargent 1965). Movement from cuticle to phloem is extremely slow (30 microns per hour), possibly due to the diffusion resistance of cell membranes encountered en route. These membranes, the plasmalemma and tonoplast, are highly impermeable and the mechanism of entry is uncertain. It has been suggested that polar solutions may enter via aqueous routes whilst non-polar molecules penetrate via lipophilic regions (Sargent 1965). Once in the phloem movement is very rapid (10-100 cm/hour), and the mechanism is believed to be controlled by metabolically active, less specialised cells associated with the sieve elements (Esau 1966). It is thought that by supplying energy for transport, the sugar content of leaves may be important in determining the efficiency of herbicide transport (van Overbeek, 1956).

On reaching the photosynthate 'sinks', regions of high metabolic activity generally situated in apical regions, the herbicide has again to overcome the diffusion resistance of the cell membrane, and organelles within the cell. The mitochondria, for example, are bounded by a double 'unit membrane' on the inner surface of which are situated many of the enzymes associated with cell metabolism including those concerned with B-oxidation (Lehninger 1965). These organelles are thought to be the possible site of action of many foliar-applied translocated herbicides.

During the past year, experiments have been carried out to determine the importance of differential uptake and movement as factors influencing the selective toxicity of 4-chloro-2 methylphenoxyacetic acid (MCPA) and 4-(4-chloro-2 methylphenoxy) butyric acid (MCPB) on bean plants (*Vicia faba*).

Studies have also been carried out on selected species of unicellular algae and on the filamentous fungus Aspergillus niger. The results of some of these earlier investigations have already been published (Kirkwood et al 1966). The present contribution is in the nature of a progress report on the work with higher plants which will continue with the support of a grant from the Agricultural Research Council.

MATERIALS AND METHODS

The MCPA and MCPB used in these experiments were labelled in the carboxyl-groups and have specific activities of 2.55 and 5.0 mc/mM respectively. Three types of investigation were carried out using bean as test plant.

(a) Qualitative assessment of herbicide uptake and movement using autoradiography.
(b) Detection of labelled herbicide residues in treated plants using chromatography combined with autoradiography.
(c) Quantitative assessment involving O_2 combustion of treated plants followed by evaluation of the liberated $C^{14}O_2$ by scintillation spectrometry.

(a) Autoradiographic techniques

The herbicides, formulated as the sodium salt with 0.05% Tergitol wetter incorporated, were applied to bean plants using an Agla micro-syringe pipette. Applications of 0.02 ml of 2.5×10^{-3}M MCPA and 2.2×10^{-3}M MCPB solutions were made to each of four rubber rings (internal diameter 6 mm) mounted with lanolin on the adaxial surface of the last two pairs of expanded leaves. The radio-active dose was 0.45 uc per plant. Corresponding doses were applied directly into the vascular system by means of 3.5 cm lengths of 1 mm polythene tubes applied to tongues of midrib tissue (Little and Blackman, 1963). The treated plants were placed in a constantly illuminated growth cabinet in which temperature and humidity were controlled at 20°C (±0.5°C) and 100% (±1%) respectively. In harvesting, the treated leaves were washed with 0.3M sucrose to remove superfluous herbicide. The plants were then sectioned, freeze-dried, mounted on lithographic paper and autoradiographs prepared using the method of Yamaguchi and Crafts (1958). The mounted specimens were covered with Melinex film (I.C.I. Ltd.) which was 6 u thick and absorbed 22% of the C^{14} radiation (Little 1962).

(b) Chromatographic detection of herbicide residues in treated plants

The importance of detecting herbicide residues in the plant and ensuring that the label is still attached to it, has been emphasised by several workers. (Wain, 1963, McCready, 1966). Extracts were prepared from replicate plants previously treated with labelled herbicide using the procedure of Fawcett et al (1959). The extracts were spotted, along with radioactive controls, on 60% Kieselguhr/40% Silica gel plates. Good separation was achieved using a liquid paraffin, benzene, acetic acid, cyclohexane solvent system. (Abbott et al 1964). Autoradiographs of the chromatograms were obtained by exposing Ilford 8" x 8" plates, type X M. for a period of 3 days.

(c) Quantitative assessment of herbicide uptake and movement

Applications of 0.03 ml of 1.25×10^{-3}, 2.5×10^{-3}, 5×10^{-3} MCPA, and 1.1×10^{-3}, 2.2×10^{-3}, 4.4×10^{-3} MCPB solutions were made to each of eight rubber rings mounted on the last two pairs of expanded leaves. The radioactive dose was held constant at 0.45 uc per plant.

The treated plants were harvested, divided into four regions viz., shoot apex, shoot, root and treated leaves and the latter washed in 0.3M sucrose to remove superfluous herbicide. After drying overnight in an oven at 50°C, the samples were combusted using an oxygen flask (Macdonald 1961, Kalberer and Rutschmann 1961, Jeffay and Alvarez 1961). The $C^{14}O_2$ evolved was absorbed in 14% ethanolamine - ethoxyethanol solutions and aliquots of 1 ml was transferred to a dioxanbased scintillation liquid for radioassay using a Packard Tricarb Scintillation Spectrometer.

RESULTS

(a) Comparison of the uptake and movement of MCPA and MCPB using autoradiography

The uptake and movement of MCPA and MCPB when applied to surface rings and by midrib incorporation can be compared in Fig. 1. The autoradiographs show that although midrib incorporation increased translocation of MCPA, MCPB remained localised in the treated leaves.

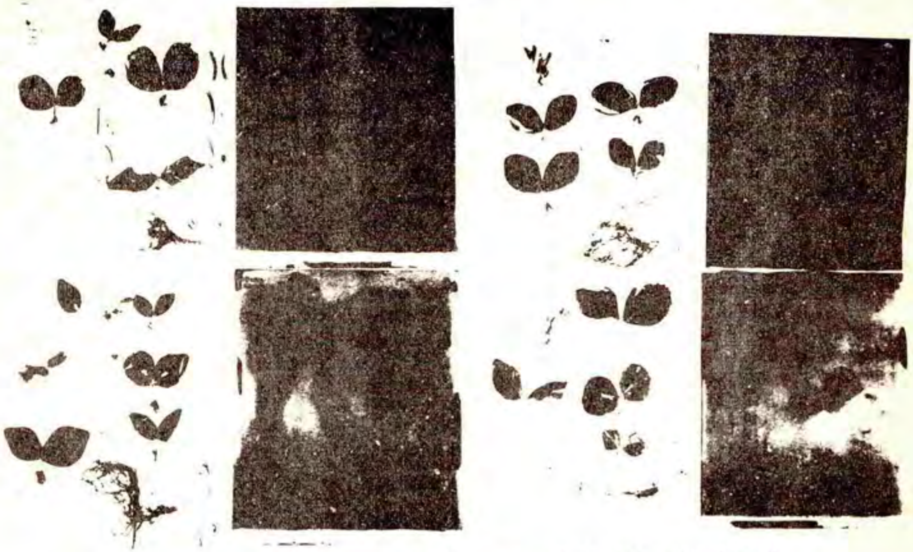


Fig. 1. Autoradiographs of plants treated with MCPA (left) and MCPB (right) using ring (upper) or tube (lower) methods of application.

(b) Detection of labelled MCPA and MCPB residues in treated plants

Chromatography followed by autoradiography of extracts of MCPA - treated plants shows close agreement of Rf between the extract and control spots, both of which have an Rf. of 0.35 (Fig. 2). This agrees satisfactorily with the Rf. of about 0.40 already recorded for MCPA using the same matrix and solvent system (Abbott et al 1964). No other spots were evident.

Chromatograms of extracts of MCPB-treated plants show spots having Rf's of approximately 0.09, 0.13, 0.35 and 0.63 (Fig. 2). Those of Rf. 0.35 and 0.63 agree well with the control spots for MCPA and MCPB respectively, though the value of 0.63 is low compared with the recorded figure of about 0.75 (Abbott et al 1964). The presence of labelled MCPA in the extract from MCPB - treated plants is regarded as evidence of B-oxidation.

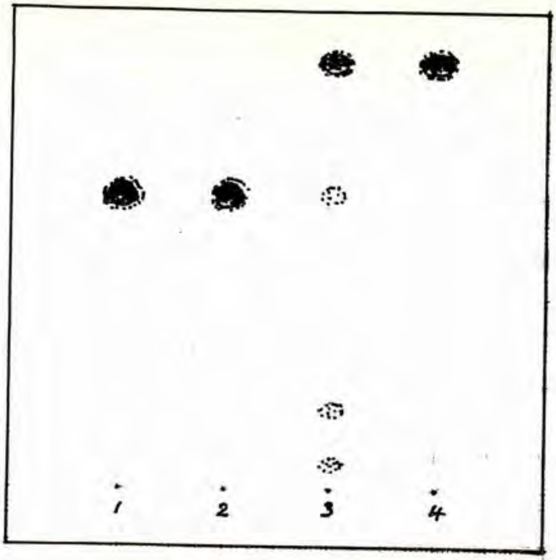


Fig. 2. Appearance of chromatogram on 60% KieselguhrG - 40% silica gel G treated with 1. MCPA-treated extract, 2. MCPA-C^{14}, 3. MCPB-treated extract, 4. MCPB-C^{14}.

(c) Quantitative determination of herbicide uptake and movement

1. The effect of herbicide concentration on the relationship between uptake and toxicity

Application of MCPA resulted in general chlorosis and epinasty which increased in severity with concentration and duration of treatment. The terminal region of plants receiving 2.5×10^{-3}M MCPA treatments recovered normal orientation and remained relatively green. Plants treated with MCPB remained healthy during the entire treatment period.

Distribution of the herbicide residues was calculated from the radioactive assays carried out by scintillation spectrometry. The results presented in graph 1 show herbicide residues per unit weight (0.1g) of plant material expressed as a percentage of total uptake; the actual weights of herbicide residue, expressed in ug and as a percentage of treatment dose are shown in Table 1.

The results portrayed in the graph, again demonstrate the major difference in distribution of MCPA and MCPB noted in the autoradiographs above. Relatively little MCPB is translocated throughout the plant, 80-95% of the amount absorbed remaining in the treated leaf. The small degree of accumulation in the shoot apex appears to decline with dose. Translocation of MCPA however is much more extensive, only 30-73% remaining in the treated leaf. Again accumulation was most marked in the shoot apex.

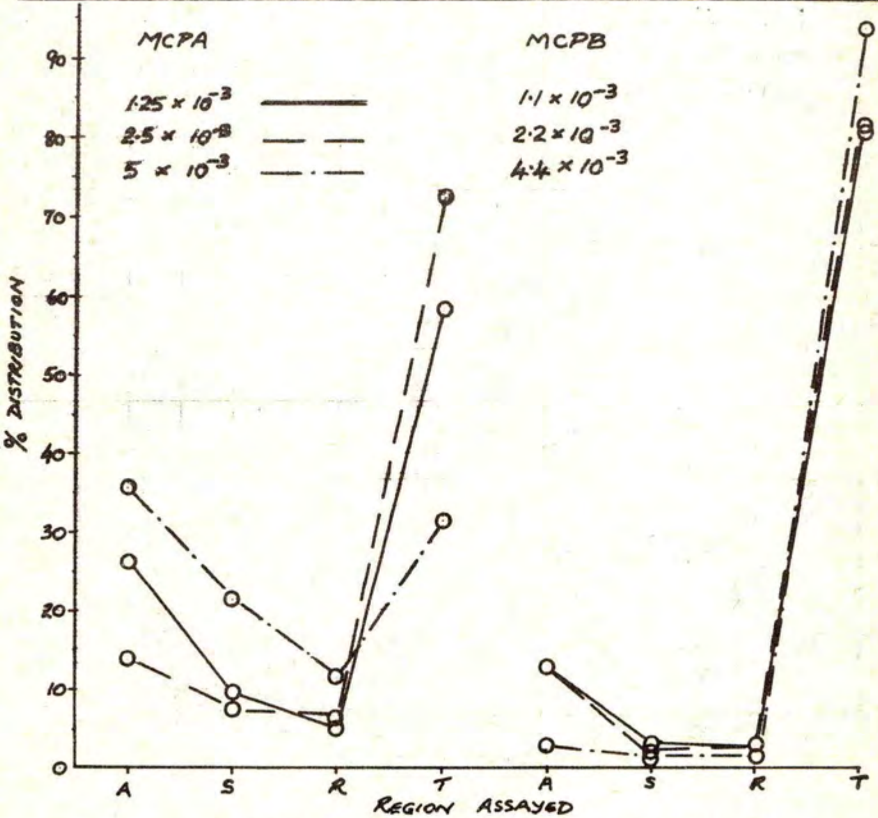
Analysis of variance of the results verified that overall herbicide residues increased with dose (P = 0.01) and that distribution varied significantly between regions (P = 0.01).

2. The effect of sucrose treatment on the relationship between uptake and toxicity

Sucrose appears to increase the severity and uniformity of chlorosis and epinasty recorded in MCPA - treated plants, but has no apparent influence on MCPB effectiveness.

Table 1. The distribution of MCPA and MCPB in the short apex (A), shoot (S), root (R) and treated leaves (T), of bean plants harvested 14 days after treatment (mean of three replicates).

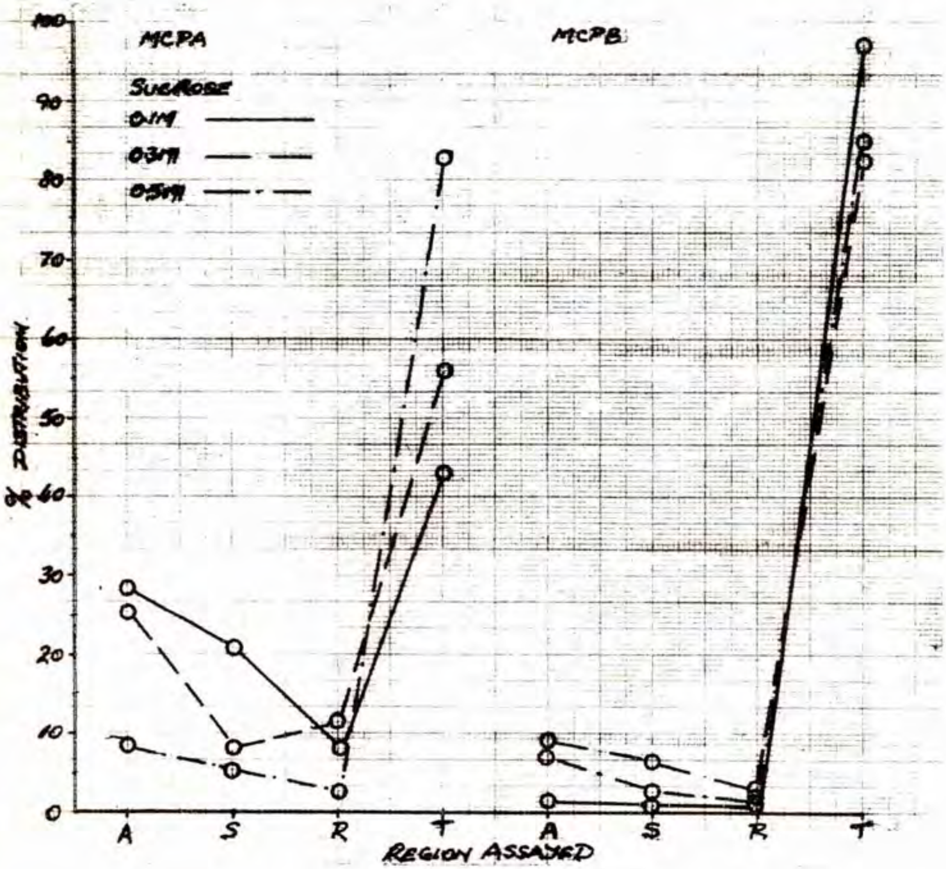
Herbicide dose (M)	Herbicide Distribution								Total Uptake	
	A		S		R		T			
	ug	% of dose	ug	% of dose	ug	% of dose	ug	% of dose	ug	% of dose
MCPA										
1.25×10^{-3}	0.4	0.5	1.4	1.8	1.4	1.7	4.9	6.1	8.1	10.1
2.5×10^{-3}	0.7	0.5	1.6	1.4	1.8	1.5	5.5	4.5	9.6	7.9
5×10^{-3}	1.5	0.7	6.7	3.4	6.3	3.1	7.5	3.7	22.0	11.0
MCPB										
1.1×10^{-3}	0.5	0.6	0.7	0.8	0.6	0.8	9.6	12.0	11.4	14.2
2.2×10^{-3}	0.8	0.7	0.8	0.6	0.7	0.6	12.0	10.0	14.3	11.9
4.4×10^{-3}	1.1	0.5	9.6	4.8	8.9	4.5	10.6	5.3	30.2	15.1



Graph 1. The effect of dose on the distribution of herbicide residues.

Table 2. The distribution of MCPA and MCPB in the shoot apex (A), shoot (S), root (R) and treated leaves (T), of bean plants harvested 10 days after treatment, (mean of three replicates).

Herb. (M)	Suc. (M)	Herbicide Distribution A ug	A % of dose	S ug	S % of dose	R ug	R % of dose	T ug	T % of dose	Total Uptake ug	Total Uptake % of dose
MCPA 2.5×10^{-3}	0.1	5.0	4.1	5.8	4.8	1.9	1.6	10.8	9.0	23.4	19.5
	0.3	1.5	1.2	2.6	2.2	4.3	3.6	8.0	6.7	16.4	13.7
	0.3	1.5	1.2	2.6	2.2	4.3	3.6	8.0	6.7	16.4	13.7
MCPB 2.2×10^{-3}	0.1	1.0	0.9	1.5	1.3	0.7	0.6	48.6	40.5	51.9	43.2
	0.3	1.0	0.8	1.5	1.3	0.9	0.8	34.1	28.4	37.6	31.3
	0.5	2.4	2.0	3.0	2.5	0.8	0.7	37.4	31.1	43.6	36.3



Graph 2. The effect of sucrose on the distribution of herbicide residues.

The radioassay results are presented in the manner described for the previous experiment (Graph 2 and Table 2). Comparison of the data recorded in Tables 1 and 2 shows that sucrose incorporation resulted in an increased overall uptake of both herbicides though the general pattern of distribution was similar (Graph 2). Sucrose significantly increased translocation of MCPA from the treated leaves into the shoot apex ($P = 0.01$), the response being most marked at the lowest concentration (0.1M). The distribution of MCPB was virtually unaffected by sucrose incorporation.

DISCUSSION

The evidence presented herein and elsewhere (Kirkwood et al 1966) demonstrates that in the plant species tested, susceptibility coincides with extensive movement throughout the plants, whereas resistance is related to virtual localisation within the treated leaves. The reasons for this translocation differential are as yet uncertain.

The possibility that selectivity is attributable to differential cuticle penetration has been examined using detached leaves and isolated cuticles. The results of short-term experiments (maximum 8 hours) reported earlier (Kirkwood et al 1966) show more rapid uptake of MCPA. It is evident, however, from the quantitative data presented in Tables 1 and 2 that this selective uptake of MCPA does not endure throughout the whole treatment period and that in the long-term a greater total uptake of MCPB is recorded, accumulation occurring in the treated leaves. Though statistically non-significant this effect was noted in both experiments and is probably real. It may be that the relatively undamaged tissue of the treated leaves continues to absorb MCPB long after the severely chlorotic and damaged MCPA-treated leaves, particularly if uptake is an active process linked to cell metabolism. It would appear then that differential penetration of the cuticle may not be the primary key to the problem, a view substantiated by the fact that by-passing the cuticle barrier had no major effect on the pattern of herbicide distribution within the plant. (Fig. 1).

The main mechanism determining selectivity of these herbicides appears to operate once the herbicide has penetrated the leaf tissue. Two possible modes of action could be suggested:

(1) at the high concentrations involved, the mechanisms of photosynthesis, respiration and translocation are locally inhibited in the treatment region, to a greater degree by MCPB than MCPA, thus preventing active movement away from the treated zone.

(2) that MCPB may be selectively adsorbed or accumulate at metabolically inactive sites where it is unavailable for translocation.

Three observations tend to favour the latter postulate. Firstly, the MCPB-treated leaves remain very healthy and except for extremely small localised, black spots there are no general symptoms of chlorosis within the treatment discs. Secondly, localisation of MCPB within the treated leaves was relatively unaffected by addition of sucrose to the treatment solution, whereas a significant increase in translocation of MCPA was recorded suggesting that sugar availability was an important limiting factor only in the case of MCPA. Thirdly, if inhibition of these physiological mechanisms does take place then MCPB must be acting as MCPB and not as MCPA, since a typical MCPA translocation pattern would reasonably have been expected but was not obtained. The possibility that MCPB is itself toxic without conversion to MCPA cannot be discounted. Work carried out on selected species of micro-organisms suggests that relatively high concentrations of MCPB (above 10^{-4}M) may be inherently toxic (Shennan and Fletcher, 1965, Smith and Shennan 1966). Similarly MCPB has been found to have a greater inhibitory effect on respiration and water uptake of excised epicotyl segments. (Smith, J.E., and Robertson, M.M., unpublished data). There is, as yet, no evidence to suggest that a comparable situation occurs in intact bean plants.

It would be reasonable to suggest that resistance to MCPB may be due to the absence of a B-oxidation system, since it is generally accepted that MCPB is in itself non-toxic requiring to be converted by B-oxidation into the toxic MCPA (Wain, 1955, 1957; Fawcett, Wain and Wightman 1960). However, chromatography of extracts of MCPB-treated plants revealed small quantities of MCPA, insufficient apparently to interfere with normal metabolism, but enough to explain observed stimulation of bean shoot growth.

This limited conversion of MCPB into MCPA may have two explanations. It may possibly be due to an inefficient B-oxidation system or simply that the MCPB failed to reach the sites of conversion in any quantity. If this latter postulate is indeed the case then it is possible to discount the treated leaves as the site of B-oxidation since the data presented in Tables 1 and 2 shows considerable uptake of MCPB in these leaves, yet chromatography of whole plant extracts, which include the treated leaves revealed meagre conversion. Furthermore, if efficient B-oxidation did occur in MCPB - treated leaves, then translocation patterns similar to MCPA - treated leaves, might reasonably have been expected, but were certainly not evident from the data presented.

It would appear that the postulation of a B-oxidation system at sites remote from the treated leaves becomes less relevant since it is evident that the vital factor determining selectivity of these two herbicides is concerned with the differential uptake and movement.

Acknowledgements

The authors wish to express gratitude to May & Baker Ltd., for supplying the isotope-labelled herbicides used in these experiments and Dr. N.G. Waton of the Department of Pharmacy, University of Strathclyde for the use of a Packard Tri-carb Scintillation Spectrometer. Thanks are also due to Dr. A. Calderbank (I.C.I. Ltd.) for helpful discussion concerning oxygen combustion of samples, and to Mrs. J. Innes for technical assistance. The project was aided by a grant awarded by the Agricultural Research Council, and one of us (M.M.R.) holds a post-graduate scholarship from the Department of Agriculture and Fisheries for Scotland.

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The photochemical reactions of photosynthesis appear to be quite susceptible to several herbicides. Indeed, the urea herbicides such as diuron are so specific in their mode of action that they have contributed considerably to the understanding of the mechanism of photosynthesis.

Perhaps one of the most interesting of the new herbicides is Ioxynil. It has been shown that ioxynil inhibits the uptake of CO_2 in whole chloroplasts at a final herbicide concentration of 1×10^{-5}M (Paton and Smith, 1965a). This result is similar to that found by Bamberger et al (1963) for CMU and the quinoline-N-oxides.

A convenient method for the evaluation of a photosynthetic inhibitor is the Hill reaction (The Hill reaction is a general term used for the measurement of photo-electron transport in chloroplasts). Ioxynil inhibits the electron transfer of the oxidant dichlorophenolinddphenol(DCPIP) by 50% at a herbicide concentration of 8×10^{-7}M (Paton and Smith, 1965a). This concentration, while in close agreement with that observed by Desmoras et al (1964) and Kerr and Wain (1964a) for the same inhibitor is very low and may not represent the true concentration affecting the physiological oxidation, since Paton and Smith (1965a) have shown that the physiological photo-reduction of pyridine nucleotide (NADP) is inhibited by 50% with a concentration of 5×10^{-5}M ioxynil. It is generally found that much higher rates of activity are found when non-physiological oxidants are used and such rates may be more susceptible to lower concentrations of an inhibitor. However, ioxynil appears to be a more efficient inhibitor of the Hill reaction than the common herbicides 2,4,5-T; 3,4,5-TBA and CIPC and as effective as diuron. Since electron transport is an essential part of photosynthesis, this blockage will lead to the cessation of ATP synthesis and to drastic changes in the physiology of the plant and ultimately death.

The inhibitory effect of ioxynil on photosynthesis can be partially reversed by cysteine and almost completely reversed by glutathione. A proposed mechanism for this reaction will be published elsewhere (Paton and Smith, 1966).

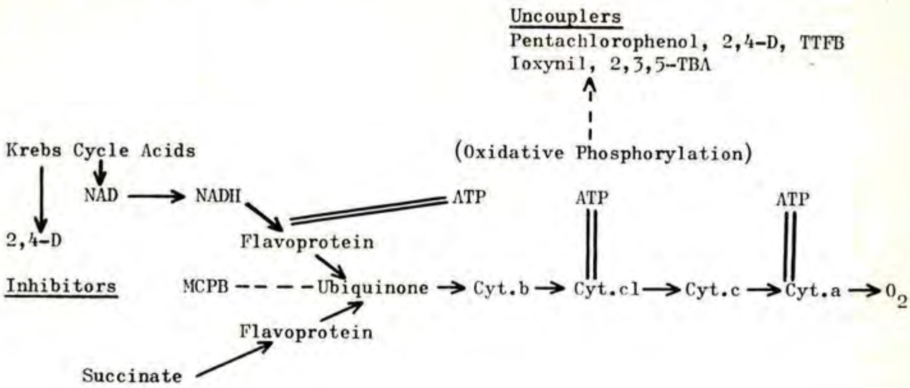
Further studies by Paton and Smith (1965b) have suggested that the actual site of action of ioxynil may be near plastoquinone, a component of the electron transport system in higher plant photosynthesis.

Respiration In respiration the free energy locked in the carbohydrate molecule is liberated and incorporated into ATP which in turn can energise all energy requiring reactions of the cell. Without ATP cellular activity would cease very rapidly. In this sense the inhibition of respiration by a herbicide would lead to a more rapid breakdown of cellular processes than a comparable inhibition of photosynthesis. Although photosynthesis is the ultimate energy supplier for the plant, the plant could exist for some time utilising stored organic material to produce ATP by respiratory breakdown.

The way in which compounds affect the respiratory electron transport pathways is much more clearly understood than the corresponding pathways in photosynthetic tissue. Most of the evidence for the effect of inhibitors on respiratory electron transport has dealt mainly with the effect of antibiotics and pharmaceutical products on plant and animal tissue and mitochondria. Very little has in fact been done on the effects of herbicides on plant mitochondrial oxidations. Although there is a vast range of herbicides in present day use only a few, in particular 2,4-D, have been studied to any depth for the effects on electron transport (Wedding and Black, 1962).

Fig. 2. shows what is now generally accepted as the major sequence of events leading to the reduction of oxygen during respiration. The final energy-yielding portions of respiration occur over the respiratory chain. Electrons are fed into the chain from Krebs cycle acids and transported along by a series of oxidation/reduction reactions involving the cytochromes and quinones. The energy released is coupled to phosphorylation reactions and leads ultimately to the formation of ATP - oxidative phosphorylation. Thus any compound which can impair this process will undoubtedly severely disrupt cellular metabolism.

Fig. 2. The pathway for the oxidation of cellular products and possible sites of action of some herbicides.



Ioxynil has been found to alter the rate of oxidation of Krebs cycle acids (Kerr and Wain, 1964b) (Foy and Penner, 1965) and Paton and Smith (unpublished results). At low concentrations ioxynil stimulates oxygen uptake whereas it inhibits O_2 uptake at much higher concentrations. These results are in keeping with the behaviour of compounds that are known uncouplers of oxidative phosphorylation.

Foy and Penner found that 7.5 x 10^{-6}M ioxynil inhibited oxygen uptake by 50% whereas work in this Department has shown that ioxynil at 5 x 10^{-6}M will only cause an 18% inhibition. It is signfiicant to note that their measurements were made over a period of 1 hour whereas in this investigation, using sensitive polarographic techniques, measurements were recorded in the first 1 - 2 minutes after addition of the herbicide. Such rapid measurement is not possible when using conventional Warburg techniques. In an isolated mitochondrial extract the response to inhibition should be almost immediate to have any real meaning and for this reason it is considered that prolonged measurement of the effect of low concentrations of inhibitors can be misleading.

The results of Kerr and Wain (1964b) and studies in this Department suggest that ioxynil at extremely low concentrations (ca 10^{-8}M) can uncouple oxidative phosphorylation in plant tissue. Parker (1965) has also shown that 1 x 10^{-6}M ioxynil can uncouple oxidative phosphorylation in rat liver mitochondria. This extreme toxicity of ioxynil to such a system is rather surprising since the compound is accepted as having a very low mammalian toxicity.

Further studies in this Department have shown that the probable site of inhibition in the respiratory chain occurs in the region of ubiquinone - an essential part of the chain.

It would appear that there is a similarity in the way in which ioxynil inhibits electron transport in photosynthesis and respiration. The main site seems to involve the inhibition of electron flow near the quinone component of electron transport. It is interesting to note that the inhibitor MCPB specifically inhibits ubiquinone reduction in *Aspergillus niger* (Smith and Shennan 1966) and in *Vicia faba* (Robertson and Smith, unpublished work).

It is clear from these studies that the concept of one site of primary action of a herbicide is not completely acceptable. Furthermore, the selective herbicidal properties of a molecule cannot be due entirely to the ability of the molecule to function as a metabolic toxin since many chemical compounds greatly influence extracted enzyme systems but are not selectively toxic to plants. For this reason selectivity of a herbicide cannot be related entirely to inhibition of a biochemical reaction but should be considered together with the biophysical factors such as uptake into plants, movement into and across membranes and cells, and translocation to active sites.

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BIOLOGICAL AND PHYSICAL ATTRIBUTES OF SEVERAL AMIBEN DERIVATIVES

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Summary Weed control with amiben, most commonly formulated as the ammonium salt, has not been as consistent in light textured soils as it has in heavier prairie soils. Studies show that the salt leaches rapidly as a result of its high water solubility and slight adsorption by the soil.

The esters of amiben are less soluble and show considerable adsorption by soil. The leaching depths of the esters are much less than that of the salt. The esters hydrolyze in the soil to give the salts. The amiben amide is inactive per se and requires hydrolysis for activation.

Field studies confirm the laboratory and greenhouse findings. In heavy soils the amiben salt produced to give slightly better weed control than did the esters. In a number of tests on lighter soils with good rainfall the esters gave better weed control and less crop injury than the salt.

INTRODUCTION

Most preemergence herbicides require rain or irrigation to wash the chemical into the soil. The ammonium salt of amiben, a highly water soluble herbicide, is no exception. In practice such chemicals pose a second problem. Heavy rain on light soil may leach the highly soluble chemical below the zone in the soil where weed seeds are germinating. The result is unsatisfactory weed control. The success of weed control in soybeans or other crops with amiben is not a simple story of crop tolerance and weed susceptibility, but a complex one of inter-relating of soil, crop, weeds and environmental conditions.

BEHAVIOR OF THE SALT OF AMIBEN IN SOIL

The amount of amiben (meaning the ammonium salt unless otherwise specified) adsorption by soil constituents and especially the initial strength of adsorption of amiben is far less than for many other herbicides (Warren, 1956). This is borne out in practice, for relatively small changes in rates are required to obtain similar weed control on sandy soil or clay loam soil. Even in muck soil, amiben moves rather readily through the soil profile. Diuron, CIPC, and PCP require several-fold changes in rate to obtain similar degrees of herbicidal effect with broad changes in soil type.

Results of experiments relating to amiben adsorption and leaching are not in complete agreement. This leads one to believe that special combination effects occur and the interaction of these effects still requires investigation. Schliebe, (1965) found that a muck soil with 40.7% organic matter and a cation exchange capacity of 65.6 adsorbed 29% of the 0.1 ppm solution of amiben and that a Sharpsburg silty clay loam with 4.4% organic matter and a cation exchange capacity of 24.5 adsorbed 9% of the amiben. A Fargo clay with 10.9% organic matter and a cation exchange capacity of 30.1 adsorbed only about 3% of the amiben. The clay content of the two soils was almost equal. This inconsistency has not been explained. When these workers evaluated clay fractions for their adsorptive capacity, amiben was adsorbed more by kaolinite and illite than by bentonite, which has a higher exchange capacity. Amiben has shown anionic properties and so it tends to exhibit properties like phosphate ions and adsorption by kaolinite would be expected. Desorption of amiben follows an unusual pattern also. Although amiben is not adsorbed in large quantities, the portion that is adsorbed is more strongly adsorbed than other chemicals such as atrazine.

With little adsorption, a soluble chemical like amiben remains in the available water in the soil. The concentration of the chemical is than (most certainly) a function of the percent field capacity of the soil at any particular moment. Assuming we are dealing with the top two inches of soil, one pound of chemical per acre would produce a concentration of 1.4 ppm. (Two acre-inches of soil weigh approximately 700,000 lbs. Lyon, 1952). Actually, however, we are not dealing with the solid portions of the soil but rather the pore space between the soil particles. For example, in a sandy soil at field capacity, water is retained at a level of 8% by weight and in a silt loam, 24% by weight. Two acre-inches of sandy soil would hold at field capacity 56,000 pounds of water and a silt loam would hold about 168,000 pounds of water. One pound of chemical per acre in the surface two inches would produce a concentration of 17 ppm in the water held by the sand and 6 ppm in the water held by the silt loam. A normally selective chemical could thus be quite toxic in the liquid phase of the sandy soil but quite safe in the silt loam. The rate at which the chemical is dispersed or leached through the soil can reduce the concentration to levels that are safe for crops and still give effective weed control.

Leaching studies by both Warren, 1963, in Indiana and by Rauser and Switzer, 1962-1963, in Ontario show amiben readily moves down through sand. However, a considerable amount of activity is retained in the upper layers of clay and muck soil columns even with a water supply that would have been sufficient to solubilize and desorb much more amiben than was present. Leaching studies have been conducted on California and Arkansas soils by Donaldson and Foy, 1965, and by Baker, Talbert and Frans, 1966. In these studies, the data do not show retention in the upper soil layer when water moves through the soil column. On the California Stockton adobe clay and Steten Island peaty muck (42% organic matter), amiben moved with the waterfront. Adsorption was found to be about 15% for amiben on the peaty muck and considerably less with other soils.

Baker found no differences in the leaching characteristics of six different soil types in Arkansas. The ammonium salt of amiben or equilibrium cation salts formed by available cations in the soil moved readily through the soil profile. In general, excessive leaching appears to be the primary reason for short-term weed control obtained with amiben (under adverse field conditions). Burnside, 1965, has shown that under some experimental laboratory conditions amiben was even more persistent than 2,3,6-trichlorobenzoic acid.

The reason for the difference in leaching patterns in different soils of the United States is not yet clear at the present time, but there appears to be a relation between the lack of leaching in the prairie type soils and satisfactory field performance of amiben. Perhaps the amiben is being temporarily trapped by the expanding and contracting lattice of the clays.

Several attempts have been made to reduce the leaching of amiben. Metallic and alkali metal salts were prepared. Iron, aluminum and even barium salts were rather soluble and did not appreciably vary the field performance of amiben. The salts apparently reach an equilibrium with the naturally occurring cations in the soil. The leaching pattern was not significantly different than that to be expected if a highly soluble salt had been used. Occasional field tests have given some slight indication of improvement in weed control.

Synthesis of amides and esters of amiben provided a series of compounds that produced major difference in the leaching characteristics of amiben, offering the following interesting possibilities:

1. More satisfactory weed control by retention of the herbicide at lethal concentrations in the upper layers of light soils. Conversely, if solubility and leaching characteristics are reduced markedly, the esters may produce poorer weed control under low rainfall conditions.

2. Greater retention in the upper layers of the soil, thereby reducing the rate of application needed.

3. Good tolerance of crops with marginal tolerance as a result of some depth protection.

LEACHING STUDIES WITH AMIBEN DERIVATIVES - METHODS AND RESULTS

Laboratory and greenhouse studies show that ester formulations of amiben have greatly reduced the rate of leaching in a given soil. Baker, 1966, using a slotted glass tube technique, determined leachability of different amiben derivatives on six soils. These soils ranged from a fine sandy loam with 4% clay to a Sharky clay with 45% clay content. The herbicide was assayed in the column by planting crabgrass in the slot and observing its growth. Amiben methyl ester was retained in the uppermost layers of the soil, but the salts were leached several inches. (Table 1.)

Table 1.

Average leaching of amiben and amiben derivatives in six soil types

Amiben formulation	Zone of activity with 0 inches as soil surface
Amiben ammonium salt	6 - 10 inches
Amiben aluminum salt	4.5 - 8.25 inches
Amiben amide	2 - 5 inches
Amiben methyl ester	0 - 2.5 inches

In the Amchem greenhouses, soil column leaching tests were run in 8 inch diameter drums 16 inches deep. The soil columns were carefully packed, the chemical was applied and the columns were slowly leached with three inches of water. The soil column was then split in half and planted with foxtail and pigweed. The rows of seed in each half of the drum were covered with sand. One soil type studied was a loamy sand from a field where amiben performance had been poor. The movement patterns of these herbicide formulations through the soil column differed significantly. (Table 2.) No weed control was obtained in the top eight inches of soil from amiben applied in the acid form. In greenhouse and field tests amiben acid performance was comparable to that of the salts.

Table 2.

Leaching of amiben, amiben amide and amiben ester in a loamy sand soil with three inches of artificial rain. (Rate 5 lb/ac a.e.)

Amiben formulation	Zone of activity with 0 inches as soil surface
Amiben acid	8.25 - 13 inches
Amiben amide	0 - 5.5 inches
Amiben ester	0 - 1.5 inches

The water solubility of the different amiben derivatives varies greatly. The amiben salts have solubilities greater than 250,000 ppm. The amiben amide has a solubility of around 1200 ppm while the methyl ester is soluble to only 120 ppm. With solubilities at these levels, retention of the ester and the amide in the upper portions of the soil would not be expected. The application of three inches of water should be sufficient to solubilize 180 pounds of the ester per acre and 800 pounds of the amiben amide per acre. Factors other than solubility must play an important part in the behavior of these chemicals in the soil.

ADSORPTION OF AMIBEN ESTERS

Fifty grams of greenhouse soil shaken for 2.5 hours with 50 ml of water containing 0, 5, 10 and 15 ppm acid equivalent of formulated butoxyethyl or hydroxypropyl ester of amiben. The slurry was centrifuged and the supernatant filtered. A 25 ml aliquot was diluted to 1 liter, diazotized and coupled. The adsorbences were measured and compared to standards. (Table 3.)

Table 3.

Adsorption of two amiben esters

Amiben ester	Concentration	Chemical in supernatant (not adsorbed)
Butoxyethyl	5 ppm	10%
Butoxyethyl	10	8
Butoxyethyl	15	7
Hydroxypropyl	5	40
Hydroxypropyl	10	44
Hydroxypropyl	15	46

HYDROLYSIS OF AMIBEN ESTERS

Hydrolysis of the amiben esters occurs in the soil, thus complicating an already difficult picture. Table 4 summarizes hydrolysis rate experiments. The time required for 50% hydrolysis is 2.9 days for the methyl ester, 7.5 days for hydroxypropyl ester and more than 16 days for the butoxyethyl ester.

Table 4.

Percent hydrolysis of esters of amiben

Amiben ester	Hours incubation										
	0	2	4	17	20	24	48	72	144	240	288
Methyl	7	7		16	22			53	76		96
Butoxyethyl	3	0		5	9			21	38		43
Hydroxypropyl	2.7		6.4			12	19	27	43	60	

In contrast to the results obtained with moist soil used for the study summarized in Table 3, virtually none of the methyl ester was converted to the salt in dry soil. The amiben amide appears to require hydrolysis before it becomes active. Spray applications produced no epinasty on tender susceptible plants, normally greatly affected by the salt or acid form. The plants showed no epinasty even when the residue of the 4 lb/ac rate on the foliage was remoistened, thus indicating that higher plants cannot hydrolyze or activate the amiben amide.

The activity of the amide used preemergence is considerably reduced by even methyl bromide type sterilization of the soil. Colby, 1966, found that the amiben amide was inactive on steamed soil but showed good activity in unsteamed soil.

In one Amchem greenhouse leaching test, the hydrolysis of the amiben methyl ester was sufficiently rapid that two bands of activity were observed in the soil column. One band coincided with previously observed ester and the other band of lesser activity coincided with that of the amiben salt.

FIELD STUDIES

Field performance reflects the laboratory and greenhouse findings with amiben and its esters. In general, on the heavy prairie (semi-podzolic) soils of the corn (maize) area, the amiben salt gives better weed control than do the esters. The difference in preemergence activity was slight in the 1966 corn and soybean experiments at the Amchem Research Farm, Clinton, Iowa. The broadleaf weeds were *Amaranthus retroflexus*, *Datura stramonium*, *Chenopodium album*, *Mollugo verticillata*, and *Polygonum pensylvanicum*. The grasses were *Setaria faberii* and *Digitaria* spp.

The esters did not appear to give complete depth protection as far as maize or beans were concerned. The beans were only slightly injured even at the 6 lb/ac rate. The maize was more susceptible than bean to amiben injury. The 4 lb/ac rate of the salt produced 30% reduction in plant growth, while the methyl ester reduced growth an average of only 13%. With this partial depth protection, there was an accompanying reduction in weed control. The results of trials in Minnesota (not reported here) were similar to those from Iowa. From a practical weed control standpoint, the esters seem to offer little or no advantage over the salt on the semi-podzolic soils.

On the Chernozem soils of Nebraska results were quite similar to those obtained on the prairie soils. The preemergence application of 4 lb/ac of the salt gave complete weed control with 20% growth inhibition of maize. The amiben methyl ester at the 4 lb/ac rate gave 100% weed control with 10% growth inhibition of maize. Some safety was obtained with the methyl ester and the slower rate of hydrolysis may have reduced the soil penetration of the butoxyethyl ester and consequently its activity (4 lb/ac, 85% weed control).

An experiment was run on a light textured phase of a Minnesota semi-podzolic soil. Maize growth was reduced 50% by 4 lb/ac of the amiben salt while no inhibition of growth was observed with the methyl ester. Grass and broadleaf weed control were equal. Apparently, hydrolysis of the amide was not rapid enough to release a herbicidal concentration of amiben before the weeds became established.

Results of an experiment conducted by D. W. Staniforth and W. G. Lovely (evaluated by S. R. McLane) on a light-textured soil in Iowa indicate that rainfall was sufficient to wash the salt of amiben to a depth below the germinating weed seeds. The esters were retained in the weed germination zone and thus produced weed control superior to the salt. (Table 5) This was particularly evident at the 2 and 3 lb/ac rates.

Table 5.

Preliminary notes on weed control and soybean response, 1966

Treatment	Rate	*Polygonum pensylvanicum* control	Soybean growth inhibition
Amiben salt	2 lb/ac	60%	0%
Amiben salt	3	70	0
Amiben salt	6	95	25
Amiben butoxyethyl ester	2	90	0
Amiben butoxyethyl ester	3	96	0
Amiben butoxyethyl ester	6	99	10
Amiben methyl ester	2	90	0
Amiben methyl ester	3	95	0
Amiben methyl ester	6	100	25

In a maize experiment, the esters had again produced better weed control than the salt. The rainfall conditions in some of the experimental area had led to spectacular differences between performance of the salt formulation and the ester derivatives of amiben. In North Carolina along the Atlantic coast, the salt gave no weed control in gladiolus, while the methyl ester and amide performed well. (Table 6) The soil types in this experiment would generally be classed as a red-yellow podzolic or lateritic soil. Field applications of amiben to these soils have produced inconsistent weed control. Poor weed control appears to result from leaching of the amiben salt down through the soil.

Table 6.

Preliminary notes on weed control in gladiolus
(W. A. Skroch, Raleigh, North Carolina)

Treatment	Rate	Weed control		Gladiolus injury
		Broadleaves	Grasses	
Amiben salt	4 lb/ac	5%	6%	0%
Amiben amide	4	72	94	0
Amiben methyl ester	4	92	90	0

Amiben injury has occasionally been observed on dry beans and snapbeans growing in Ontario, Canada, on light gray brown podzolic soils. Controlled moisture experiments at the Ridgetown Station showed marked depth protection with the methyl ester of amiben compared to the salt. The current season's tests on snapbeans produced similar results under natural rainfall conditions. (Table 7) The primary grass was a *Digitaria* spp. The broadleaf weeds were *Amaranthus retroflexus*, *Chenopodium album*, and *Portulaca oleracea*.

Table 7.

Preliminary notes on weed control in snapbeans in Ontario
(Rudy Brown, Ridgetown, Ontario) (Evaluated by J. Kirch, Amchem Products, Inc.)

Treatment	Rate	Weed control		Reduction in
		Broadleaves	Grasses	Crop vigor
Amiben salt	2 lb/ac	63%	70%	10%
Amiben salt	3	83	80	20
Amiben methyl ester	2	80	83	0
Amiben butoxyethyl ester	2	90	90	0
Amiben butoxyethyl ester	3	100	90	0

The butoxyethyl ester controlled grass weeds 90% compared to 70% with the salt. The salt also reduced crop vigor somewhat.

The safety margin provided by use of the amiben esters is even more evident in a snapbean experiment on gray grown podzolic soils in the northwestern United States. (Table 8) No injury was observed even with 6 lb/ac rates of the amiben esters.

Table 8.

Preliminary notes on weed control in snapbeans in Oregon, 1966
(Garvin Crabtree, Corvallis, Oregon)
(Evaluated by J. McKinley, Amchem Products, Inc.)

Treatment	Rate	Broadleaf control	Injury to beans
Amiben salt	2 lb/ac	95%	10%
Amiben salt	4	98	25
Amiben salt	6	100	30
Amiben methyl ester	2	85	0
Amiben methyl ester	4	95	0
Amiben methyl ester	6	100	0
Amiben butoxyethyl ester	2	75	0
Amiben butoxyethyl ester	4	85	0
Amiben butoxyethyl ester	6	90	0

Additional tests in 1966 on sandy soils in the coastal region of Maryland produced results similar to those reported from Oregon.

DISCUSSION

Field results generally support the greenhouse and laboratory studies of amiben derivatives with regard to leaching, soil adsorption, hydrolysis, and solubility. Further studies are required to define more clearly the significance of water solubility of the esters. Preliminary solubility determinations have established solubilities of 2.4 ppm for the butoxyethyl ester and 0.12 ppm for the hydroxypropyl ester. These values are a great deal lower than that listed for the methyl ester (120 ppm). A re-evaluation of these solubilities are currently underway in our laboratory.

Laboratory studies have not been conducted to determine the adsorptive effects of the organic matter and clay components of the soil. Indications from field studies, in the higher organic soil areas, are that the esters are adsorbed more by the organic matter. The butoxyethyl ester was rated considerably below the salt in the Nebraska tests. Adsorption by the higher organic matter of this soil may have accounted for the decreased activity.

Hydrolysis of the esters was very slow in dry soil. In field practice the spray application on the soil surface would in most cases deposit the material on soil that was dry or would dry within a few minutes. The ester hydrolyzes only when water washes it into the soil. In the field most cases of crop inhibition occur when the salt of amiben has been leached into the soil around the seed, before the seed has had an opportunity to imbibe water. Under this condition the seed swells and begins growth in a solution of relatively high amiben concentration. If more rain follows very soon to dilute the concentration of amiben around the seed the likelihood of crop injury is reduced. Esters, with a lower level of initial leaching, give protection by not reaching the region of crop seed germination. Hydrolysis is sufficiently slow under dry conditions that the ester remains in ester form until rain comes. After the crop has germinated it does not seem to be as sensitive to amiben and the presence of amiben in the upper root zones at this time has not resulted in growth inhibition.

Weed control in light soils is lengthened by using amiben esters. The persistence of the ester is in turn regulated by the rate of hydrolysis to the salt, which depends on the degree of microbial activity. If conditions are poor for microbial activity, the esters should be more persistent in the upper layers of the soil, consequently giving longer term weed control.

The degree of weed control and crop injury obtained in a given situation is dependent on the leaching behavior of the amiben esters and salts. This, in turn, is controlled by the solubility of the compound, its degree of adsorption by a particular soil type, the amount and rate of rainfall, and the hydrolysis rate of the ester. The reproducibility of field results or the dependability of the compound for weed control is determined by the number of times all these factors are aligned in an appropriate manner.

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AUTUMN AND SPRING APPLICATIONS OF HERBICIDES FOR SWARD DESTRUCTION

Research Report

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Summary A comparison is made between the effects of paraquat, dalapon and amino-triazole applied alone in November to a lowland Agrostis/Fescue sward or followed by a further application of paraquat in the Spring. The results showed that good control of grasses was obtained by autumn applications alone but the broad-leaved weeds were not controlled adequately. Subsequent low doses of paraquat in the spring extended the duration of control and allowed lower doses of the main chemicals to be used in the autumn. Though effective on the grasses, the treatment failed to control broad-leaved weeds adequately.

INTRODUCTION

Sward destruction by chemicals in the absence of overall cultivation has two main functions:

1) To eliminate the bulk of live vegetation to facilitate the sowing of a crop.
2) To provide a weed-free environment for the establishment of a crop.

To these ends, a number of trials have been conducted in order to investigate and compare the ways in which paraquat, dalapon and amino-triazole can destroy various swards at different times of the year. Douglas and McIlvenny (1962); Davies et al. (1960); Allen (1965).

In general experience suggests that spring is the worst time to attempt a lasting destruction of grassland as its capacity for regrowth is greatest at this time of the year. On the other hand, destruction from July onwards into autumn and winter may be relatively long lasting if for no better reason than that the period of destruction enters a season characterised by biological inertia. Moreover it may be that translocation through plant systems is more extensive late in the growing season.

The basis of the experiment described below was that a typical lowland Agrostis/Fescue sward should be destroyed in preparation for the direct drilling of a crop in April. The object was to compare paraquat, dalapon and amino-triazole applied in the autumn alone or followed by a further application of paraquat in the spring. The criterion of success was the extent to which the treatments prevented regeneration up to the end of May, a month after the new crop would have been sown. To allow every chance for regeneration no crop was in fact sown.

METHOD AND MATERIALS

The experiment was located at Begbroke Hill, Oxford, on flat, poorly drained ground, 200 ft above sea level. The soil is a medium-heavy to light alluvium with a gleyed, highly calcareous gravel below the permanent water table. The site was occupied initially by long-established pasture dominated by Agrostis species and Festuca rubra. Holcus lanatus, Dactylis glomerata, Anthoxanthum odoratum and Alopecurus pratensis were strongly represented amongst the grasses and Plantago lanceolata, Rumex acetosa and Ranunculus species amongst the dicotyledonous species. The field had been grazed from 1961 onwards at a low stocking rate.

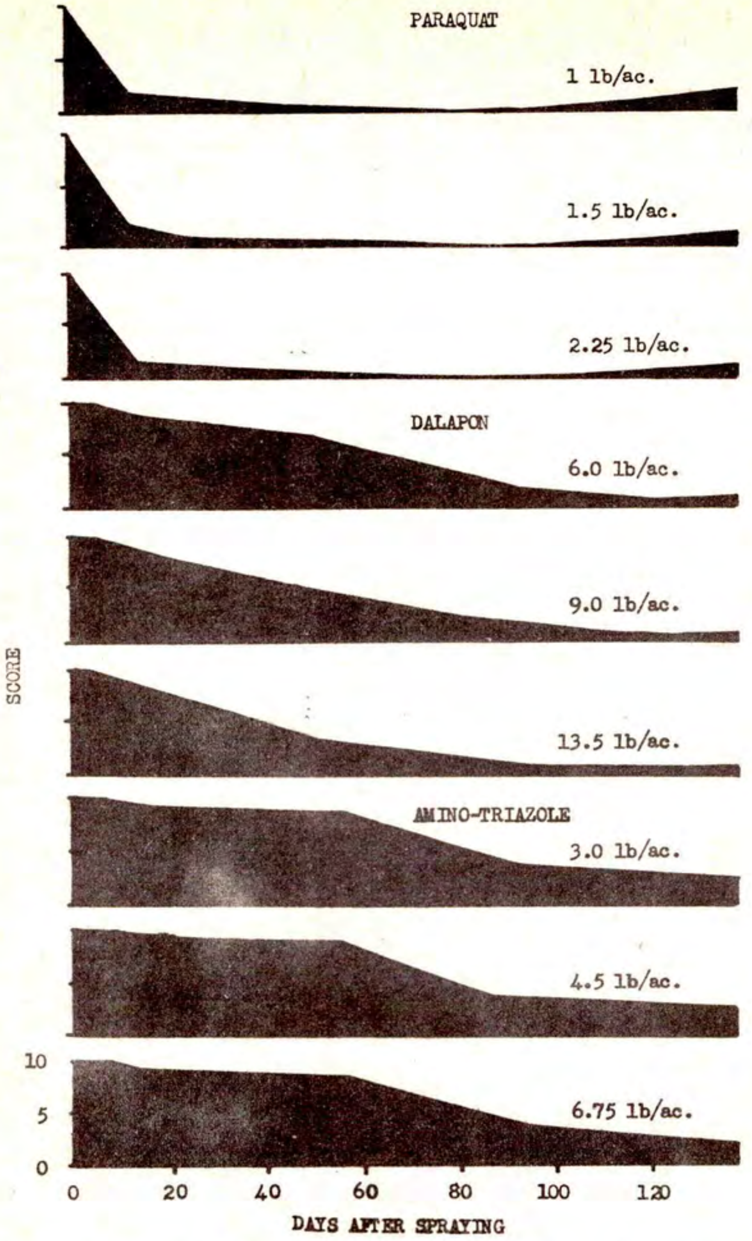

Fig. 1. Herbicidal effects on the vegetation of the pasture during the 18 weeks after spraying paraquat, dalapon and amino-triazole on 22nd November 1963, assessed by scoring for relative amounts of green foliage. 0 = absence of green foliage: 10 = amount of foliage comparable with unsprayed control.

Treatments

Paraquat	at 0,1,1.75 and 2.25 lb a.i./ac.	) applied at random
Dalapon	at 0,6,9 and 13.5 lb a.e./ac.	) on 22nd November, 1963
Aminotriazole	at 0,3,4.5 and 6.75 lb a.i./ac.	) to plots 28 x 7 ft replicated x 4

Paraquat at 0,0.25, 0.5 and 1 lb a.i./ac. - applied on 10th April, 1964 in strips 7 ft wide at right angles to the autumn treatments in a plaid design. All chemicals were applied with 0.1% Agral 90 in aqueous solution at 30 gal/ac with an Oxford Precision Sprayer fitted with size .0 ceramic fan jets and working at 30 lb/in^2 pressure.

Assessments

The reduction in the bulk of green vegetation following the autumn treatments was scored in comparison with that on the unsprayed controls. Point quadrats were used for an assessment of the botanical composition on 7th April, 1964, prior to the application of spring treatments. The first contact only with each species was recorded according to the method described by the Grassland Research Institute (1961). In all point assessments the central 5 x 5 ft square of each plot was analysed. Cuts for yield and botanical separation were carried out on the plots of 3 replicates only, on 27th May, 1964. A motor-scythe with a 3 ft cutter bar was used to remove a 6 x 6 ft square of vegetation from each plot. Random samples were taken and weighed together with the remaining vegetation from each plot. The samples were stored at $-18^{\circ}C$ prior to separation into species, dried at $100^{\circ}C$ for at least 6 hours and weighed.

RESULTS

The effects of the herbicides on the sward were similar to those described by Elliott (1960), who distinguished three main phases of sward change after spraying: first the period of direct chemical action, second a static period while chemical residues disappear from the soil and third the regrowth to a new plant community.

1. Sward response to the November applications

The speed of herbicidal action and the extent to which the aerial growth of the pasture was killed by paraquat, dalapon and amino-triazole can be judged by comparing the graphs in Fig. 1. Paraquat provided the most thorough and rapid effects in the first instance by reducing the green material present by the 20th day to less than 1/10th of that on untreated plots. In contrast, dalapon and amino-triazole were slower, their effects being spread over 100 and 120 days respectively. The dose of dalapon appeared to influence the speed at which the effects appeared but this was not apparent with amino-triazole and paraquat. Amino-triazole failed to achieve the suppression provided by paraquat or dalapon.

By the middle of March (120 days after spraying) the plots treated with paraquat and dalapon were showing signs of regrowth. Those treated with amino-triazole were not.

The botanical composition of the sward following the various treatments was assessed on 7th April, prior to the application of paraquat on 10th April, 1964. The summarised results may be seen in Table 1. No treatments prevented some grass shoots being present on 7th April. Dalapon and paraquat were the most successful and about comparable in reducing the incidence of live grass to less than 1/10th of that on the untreated swards. Amino-triazole was less effective. All treatments were unsuccessful on the broad-leaved species and no herbicide reduced the incidence to less than a half of that on the untreated plots. The inability of the herbicides to provide a long term suppression of total herbage is indicated by the figures for soil and soil covered by dead vegetation.

Although presented in summary form this assessment on 7th April also distinguished between the species. The lowest doses of paraquat and dalapon eliminated aerial growth of Agrostis species, Festuca rubra, Anthoxanthum odoratum, Dactylis glomerata and Holcus lanatus. Dalapon also gave good control of Alopecurus pratensis but this species recovered from even 2.25 lb/ac paraquat. Amino-triazole provided only a partial control of these species.

TABLE 1

Summarised assessment of main sward components on 7th April, 1964, following treatment on 22nd November, 1963. (based on the number of first contacts per species per 100 points per plot. Means of 4 replicates).

Treatments applied on 22nd November, 1963.		Mean contacts per 100 points: Grasses	Broad-leaved species	Soil or soil covered by dead vegetation
Unsprayed Control		100.9	30.9	6.2
Paraquat lb/ac	1.0	10.8	19.5	79.8
	1.5	7.9	25.7	69.3
	2.25	6.6	16.9	83.3
Dalapon lb/ac	6.0	11.4	28.0	67.0
	9.0	10.8	32.2	62.3
	13.5	2.4	23.3	75.3
Amino-triazole lb/ac	3.0	30.8	28.1	60.5
	4.5	27.4	20.2	63.6
	6.75	16.4	16.4	64.3

The green vegetation shown in Table 1 was that which received the application of paraquat on 10th April. Where no further herbicide was applied the regeneration continued to develop with the improvement in growing conditions and the extent of the recovery was recorded on 27th May (Table 2).

This assessment indicated that the ability of dalapon and paraquat to suppress the grasses persisted well up to the end of May; higher doses being better than low in this respect. Amino-triazole however, was less adequate even at the highest dose. In contrast to the grasses the suppression of broadleaved species was not maintained on plots treated with paraquat and dalapon and yields exceeded those on the unsprayed control plots. Amino-triazole alone continued to provide a moderate suppression of broadleaved weeds.

2. Sward response to November and April treatments combined

a) On the grasses: The use of the split herbicide application was more efficient in reducing the herbage than was the use of high doses applied alone in November. Paraquat even at 0.25 lb/ac applied in April reduced the regrowth on all the plots treated in November as measured on 27th May (Table 2). Paraquat/paraquat and dalapon/paraquat combinations were more efficient than those with amino-triazole. There appeared to be little advantage in applying doses of paraquat larger than 0.25 lb/ac to plots previously treated with paraquat or dalapon but the higher doses gave further reductions on the amino-triazole plots.

Table 2.

Total weight of live vegetation harvested on 27th May, 1964 and oven dried at 100°C. Dry matter g/yd²/treatment.
(means of 3 replicates reduced to nearest g/yd²)

Treatments applied 22.11.63. \ 1 lb/ac Paraquat applied 10.4.64.		Total live vegetation				Grasses				Broad-leaved species			
		0	0.25	0.5	1.0	0	0.25	0.5	1.0	0	0.25	0.5	1.0
Control	0	186	96	55	27	146	68	33	13	41	29	22	14
Paraquat lb/ac	1.0	70	23	18	14	21	1	4	3	49	22	14	11
	1.5	46	17	24	14	9	2	5	2	37	15	20	12
	2.25	52	16	17	12	8	2	3	T	44	14	15	12
Dalapon lb/ac	6.0	63	23	18	17	9	2	1	1	54	21	18	15
	9.0	55	42	30	17	4	1	1	1	51	41	28	17
	13.5	32	13	16	8	1	1	T	T	32	12	16	8
Amino-triazole lb/ac	3.0	63	19	8	4	44	13	6	1	19	6	2	3
	4.5	50	12	15	3	24	8	4	1	26	4	11	3
	6.75	58	13	6	7	43	7	3	1	15	6	3	5

T = less than 0.5 g/yd².

Table 3.

Effects of treatments on the yield of species assessed on 27th May, 1964. Results expressed as percentages of unsprayed control yield (100).

		Agrostis spp. Paraquat lb/ac				Holcus lanatus Paraquat lb/ac				Alopecurus pratensis Paraquat lb/ac				Dactylis glomerata Paraquat lb/ac			
		0	0.25	0.5	1.0	0	0.25	0.5	1.0	0	0.25	0.5	1.0	0	0.25	0.5	1.0
Control	0	100	49	18	3	100	37	18	14	100	84	73	15	100	49	17	16
Paraquat	1.0	21	-	2	2	-	-	-	-	182	6	25	10	6	1	2	3
lb/ac	1.5	3	-	3	2	-	-	-	-	61	7	30	3	-	-	-	2
	2.25	-	-	1	-	-	-	-	-	46	14	15	-	-	-	-	-
Dalapon	6.0	4	4	-	1	-	-	-	-	13	2	-	4	11	-	-	-
lb/ac	9.0	3	-	-	4	-	-	-	-	3	-	2	3	-	-	-	-
	13.5	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
Amino-triazole	3.0	66	9	34	-	6	1	-	-	184	74	28	3	2	2	1	-
lb/ac	4.5	15	5	-	-	5	-	-	-	73	14	19	-	2	-	-	-
	6.75	9	3	1	-	7	5	-	-	164	16	15	-	4	1	-	-
		Festuca rubra				Other grass				Ranunculus spp.				Rumex acetosa			
Control	0	100	57	24	10	100	30	14	5	100	4	4	-	100	38	10	78
Paraquat	1.0	1	-	-	-	2	1	1	-	28	-	-	10	428	36	63	21
lb/ac	1.5	-	-	2	-	2	2	2	-	-	-	-	-	257	81	44	46
	2.25	-	-	-	-	8	2	-	4	7	-	-	-	234	24	28	2
Dalapon	6.0	7	1	-	-	1	1	1	1	139	-	-	-	209	46	12	7
lb/ac	9.0	6	1	1	-	3	2	1	1	92	93	-	-	175	91	67	13
	13.5	1	2	-	-	1	-	1	-	46	1	-	-	203	30	16	18
Amino-triazole	3.0	16	6	3	-	32	6	1	2	109	-	-	-	66	37	9	6
lb/ac	4.5	16	5	2	-	22	2	1	1	57	1	-	-	273	43	9	6
	6.75	25	4	1	-	25	5	2	3	145	-	-	-	119	13	17	28
		Legumes				Taraxacum officinale				Plantago lanceolata				Other dicot. spp.			
Control	0	100	85	100	29	100	98	23	15	100	92	94	39	100	78	40	75
Paraquat	1.0	105	33	28	4	0	16	34	23	90	95	29	34	212	107	41	110
lb/ac	1.5	41	9	33	4	4	26	26	14	99	52	51	29	147	69	246	117
	2.25	67	10	10	2	83	86	25	27	101	13	27	7	285	191	183	241
Dalapon	6.0	32	2	6	2	52	94	17	50	96	39	65	51	126	44	20	58
lb/ac	9.0	26	61	19	8	42	61	65	41	135	201	103	94	140	38	33	28
	13.5	1	2	10	2	128	18	48	10	84	46	63	35	98	26	23	23
Amino-triazole	3.0	25	58	34	4	-	1	-	-	1	1	2	1	200	37	13	63
lb/ac	4.5	52	12	31	10	-	1	39	17	-	3	6	7	252	17	208	13
	6.75	107	43	30	8	30	6	1	17	-	10	-	-	78	20	34	98

b) On the broad-leaved species: Compared with the performance on the grasses, the split applications were less successful. The least broad-leaved vegetation occurred on those plots that had been treated with amino-triazole/paraquat combinations. All the treatments involving paraquat and dalapon in November gave a relatively poor sup ression of broad-leaved species as judged on 27th May.

c) On total vegetation: As a result of the effects described above the plots contained similar amounts of total vegetation on 27th May. However, the amino-triazole plots contained a mixture of grasses and broad-leaved species while the paraquat and dalapon plots contained only the latter. In general the quantity of herbage resulting from any of the November treatments followed by 0.25 lb/ac paraquat was about 1/10th of that on the untreated plots. Higher doses of paraquat in the spring further decreased this quantity.

d) On individual species: During the assessment on 27th May two replicates were sorted into species for 'dry-weight' estimations. The results are presented in Table 3 but the information is of limited reliability and is not discussed.

DISCUSSION

The results confirm the inability of a single, reasonable dose of paraquat, dalapon or amino-triazole to kill entirely the perennial plants in this type of Agrostis/Fescue sward. The best control was obtained by following a November treatment with a low dose of paraquat in the spring. Observations made in the spring showed that the live vegetation was composed partly of seedlings and partly of regeneration from unkilled roots, the latter being probably the most important. Since experience has shown that the chemicals perform better in the autumn than in the spring when used in a single application, these results suggest that a split treatment will generally provide the best control. However, it should be remembered that the crops and fertilisers which could both influence the situation were absent in this experiment.

The grasses were controlled well by paraquat and dalapon applied in November and this effect was enhanced by paraquat in the spring. The results suggest that there is scope for reducing the autumn doses of paraquat and dalapon below those used in this experiment.

Despite the ability of paraquat to scorch the broad-leaved herbage and amino-triazole to exert a more lasting suppression, these plants were poorly controlled. The experiment thus emphasized the need for new treatments to control these species.

An additional advantage of the split application is that it allows more than one chemical to be applied. In consequence there is less likelihood of a species surviving because it is resistant to one of the herbicides - as was the case in this experiment with Alopecurus pratensis, which proved resistant to paraquat but succumbed to dalapon.

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A PROGRESS REPORT ON THE USE OF FERTILISERS AND PARAQUAT ON A HILL SWARD

Research Report

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Summary. Hill grazings at an elevation of 800 feet dominated by bracken, bent and fine leaved fescues have been treated in order to obtain information concerning methods of improvement other than ploughing and reseeding. Spraying with paraquat at the rate of 2 lb a.i. per acre was carried out in July 1963 and lime was applied. In order that mat breakdown should proceed seeding was delayed until April 1964, but before seeding a series of plots were sprayed again (i.e. twice sprayed) with 2 lb a.i. per acre. Seeding was attempted by three methods, and for comparison purposes treatments included the old sward with and without manure.

INTRODUCTION

There are many examples of dramatic improvements on hill pastures by ploughing and reseeding. However, there are large areas that by reason of elevation, slope and access cannot be so treated. Again, even where conditions are favourable for reclamation machinery costs can be prohibitive. In such a context paraquat would appear to be very promising but as yet only limited critical work involving detailed botanical analysis and dry matter production is available for hill pastures. This project, which will be continued for at least a further two years, is an attempt to obtain such information.

EXPERIMENTAL METHOD

The soil depth is classified as a ligula grit overlying Cambrian shale with a p.H. of 4.6 and low in phosphate but medium high in potash. There was a thick mat and at the end of May bracken would account for approximately 50% of dry matter production.

The experimental design was a randomised block with eight treatments each replicated four times. The treatments were:

(a) old sward not manured
(b) old sward manured
(c) seeded by cultivation after two sprayings
(d) seeded by cultivation after one spraying
(e) seeded by treading of sheep after two sprayings
(f) seeded by treading of sheep after one spraying
(g) surface seeding after two sprayings
(h) surface seeding after one spraying .

The cultivation treatments were an attempt to pierce the surface mat by one pass with a small horticultural tool with a pick-attachment - after seed had been broadcast. In effect the 'seed bed' was very crude, consisting of large pieces of surface mat - but even so exposing a fair amount of soil. Seeding by the treading of sheep involved broadcasting the seed and then penning two sheep for three days in each plot - the equivalent of 400 sheep per acre. Surface seeding was achieved by casting the seed on the undisturbed mat surface.

The plots ($\frac{1}{200}$ acre) were sprayed with 2 lb a.i. of paraquat on July 19th, 1963 and the equivalent of 2 tons of ground limestone per acre applied to all but treatment (a). The twice sprayed plots were treated on April 21st, 1964 with paraquat at 2 lb a.i. Treatments (b) to (h) received the equivalent of 5 cwt per acre of a 12.12.18 compound fertiliser and seeding was completed between April 27th and 30th using the equivalent of 30 lb S23 Perennial Ryegrass and 2 lb S100 White Clover per acre. Treatments (b) to (h) received the equivalent of 41 units of nitrogen per acre after the first and second cuts, but no fertiliser was applied after the third cut.

EXPERIMENTAL RESULTS

Production for 1964 is set out in Table No.1.

Table 1.

Dry matter and crude protein content for 1964 according to treatment

Treatment	1st cut D.M.	1st cut C.P.	2nd cut D.M.	2nd cut C.P.	3rd cut D.M.	3rd cut C.P.
	lbs/ac	%	lbs/ac	%	lbs/ac	%
(a) Old sward	736	13.1	2183	11.6	-	-
(b) Old sward manured	1819	16.0	4204	14.5	911	15.8
(c) Cultivated (2 sprays)	2331	18.6	2010	18.4	1060	17.4
(d) Cultivated (1 spray)	2396	16.0	2430	16.7	669	18.7
(e) Seeded by sheep (2 sprays)	2324	18.0	1858	18.9	582	19.5
(f) Seeded by sheep (1 spray)	2782	14.2	2398	16.0	668	18.0
(g) Surface seeded (2 sprays)	2936	15.4	1764	16.2	-	-
(h) Surface seeded (1 spray)	2889	14.9	2360	14.2	-	-

The results in Table 1 have not been statistically analysed because the cuts were made on different dates and in the case of three treatments there was only sufficient growth for two cuts to be made. Botanical analysis, based on separation of the components from a random sample of approximately 1½ lbs and then drying, are given in Table No.2.

Table 2.

Botanical composition
(percentage contribution to dry matter)

Plant	(a) Old Sward	(b) Old Sward Manured	(c) Seeded by Cultivation 2 Sprays	(d) Seeded by Cultivation 1 Spray	(e) Seeded by Sheep 2 Sprays	(f) Seeded by Sheep 1 Spray	(g) Surface Seeded 2 Sprays	(h) Surface Seeded 1 Spray
Cut No.1								
Grass	56.0	64.3	13.6	15.6	7.5	19.0	9.6	22.6
Clover	0.5	-	1.0	2.6	1.5	4.1	0.2	2.4
Herbs	3.5	0.7	30.8	26.5	31.3	27.6	24.4	23.5
Bracken	40.0	35.0	54.6	55.3	59.7	49.3	65.8	51.5
Date of cut	May 29th	May 29th	July 14th	June 30th	July 14th	June 30th	July 14th	June 30th
Cut No.2								
Grass	57.7	83.2	66.7	53.4	43.5	67.2	53.3	50.2
Clover	0.8	0.4	5.3	6.7	13.7	4.1	9.4	7.6
Herbs	4.5	1.2	9.4	17.7	24.3	9.2	21.1	7.4
Bracken	37.0	15.2	18.0	22.2	18.5	19.5	10.2	34.8
Date of cut	Sept. 20th	Aug. 21st	Aug. 24th	Aug. 24th	Aug. 24th	Aug. 24th	Sept. 20th	Sept. 20th
Cut No.3								
Grass	-	94.6	94.0	91.0	80.8	94.0	-	-
Clover	-	2.1	3.7	7.2	9.6	3.5	-	-
Herbs	-	2.8	2.3	1.8	3.6	1.9	-	-
Bracken	-	0.5	-	-	-	-	-	-
Date of cut	not cut	Oct. 15th	Oct. 15th	Oct. 15th	Oct. 15th	Oct. 15th	not cut	not cut

The above figures show that in the first cut bracken contributed between 50% and 65% of the total production from the seeded plots but was a lower proportion of the other two treatments. Again herbs - mainly sorrel and yarrow were of the order of 25% in the seeded plots but extremely small on the old swards. in cut No.2 the contribution of bracken declined and there was also a substantial reduction in the herb % on some of the treatments other than the old swards, and clover also increased. At the end of the season, as seen from cut No.3, grass contributed 90% or more of total production while the herb contribution was very small.

The manurial scheme for 1965 was as follows. In April the equivalent of 5 cwt of a 12.12.18 compound fertiliser was applied, and after each cut (except the last one) the equivalent of 41 units/acre of nitrogen applied to all treatments other than (a).

Results for 1965 are given in the following tables:-

Table 3.

Dry matter and crude protein content for 1965 according to treatment

Treatment	May 26 D.M.	May 26 C.P.	June 29 D.M.	June 29 C.P.	Aug. 16 D.M.	Aug. 16 C.P.	Nov. 10 D.M.	Nov. 10 C.P.	Totals
	lbs/ac	%	lbs/ac	%	lbs/ac	%	lbs/ac	%	lbs/ac
(a) Old sward	377	14.0	620	14.1	648	14.4	423	14.3	2,068
(b) Old sward manured	2,249	17.1	2,000	17.9	2,881	16.6	1,897	18.5	9,027
(c) Cultivated (2 sprays)	3,181	15.4	2,360	17.3	3,209	15.4	1,992	18.8	10,742
(d) Cultivated (1 spray)	2,603	17.1	2,410	17.0	3,143	16.1	2,119	17.8	10,725
(e) Sheep (2 sprays)	3,023	16.4	2,760	17.5	3,059	16.0	1,976	19.1	10,818
(f) Sheep (1 spray)	2,564	15.9	2,400	17.5	3,216	15.0	2,109	18.3	10,289
(g) Surface (2 sprays)	2,456	17.6	2,670	16.2	2,788	15.7	1,850	18.9	9,764
(h) Surface (1 spray)	2,255	17.8	2,330	17.0	3,188	16.3	1,896	18.4	9,669
L.S.D. (Tukey)	790	N.S.	552	3.5	698	N.S.	386	2.52	

Manuring the old sward produced dramatic increases in both dry matter and crude protein. All treatments involving reseeding have given encouraging returns.

Table 4 provides the botanical composition of the dry matter at each of the four cuts.

Table 4

Botanical composition (% contribution to dry matter)

Plant	(a) Old Sward	(b) Old Sward Manured	(c) Seeded by Cultivation 2 Sprays	(d) Seeded by Cultivation 1 Spray	(e) Seeded by Sheep 2 Sprays	(f) Seeded by Sheep 1 Spray	(g) Surface Seeded 2 Sprays	(h) Surface Seeded 1 Spray
				May				
Grass	87.1	95.1	92.9	90.0	86.0	91.2	83.3	90.3
Clover	0.3	0.1	1.8	5.3	7.3	2.2	6.1	3.0
Herbs	12.6	4.4	5.3	4.7	6.7	6.6	10.6	6.7
Bracken	-	-	-	-	-	-	-	-
				June				
Grass	48.0	94.9	93.8	84.4	86.8	91.4	88.0	89.4
Clover	0.3	0.6	2.8	6.7	5.0	1.4	4.9	2.3
Herbs	9.7	2.4	2.0	4.3	2.7	1.9	2.6	4.0
Bracken	42.0	2.1	1.4	4.6	5.5	5.3	4.5	4.3
				August				
Grass	51.2	89.8	88.6	86.0	85.8	90.0	86.4	83.9
Clover	0.8	0.7	3.7	5.1	6.7	3.0	3.5	2.7
Herbs	3.2	1.8	0.5	0.6	1.3	1.5	1.9	2.0
Bracken	44.8	7.7	7.2	8.3	6.2	5.5	8.2	11.4
				November				
Grass	94.9	98.1	99.0	97.3	97.4	98.9	98.3	98.5
Clover	-	0.5	0.6	1.8	2.0	0.7	1.5	0.7
Herbs	5.1	1.4	0.4	0.9	0.6	0.4	0.2	0.8
Bracken	-	-	-	-	-	-	-	-

Table 5 gives the contribution of the various species to the swards as assessed by the % ground cover method - in late April, 1965.

Table 5

Botanical composition (% ground cover)

Treatment	Perennial Ryegrass	White Clover	Fescues	Bent	Other Grasses	Herbs	Bare Ground
(a) Old sward	-	1.0	47.8	34.8	2.0	14.4	-
(b) Old sward manured	0.8	2.2	34.8	23.6	24.5	14.1	-
(c) Cultivated (2 sprays)	84.1	12.0	1.2	-	-	2.3	0.4
(d) Cultivated (1 spray)	65.9	9.4	13.0	3.3	2.2	5.2	1.0
(e) Seeded by sheep (2 sprays)	61.8	24.9	3.0	-	1.0	8.2	1.1
(f) Seeded by sheep (1 spray)	59.6	4.9	22.9	1.4	5.6	5.6	-
(g) Surface seeded (2 sprays)	51.4	22.8	7.0	-	4.7	13.9	0.2
(h) Surface seeded (1 spray)	32.4	9.6	28.4	5.1	11.1	13.2	0.2

DISCUSSION

The results for 1965 show the response of the old sward to manuring. The difference in dry matter over the season is of the order of 7000 lb of dry matter per acre; the quality (as judged by % crude protein) of the manured old sward was also better.

Spraying twice with paraquat as compared with a single spray had very little effect on production except under the sheep seeded treatment where there was a difference in favour of the double spraying, but this was not significant at any of the four cuts. However, spraying twice decreased the amount of fescues in the sward.

The sprayed treatments produced more than the manured old sward - at most this was approximately 1,800 lbs (treatment e) and least with the comparison of the manured old sward and treatment (h) where the figure was approximately 650 lbs.

Research Summary

SOME FACTORS INFLUENCING THE SELECTIVITY OF PARAQUAT IN GRASSLAND

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Cultural methods of improving grassland composition and productivity require a considerable time to achieve the desired effect. The possibility of inducing more rapid changes in sward composition, using Paraquat, has been investigated by several workers. Its selective use is influenced by:- (a) Concentration; (b) Initial sward composition; (c) Physiological age of the sward components; (d) Soil nutrient status.

The experiment summarized here examined the influence of factors (a), (b) and (d) on the selectivity of Paraquat in mixtures of *Holcus lanatus* and *Lolium perenne* (var. S.321).

METHOD AND MATERIALS

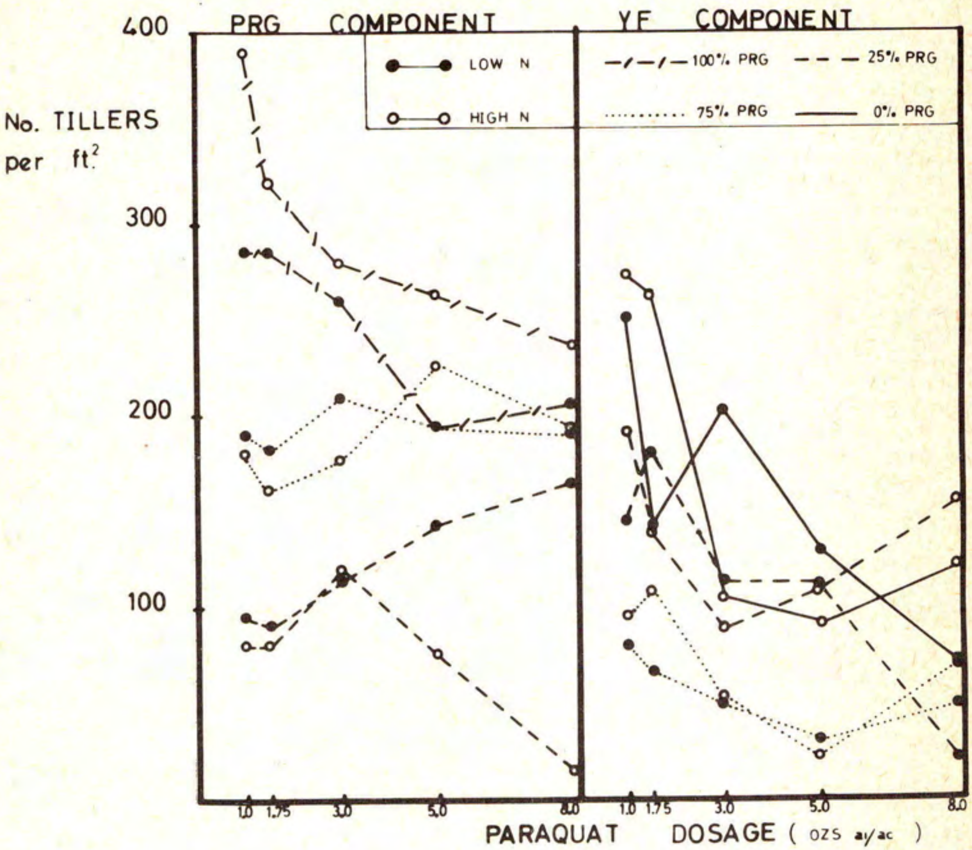
Forty boxes of soil (24 in. x 18 in. x 4 in.) were sown on 11/5/65, to produce the following swards:- (i) 100% *Lolium*; (ii) 75% *Lolium* + 25% *Holcus*; (iii) 25% *Lolium* + 75% *Holcus*; (iv) 0% *Lolium* (i.e. 100% *Holcus*). Seven weeks after sowing, the boxes were cut. A week later, they received the equivalent of either 10 or 50 units N/ac. and during the ninth week a basal PK application was made. Eleven weeks after sowing, the boxes were sprayed with one of the following rates:- 1.0, 1.75, 3.0, 5.0, 8.0, ozs. a.i./ac. in 40 galls. water. The re-growth was cut on 3/12/65, and a tiller count taken on 29/4/66.

RESULTS

The number of tillers in pure stands of *Lolium* and *Holcus* decreased as Paraquat dosage increased (Fig. 1). In the 75% *Lolium* mixture, increasing the rate from 1.0 to 5.0 ozs. a.i./ac. resulted in a slight increase in *Lolium* tillers and a concomitant decrease in *Holcus* tillers, but at 8.0 ozs. a.i./ac., *Lolium* showed a decrease and *Holcus* an increase in tiller number. In the 25% *Lolium* mixture, the effect of application rate depended on the nitrogen treatment. At the higher nitrogen level, the number of *Lolium* tillers increased as the application rate increased from 1.0 to 3.0 ozs. a.i./ac., but decreased rapidly thereafter. Conversely, the *Holcus* component decreased at the lower rates and increased at the higher rates, changing the percentage *Lolium* in the mixture from 30 to 7. At the lower nitrogen level, increasing Paraquat from 1.0 to 8.0 ozs. a.i./ac. gave a 70% increase in *Lolium* tillers and a concomitant decrease of 88% in *Holcus* tillers, thus changing the percentage *Lolium* in the mixture from 40 to 90.

Initial sward composition had little effect on the selectivity of Paraquat at the high nitrogen level, but did alter the application rate at which the number of *Lolium* tillers in the mixture was maximal. At the low nitrogen level, *Holcus* proved very susceptible to Paraquat when it was initially the dominant sward-component, but much less susceptible when *Lolium* was initially the dominant component.

TILLER COUNTS/ft² 29/4/66



A RENOVATION TECHNIQUE FOR MARSH LAND

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Direct drilling techniques for improving poor pasture at Aberystwyth have not been successful in the past partly because of the lack of suitable machinery for dealing with swards characterised by a highly developed mat. However, the development of new machines has led to a re-appraisal of direct drilling as a means of establishing pasture plants in swards treated with herbicides. During the last two years, some practical experience has been gained with equipment designed for the purpose in a series of pasture establishment studies over a wide range of pasture types. One such project reported in this paper is a comparative trial between direct drilling and rotary cultivation as practical means of re-seeding a marsh, which being a heavy impervious clay (pH 5.5) and covered by a thin layer of peat with little downward water movement, was regarded as unsuitable for ploughing. Such land is a frequent problem to the improver in West Wales. The inital botanical composition (Table I) showed that the area was dominated by rushes (36.0%), mostly Juncus effusus (Common rush), but some Juncus articulatus (Jointed rush), and other poor grasses, particularly Agrostis stolonifera (Creeping bent) (11.5%).

Pre-treatments

Before dividing the area into experimental treatments, immediate removal of rough growth from the site by burning was necessary. To facilitate this, the green growth was desiccated by applying 2 pints per acre of paraquat ($\frac{1}{2}$ lb. a.i.) in 20 gallons of water, on the 12th May in warm sunny conditions, by a tractor-mounted low volume sprayer. After burning, the remaining trash was topped by a forage harvester. A further 2 pints of paraquat were applied on the 10th June to the re-growth, resulting in a very satisfactory kill. Approximately 3 tons per acre of ground limestone (56% n.v.) was applied immediately prior to seeding.

Experimental treatments

Approximately $\frac{1}{8}$ of an acre of the trial area was left uncultivated as a control (treatment A), the remainder being divided into two approximately equal $\frac{1}{2}$ acre plots, one being cultivated and drilled simultaneously by the "contravator-seeder"* on the 29th June (treatment B), and the other being rotary cultivated and then sown by hand on the 1st July (treatment C). The seeds mixture, which consisted of a perennial ryegrass, timothy and white clover mixture, was sown at the rate of 30 lb. per acre. Both areas were fertilized by hand with 3 cwt. of compound fertilizer (12% N, 12% P_2O_5, 18% K_2O) and rolled with a Cambridge ring roll.

Subsequent management

The first grazing with 48 lambs was carried out on the 9th August, 6 weeks after sowing. Because of the presence of Juncus articulatus, the whole site was then topped by forage harvester on the 11th August. At the same time, 30 units of nitrogen was applied to the reseeded areas. To control further rush re-growth, and a few dicotyledonous species, 5 pints per acre of a M.C.P.A./M.C.P.B. mixture (30 oz.a.i.) were applied to the whole site on the 26th August. A second grazing was possible from the 3rd to the 6th September with a similar group of lambs, after which a further 45 units of nitrogen was applied. This subsequently provided keep for pregnant ewes in early January, and for store cattle later.

* Marketed by "Sisis" Equipment (Macclesfield) Ltd.

The effect of herbicides and cultivations on subsequent botanical composition

Germinating grass and clover seedlings were observed on treatment B in the slits left by the contravator, and on the rotary cultivated plot on treatment C, within 10 and 12 days of sowing, respectively. The effect of the herbicides (treatment A), in the absence of cultivation and new seeds, resulted in a high percentage of moss and bare ground (35.3%) and a very mixed ground cover in which the desirable grasses (1%) Poa spp. (10.5%) and *Alopecurus geniculatus* (8.5%) contributed the highest percentages.

The almost complete control of rushes, dicotyledonous weeds, and poor grasses, and the subsequent establishment of improved grasses by cultivations, on treatments B and C can be seen in Table 1. Although both sown areas can be regarded as first class rye-grass swards, the slightly higher percentage of *Poa* spp. and bare ground on the rotary cultivation plot (treatment C) reflects a less uniform establishment compared with the direct drilled area (treatment B). Furthermore, the minimum disruption of the surfact, although being sufficient for sown pasture plants, avoided any rapid germination and colonisation by dormant weed seeds, particularly rushes, and at the same time left the surfact firm enough to support grazing stock without causing poaching, an important factor with such land for all the year round grazing.

Acknowledgements

The author wishes to thank Professor W. Ellison for providing facilities at Frongoch Farm, and "Sisis" Equipment (Macclesfield) Ltd., for the loan of equipment.

Table 1

Effect of herbicides and cultivations on botanical composition

(percentage ground cover)

	Original sward	Treatments A Herbicides only	B Herbicides and "contravation"	C Herbicides and rotary Cultivation
Perennial rye-grass (*Lolium perenne*)	-	9.1	59.0	54.0
Timothy (*Phleum pratense*)	-	1.0	20.5	20.3
Whiteclover (*Trifolium repens*)	-	1.0	1.0	T*
Rushes (*Juncus effusus*, and some *Juncus articulatus*)	36.0	5.9	1.5	T
Marsh foxtail (*Alopecurus geniculatus*)	-	8.5	T	0.5
Yorkshire fog (*Holcus lanatus*)	5.5	7.8	2.4	4.0
Creeping bent (*Agrostis stolonifera*)	11.5	3.3	2.0	3.2
Sweet vernal (*Anthoxanthum odoratum*)	4.5	3.6	2.0	3.2
Meadow grasses (*Poa* spp.)	6.0	10.5	2.0	5.2
Moss and bare ground	25.5	35.3	4.6	8.3
Dicotyledonous spp.	6.5	1.3	0.5	-
Other grasses	4.5	12.7	5.2	1.5

*T = trace

THE ROLE OF PARAQUAT IN PASTURE RENOVATION

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SUMMARY

Observations are made on experience gained from a series of unreplicated field trials carried out throughout the British Isles between 1960 and 1966 to study the use of paraquat in pasture improvement. The optimum rates and time of application of the chemical and the utilisation of conventional implements and specialised seed drills are described.

INTRODUCTION

Trials investigating a chemical means of sward destruction prior to re-seeding are reported by Elliott (1, 2) and Ormrod (3, 4). These trials showed that dalapon was an efficient grass killer but that its residual activity in soil enforces a postponement of sowing grass seed. This delay allowed regeneration of certain grasses and a rapid increase in ground cover by broad-leaved weeds.

In 1960, research workers at the Jealott's Hill Laboratories had appreciated some of the properties of paraquat which are :-

(a) It kills or desiccates any green tissue which it touches.

(b) It is rendered ineffective on contract with the clay fraction of the soil.

(c) It is rapidly absorbed into foliage, making it virtually rain-fast.

These properties are described in a later paper by Springett (5) and its fate in plants by Calderbank (6). These properties indicated that the new material was capable of destroying unwanted swards in preparation for re-seeding. It was first tested as a means of "chemical ploughing" of intractable land. The first field experiments, carried out on difficult terrain in the Caernarvonshire Hills, are described by Douglas (7). The re-seeding was successful and the output in liveweight of sheep from the re-seeded pasture showed a tenfold increase per unit area over the untreated hill grazing.

In 1961 a series of field trials to embrace the widest range of grassland conditions throughout the British Isles was planned. Their operation was closely co-ordinated with the critical agronomic and machinery experiments of the research workers. Initially they were conducted entirely with the farmers' implements and labour but latterly the direct drills, which are not farmer owned, have been incorporated into trials. The general plan was to repeat a single project on 12 sites spread throughout the country. A typical project consisted of the use of one common farm implement, possibly a disc harrow, used to surface cultivate grassland which had been sprayed with two rates of paraquat at two periods of the year. The plot size for an individual treatment was at least one acre in size. When these trials had established a principle, the project was then simplified in content, but increased in area and in number of sites. The results were assessed by a visual estimate of ground cover of plants in random foot square quadrats.
In 1963 for example over 90 trials, each exceeding 2 acres in extent, were assessed to substantiate the existing recommendation for the application of 1 lb ion/ac paraquat followed by rotary cultivation as a preparation for re-seeding -Allen (8).

In 1966 over a hundred field scale trials were laid down by drilling with rotary direct seeders. Most of the latter work was carried out by eight agricultural contractors in the North and South West of England who undertook the whole operation from sward preparation to seed drilling.

The operations involving the use of paraquat in pasture improvement may be divided into two main sections.

(1) The elimination or suppression of unwanted species and

(2) Preparation of a suitable environment for the establishment of the new grass seeds.

(1) THE ELIMINATION OR SUPPRESSION OF UNWANTED SPECIES

Paraquat kills grasses but the susceptibility to a given rate of application varies among species. The susceptibility of a species to a given rate also varies with the season of application. Reports on the variation in susceptibility have been published by Jones, L (9), Jones and David (10), Allen, G.P. (11), Blackmore (12), Douglas (13) and seasonal susceptibility by Heddle & Young (14).

Two uses of paraquat are discussed below :-

Firstly the elimination of unwanted species in order to encourage the expansion of productive species - selective use. Secondly the complete suppression of the unwanted sward to permit the establishment of the new seed - sward elimination.

(a) The Selective Use of Paraquat

Research workers in this country and New Zealand have shown that Poa spp and Agrostis stolonifera are susceptible to paraquat and that clovers are virtually unaffected. On the other hand Cocksfoot and fine-leaved Fescues are relatively resistant. In our field-scale trials we have generally not succeeded in producing the required upgrading of pastures by the selective use of low rates of paraquat. In the 1963 series, there was one spectacular result in Radnorshire where 0.25 lbs ion/ac paraquat removed Poa species completely from a pure Cocksfoot sward. There are several recorded cases where lucerne stands, sprayed before the commencement of spring growth with 0.25 lbs/ac paraquat were cleared of Poa spp.

While selective upgrading with paraquat is as yet impracticable, it has been frequently observed that animals prefer the regrowth on the sprayed plots to the adjacent untreated areas. The common factor in all cases has been an increase in the proportion of white clover.

(b) Sward Elimination

(i) Application of paraquat

It is of paramount importance that the chemical should be applied efficiently. The commonest failure in trials has been the striped effect due to the spray boom being set too low. It must be set at least 21" above the top of the sward.

Grasses are at their most susceptible stage to paraquat applications after they have passed their peak growth period and before winter dormancy begins. Least damage is expected from applications of paraquat made just before their period of vigorous spring growth. Good coverage by spray is essential and for this reason a target of a maximum of 3" of green leaf is ideal.

An adequate kill of grasses in an open sward is not difficult. Complications arise in the older swards particularly those which have developed a 'mat' and have become tufted through selective grazing. The reduction of the excess growth by cutting or heavy grazing before spraying is essential. So also is the removal of any top growth which may protect the prostrate species. Inadequate sward preparation was responsible for a considerable proportion of disappointing results in the early years of the programme. The main grass species which caused the difficulty initially were Agrostis stolonifera, Alecopecurus pratense, Festuca rubra and Deschampsia caespitosa. It was later established that all four could be eliminated by the correct timing of the chemical application and by surface rotary cultivation.

Time of Spraying

Some early experiments on deuse stands of Agrostis showed some improvement of kill by drastic surface cultivation in the autumn preceeding a July application.

Fescue dominant lowland swards are best sprayed in the November/December period and sown in the spring. Heddle and Young (14) showed that sheeps fescue was most susceptible in this period. Red fescue responds in a similar manner.

Hill swards consist of a community of grasses with a considerable variation in times of peak growth. They often have a greater bulk of herbage than can be adequately covered by a normal spraying machine. This has to be reduced. Normally it is too unpalatable for grazing so cutting and removing or burning is required. In four of our trials,spring burning prior to September spraying proved adequate. The timing of spraying will depend on the dominant grasses. Fescue causes the greatest complication as spraying cannot be done until September at the earliest although the season can be extended to December with confidence. The spraying of the two Fescue sites in 1966 was delayed until February and in 1965 one February application of spray was made while parts of the field were covered with over one inch of snow. A good kill of Fescue was obtained on these sites. The other common hill grasses, Moor Mat Grass (Nardus stricta), Creeping soft grass and Yorkshire Fog (Holcus spp) and Tussock Grass (Deschampsia caespitosa), are susceptible in the July/August period and Molinia (Molinia caerulea) in the late summer up to early September.

On all sward types 1 lb/ac paraquat has suppressed and killed most non rhizomatous grasses when applied at the most susceptible period of growth. The most difficult common grass to suppress in all trials at the above rate has been Cocksfoot (Dactylis glomerata).

(ii) Cultivation after spraying

The incorporation of the desiccated sward into soil by shallow surface rotary cultivations usually completely eliminates the old sward. Other forms of cultivator will fulfull this function where soil conditions are suitable.

In trials four particularly troublesome grasses have been eliminated by rotary cultivation after an application of 1 lb/ac paraquat viz Cocksfoot (Dactylis glomeoata), Meadow Foxtail (Aleopecurus pratensis), Floating Foxtail (Aleopecurus geniculatus) and Tussock grass (Deschampsia caespitusa). The cultivation should not be applied until the paraquat effect has reached its maximum, usually about 10 days, and not delayed until recovery of the sprayed plants begins.

(2) PREPARATION OF A SUITABLE ENVIRONMENT FOR THE ESTABLISHMENT OF THE NEW SEEDS.

The demands of the establishing seeds are simple. The seed and root must continue to obtain moisture, the shoot must receive light, the seedling must not be subjected to excess competition from other plants and adequate nutrients must be available. When an open sward, which has been sprayed, dies back to expose friable soil, there are few problems in placing the seed in the correct environment. They may be cut in with a conventional corn drill or broadcast and harrowed in with rigid tine or flexible harrows. Care must be exercised in the use of a dish disced corn drill. When it 'moulds' a curved vertical slot without producing crumbled soil, there is a danger that shoots from the germinating seed will fail to penetrate the compacted soil. This technique has been used mainly for sowing short leys and has been operated throughout the country for the past three years. A variation used on some of the heavier soils is to cultivate or disc harrow the field after spraying and to drill the seed with the seed feed tube hanging free from the coulter.

Rotary Cultivation

On older pastures when any form of litter is present it is essential to incorporate it into the soil before broadcasting the seed. This cultivation may be carried out by many types of implement of which the rotary cultivator gives most consistent results. Normally two passes of the machine with an intervening rolling are adequate. Penetration should be no deeper than is required to mix in the trash. Deep penetration causes an unnecessarily 'puffy' seedbed. A thick, dry mat of grass can also cause a loose seedbed. Adequate rolling is imperative. There are few conditions of lowland pasture where this technique is not applicable.

Disc and Tine Harrows

Most forms of harrows may be used providing the sward and soil are in suitable condition, i.e. sufficiently damp to allow penetration but not wet enough to cause clogging of the tines. Trials by Douglas (15) showed that generally disc harrows were least desirable because their cutting action cause regeneration of unwanted species, particularly those having stolons or rhizomes. In some of our development trials, it was found that up to nine passes of the disc harrow were required to produce a seedbed and the stimulated weed population frequently swamped the sown seed. In others four passes were sufficient and the old sward suppressed when an interval of about ten days was allowed between spraying and discing. Rigid tines proved particularly successful in surface cultivating riverside meadows in Herefordshire, Cumberland and Shropshire. Some of the cultivations were made in spring on sites which had been sprayed in the preceeding October. The pitchpole harrow was successfully used in Dorset on moist heavy loam. The following table gives the result of the trial.

Table 1 : Ryegrass/Timothy mixture sown August 1965 assessed September 1966.
Unsprayed area pitchpole harrowed five times.
Sprayed area pitchpole harrowed three times.

	% of useful species as proportion of total grass	% ground cover				Broad leaved weed
		Useful sp	Unsown sp	Clover	Base Ground	
Sprayed 1 lb paraquat	76	68	17	2	6	7
Unsprayed	50	45	45	2	6	6

Reseeding Rough Land

On very rough pasture and hill land it is necessary to remove top growth and disintegrate layers of trash or mat in varying stages of decomposition.

Some of the top growth may have been cut or burnt before spraying. If there is a considerable amount of litter remaining after spraying, it should be burnt. In several trials in the North of England, it has been possible to burn the residual trash until a seedbed has been exposed. Seed is then broadcast and trodden in by sheep. Some of the sites seeded in this manner in 1962 were assessed in October 1966 and found to contain up to 64% of useful grass in total grass content.

Most of the grasses in hill swards require late season spraying and reseeding in spring. This exposure to winter conditions results in a considerable breakdown of fibre especially if the land has been limed. The rotary cultivator has been used with success on a number of properly prepared sites, but its use is limited by the stone frequently found in hill land.

The Direct Drills

Direct drills became available in prototype form from 1964 onwards. These machines are able, in many situations, to create the essential environment for seeds in one operation.

Three types have been used in this series of grassland trials viz :-

(1) The Fernhurst prototype drill which feeds seed direct through a knife coulter which widens a slot cut by a preceeding non powered plane disc.

(2) The Howard Rotaseeder feeds seed direct into slots an inch wide which are set at five inches apart. The powered cutting blades rotate in the direction of travel.

(3) The Sisis Contravator and Lospred liberates seed above slots about three quarters of an inch wide. The powered straight tines rotate against the direction of travel.

Experience has been gained on over a thousand acres of reseeding by the above machines. The machines will function under a wide range of conditions but they should never be used for sowing grass seed when soil conditions are too wet for normal cultivations.

Some very successful reseeding of intensive lowland pasture has been done with the Fernhurst coulter. Success has been limited in poorly prepared swards and where the slot above the germinating seed has been closed by the residual mat or trash of the preceeding sward. Both of the powered rotary drills are commercially available and have been widely tested during 1966 in critical trials and extensive operations. Because of their cutting action through the residual trash, they place the seed in an area of cultivated soil within the slot and produce a condition which allows the germinating seedling free access to light.

Both machines have been used in the growing of pioneer crops on very rough hill land, in all types of grassland including the most rapid renewal of intensive pasture. Present limitations are the weight, cost and power demand of the machines, but they have proved that it is possible to renew a pasture with three tractor operations viz spraying, fertiliser, distribution and drilling.

CONCLUSION

In the past six years, a better understanding has been gained on the response of unwanted grasses to applications of paraquat. Many combinations of chemical and cultivations have been examined.

Two new types of drill are already available which have overcome many of the problems which beset the early field trials. Development work continues, further investigating indications from past trials.

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EFFECT OF HERBICIDES ON GRASS AND CLOVER SEEDLINGS

Research Report

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Summary Growth regulator herbicides were applied to seedling grasses and clovers at varying stages of development to test how early they can safely be sprayed to control broad-leaved weeds. Most treatments had some temporary effect on grass seedlings, but little difference was observed between species at identical growth stages. Results are compared with current recommendations, which - in general - are confirmed. Effects obtained on seedling clovers are also discussed.

INTRODUCTION

For all grassland sowings, successful establishment is important, and this often requires control of broad-leaved weeds at an early stage. It is therefore important to know how soon herbicides can be used. This information is particularly important for grasses or clovers sown without a cover crop, as in some seed crop sowings or in trials and experiments. In such conditions there is no cover crop to dictate or affect the time of spraying, and the weeds grow faster with no competition. Moreover, information and recommendations about undersown cereals generally relate to mixtures including clover, which determines the feasibility of spraying. But if grass alone is sown, as for a seed crop or in plots, the scope for herbicide use is greatly increased.

To supplement the information available in the Weed Control Handbook (Woodford & Evans (1965)) and from manufacturers' experience, the experiments described here were started. They were meant primarily to provide some first-hand information for advice to seed growers and for plot management at N.I.A.B.. But it has since become apparent that there is not much information on this subject, and the results are published, in spite of their limitations, as a basis for possible further experiments.

METHODS AND MATERIALS

The crop varieties in the three experiments were perennial ryegrass S.23; Italian ryegrass S.22; cocksfoot S.143; meadow fescue S.215; tall fescue S.170; timothy S.48; white clover S.100; and red clover S.123.

They were sown in single rows, 21 in. apart, on 25 April 1963, 12 May 1964 and 12 May 1965 for Experiments 1, 2 and 3 respectively.

The herbicide treatments are listed in Tables 2-4. They were applied across the rows with a knapsack sprayer fitted with a constant pressure valve to give 10 lb p.s.i. at the nozzle and delivering approx. 40 gal/ac through 6 Dorman No. 2 "no drift" jets mounted 12 in. apart, held 18 in. above the ground.

Spraying dates and recording dates were:-

	Spraying dates and approx. interval after sowing	Scoring: interval after spraying
Experiment 1 (1963)	27 May ($4\frac{1}{2}$ weeks)	7 weeks
	6 June (6 ")	6 "
	27 June (9 ")	3 "
Experiment 2 (1964)	16 June (5 weeks)	7 "
	2 July (7 ")	5 "
Experiment 3 (1965)	3 June (3 weeks)	3 "
	21 June (6 ")	3 "

The average stage reached by each crop variety at spraying is shown in Table 1.

The plots were scored on a 9-0 scale, 9 denoting no damage and 0 complete kill.

Table 1

Stages at spraying: numbers of leaves and tillers

	Ital. rye-grass S.22	Per. rye-grass S.23	Meadow fescue S.215	Tall fescue S.170	Cocks-foot S.143	Timothy S.48	White clover S.100	Red clover S.123
Experiment 1								
1st date Leaves	$2\frac{1}{2}$	$2\frac{1}{2}$	2	2	2	$2\frac{1}{2}$	spade leaf	1 true leaf
1st date Tillers	0	0	0	0	0	0		
2nd date Leaves	10	8	7	3	4	4	2 true leaves	3 true leaves
2nd date Tillers	3	2	2	1	1	1		
3rd date	Tillering well advanced						Numerous true leaves	
Experiment 2								
1st date Leaves	12	12	5	4	6	4	1 true leaf	2 true leaves
1st date Tillers	4	4	2	1	2	2		
2nd date Tillers (leaves for clovers)	7-10			4	5	3	5 true leaves	4 true leaves
Experiment 3								
1st date Leaves	4	2	2	1	2	2	spade leaf	spade leaf
1st date Tillers	1	0	0	0	0	0		
2nd date Leaves	5	5	4	3	3	3	2 true leaves	3 true leaves
2nd date Tillers	3	3	2	1	1	0		

Table 2.

Average scores for the six grass varieties at the stages shown

(9 = no effect: 0 = dead)

Herbicide and rate (oz/ac)		Number of tillers None	1-2	3-4	5 or more
MCPA	16	-	8	7	8
Mecoprop	40	7	8	9	9
	80	5	8	9	-
Dichlorprop	20	8	-	-	-
	40	7	8	8	8
MCPA/dichlorprop	20	8	-	-	-
	40	7	7	7	9
Ioxynil	8	-	8	8	9
	16	-	7	8	8
Ioxynil/MCPA	8+8	-	6	7	9
	16+16	-	6	7	9
Ioxynil/mecoprop	6+24	7	8	8	8
	12+48	6	7	7	8
Ioxynil/dichlorprop	4+28	8	8	9	-
	8+56	6	8	8	-
Bromoxynil/mecoprop	6+24	8	8	7	-
	12+48	7	8	9	-
Picloram	2	-	8	8	8
Picloram/mecoprop	0.75+24	7	8	9	-
	1.5 +48	7	9	9	-
MCPA/dicamba	9+0.65	9	-	-	-
	18+1.3	9	8	9	9
	36+2.6	-	6	8	9
MCPA/2,3,6-TBA	12+4	8	8	9	-
	24+8	7	8	9	-
MCPA/mecoprop/2,3,6-TBA/dicamba	8+12+2+1.5	7	8	8	-
	16+24+4+3	7	8	8	-

Table 3

Scores for each grass variety at the first three stages shown in Table 2. (9 = no effect: 0 = dead)

Herbicide and rate (oz/ac)	Variety / No. of tillers	S 22 It.ryeg. 0	1-2	3-4	S 23 per.ryeg. 0	1-2	3-4	S 215 m.fes. 0	1-2	3-4	S.170 tall fes. 0	1-2	3-4	S 143 c'foot 0	1-2	3-4	S 48 timothy 0	1-2	3-4
MCPA	16	-	-	7	-	-	7	-	9	-	-	7	7	-	7	-	-	9	7
Mecoprop	40	-	9	9	7	-	9	7	9	-	7	8	7	7	8	-	7	7	9
	80	-	7	9	5	-	9	5	7	-	5	7	-	5	9	-	5	-	-
Dichlorprop	20	9	-	-	9	-	-	9	-	-	5	-	-	9	-	-	7	-	-
	40	7	-	9	7	9	7	7	8	-	5	8	7	7	8	-	7	8	7
MCPA/dichlorprop	20	9	-	-	7	-	-	7	-	-	7	-	-	9	-	-	7	-	-
	40	9	-	8	7	9	7	7	8	-	5	5	7	9	8	-	7	7	7
Ioxynil	8	-	-	9	-	-	9	-	9	-	-	7	7	-	9	-	-	7	9
	16	-	-	9	-	-	9	-	7	-	-	7	7	-	9	-	-	7	9
Ioxynil/MCPA	8+8	-	-	7	-	-	7	-	7	-	-	3	5	-	7	-	-	7	9
	16+16	-	-	7	-	-	7	-	7	-	-	5	5	-	7	-	-	7	9
Ioxynil/mecoprop	6+24	-	7	7	7	-	8	7	7	-	7	8	7	7	8	-	8	7	9
	12+48	-	7	8	7	-	8	5	7	-	5	6	3	5	8	-	8	5	7
Ioxynil/dichlorprop	4+28	-	7	9	7	-	9	9	9	-	9	9	-	7	7	-	8	-	-
	8+56	-	7	7	7	-	9	5	9	-	7	7	-	5	9	-	6	-	-
Bromoxynil/mecoprop	6+24	-	9	7	9	-	7	7	7	-	9	9	-	9	7	-	8	-	-
	12+48	-	5	9	7	-	9	5	9	-	7	9	-	7	9	-	7	-	-
Picloram	2	-	-	9	-	-	9	-	9	-	-	7	7	-	9	-	-	9	7
Picloram/mecoprop	0.75+24	-	7	9	7	-	9	7	9	-	7	9	-	7	9	-	8	-	-
	1.5+48	-	9	9	7	-	9	5	9	-	7	9	-	9	9	-	8	-	-
MCPA/dicamba	9+0.65	9	-	-	9	-	-	9	-	-	9	-	-	9	-	-	9	-	-
	18+1.3	9	-	9	9	9	9	9	8	-	9	7	7	9	9	-	7	6	9
	36+2.6	-	-	7	-	-	9	-	7	-	-	7	7	-	5	-	-	7	9
MCPA/2,3,6-TBA	12+4	-	9	9	9	-	9	7	9	-	9	9	-	9	7	-	8	-	-
	24+8	-	9	9	9	-	9	5	9	-	7	9	-	7	7	-	6	-	-
MCPA/mecoprop/	8+12+2+1.5	-	7	9	7	-	7	7	9	-	7	9	-	5	7	-	7	-	-
2,3,6-TBA/dicamba	16+24+4+3	-	7	7	7	-	9	7	9	-	7	9	-	7	7	-	7	-	-

Table 4

Scores for clover seedlings at the stages shown. (9 = no effect: 0 = dead)

Herbicide and rate (oz/ac)		White clover S.100				Red clover S.123				
		Spade leaf	True leaves 1	2	5	Spade leaf	True leaves 1	2	3	4
MCPA	16	-	5	-	7	-	-	7	-	9
Mecoprop	40	1	1	3	3	1	-	3	3	5
	80	0	-	1	-	1	-	-	3	-
Dichlorprop	20	1	-	-	-	-	5	-	-	-
	40	1	3	0	1	-	5	3	0	1
MCPA/dichlorprop	20	5	-	-	-	-	3	-	-	-
	40	1	1	0	3	-	3	3	1	3
Ioxynil	8	-	5	-	7	-	-	5	-	5
	16	-	3	-	5	-	-	5	-	5
Ioxynil/MCPA	8+8	-	5	-	7	-	-	5	-	7
	16+16	-	3	-	7	-	-	5	-	7
Ioxynil/mecoprop	6+24	0	1	1	5	0	-	3	3	5
	12+48	0	1	1	3	0	-	1	1	1
Ioxynil/dichlorprop	4+28	1	-	1	-	3	-	-	5	-
	8+56	0	-	1	-	0	-	-	3	-
Bromoxynil/mecoprop	6+24	1	-	3	-	3	-	-	5	-
	12+48	0	-	1	-	1	-	-	3	-
Picloram	2	-	1	-	3	-	-	1	-	1
Picloram/mecoprop	0.75+24	0	-	3	-	1	-	-	3	-
	1.5 +48	0	-	1	-	0	-	-	1	-
MCPA/dicamba	9+0.65	3	-	-	-	-	1	-	-	-
	18+1.3	1	3	0	5	-	1	1	1	5
	36+2.6	-	1	-	1	-	-	1	-	0
MCPA/2,3,6-TBA	12+4	1	-	5	-	1	-	-	3	-
	24+8	1	-	5	-	3	-	-	3	-
MCPA/mecoprop/	8+12+2+1.5	1	-	3	-	1	-	-	3	-
2,3,6-TBA/dicamba	16+24+4+3	0	-	1	-	0	-	-	1	-

RESULTS

The scores for grasses are shown in Tables 2 and 3, representing all spray dates except the 3rd date of Experiment 1, from which damage was unexpectedly heavy. The grasses were well tillered, and should normally have been resistant to treatments, but drought conditions at and after spraying probably caused the damage.

The scores in Table 2 are the averages (rounded to the nearest whole number) of the scores for all six grass varieties, at each of the stages shown in the column headings. Table 3 gives, for each grass variety separately, the rounded average for each of the three youngest stages. These methods of presentation are necessary because, in spite of simultaneous sowing, varieties were at different stages when sprayed. There are numerous anomalies in the pattern of scores, because the results are drawn from different experiments, but there appears to be sufficient consistency to justify this method of presentation.

Scores for the clovers are given in Table 4. The majority of treatments would not be considered appropriate for clovers, but the scores are shown for two reasons; to give an index of treatment effects on broad-leaved species, and to indicate which treatments might be used on clovers in an emergency when some damage is acceptable.

DISCUSSION

Grasses The scores in Tables 2 and 3 show that most treatments had some effect on the grass seedlings, and would probably have caused some loss of dry matter production during a short period after spraying. But for undersown leys or seed crops - where successful establishment is more important than bulk of production in the crop's first few months - these temporary checks can be ignored. In order to frame recommendations, an arbitrary line of acceptance has to be drawn.

The 1965 Weed Control Handbook lists the following as the maximum recommended doses (for ryegrass, cocksfoot and meadow and red fescue) at the start of tillering (i.e. "1-2 tillers" in Tables 2 and 3). The scores shown for these doses in Table 2 are listed alongside.

	oz/ac	Score for 1-2 tiller stage in Table 2.
MCPA	16	8
MCPA/2,3,6-TBA	12+4	8
MCPA/dicamba	13.5+1	8 for 18+1.3
Mecoprop	40	8
Dichlorprop	40	8

This comparison of the limited evidence from these experiments with the wider experience reflected in the Handbook recommendations indicates, as would be expected, that scores of 8 (and of course 9) in Tables 2 and 3 can be taken to mean that a treatment is safe. A score of 7 suggests caution, and the need for further evidence or comparison with other results. A score of 6 or less suggests a treatment should be considered unsafe at the stage shown. But it must be emphasized that the information in the Tables is hardly sufficient for making general recommendations. In particular, the unexpected damage at the third date of Experiment 1 gives a warning that factors other than growth stage must be considered whenever spraying is planned.

Table 3 shows little difference between species at identical stages of growth, assuming the varieties are typical of the species. This is at variance with the Weed Control Handbook recommendation, established over several years, to reduce the dose of some herbicides for timothy. For example, timothy seems as resistant as ryegrass or cocksfoot to MCPA 16 oz/ac. On the other hand, timothy seems more susceptible to MCPA/dicamba than the other species, thus confirming the Handbook's reduction of dose. Of the six species tested, tall fescue is the only one showing conspicuously poor tolerance of some herbicides compared with the other species, but this may only be a reflection of conditions in these experiments and should not be taken as a general rule without further checking.

Clovers. The only herbicide in Table 4 which would be considered for use on clovers is MCPA. The Handbook gives 8 and 12 oz/ac as tolerable on white and red clover respectively after 3 trifoliate leaves have appeared. The results for 16 oz/ac agree with this, allowing for the safety margin in the recommendation.

Acknowledgments

The authors gratefully acknowledge the help of manufacturers who supplied herbicides and information.

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FURTHER EXPERIMENTS WITH GROWTH REGULATOR HERBICIDES ON S.48 TIMOTHY SEED CROPS.

Research Report

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Summary Trials are described in which growth regulator herbicides were applied to S.48 seed crops to obtain information on the use of these herbicides on grass seed crops prior to harvest (i.e. application in the 4-5 weeks before ear emergence). Spraying was carried out before, during and after the currently recommended "safe period". There was a clear pattern of decreasing seed yield with successively later spraying dates. Some reduction in germination also occurred. Revised recommendations for the use of growth regulator herbicides on grass seed crops are suggested.

INTRODUCTION

A previous paper (Arthur and Shildrick 1964) described trials which cast doubt on the recommendation, accepted for several years, that if growth regulator herbicides are to be used in grass seed crops in the year of harvest they should be applied in the 4-5 weeks before ear emergence. These trials were on S.53 meadow fescue and S.48 timothy.

Further trials on S.48 timothy were made in 1964 and 1965 with two aims:-

1. To confirm the previous results, and give information on which to base a revised recommendation.
2. To compare some new herbicides with those previously tested.

For most herbicides, the normal rate for use on cereals and the double (overlap) rate were tested. The growth stages correspond approximately to the middle 3 of the 5 taken for the previous trials (Arthur and Shildrick 1964), omitting the date about 9-11 weeks before 5% ear emergence, and the one 3-4 weeks after 5% ear emergence.

METHODS AND MATERIALS

Table 1 summarizes crop and plot details and spray dates. Table 2 shows herbicide treatments. Plots were sprayed with a knapsack sprayer fitted with a constant

Table 1.

Experimental details

Crop species and variety	Drill width and harvest year	Plot size and number of replicates	Spray dates	Approx. interval from 5% ear emergence	Area harvested from each plot and date
1964 Experiment 1					
Timothy S.48	21 in. 1st.	7 x 15 ft 4 reps.	A 7 May B 3 June C 23 June	- 6 weeks - 2 weeks + 1 week (40%)	2 x 6 ft length of row = 2.33 sq. yd 18 & 20 August
1965 Experiment 2					
Timothy S.48	21 in. 2nd.	7 x 30 ft 3 reps.	A 6 May B 2 June C 24 June	- 7 weeks - 3 weeks 0 (5-10% emerged)	2 x 10 ft length of row = 3.89 sq. yd 31 August

pressure valve to give 10 lb p.s.i. at the nozzle and delivering approx. 40 gal/ac through 6 Dorman No. 2 "no drift" jets mounted 12 in. apart. Both trials were sprayed with the rows. The boom was knee-high for the first two stages but at ear emergence was higher to ensure that as far as possible the first intersection of the spray cones was just above the top of the timothy heads.

In both experiments, the spray dates corresponded to the following crop growth stages:-

A = Primordial apex elongated; some at "double ridge" stage.
B = Inflorescence developing.
C = Ear emergence.

The plots were trimmed by cutting, and cultivated between the rows in the autumn before spraying, but received no herbicides in the year of trial except those applied experimentally.

Seed was harvested by hand from the centre of each plot (areas and dates as shown in Table 1). After harvesting the timothy was tied in sheaves and left stooked on the field to weather, the sheaves being turned once. After hanging in sacks under cover to dry the samples were threshed with a "Garvie" drum thresher (drum speed 1000 revs/min.) and then rubbed through a 1 mm. wire mesh to break the glumes. Finally the samples were cleaned through a small "Boby" dresser, the seed being collected under a 1.5 mm. round hole sieve after the broken glumes had been removed by blowing. The seed remaining was weighed and then the replicates bulked and sampled for germination tests.

RESULTS

Table 2 shows the two years' results, in terms of clean seed yield and seed germination.

Seed yield. In both years there is a clear pattern of yield decreasing with successively later spraying dates within the period under examination, i.e. from 6-7 weeks before ear emergence until early ear emergence. The 1965 results show this trend without exception: the 1964 figures show some anomalies, chiefly with picloram and ioxynil.

Whereas in 1964 the lower rates on date A generally gave yields similar to the control, in 1965 all yields but one were less than the control, and the only treatment common to both years (mecoprop 40 oz/ac) gave a lower yield pattern in 1965 than 1964.

Double (overlap) rates generally reduced yields, although only one caused serious reduction on the A dates.

Seed germination. As the seed of replicates was bulked before testing, it is not possible to calculate significant differences as for yields. Nevertheless, it is apparent that for most treatments, there was no effect on germination from spraying at dates A or B, while the majority show some effect at date C. The mixtures including 2,3,6-TBA and dicamba are conspicuous for their effects at both B and C dates.

DISCUSSION

The general pattern of results confirmed those of the trials in 1961 and 1962, so that for S.48 timothy at least it is clearly inadvisable to spray later than about 6 weeks before ear emergence, i.e. spraying should not be later than mid-May. The 1964-5 trials were limited to S.48 timothy, but those in 1961 and

Table 2.

Results

Herbicides and doses in oz a.i./ac		Seed yield as % of control: Spray date A	B	C	Germination %: Spray date A	B	C
Experiment 1. 1964							
2,4-D (ester)	12	126	98	88	95	96	95
"	24	98	93	-	97	94	-
Mecoprop	40	102	93	76	96	97	93
"	80	79	86	-	97	98	-
MCPA/2,3,6-TBA	12 + 4	110	69 *	64 *	97	94	89
"	24 + 8	94	88	-	92	87	-
MCPA/dicamba	18 + 1.3	99	58 **	63 *	96	87	89
"	36 + 2.6	100	39 **	-	93	83	-
Picloram	2	81	92	142	96	95	96
Ioxynil	16	105	76	94	97	96	96
Control		100 (552 lb/ac clean seed)			97		

S.D. (P = 0.05)* = 163 lb (30%)
(P = 0.01)** = 217 lb (39%)

Herbicides and doses in oz a.i./ac		Seed yield as % of control: Spray date A	B	C	Germination %: Spray date A	B	C
Experiment 2. 1965							
Mecoprop	40	89	80 **	43 **	94	93	84
Ioxynil/mecoprop	6 + 24	93	74 **	69 **	94	94	89
" "	12 + 48	93	75 **	43 **	93	94	87
Ioxynil/dichlorprop	4 + 28	107	83 *	80 **	93	92	92
" "	8 + 56	88	86 *	62 **	95	96	90
MCPA/mecoprop/2,3,6-TBA/dicamba	8+12+2+1.5	97	75 **	15 **	93	83	48
	16+24+4+3	86 *	49 **	8 **	84	77	48
Picloram/mecoprop	0.75+24	96	82 **	74 **	96	93	87
" "	1.5+48	94	76 **	29 **	94	93	83
Control		100 (578 lb/ac clean seed)			95		

S.D. (P = 0.05)* = 78 lb (14%)
(P = 0.01)** = 104 lb (18%)

1962 included S.53 meadow fescue. The results with this variety were not as clear as with S.48 timothy. It is planned to make further trials in 1967 with S.321 perennial ryegrass and S.37 cocksfoot (both more widely grown than S.53 meadow fescue) to check how far the results with S.48 timothy apply to other species. Until there is further evidence, it seems advisable to amend the recommendations for the use of growth regulator herbicides on grass seed crops prior to harvest as shown in Table 3. The recommendations are not altered for the earlier-heading species and varieties, but for all timothies mid-May is taken arbitrarily as the latest safe time. The period for S.23 perennial ryegrass is slightly altered to fit the pattern, although there is no evidence that this is necessary. It must be emphasized that although, for convenience, spraying recommendations are given by calendar dates, these dates are related to a growth stage, i.e. ear emergence; and if the time of emergence is altered by season or locality, the time of spraying must be adjusted too.

Table 3.

Summary of previous and revised recommendations.

(All dates apply to Cambridge and might need to be adjusted for other places)

Variety	Normal start of ear emergence (Cambridge)	Previously recommended spray period	Revised recommendation for spraying
S.345 cocksfoot S.59 red fescue S.170 tall fescue	4th week April to 1st week May	April	April
S.24 perennial ryegrass S.37 cocksfoot	1st week May		
S.26 cocksfoot S.215 meadow fescue	2nd week May	2nd week April to 1st week May	2nd week April to 1st week May
S.143 cocksfoot	2nd to 3rd week May	Mid-April to mid-May	Mid-April to mid-May
S.53 meadow fescue S.22 Italian ryegrass	3rd week May	Late April to mid-May	Late April to mid-May
S.321 perennial ryegrass S.101 perennial ryegrass	3rd to 4th week May		
S.23 perennial ryegrass	4th week May	End April to end May	
S.352 timothy S.50 timothy	4th week May to 1st week June		
S.51 timothy	1st to 2nd week June	Mid-May to early June	
S.48 timothy	2nd to 3rd week June	Mid-May to mid-June	

All the herbicides in the trials can apparently be used safely at the lower rate tested, within the recommended period; double (overlap) rates do not in general cause appreciable loss within that period, but have serious effects at later stages. The treatments including 2,3,6-TBA and dicamba were more damaging than the others, and as the 1961-2 trials showed the same, special caution seems to be required with these herbicides.

Acknowledgments

The authors gratefully acknowledge the help of all the various manufacturers who supplied herbicides and information.

References

ARTHUR, T.J., and SHILDRICK, J.P. (1964) Growth regulator herbicides on grass seed crops prior to harvest. Proc. 7th Brit. Weed Control Conf. 361 - 366.

FURTHER EXPERIMENTS ON THE CONTROL OF ALOPECURUS MYOSUROIDES (BLACKGRASS) AND OTHER GRASS WEEDS IN GRASS SEED CROPS

Research Report

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Summary Experiments were made in two seasons, to confirm the tentative recommendation (based on previous work) for the use of prometryne to control seedling grasses in grass seed crops, and to test other promising herbicides. The results apply chiefly to blackgrass control, but also cover *Poa trivialis* and crop grass seedlings. The recommendation is confirmed, with some modification. No herbicide was found preferable to prometryne, although dichlobenil and mono-linuron came close to it, on a combination of all factors.

INTRODUCTION

A previous paper (Arthur and Shildrick 1964) described experiments in 1962-4 which led to the following tentative recommendation in the 1965 Weed Control Handbook:-

"Well established seed crops of perennial ryegrass, cocksfoot, timothy, meadow fescue and tall fescue, on medium and heavy soils, may be sprayed in autumn or winter with 1.5 lb/ac prometryne for control of seedling grasses, particularly *Alopecurus myosuroides* (blackgrass). There is no information yet available on doses appropriate for light or highly organic soils. The grass seed crops should be direct-sown and at least four months old. The seedling grasses should have germinated but should not have more than three to four leaves. Applied on a crop which has not reached the stage described, this dose may cause crop damage and overlapping should be avoided for the same reason. Italian ryegrass is more susceptible to damage from the herbicide than the species mentioned above. The use of prometryne in the spring of a harvest year is not recommended because there is a risk of crop damage, and blackgrass plants larger than seedlings may not be controlled effectively."

Work in France by De Gournay (1964, 1965) has led to the recommendation of dichlobenil 4 kg/ha for the control of volunteer plants and other weed grasses in established herbage seed crops. He found that prometryne 0.8-1.8 kg/ha gave variable results, whereas chlorpropham 4 kg/ha, diuron 1.5-2.5 kg/ha and simazine 0.8-1.5 kg/ha gave adequate control of weed grasses but caused excessive crop damage. Furtick (1964) reports that in N. America established perennial grass crops can be selectively weeded through the use of residual soil chemicals applied in the autumn or early winter. Simazine at 1.6 and 3.2 lb/ac, and propazine at 3.2 lb/ac gave complete grass weed control but only simazine 1.6 lb/ac did not affect seed yield substantially. Prometryne 2 lb/ac gave reasonably good control of *Bromus tectorum* and *Vulpia myuros* in an established crop of Kentucky bluegrass without any reduction in crop yield. Prometryne at 3 & 4 lb/ac caused some reduction in the crop yield.

The experiments described in this paper were made in 1964-6 with three aims:-

1. To confirm the recommendation for prometryne $1\frac{1}{2}$ lb/ac.
2. To extend it, if possible, e.g. to spring treatments.
3. To seek herbicides which would give better results in overall application.

Only treatments requiring normal overall application were considered. Incorporation deters farmers and may make a treatment unreliable; while inter-row band application does not control weeds growing in, or close to, crop rows, and therefore often fails to give the very complete control which is required, at least for blackgrass. (The Seeds Regulations, 1961, require blackgrass seed to be declared at sale if present in grass seed at a level roughly equivalent to 1 seed in 1,250 crop seeds).

The two main experiments, Nos 1 and 2, were made in successive autumn-to-spring seasons on heavy clay on the N.I.A.B. trial ground at Cambridge, on the same pattern as experiment No 5 in 1963-4 (Arthur and Shildrick 1964). One subsidiary experiment, No 3, was also at the N.I.A.B., but the others (Nos 4-6) were made on seed crops on clay soils in East Anglia.

METHODS AND MATERIALS

Herbicide treatments and spraying dates: The herbicide rates are shown in the tables, all in lb/ac active ingredient. The prometryne/simazine mixture was a proprietary one in the proportion 13:3.

For two herbicides there is, as yet, no accepted common name and they are referred to in this paper as shown:-

6-t-butyl - 2 - chloro-o-acetotoluidide -
referred to as "CP. 31675"

1,1-dimethyl - 4,6-diisopropyl-5-indanyl ethyl ketone, and
1,1-dimethyl -4,6-diisopropyl -7-indanyl ethyl ketone -
Referred to as "Sindone"

All treatments were as liquid sprays, except chlorthiamid applied as granules. No incorporation or other special cultivations were done.

Application: Knapsack sprayer fitted with reduction valve to give 10 lb/p.s.i. at the nozzles and delivering approx. 40 gal/ac through 6 Dorman No. 2 "no drift" jets mounted 12 in. apart.

Plot size: All 7 ft wide (sprayed width 6 ft): 20-30 ft long in Experiments 3-5.

Replicates: 3 in Experiments 1-3, 4 in Experiments 4-6.

Records: Crop tolerance and kill of blackgrass and other grass weeds scored by eye: in both respects 9 is the most desirable result (i.e. full kill of weeds or complete crop tolerance) and 0 is the least desirable.

Details of crop and weed grasses:

PRG = perennial ryegrass   IRG = Italian ryegrass   CK = cocksfoot
MF = meadow fescue   TF = tall fescue   TM = timothy
RC = red clover

Experiment	Crop variety or weed grass	Sowing date	Management before spraying	Spray dates
No. 1	Crop varieties (all in 21 in. rows):-			
	S.23, S.24 PRG. S.22 IRG. S.143, S.345 CK. S.215 MF. S.170 TF. S.48 TM. S.123 RC.	12 May 64	Cut 21 Sep to 3-4 in.	A - 6 Nov 64 B - 8 Apr 65
	S.23 PRG. S.22 IRG.	17 Jul 64		
	Weed grasses (Poa and Bromus in 21 in. rows: Alopecurus in 18 in. band):-			
	Poa trivialis	27 Aug 64		
	Bromus mollis	17 Jul 64		
	Alopecurus myosuroides	17 Sep 64 16 Feb 65		
No. 2	Crop varieties (all in 21 in. rows):-			
	Same as in Experiment 1	12 May 65 26 Jul 65	Cut 6 Aug to 3-4 in. and (except plots sprayed 22 Sep) cut 18 Oct to 3-4 in.	A - 22 Sep 65 B - 22 Nov 65 C - 30 Mar 66
	Weed grasses (all in 21 in. rows except Alopecurus in 36 in. band):-			
	Poa trivialis Agrostis Bromus mollis	13 Sep 65		
	Alopecurus myosuroides	13 Sep 65 9 Mar 66		
No. 3	S.48 TM. (2nd year) 21 in. rows	1963	Harvested for seed, cut and burnt Sep 64	26 Oct 64
No. 4	S.143 CK. (2nd year) 7 in. rows	1964	Cut when companion red clover harvested Oct 65	3 Mar 66
	A. myosuroides P. trivialis	Natural		
No. 5	S.48 TM. (3rd year) 24 in. rows	May 63	Cut Jan 66	8 Mar 66
	A. myosuroides	Natural		
No. 6	S.48 TM. (1st year) 24 in. rows	May 65	Cut Jan 66	8 Mar 66
	A. myosuroides	Natural		

Table 1.

Experiments 1 and 2: Crop tolerance. (9 = no effect: 0 = kill)

See text of "Results" for explanation of the 3 values in each column

Herbicide and rate (lb/ac)	Experiment and spray date	2A	1A	2B	2C	1B
	Month of spraying	Sep	Nov	Nov	Mar	Apr
	Age at spraying*	$4\frac{1}{2}$ months	6 months	$6\frac{1}{2}$ months	$10\frac{1}{2}$ months	11 months
	Recorded (wks. after spraying)	37	28	29	11	8
Prometryne	$1\frac{1}{2}$	-	9 (8,8)	-	-	9 (9,9)
"	2	9 (9,1)	-	8 (4,9)	8 (8,9)	-
"	3	-	8 (7,8)	-	-	8 (8,9)
"	4	5 (3,0)	-	7 (2,7)	7 (6,8)	-
Prometryne/simazine	$1\frac{1}{2}$	-	9 (8,8)	-	-	9 (9,9)
" "	2	7 (5,3)	-	8 (2,6)	-	-
" "	3	-	7 (5,5)	-	-	7 (7,8)
" "	4	4 (1,0)	-	8 (2,7)	-	-
G. 36392/simazine	1	9 (9,7)	-	9 (8,9)	-	-
" "	2	9 (9,3)	-	9 (7,8)	-	-
Desmetryne	1	-	9 (7,7)	-	-	9 (8,8)
Propazine	$\frac{1}{2}$	-	9 (8,9)	-	-	8 (7,9)
"	1	-	9 (8,9)	-	-	8 (7,9)
Ametryne	$1\frac{1}{2}$	-	-	8 (5,7)	-	-
Dichlobenil	1	-	8 (7,8)	-	-	9 (9,9)
"	$1\frac{1}{2}$	9 (9,5)	-	9 (9,8)	9 (9,9)	-
"	2	-	8 (8,8)	-	-	9 (8,9)
"	3	9,(9,3)	-	9 (9,7)	9 (9,9)	-
Chlorthiamid (granules)	1	-	5 (6,4)	-	-	5 (5,6)
	2	-	3 (3,2)	-	-	3 (3,4)
Mono-linuron	1	9 (9,5)	-	9 (5,7)	9 (8,9)	-
	2	8 (7,0)	8 (6,6)	8 (3,7)	7 (6,8)	-
Tri-allate	2	-	9 (8,8)	-	-	9 (8,9)
"	4	-	9 (8,9)	-	-	8 (7,9)
Norea	1	9 (9,5)	-	-	-	-
"	2	9 (7,5)	-	-	-	-
Sindone	1	9 (9,9)	-	-	-	-
"	2	9 (8,9)	-	-	-	-
Siduron	2	9 (9,9)	-	-	-	-
"	4	9 (9,7)	-	-	-	-
CP. 31675	2	9 (7,5)	-	-	-	-
Asulam	2	-	8 (8,9)	-	-	9 (9,9)
" (with wetter)	2	-	8 (8,7)	-	-	7 (8,7)
"	4	-	7 (8,8)	-	-	8 (8,8)

* Age of late sown ryegrasses at spraying in months: 1A $3\frac{1}{2}$; 1B $8\frac{1}{2}$; 2A 2; 2B 4; 2C 8

Table 2.

Experiments 1 and 2. Control of Alopecurus myosuroides

(9 = complete kill: 0 = no effect)

Herbicide and rate (lb/ac)								
Experiment and spray date		2A	2C	1A	1B	2B	2C	1B
Month of spraying		Sep	Mar	Nov	Apr	Nov	Mar	Apr
Growth stage at spraying								
Recorded (weeks after spraying)		31	11	28	8	22	11	8
Prometryne	1½	-	-	8	8	-	-	0
"	2	9	9	-	-	4	0	-
"	3	-	-	9	9	-	-	6
"	4	9	9	-	-	9	7	-
Prometryne/simazine	1½	-	-	8	8	-	-	0
" "	2	9	-	-	-	8	-	-
" "	3	-	-	9	9	-	-	6
" "	4	9	-	-	-	9	-	-
G. 36392/simazine	1	3	-	-	-	1	-	-
" "	2	7	-	-	-	1	-	-
Desmetryne	1	-	-	8	8	-	-	1
Propazine	½	-	-	8	9	-	-	0
"	1	-	-	9	9	-	-	0
Ametryne	1½	-	-	-	-	3	-	-
Dichlobenil	1	-	-	6	8	-	-	2
"	1½	5	8	-	-	8	0	-
"	2	-	-	8	8	-	-	2
"	3	8	8	-	-	8	0	-
Chlorthiamid (granules)	1	-	-	8	9	-	-	7
	2	-	-	9	9	-	-	8
Mono-linuron	1	8	8	-	-	2	0	-
"	2	9	9	9	-	6	2	-
Tri-allate	2	-	-	6	6	-	-	1
"	4	-	-	8	9	-	-	1
Norea	1	3	-	-	-	-	-	-
"	2	7	-	-	-	-	-	-
Sindone	1	1	-	-	-	-	-	-
"	2	1	-	-	-	-	-	-
Siduron	2	8	-	-	-	-	-	-
"	4	8	-	-	-	-	-	-
CP. 31675	2	7	-	-	-	-	-	-
Asulam	2	-	-	2	9	-	-	0
" (with wetter)	2	-	-	6	9	-	-	3
"	4	-	-	5	9	-	-	2

Table 3.

Experiments 1 and 2. Control of weed grasses other than *Alopecurus myosuroides*

(9 = complete kill: 0 = no effect)

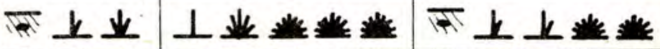
Herbicide and rate (lb/ac)		*Agrostis* sp.			*Bromus mollis*					*Poa trivialis*				
Experiment and spray date		2A	2B	2C	2A	2B	2C	1A	1B	2A	1A	2B	1B	2C
Month of spraying		Sep	Nov	Mar	Sep	Nov	Mar	Nov	Apr	Sep	Nov	Nov	Apr	Mar
Growth stage at spraying														
Recorded (wks. after spraying)		31	22	11	31	22	11	28	8	31	28	22	8	11
Prometryne	1½	-	-	-	-	-	-	3	0	-	9	-	1	-
"	2	9	1	0	9	0	0	-	-	6	-	0	-	0
"	3	-	-	-	-	-	-	5	2	-	9	-	4	-
"	4	9	0	0	9	4	2	-	-	8	-	0	-	2
Prometryne/simazine	1½	-	-	-	-	-	-	1	1	-	9	-	4	-
" "	2	9	2	-	9	2	-	-	-	8	-	0	-	-
" "	3	-	-	-	-	-	-	8	3	-	9	-	8	-
" "	4	9	4	-	9	2	-	-	-	9	-	0	-	-
G.36392/simazine	1	9	0	-	2	0	-	-	-	3	-	0	-	-
"	2	8	0	-	6	0	-	-	-	8	-	0	-	-
Desmetryne	1	-	-	-	-	-	-	4	0	-	9	-	9	-
Propazine	½	-	-	-	-	-	-	2	0	-	5	-	4	-
"	1	-	-	-	-	-	-	5	3	-	8	-	8	-
Ametryne	1½	-	0	-	-	0	-	-	-	-	-	0	-	-
Dichlobenil	1	-	-	-	-	-	-	2	0	-	8	-	2	-
"	1½	6	0	0	2	0	0	-	-	4	-	2	-	0
"	2	-	-	-	-	-	-	2	0	-	9	-	5	-
"	3	9	0	0	6	0	0	-	-	6	-	2	-	0
Chlorthiamid (granules)	1	-	-	-	-	-	-	2	3	-	9	-	9	-
"	2	-	-	-	-	-	-	6	5	-	9	-	9	-
Mono-linuron	1	9	0	0	2	0	0	-	-	9	-	0	-	0
"	2	9	0	0	9	0	4	4	-	9	9	2	-	4
Tri-allate	2	-	-	-	-	-	-	1	2	-	4	-	2	-
"	4	-	-	-	-	-	-	1	2	-	7	-	2	-
Norea	1	8	-	-	0	-	-	-	-	4	-	-	-	-
"	2	9	-	-	4	-	-	-	-	8	-	-	-	-
Sindone	1	8	-	-	0	-	-	-	-	2	-	-	-	-
"	2	6	-	-	0	-	-	-	-	2	-	-	-	-
Siduron	2	0	-	-	0	-	-	-	-	0	-	-	-	-
"	4	0	-	-	0	-	-	-	-	0	-	-	-	-
CP. 31675	2	8	-	-	0	-	-	-	-	4	-	-	-	-
Asulam	2	-	-	-	-	-	-	3	0	-	8	-	4	-
" (with wetter)	2	-	-	-	-	-	-	4	2	-	9	-	6	-
"	4	-	-	-	-	-	-	5	2	-	9	-	7	-

Table 4.

Results of Experiment 3

Sprayed: 26 Oct 64
Recorded: 29 Mar 65 (22 weeks after spraying)

Herbicide and rate (lb/ac)		Kill of timothy seedlings sprayed at one leaf stage (9= complete kill:0=no effect)	Crop tolerance (9=no effect:0=dead)	Yield clean timothy seed (lb/ac)
Prometryne	$1\frac{1}{2}$	6	9	581
"	3	9	9	518
Mono-linuron	1	8	9	
"	2	9	9	
CP. 31675	1	7	7	438 *
"	2	8	4	356 *
Di-allate	2	5	9	
"	4	7	9	
Tri-allate	2	4	9	
"	4	8	9	
Not sprayed		0	9	591

S.D. (P = 0.05)* = 139

Table 5.

Results of Experiments 4, 5 and 6
(All sprayed March 1966)

		Blackgrass kill (9 = complete kill: 0 = no effect)			Crop tolerance (9 = no effect: 0 = dead)		
Experiment No.		4	5*	6	4	5	6
Stage or age at spraying					2 years	3 years	10 months
Recorded (weeks after spraying)		19	25	25	19	25	25
Prometryne	2	9	8	9	9	9	9
"	4	9	9	9	8	8	8
Dichlobenil	2	9	8	-	9	9	-
Mono-linuron	2	9	9	-	5	7	-

* The results in this column apply also to timothy seedlings from shed seed, which were at the 1 leaf stage at spraying.

Table 6.

Changing weed reaction to treatments in Experiment 4, shown by weed kill scores

(9 = complete kill: 0 = no effect)

Recording date		5 Apr	26 Apr	11 May	12 Jul	5 Apr	26 Apr	11 May	12 Jul	5 Apr	26 Apr	11 May	12 Jul
Herbicide and rate (lb/ac)		Kill of blackgrass plants ( ) present at spraying 3 Mar				Kill of blackgrass germinated after spraying ( )				Kill of *Poa trivialis* plants present at spraying ( )			
Prometryne	2	9	9	9	9	0	0	8	9	4	3	2	0
"	4	9	9	9	9	0	4	8	9	6	7	5	2
Dichlobenil	2	4	7	8	9	9	9	0	9	1	2	0	0
Mono-linuron	2	9	9	9	9	0	5	8	9	8	9	9	9

RESULTS

The two main experiments are summarized in Tables 1, 2 and 3, while the four smaller ones are in Tables 4, 5 and 6.

In Tables 1, 2 and 3 the columns are arranged in sequence of plant maturity at spraying, the oldest on the right. For crop species the age in months is given in the Tables. The average height of the crop rows from ground level is given below, as the best simple index of crop condition and leaf density -

Experiment	date	crop		height		height
1	A -	crop grasses		6 in.	clovers	3 in.
	B -	"	"	9 in.	"	4 in.
2	A -	"	"	11 in.	"	9 in.
	B -	"	"	6 in.	"	3 in.
	C -	"	"	8 in.	"	2 in.
3		Crop grass		6 in		
4		"	"	4-5 in.		
5		"	"	6-7 in.		
6		"	"	6-7 in.		

For weed grasses the following symbols are used in the Tables:-

Pre-emergence	one leaf	start of tillering	2 tillers	3-4 tillers	well-tillered

In Table 1, the unbracketed crop tolerance figures give the average score for the May-sown grasses and represent the effect of treatments on well-established grasses at the stage for which prometryne treatment is already recommended in the Weed Control Handbook. The bracketed figures show the effect on May-sown S.22 Italian ryegrass and July-sown S.23 perennial ryegrass respectively, for which the normal recommendation would not apply or would need qualification. For clarity, results for S.123 red clover are omitted, although in fact they were close to the unbracketed crop tolerance figure for all treatments except asulam 2 lb/ac (with wetter), which was more damaging than average, and the two chlorthiamid treatments, which had little or no effect on the clover.

Table 7.

Classification of treatments according to crop tolerance and control of blackgrass up to the two-tiller stage

(Brackets round treatments denote that classification is based on one result only, or is estimated from results other than on seedling blackgrass)

Crop tolerance	Kill of blackgrass seedlings: Very good	Good	Fair	Poor
Very good	Prometryne 2	Prometryne $1\frac{1}{2}$ Prometryne/ simazine $1\frac{1}{2}$ Desmetryne 1 Dichlobenil 2 " 3 Mono-linuron 1 (Siduron 2) (" 4)	G. 36392/ simazine 2 Dichlobenil 1 " $1\frac{1}{2}$ Tri-allate 2 (Di-allate 4) (Norea 2)	G. 36392/ simazine 1 (Norea) 1) (Sindone 1) (" 2) (Di-allate 2)
Good	Prometryne 3 Propazine $\frac{1}{2}$ " 1 Tri-allate 4	(Ametryne $1\frac{1}{2}$)		Asulam 2
Fair or poor	Prometryne 4 Prometryne/ simazine 2 " 3 " 4 Chlorthiamid 1 " 2 Mono-linuron 2		Asulam 2 (+ wetter) " 4 (CP. 31675 1) (" " 2)	

Figure 1.

Comparison of herbicides according to cost per acre (All rates in lb/ac a.i)

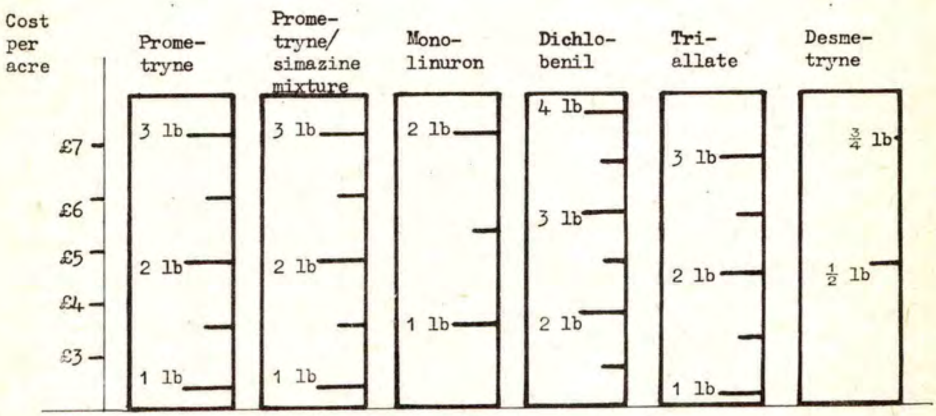


Table 2 applies only to blackgrass, while Table 3 deals with three other grass weeds. Table 4 applies only to crop seedlings as the object of control. Such seedlings are undesirable in seed crops entered for certification because if more than 15% of the seed heads in a crop are on plants derived from shed seed the crop is liable to be rejected. In Table 5, results apply to blackgrass in all three experiments, and also to crop seedlings in Experiment 5. Table 6 shows, inter al , effects on Poa trivialis in Experiment 4.

All scores for weed control and crop tolerance represent the final assessment, about one or two months prior to harvest. They therefore ignore any temporary effects on the crop, while they represent - for weed grasses - the effect of crop competition, or lack of it, in addition to the herbicide. In Experiments 1 and 2, all weed grasses were in an open environment, ideal for recovery; whereas in the other Experiments they were between crop rows which, even when wide-drilled, had made a canopy across the inter-row spaces by the final recording date. The latter point is among those illustrated in Table 6, where successive assessments of the weed kill revealed the changes which occur in actual crops - as opposed to trials with their necessarily artificial conditions. A month after spraying, the blackgrass present at spraying had been killed by the prometryne and mono-linuron treatments, but only after two months was the dichlobenil treatment giving the same effect. But there was also germination of blackgrass after spraying: at first the new seedlings appeared to be unaffected by prometryne and mono-linuron, but after two months they took effect, and crop competition completed the kill. Dichlobenil, on the other hand, was effective in preventing germination for about seven weeks after spraying, but a further wave of blackgrass seedlings germinating between 26 April and 11 May were not affected by the dichlobenil (score 0 on 11 May). They were however finally killed, by crop competition and not by the herbicide (score 9 on 12 July). The scores for Poa trivialis show, like those for the blackgrass present at spraying, the same quicker effects of prometryne and mono-linuron than of dichlobenil; but also show recovery by Poa in contrast to blackgrass, so that only mono-linuron gave satisfactory final control (though crop damage was unacceptable: see Table 5).

Experiment 3, shown in Table 4, was the only one in which crop seed yields were measured, and then only for some treatments. Four square yards in each plot were cut by hand, followed by stooking, threshing, hulling and sieving. The general level of effect of the herbicides in this experiment was reduced by absorption onto patches of trash left unburnt when the crop was cleaned up after harvest.

DISCUSSION

The major point from Table 1 is that there is no difference in crop tolerance scores between autumn and spring treatments, and the caution about spring treatments is no longer necessary. The comments that follow apply to all treatments regardless of date of spraying (although stage of crop development remains important, and is discussed).

Table 7 classifies treatments according to two aspects, control of blackgrass seedlings and crop tolerance. Figure 1 compares rates of several herbicides according to current costs, and is referred to in the following notes on the merits of the most promising treatments.

Prometryne. The rate of 2 lb/ac appears generally preferable to $1\frac{1}{2}$ lb/ac, as Tables 2 and 4 show that $1\frac{1}{2}$ lb/ac is inadequate for complete seedling control. Nevertheless 2 lb/ac can on occasion have a slight effect on the crop, and the timothy seed yields in Table 4 sound a warning note, because 3 lb/ac did not appear to affect the crop but nevertheless reduced yield (even though the reduction is not significant at $P = 0.05$).

Prometryne/simazine mixture. It was thought this might be useful to deal with successive blackgrass germinations, but it caused slightly more crop damage than prometryne alone. It was not tested in the conditions when it might show its advantage over prometryne - when there is spring germination after autumn application - but Table 6 indicates that prometryne alone at 2 lb/ac (perhaps aided by crop competition) can deal effectively with blackgrass germinating several weeks after spraying. On present evidence there is no justification for using the prometryne/simazine mixture against seedling blackgrass. Table 3 suggests that it may be slightly better than prometryne (at equal rate and cost) for more resistant grass weed problems - though there is also more hazard to the crop.

Dichlobenil. This was safe on the crop even at 3 lb/ac, but the control of weed grasses was never complete, by contrast with prometryne 2 lb/ac (although it gave good results on date B of Experiment 2 when prometryne 2 lb/ac did not). Nevertheless, at the current prices shown in Figure 1, prometryne 2 lb/ac is cheaper than dichlobenil 3 lb/ac, and therefore preferable for blackgrass control. Although in Table 3 dichlobenil looks promising for control of Poa trivialis, it shows poor results in Table 6.

Mono-linuron. At 1 lb/ac the crop tolerance is very slightly better, but the weed control worse, than for prometryne 2 lb/ac. If comparison is made at double rates (i.e. mono-linuron 2 lb/ac and prometryne 4 lb/ac), crop tolerance and seedling blackgrass control are very similar, but prometryne is better against established blackgrass (Table 2) while mono-linuron is more effective against Poa trivialis (Tables 3 and 6). It appears therefore that against blackgrass a rate higher than 1 lb/ac mono-linuron would be needed to be as effective as prometryne 2 lb/ac (and in that case there would be little difference in cost: see Figure 1). But against Poa trivialis, mono-linuron is likely to be cheaper than prometryne for equivalent results. Further testing however is needed, because the only really good results against Poa were with 2 lb/ac (Table 6) which caused unacceptable crop damage.

Tri-allate. At 4 lb/ac this gave moderately good results (as in previous years) but Figure 1 shows that the herbicides already discussed give equal results more cheaply.

Desmetryne. This herbicide, at 1 lb/ac, is comparable to prometryne $1\frac{1}{2}$-2 lb/ac against blackgrass, and in Experiment 1 (Table 3) was very effective against Poa trivialis. But cost rules out its practical application.

Propazine. As in the previous report, 1 lb/ac shows good results, and so does $\frac{1}{2}$ lb/ac, but as the herbicide is not being marketed further examination is pointless.

Siduron. The single set of results indicate that this may repay further study, although as it is only for pre-emergence use it may be less effective in field conditions than in trials.

These comments have chiefly related to control of seedling blackgrass in established seed crops. Table 2 shows that even moderate kill of established blackgrass can only be achieved by rates which cause unacceptable crop damage. Table 3 shows that Bromus mollis, Poa trivialis and Agrostis can also be controlled by many treatments at early stages, but by none at later stages. Nevertheless, it may be misleading to consider all grass weeds as identical problems. Some apparent differences in herbicide response between blackgrass and Poa trivialis have been mentioned above, and Table 3 shows, for example, a surprising resistance by Poa to all treatments on Date 2B.

As regards the earliest safe crop stage, the main crop tolerance scores in Table 1 are for crops at least 4 months old. The July-sown S.23 perennial ryegrass (second of the bracketed figures in Table 1) was only slightly less resistant than the general average when sprayed at 4 months (Date 2B) and $3\frac{1}{2}$ months (Date 1A), but at 2 months (Date 2A) was very susceptible. Italian ryegrass has been found previously to be more susceptible than other species, and the tolerance scores for it (first bracketed figures in Table 1) confirm this, particularly those for Date 2B. At some dates Italian ryegrass was not seriously damaged, but until the reason for this is understood, no treatment can be recommended.

Conclusions

1. The tentative recommendation is confirmed, with an increase of rate to 2 lb/ac prometryne.

2. The recommendation can be extended to permit spring treatments, although such treatments will only be worthwhile against spring-germinating weeds.

3. No herbicides show marked improvement over prometryne on efficiency and cost, although dichlobenil and mono-linuron are close competitors. There is evidence that mono-linuron may be preferable for controlling *Poa trivialis.*

Acknowledgments

The authors acknowledge gratefully the help of the Weed Research Organisation, Oxford, who advised on potentially promising treatments; and of various manufacturers who supplied herbicides and information.

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WEED CONTROL IN RED CLOVER INTENDED FOR THE PRODUCTION OF FODDER OR SEED

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Summary In the tests carried out, during 1966, on red clovers with 2 to 4 trifoliate leaves, dinoseb (acetic ester and amine salt), which was tolerated by the crops, produced limited weed control due to the fact that it was applied on fairly large weeds. The more efficient dinoterb proved to be more toxic for red clovers. Combinations of MCPB and dinoseb and of MCPB and carbamate 11561 RP, which were non-phytotoxic, offered a wider weed control range than that produced by each of their components. In winter applications, paraquat, dichlobenil and carbamate 11561 RP proved to be selective in established crops, and active against the annual grasses. 11561 RP produced a certain effect against *Agropyron repens.* Dichlobenil was very active against a wider range of dicotyledons.

INTRODUCTION

In France red clover crops cover a large area in the order of 1 million hectares.

When it is intended for fodder production, red clover is grown alone, or sometimes in association with Italian ryegrass. It is often sowed under the cover of a cereal, which permits easier control of weeds at that time of the year. Following that period, the crop competes successfully with weeds. However, certain undesirable plants, suchas *Plantago lanceolata*, *Alopecurus myosuroides*, etc., may invade the crop.

Crops intended for the production of seed are sowed with wide spacing (20 to 40 cm), which makes them less competitive with weeds. They must, in addition, be kept clean throughout their life, so that their weed control poses some important problems.

The trials described below were part of the work that was begun in 1963 (FAIVRE-DUPAIGRE and BOUCHET, 1964 ; FAIVRE-DUPAIGRE, et al., 1965). Various weed-killers were tested, some when establishing the crops, some on already-established crops which were treated in winter during the dormant period.

METHODS AND MATERIALS

1) Weed control of establishing crops :

Herbicides used :	Doses, in kg/ha a.i.
dinoseb (acetic ester)	0.8 - 1.6 - 3.2
dinoseb (amine salt)	0.55 - 1.1 - 2.2
2,4-dinitro-3-butyl-6-phenol ammonium salt (dinoterb)	0.5 - 1 - 2
MCPB	1 - 2 - 4
D (-) (phenylcarbamoyloxy-2-N-ethylpropionamide) (11561 RP)	1 - 2 - 4
4-chloro-2-oxobenzothiazolin-3-yl-acetic acid (benazolin)	0.15 - 0.3 - 0.6
MCPB + dinoseb (acetic ester)	1 + 0.8 - 2 + 1.6
MCPB + dinoseb (amine salt)	1 + 0.55 - 2 + 1.1
MCPB + dinoterb	1 + 0.5 - 2 + 1
MCPB + 11561 RP	1 + 1 - 2 + 2
MCPB + benazolin	1 + 0.15 - 2 + 0.3
dinoseb (acetic ester) + benazolin	0.8 + 0.15 - 1.6 + 0.3

5215 SN (formula including : 2,4-DB 250 g/l ;
MCPA 45 g/l ; benazolin 30 g/l) 2 - 4 kg/ha a.i.

All the above products were compared in eight trials conducted in the West, the North-West and the North-East of France on red clovers with from 2 to 4 trifoliate leaves.

MCPB, dinoseb (acetic ester) and 11561 RP, used alone or in 2/2 combinations, were the subject of yield trials for fodder and seed (table 1).

Table 1.

Yield trials of red clover (young crops) with dinoseb (acetic ester), MCPB and 11561 RP

No	sites	soil type	red clover variety	sowing date	treatment date	crop stage
1	Seine-et-Oise	calcareous clay	Crop	26.4.66	28.5.66	2-3 leaves
2	Eure-et-Loir	sandy loam	Kuhn	26.4.66	3.6.66	3 leaves
3	Eure	sandy loam	Alpille	29.4.66	8.6.66	3 leaves
4	Oise	silt	Flamand	27.4.66	22.6.66	2-3 leaves

2) Weed control of established crops :

Herbicides used :	Doses, in kg/ha a.i.
dichlobenil	3 - 6
chlorthiamid	2 - 4
buturon	2 - 4
paraquat	0.4 - 0.8
diquat	0.4 - 0.8
D (-) (phenylcarbamoyloxy-2-N-ethylpropionamide) (11561 RP)	2 - 4
dichlobenil + 11561 RP	1.5 + 1 - 3 + 2
chlorthiamid + 11561 RP	1 + 1 - 2 + 2
dichlobenil + buturon	1.5 + 1 - 3 + 2
11561 RP + MCPB	1 + 1 - 2 + 2
paraquat + diquat	0.24 + 0.16 - 0.48 + 0.32

Table 2.

Yield trials of red clover (established crops) with dichlobenil and 11561 RP

No	sites	soil type	red clover variety	sowing date	treatment date
1	Oise	sandy loam	Flamand	spring 65	28.1.66
2	Yonne	calcareous clay	Goliath	spring 65	2.2.66

RESULTS

Observations made on the principal weeds present in the trials, for the average dose of each weed-killer, have been summarized in tables 3 and 5. This information is only valid for comparison purposes, as the number of observations was small and varied according to the weed species.

1) Weed control when establishing red clover crops (table 3)

a) Phenols :

Dinoseb (acetic ester) gave more uniform results than ammonium salt dinoseb

Table 3.

Herbicidal efficiency on the principal weeds present in the trials on young red clovers
(Scale from 0 = no effect, to 10 = total destruction)

Weeds \ Chemicals	Dinoseb (acetic ester) 1.6 kg/ha	Dinoseb (amine salt) 1.1 kg/ha	Dinoterb 1 kg/ha	MCPB 2 kg/ha	11561 RP 2 kg/ha	Benazolin 0.3 kg/ha	MCPB + dinoseb (a. ester) 1 + 0.8 kg/ha	MCPB+dinoseb (amine salt) 1 + 0.55 kg/ha	MCPB + dinoterb 1 + 0.5 kg/ha	MCPB + 11561 RP 1 + 1 kg/ha	MCPB + benazolin 1 + 0.15 kg/ha	Dinoseb (a. ester) + benazolin 0.8 + 0.15 kg/ha	5215 SN 2 kg/ha
Annual grasses (1)					7					5			
Anagallis arvensis L.	8	7	9	2	0	1	4	6	9	3	0	6	6
Brassica oleracea L.	10	4	9		0	0						7	10
Capsella bursa-pastoris (L.) Medic.	9	9	10	6	2	0	9	9	6	4	4	10	7
Chenopodium album L.	4	3	6	10	4	1	10	8	10	10	10	2	10
Fumaria officinalis L.	7		10	4	0	0	7	8	10	10	6	8	4
Picris echioïdes L.	4		2	8	0	2	6	3	2	4	8	2	9
Plantago lanceolata L.	5	8	7	5	0	0	5	4	10	5	4	2	9
Polygonum aviculare L.	1	1	2	7	4	0	2	4	5	7	5	0	6
Polygonum convolvulus L.	3	4	3		5	0						0	3
Polygonum persicaria L.	3	2	3	7	6	0	4				5	1	5
Raphanus raphanistrum L.	10	10	10	3	3	0	10	9	10	6	7	6	8
Rumex acetosella L.	7	7	7	9			5	5	10			0	
Sinapis arvensis L.	10	8	10	9	3	2	9	10	10	10	10	6	9
Sonchus sp.	5	3	4	6	0	0	4	3	3	5	2	1	6
Stellaria media (L.) Vill.	6	5	7	0	5	9	5	3	5	4	7	10	9
Veronica sp.	8	8	9	2	7	0	5	5	8	4	0	5	3

(1) Chiefly : Alopecurus myosuroïdes Huds., Lolium rigidum Gaud., Apera spica-venti (L.) Beauv., Setaria viridis (L.) Beauv., Avena fatua L., Echinochloa crus-galli (L.) Beauv., Digitaria sanguinalis (L.) Scop.

in trials carried out on lucerne in 1965 (FAIVRE-DUPAIGRE and BOUCHET, 1965). In 1966, its efficiency proved to be low against some dicotyledons, such as Chenopodium album and Stellaria media.

Amine salt dinoseb was tolerated by red clover. Its herbicidal action came very near to that of acetic ester dinoseb.

Dinoterb proved to be more toxic for the crop. Although it was tolerated at a dose of 0.5 kg/ha, it produced a visible depressive effect of 20 per cent at a dose of 1 kg/ha, and of 35 per cent at a dose of 2 kg/ha. However, in the majority of cases, the depression was no longer visible on second mowing. The product offered an excellent herbicidal efficiency at a dose of 1 kg/ha ; it was far more active than acetic ester dinoseb against Chenopodium album.

b) MCPB :

It will be noted (table 4) that the dose of 2 kg/ha of MCPB did not cause any significant reduction of red clover yield. This product was much more active than phenols against Chenopodium album (table 3).

c) 11561 RP :

The dose of 2 kg/ha of 11561 RP did not result in a significant reduction of red clover yield (table 4).

This weed-killer is above all active against grasses. It was not completely effective against annual grasses, (especially Alopecurus myosuroides), as only 80 per cent were destroyed with a dose of 4 kg/ha.

Table 4.

Fodder yield of red clover (young crops) after spraying with dinoseb (acetic ester), MCPB and 11561 RP (1)

Doses / Trials	Control	MCPB	11561 RP	dinoseb acetic ester	MCPB+11561 RP		MCPB+dinoseb acetic ester		L.S.D.	Coeff. of var. %	Control yield (2)
		2kg/ha	2kg/ha	1.6 kg/ha	1 + 1 kg/ha	2 + 2 kg/ha	1+ 0.8 kg/ha	2+ 1.6 kg/ha			
1 (1st mowing)	100	98.51	95.53	95.91	104.08	95.91	94.79	94.79	N.S.	9.96	26.9
2 (1st mowing)	100	105.42	102.40	98.79	103.01	103.01	98.19	98.19	5.16	4.42	16.6
3 (1st mowing)	100	118.08	106.38	112.76	113.82	119.14	105.31	117.02	8.87	7.20	9.4
4 (1st mowing)	100	90.03	99.61	94.25	90.03	82.37	101.53	90.80	11.69	9.64	26.1

(1) Underlined results are different from those of the untreated control plot at the level of significance - P = 0.05.
(2) in t/ha of fresh matter.

d) Benazolin :

At 0.3 kg/ha and above, benazolin produced a temporary depressive effect on red clover which was accompanied by a very typical curling of the leaves. This substance offers an advantage only in combination with other chemicals, given its restricted herbicidal range. It proved to be very efficient against Stellaria media at a dose of 0.3 kg/ha.

e) Product combinations :

MCPB + dinoseb (acetic ester) ; MCPB + dinoseb (amine salt).

These two mixtures gave a wider range of weed control than that of each

Table 5.

Herbicide efficiency on weeds present in trials on established red clovers
(Scale from 0 = no effect, to 10 = total destruction)

Weeds \ Chemicals	Dichlobenil 3 kg/ha	Chlorthiamid 2 kg/ha	Buturon 2 kg/ha	Paraquat 0.4 kg/ha	Diquat 0.4 kg/ha	11561 RP 2 kg/ha	Dichlobenil + 11561 RP 1.5 + 1 kg/ha	Chlorthiamid + 11561 RP 1 + 1 kg/ha	Dichlobenil + buturon 1.5 + 1 kg/ha	11561 RP + MCPB 1 + 1 kg/ha	Paraquat + diquat 0.24 + 0.16 kg/ha
Annual grasses (1)	7	7	4	9	3	9	8	8	7	7	
Agropyron repens(L.)Beauv.	4	0	0	4	0	5	5	5	0	3	0
Cirsium arvense (L.) Scop.			0	0	0	0	0	0	0	0	0
Daucus carota L.			0	0		0	0				0
Galium aparine L.	1	4	0	2	3	3	5				1
Lamium purpureum L.	8	9	10	5		2	0		8		10
Matricaria sp.	8	5		3	3	0	0			0	
Melandrium dioïcum Cross et Germ.	1	0	0	0	0	3	0		3		0
Myosotis arvensis (L.) Hill		9	0	0	0	0	0		10		0
Plantago lanceolata L.	5	5	2	0	0	1	3		2	5	1
Picris echioïdes L.	4	4	0	0	2	0	2		1		0
Rumex acetosella L.	8	7	0	0	1	4			2	6	0
Senecio vulgaris L.	8	7		4	7	0	2		1		2
Sonchus sp.	7	5		2	2	0	4		4		3
Stellaria media (L.) Vill.	7	8	6	10	9	7	8	8	6	6	10
Taraxacum officinale Weber	6	7	0	0	1	0	2	0	1	0	0
Veronica sp.	8	8	5	4	5	4	4		2		3
Verbena officinalis L.	5	5	0	0	0	0	0		0		0

(1) chiefly : Alopecurus myosuroïdes Huds, Lolium rigidum Gaud., Apera spica-venti (L.) Beauv., Setaria viridis (L.) Beauv., Avena fatua L., Echinochloa crus-galli (L.) Beauv., Digitaria sanguinalis (L.) Scop.

of their components, without any additional phytotoxicity. In both cases, the weakest dose applied (1 + 0.8 kg/ha and 1 + 0.55 kg/ha respectively) proved to be insufficient against a number of dicotyledons (table 3). These two combinations behaved in a fairly similar manner, the combination including acetic ester dinoseb being slightly more active than that containing amine salt dinoseb against Stellaria media and Picris echioides.

MCPB + dinoterb.

These two herbicides used as a mixture caused a marked slow-down of red clover growth at the weakest dose (1 + 0.5 kg/ha). Their weed-killing action was sufficient with that dose, against the majority of dicotyledons. However, certain plants, such as Picris echioides and Sonchus sp., proved to be somewhat resistant.

MCPB + 11561 RP.

This product mixture was fairly well tolerated by red clover. The dose of 2 + 2 kg/ha, however, caused a slight decrease in yield on first fodder cutting in 1 trial out of 4 (table 4). With a dose of 1 + 1 kg/ha, only 50 per cent of the grasses were killed, and even with 2 + 2 kg/ha the graminicidal effect was not complete. The results obtained against dicotyledons are more satisfactory, in spite of rather poor effect on Anagallis arvensis, Stellaria media and Raphanus raphanistrum.

MCPB + benazolin ; dinoseb (acetic ester) + benazolin.

These mixtures caused temporary curling of red clover leaves. Their action against Stellaria media was better than that of MCPB or acetic ester dinoseb used alone.

5215 SN.

With a dose of 1 kg/ha and above, 5215 SN produced a marked shortening of red clover. The product became very phytotoxic from a dose of 2 kg/ha onwards. The dose of 2 kg/ha was very efficient against most dicotyledons present in the trials (table 3).

2) Weed control in established crops (table 5) :

Dichlobenil :

This product did not significantly reduce the yield of red clover, even at a dose of 6 kg/ha (table 6), although it caused a delay in spring growth. At a dose of 3 kg/ha, it was not completely effective against annual grasses. On the other hand, it proved to be very active against a number of dicotyledons. Galium aparine and Melandrium dioicum were not destroyed by 6 kg/ha.

Paraquat :

Paraquat was selective for red clover, even at a dose of 0.8 kg/ha. With a dose of 0.4 kg/ha it killed annual grasses as well as Stellaria media.

Diquat :

This product was tolerated by red clover at a dose of 0.8 kg/ha, which proved to be insufficient against annual grasses. At 0.4 kg/ha, diquat killed Stellaria media and had a clear, though insufficient effect, on Senecio vulgaris and Veronica sp.

11561 RP :

This carbamate had no effect on red clover yield at the dose of 2 and 4 kg/ha (table 6). At 2 kg/ha, it killed annual grasses. At 4 kg/ha, it had a depressive effect on Agropyron repens which was estimated at 70 per cent.

Dichlobenil + 11561 RP :

The combination of dichlobenil and 11561 RP did not reduce red clover yield significantly, even at a dose of 3 + 2 kg/ha (table 6). Its weed-killing capacity, which was weak at a dose of 1.5 + 1 kg/ha, was not always satisfactory against dicotyledons at a dose of 3 + 2 kg/ha.

Table 6.
Fodder yield of red clover (established crops) after spraying with dichlobenil and 11561 RP (1)

Doses / Trials No	Control	Dichlobenil		11561 RP		Dichlobenil + 11561 RP		L.S.D.	Coeff. of var. %	Control yield (2)
		3kg/ha	6kg/ha	2kg/ha	4kg/ha	1.5 + 1kg/ha	3 + 2 kg/ha			
1 1st mowing	100	103.50	95.71	104.66	98.05	105.44	100.38	5.56	4.66	25.7
2nd mowing	100	105.88	104.27	101.06	99.46	102.67	104.81	N.S.	9.61	18.7
2 1st mowing	100	92.22	95.27	96.28	107.77	96.68	88.85	N.S.	12.54	29.6

(1) Underlined results are different from those of the plot treated at the weakest dose of the same compound at the level of significance P = 0.05.
(2) in t/ha of fresh matter.

The herbicides or mixtures that follow did not offer any particular advantage for weed-killing : buturon and mixtures of chlorthiamid + 11561 RP, of 11561 RP + MCPB, and of diquat + paraquat.

On the other hand, chlorthiamid and the combination of dichlobenil and buturon proved to be toxic for the crop.

DISCUSSION

1) **Weed control when establishing red clover crops** :

The spring of 1966 was very cold, so that young red clovers could only grow very slowly. This explains the poor results obtained with dinoseb (acetic ester or amine salt). In fact, this product has been applied often against weeds such as *Chenopodium album*, *Anagallis arvensis*, etc., which grow better than red clover at low temperatures and have outgrown their stage of sensitivity at the time of treatment. Under these conditions, dinoterb proved to be very much more active, but also more phytotoxic. It is, however, not possible to form a definite opinion on dinoterb, as the experimental formula used has had to be modified. The effect of acetic ester dinoseb and that of amine salt dinoseb were influenced in a similar manner by the temperature at the time of treatment. These two products had the best efficiency above 20°C. Their phytotoxicity increased slightly when they were used above 30°C. On the other hand, their effect became small at a temperature below 12°C.

Dinoterb proved to become active at a temperature of 7°C. An increase in its phytotoxicity was noted after treatment carried out at more than 25°C.

11561 RP has rarely controlled grasses in a satisfactory manner. This is contrary to the results obtained in 1965, as well as to those obtained with winter applications in 1966. It can be assumed that, in spring, the product is rapidly destroyed by the microflora in the soil, and that it cannot therefore kill late emerging grasses. 11561 RP cannot be used (alone or in a mixture) on red clover sowed under the cover of cereals, as it is toxic for them.

The combination of MCPB + acetic ester dinoseb, and that of MCPB + amine salt dinoseb were very efficient against dicotyledons at the strongest doses tested (2 + 1.6 kg/ha for the first combination, 2 + 1.1 kg/ha for the second), but were not sufficiently active at small doses (1 + 0.8 and 1 + 0.55 kg/ha). It would be instructive to investigate, in each case, a medium dose, 1.5 + 1.2 kg/ha and 1.5 + 0.9 kg/ha respectively, in order to determine the useful doses for these combinations. The MCPB and dinoterb mixture must be re-investigated, using a more satisfactory dinoterb formula, in order to determine the threshold of tolerance of the latter product in respect of red clover.

The combination of MCPB and 11561 RP, which is ineffective against late emergence of grasses, was more efficient than MCPB alone against dicotyledons.

Treatments combining benazolin and acetic ester dinoseb or MCPB could only control a restricted number of dicotyledons. It would be advisable to experiment with a combination of these three herbicides, and to try to make good use of the effect of benazolin on Stellaria media and Galium aparine (effect noted by LUSH, 1965). One could also consider reinforcing the action of MCPB + 11561 RP mixture against dicotyledons by adding benazolin or dinoseb.

2) Weed control of established crops :

Three products proved to be both selective for red clover, and active against grasses in winter application, namely dichlobenil, paraquat and 11561 RP. Only 11561 RP showed (at a dose of 4 kg/ha) a good effect on Agropyron repens, a plant which has been increasingly invading certain regions in the North of France.

Dichlobenil showed an interesting though rarely complete activity against dicotyledons. Chlorthiamid also proved to be rather efficient against these weeds at a dose of 2 kg/ha, but was toxic for the red clover at that dose.

The herbicides investigated did not prove to be very efficient. This is probably due to the fact that the modes of action of the products combined are closely related each other, and not complementary. It would be interesting to investigate mixtures of herbicides having very dissimilar modes of action, as for instance a mixture of a contact herbicide, such as paraquat and dichlobenil, or 11561 RP, the latter being weed-killers whose action is much slower.

Acknowledgements

The authors acknowledge gratefully MM. Dagneaud and Maumené (I.T.C.F.), Cosentino, Hélias and Mimet (F.N.A.M.S.), Lavandier and de Bury (Ets Géroudet), Brunet (C.E.T.A. - Eure), Boilletot (Ch. agric. Sarthe), Henriot and Demaine (Ch. agric. S-et-O), who have collaborated in carrying out these trials.

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DEVELOPMENT OF GRASSES, CLOVERS AND WEEDS IN RELATION TO METHODS OF ESTABLISHMENT.

Research Report

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Summary The interaction between 2 ley mixtures and weeds was studied by comparison with unsown plots on each of 4 seedbeds derived from old *Agrostis/Fescue* pasture. The distribution of buried viable seed following seedbed preparation is also described. Improved crop development and reduced weed occurred as seedbed preparation increased from chemical sward destruction alone, through rotary cultivation, to shallow and deep ploughing. Weeds emerged according to the action of cultivations in redistributing seed and live vegetation within the soil. Ryegrass was more aggressive than timothy/fescue in reducing weeds.

INTRODUCTION

The control of indigenous plants and their capacity to recolonise from viable remains or buried seed are important to the success of grassland reseeding. The first factor also influences the physical nature of the seedbed and the second, through competition, the development of the crop. The performance of the undesirable plants can in turn be influenced by the method of seedbed preparation and by the aggressiveness of the sown species.

The experiment described below was set up to compare the effects of various seedbed preparations on the vegetation and the buried seed of an old *Agrostis/Fescue* pasture. An additional object was to study the ability of the indigenous flora to recolonise against a background of ryegrass/clover and timothy/meadow fescue/ clover leys sown on the seedbeds.

METHOD AND MATERIALS

The experiment was located at Begbroke Hill, Oxford, on level, poorly-drained ground, 200 ft above sea level. The soil is a medium-heavy to light-textured alluvium with gleying present below the level of the permanent water table. The depth of the water table in the drier areas ranged from 25-30 in. and in the wetter areas from 0-14 in. The average annual rainfall is about 25 in. The site was occupied initially by old permanent pasture dominated by *Agrostis* species and *Festuca rubra*. A complex mixture of sub-dominants included *Holcus lanatus*, *Anthoxanthum odoratum*, *Dactylis glomerata*, *Plantago lanceolata* and *Trifolium* species. Prior to experimentation the field had been grazed at a low stocking rate and occasionally mown.

The experiment had a randomised block, split-plot design in triplicate and was repeated at 3 points along a gradient over a known water table. Each replicate of 24 x 70 yd contained 4 main plots of 20 x 6 yd, each split into 3 sub-plots 18 x 20 ft.

Treatments

The major treatments were the methods of seedbed-establishment.

1) **Paraquat at 2 lb a.i./ac plus 0.1% Agral 90 applied in 32 gal/ac aqueous spray solution on 31st March, 1964.** No subsequent cultivation.
2) Ditto; followed by rotary cultivation to 2-4 in. twice over on 15th April, 1964, on which date there was less than 10% ground cover of vegetation following the application of paraquat on 31st March.
3) Shallow-ploughing to 4-5 in. on 11th March, 1964.
4) Deep-ploughing to 8-9 in. on 11th March, 1964: both ploughing treatments were followed by discing and the Cambridge roller on 14th April, 1964.

Each of the above treatments was split for:-

a) No seed.
b) 22 lb/ac S 23 perennial ryegrass and 3 lb/ac S 100 white clover.
c) 8 lb/ac S 48 timothy, 10 lb/ac S 53 meadow fescue and 2 lb/ac S 100 white clover.

The seed was broadcast on 23rd April, 1964, and rolled in.

Assessments

Buried seed was sampled in 2 x 1 in. diam. cores to a depth of 10 in. in each seedbed on 27th April, 1964. Ten sets of cores per main plot were bulked and the emerging seedlings were identified, counted and removed over a period of one year under greenhouse conditions. Specific frequency and cover were assessed by point quadrat on 22nd May, 11th June and 14th October, 1964, and on 3rd March, 1965. The first contact only with each species was recorded according to the method described by the Grassland Research Institute (1961). Cuts for yield and botanical composition were made with a motor-scythe on 27th July, 1964. Random samples were taken from the cut plot and weighed together with the remaining vegetation. Samples were stored at -18°C prior to separation into species, dried at 100°C for at least 6 hours and weighed.

Assessments made at the dry (D) and wet (W) ends of the moisture gradient only are presented.

Management

The area was cut over on 27th July, 1964, and grazing started on 12th August, 1964.

RESULTS

1. The effect of seedbed preparation on the distribution of viable seeds in the soil.

The number of seeds that occurred in the consecutive 2 in. layers of the soil profile are illustrated in Fig. 1. The plots sprayed with paraquat alone, were used to indicate the undisturbed profile. The maximum occurrence of seed was in the 0-2 in. layer. About half this amount was found in the 2-4 in. and a quarter in the 4-6 in. layers. The 6-8 in. and 8-10 in. layers contained only small amounts of seed.

The effect of soil disturbance was to redistribute the seed in the profile. Rotary cultivation, which mixed the top few inches of soil only, diluted the amount in the 0-2 in. layer and increased the amount in the 4-6 in. layer. Shallow ploughing, which was accompanied by good inversion of the furrow slice, placed maximum amounts of seed at a depth of 2-6 in. Deep ploughing had a similar effect but increased the amount of seed over a somewhat greater depth. The general

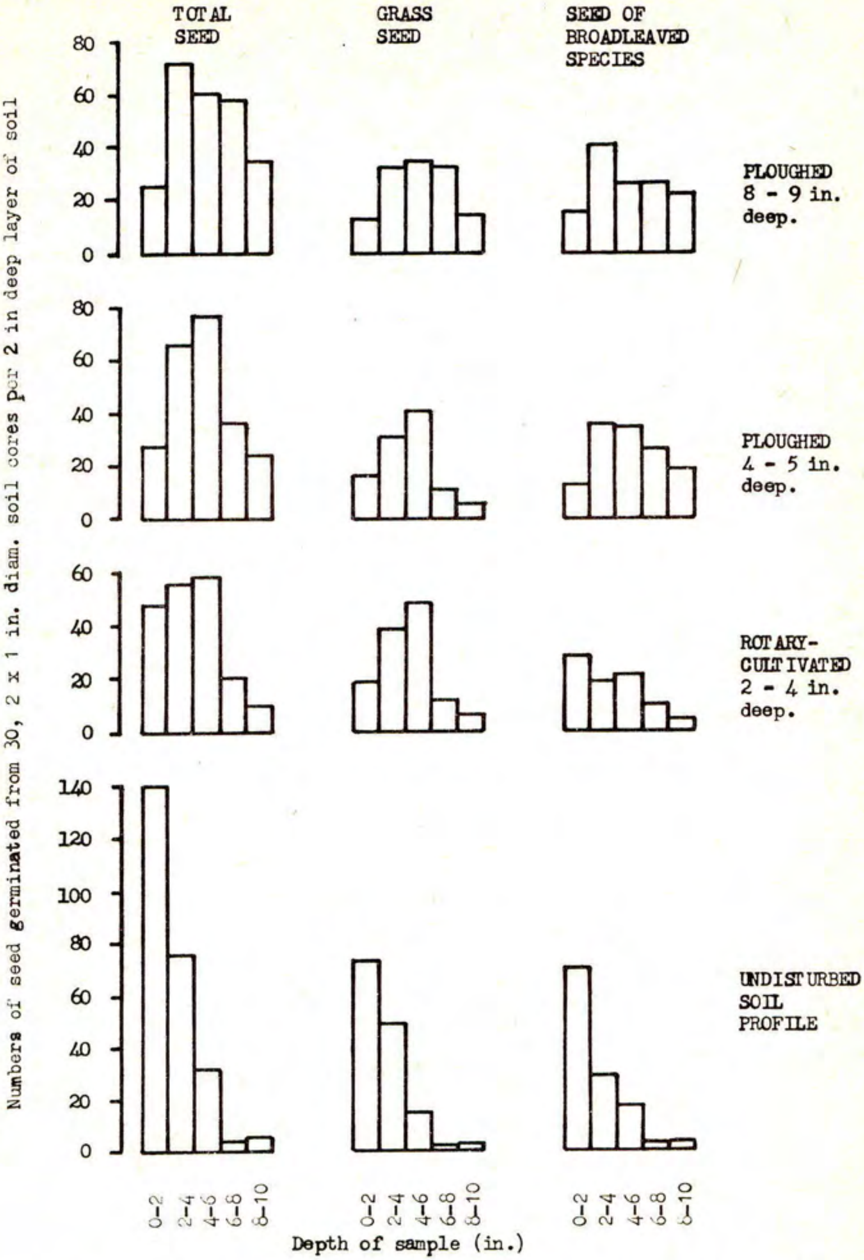

Fig.1. Numbers of seed germinated from 2in. deep layers of the soil profile following seedbed preparation on 27th April 1964.

Table 1

First contacts per species per 300 points per treatment at dry (D) and wet (W) ends of the moisture gradient assessed on 22nd May, 1964 (totals of 3 replicates).

Species, etc.	Timothy/meadow fescue/ White clover								Perennial ryegrass/ White clover								No crops sown							
	Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Timothy	14	14	12	17	16	8	4	8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Meadow fescue	3	4	3	3	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Perennial ryegrass	0	0	0	0	0	0	0	0	19	28	26	16	17	10	8	3	0	0	0	0	0	0	0	0
Weed grass	2	0	0	1	2	4	44	61	3	2	2	3	5	2	29	81	8	0	0	3	5	5	23	66
White clover	2	3	2	11	1	3	3	20	1	2	2	4	2	2	5	33	1	0	0	1	1	5	1	32
Broad leaved weeds	8	6	9	10	17	10	130	113	5	4	7	0	14	17	136	74	4	6	0	7	10	6	140	93
Bare soil	273	265	270	255	232	238	15	44	271	261	255	270	244	229	15	37	275	284	282	284	243	244	4	27
Dead vegn. alone/soil	0	8	4	5	33	36	127	84	1	2	4	7	20	40	132	119	8	2	2	5	39	41	148	120
Other dead vegn.	1	0	0	3	2	4	111	110	0	0	1	0	2	1	116	101	1	0	0	2	3	2	115	124

Table 2

First contacts per species per 300 per treatment at dry (D) and wet (W) ends of the moisture gradient assessed on 11th June, 1964 (totals of 3 replicates).

Species, etc.	Timothy/meadow fescue / White clover								Perennial ryegrass/ White clover								No crops sown							
	Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Timothy	57	51	42	68	31	25	N.A.		0	0	2	0	1	1	N.A.		0	0	0	1	0	0	N.A.	
Meadow fescue	9	9	9	15	11	4			0	0	0	0	0	0			0	0	0	1	0	0		
Perennial ryegrass	0	1	0	0	0	0			95	69	76	71	62	42			0	2	0	0	1	0		
Weed grass	5	2	6	17	17	7			7	9	11	8	9	17			14	16	9	13	14	20		
White clover	9	3	6	14	8	8			9	6	8	3	5	9			1	0	0	1	0	9		
Broad leaved weeds	9	26	20	23	81	27			25	27	16	20	99	69			43	38	39	30	66	40		
Bare soil	215	207	218	180	158	199			175	191	191	202	132	156			242	243	252	255	199	195		
Dead vegn. alone/soil	1	6	2	3	17	37			0	5	1	2	14	34			6	4	1	4	23	37		
Other dead vegn.	0	2	0	2	3	2			0	1	0	0	7	1			0	1	0	1	1	10		

N.A. Not assessed as vegetation too high for point quadrats.

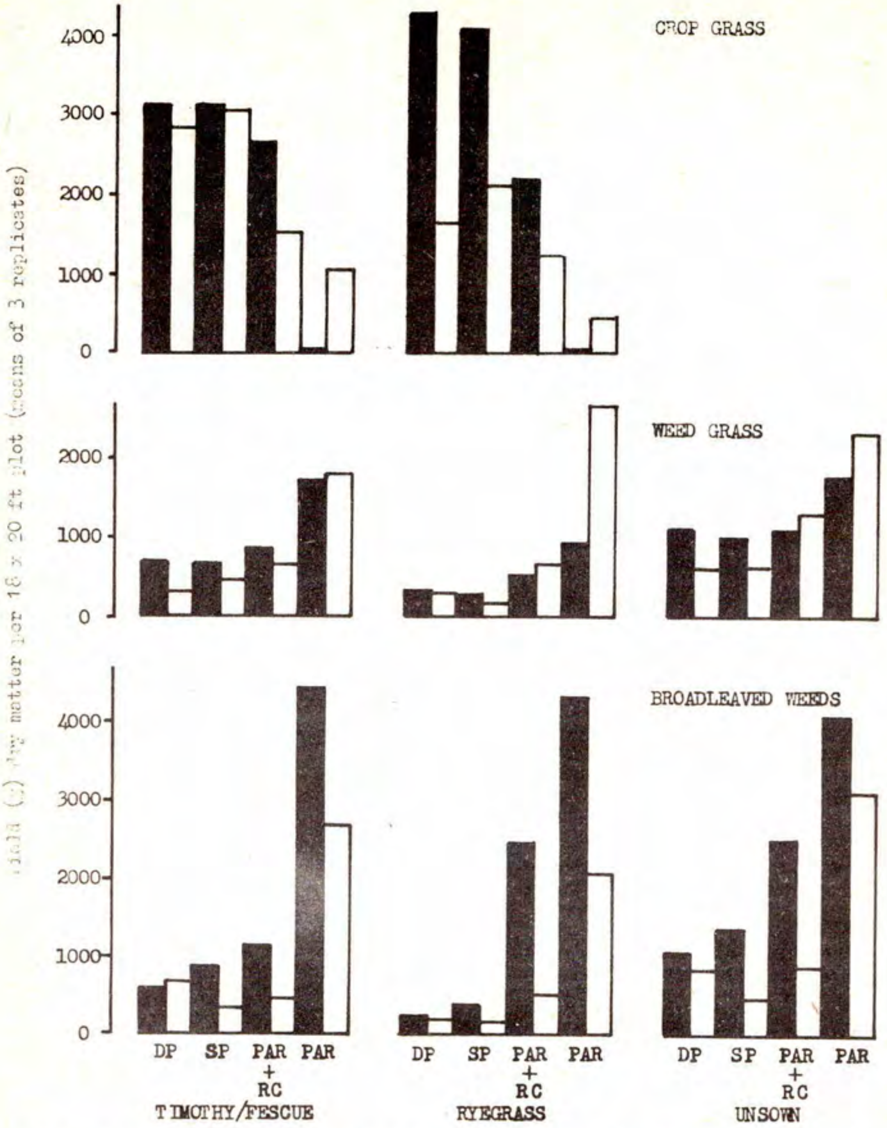

Fig.2. Yields (dry matter g/plot) of crop grass, weed grass and broadleaved weeds, at the dry and wet ends of the moisture gradient, following the various methods of seedbed preparation; assessed 27th July 1964 (means of 3 replicates).

■ = Dry □ = Wet

DP = ploughing 8 - 9 in. SP = ploughing 4 - 5 in.

PAR + RC = paraquat + rotary cultivation 2 - 4 in.

PAR = paraquat alone

Table 3

<u>First contacts per species per 300 points per treatment at dry (D) and wet (W) ends of the moisture gradient assessed on 14th October, 1964 (totals of 3 replicates).</u>

	Timothy/meadow fescue / White clover								Perennial ryegrass/ White clover								No crops sown							
Species, etc.	Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Timothy	74	109	88	114	64	79	3	10	0	0	1	3	0	5	1	0	3	1	8	10	4	4	1	0
Meadow fescue	27	32	36	47	22	24	1	6	0	0	0	0	0	0	0	0	1	1	0	2	1	0	0	1
Perennial ryegrass	2	7	1	6	3	6	0	8	150	199	145	158	90	128	11	23	7	11	4	2	0	2	0	0
Weed grass	25	41	26	40	43	104	46	109	9	26	10	27	23	92	24	109	70	128	57	114	80	163	28	72
White clover	20	25	38	34	24	23	10	69	15	21	8	18	10	16	6	71	12	10	28	6	6	31	5	50
Broad leaved weeds	68	42	67	64	134	110	234	189	23	47	34	75	160	121	227	113	122	110	98	105	210	146	221	175
Bare soil	45	13	37	24	33	12	19	11	67	25	66	27	24	14	22	12	91	55	91	34	39	19	12	15
Dead vegn. alone/soil	79	79	58	55	53	42	56	42	58	41	64	49	47	36	70	49	41	52	49	67	42	45	78	73
Other dead vegn.	139	166	143	195	158	214	166	192	99	188	109	177	154	193	159	179	68	131	77	139	135	173	163	161

Table 4

First contacts per species per 300 points per treatment at dry (D) and wet (W) ends of the moisture gradient assessed on 3rd March, 1965 (totals of 3 replicates).

Species, etc.	Timothy/meadow fescue/ White clover								Perennial ryegrass/ White clover								No crops sown							
	Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone		Deep plough		Shallow plough		Paraquat and rot.cult.		Paraquat alone	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Timothy	113	106	108	116	61	74	6	18	0	0	0	0	0	1	1	0	18	2	4	2	2	3	2	0
Meadow fescue	23	9	26	11	12	5	0	0	0	0	0	0	0	1	0	0	5	1	0	1	1	0	0	0
Perennial ryegrass	3	16	3	10	6	7	0	2	194	177	188	193	133	134	18	36	23	27	13	0	7	4	0	5
Weed grass	43	49	36	50	69	107	58	118	14	24	18	26	15	58	56	90	122	155	131	145	105	163	56	101
White clover	11	11	20	22	5	20	2	55	1	4	4	9	12	14	7	73	6	5	10	4	6	13	0	49
Broad leaved weeds	32	25	46	40	69	68	126	9	24	38	36	32	83	63	154	65	59	79	57	88	93	70	107	89
Bare soil	32	15	27	15	28	10	27	14	25	12	28	15	17	16	18	15	46	23	52	21	37	17	30	19
Dead vegn. alone/soil	88	103	72	98	94	79	118	83	59	75	48	57	89	73	98	88	51	58	72	83	88	77	135	97
Other dead vegn.	162	167	165	178	149	184	119	185	172	185	187	208	161	187	130	150	143	178	129	161	142	186	103	149

effect was to reduce the quantities of seed in the top 2 in. as compared with the undisturbed profile.

2. Crop establishment

A point assessment on 22nd May, 1964, showed that the ground cover of both grass crops was similar on corresponding seedbeds despite the higher seed rates used on the timothy/fescue plots. This was due mainly to poor establishment by the fescue (Table 1).

The crop cover was highest on the ploughed plots, which were similar, and nearly as high on the rotary-cultivated plots. The crop cover was very low on the undisturbed plots and would not have been acceptable from a farmer's point of view. Later assessments confirmed the persistence of these differences (Tables 2, 3, 4 and Fig. 2).

Both of the crops produced more herbage on the cultivated plots of the dry than on those of the wet block but this difference was more marked in the case of ryegrass. On 27th July, ryegrass was found generally to outyield timothy/fescue on the dry plots but the reverse occurred on the wet plots of corresponding seedbeds (Fig. 2).

3. Weed invasion

The assessment on 22nd May showed that weeds were present from an early stage in the development of the swards. There were more broadleaved weeds than grass weeds. In contrast to the crops, most weed was found on the uncultivated plots, less on the rotary-cultivated and least on the ploughed plots. The continued development of weeds on both the sown and unsown plots was shown by later assessments (Tables 2, 3, 4 and Fig. 2).

4. Interactions between crops and weeds

The effect of crop growth on the grass and broadleaved weeds was gauged by comparing weedgrowth on sown and unsown plots. During the early stages of sward development the crop exceeded the weed cover only on the ploughed plots (Table 1). Crop and weed made similar contributions to the vegetation covering the rotary-cultivated plots. The weeds were almost completely dominant on the undisturbed plots. On 22nd May, the weed cover was similar on the sown and the unsown plots of corresponding seedbeds and this suggested that little or no competition was occuring.

By 11th June, the weeds covered more ground on the unsown than the sown plots. This suggested an interaction between the crop and weed although the cover of bare soil and soil covered by dead vegetation alone, indicated that the canopy of live vegetation was still far from complete.

At harvest, on 27th July, the weights of grass and broadleaved weeds were greater from the timothy/fescue than from the ryegrass plots that had been cultivated and were greater still from the corresponding, unsown plots (Fig. 2). There was little difference between the sown and the unsown, undisturbed plots, probably due to the negligible establishment of the crop species.

The consequences of the various treatments in terms of weed and crop may be summed up by the results of the point quadrat assessment carried out on 12th March, 1965, nearly one year after sowing (Table 4). The best establishment of the cleanest crop was achieved by ploughing. Rotary cultivation provided a good establishment of a weed-infested crop; while paraquat alone provided a poor establishment and in consequence the ground was colonised by weeds. Ryegrass continued to provide a greater suppression of weeds than the timothy/fescue crop.

DISCUSSION

The results suggest that cultivation was essential in this experiment, in order to obtain an adequate establishment of crop species. Crops developed best on the ploughed plots and moderately well on the rotary-cultivated plots. They failed to establish properly on the undisturbed plots treated only with paraquat.

The success of crops sown on the cultivated plots may have been due to the better contact that their seed made with the mineral soil and other sites for germination and establishment. It is also likely that their performance was affected by the level of weed infestation. Weather during the 6 weeks following sowing was relatively warm with adequate rainfall.

Weed emergence was shown to be dependent on the action of the cultivations in redistributing the buried seed and live plants within the soil profile. Where the soil was not disturbed, in the case of plots treated with paraquat alone, the control of vegetation was short-lived. The part that paraquat played in controlling vegetation when used in combination with rotary cultivation could not be assessed. However, Evans (1964) reporting on similar work noted that although the occurrence of unsown grasses in the new sward generally was reduced by cultivations and further reduced by the herbicide it was not eliminated.

The results therefore suggest that if the distribution of viable seed is known prior to reseeding the effects of different seedbed preparations can be forecast, at least to some extent. This, coupled with a knowledge of crop performance and site, could lead to a safer choice of technique for reseeding.

Finally the results lead to the speculation that if weeds could be removed from the establishing ley, differences in crop development due to different methods of seedbed preparation may be reduced and the new techniques made more comparable with the old.

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THE USE OF ASULAM FOR THE CONTROL OF DOCKS IN PASTURE

Research Report

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Summary Asulam (methyl 4-amino benzenesulphonylcarbamate) at $2\frac{1}{4}$-3 lb/ac in grassland has given promising control of docks. This has often been accompanied by a favourable change in the composition of pasture constituents. *Holcus lanatus* is completely controlled, and *Agrostis stolonifera* severely checked. *Lolium perenne* is resistant.

In orchards asulam at 4 lb/ac has given excellent control of docks with residual activity on dock seedlings eight months after spraying.

INTRODUCTION

Discovery of the benzensulphonylcarbamate herbicides was announced in 1965 (Cottrell and Heywood 1965) and the tolerance of grass species, crops, and a limited number of weeds has since been described (Ball et al 1965).

Experiments at the Weed Research Organisation, Oxford showed that asulam, particularly when applied in the autumn, gave very effective control of docks. Asulam also has a selective effect on grasses, favouring the better pasture species at doses below 4 lb/ac. At higher doses it gives more complete grass control and also control of other broad leaved weeds. The main purpose of our programmes was to assess the field activity of asulam, particularly when applied in the autumn, against seedling and established docks in permanent pasture and in orchards, and at the same time to investigate the effect on the other sward constituents. Sites with high dock populations were chosen.

METHOD AND MATERIALS

Type of experiment	Formulation of asulam	Time of spraying	Spraying equipment	Volume gal/ac	Dose a.i.	No. of sites	Plot size
Pasture	75% potassium salt	Autumn 1965	Farmer's own equipment	20-25	36-48 oz/ac	5	$\frac{1}{2}$ acre
Orchard	80% wettable powder	Spring 1965 and Autumn 1965	Precision small plot sprayer	25-30	4-16 lb/ac	2	8ft x 12ft

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RESULTS

In the orchard experiments a quadrat measuring 5 ft x 2 ft 6 in. was used to assess the percentage ground cover of each species present. The percentage ground cover of docks in each treatment from a pear orchard sprayed in autumn 1965 are given in Table 1, and the numbers of docks in each treatment from an apple orchard sprayed in spring 1965 are given in Table 2. The emergence of dock seedlings over an 8 week period in the spring following the autumn application of asulam was recorded for each plot using a square foot quadrat. The results of these assessments are included in Table 1.

In the pasture experiments 15 random half square yard quadrat counts were made per treated acre before spraying and at $1\frac{1}{2}$, 5 and 7 month intervals afterwards. The number and growth stage of the docks was recorded in each quadrat and these results are given in Table 3. At the same time an estimate was made of the percentage ground cover of each grass and clover species present in the quadrats. The percentage ground cover of each sward constituent at the time of spraying with asulam and 7 months afterwards is given for 2 sites, both of which contained Holcus lanatus, in Table 4.

Table 1.

Effect of autumn applications of asulam on established docks and residual activity on dock seedlings in an orchard of Conference and Comice pears

Site: Great Horkesley, Essex

Date of application: 5th October, 1965

Compound	Dose lb a.i./ac	Percentage ground cover of docks after weeks and date					Number of dock seedlings per 3 ft^2 after weeks and date				
		Prespray 5/10	8 29/11	16 25/1	24 22/3	32 18/5	27 14/4	29 26/4	30 5/5	33 25/5	35 8/6
Asulam	4	45	10	5	4	6	1	1	3	2	1
Asulam	8	28	3	2	3	0	0	0	1	0	0
Asulam	16	30	0	0	0	0	0	0	0	0	0
Aminotriazole	2	39	2	2	1	27	18	30	34	28	42
Aminotriazole	4	30	3	0	1	33	-	-	-	-	-
MCPB	1	47	4	5	13	21	39	43	58	61	62
Unsprayed	0	21	7	7	19	36	10	12	60	60	60

Table 2.

Control of docks in an apple orchard by spring application of asulam

Site: Ongar, Essex
Date of application: 25th March, 1964

Docks per 5 square yards - Numbers and bulk (numbers x height in inches)

Compound	Dose lb/ac	Prespray Numbers	Prespray Bulk	After 5 months Numbers	After 5 months Bulk
Unsprayed control	0	99	234	8	204
Asulam + 0.125% Ethylan PB	4	77	213	0	0
" " "	8	94	212	0	0
" " "	16	299	679	0	0
Asulam no wetter	4	37	104	1	4
" " "	8	186	454	0	0
" " "	16	222	493	0	0
Aminotriazole	4	29	68	4	39
Dichlorthiobenzamide	6.75	124	316	10	336

Table 3.

Control of docks in pasture by autumn application of asulam

Total number of dock plants in 7½ square yards

Site	Asulam 3 lb/ac At spraying Oct. 65	Asulam 3 lb/ac After 7 months May 66	Asulam 2¼ lb/ac At spraying Oct. 65	Asulam 2¼ lb/ac After 7 months May 66
1. Kilmington, Wilts	64	8	89	8
2. Warminster, Wilts	258	5	Not applied	
3. Wellington, Somerset	75	15	Not applied	
4. Dunster, Somerset	197	50	Not applied	
5. Crediton, Devon	78	15	67	8

Table 4.

Change in percentage ground cover by pasture constituents 7 months after spraying with asulam

Site	Sward constituents	Percentage ground cover by individual species			
		Asulam at 3 lb/ac:		Asulam at $2\frac{1}{4}$ lb/ac:	
		At spraying Oct. 65	After 7 months May 66	At spraying Oct. 65	After 7 months May 66
4. Dunster, Somerset	Agrostis stolonifera	15	36	not applied	
	Festuca rubra	1	0		
	Holcus lanatus	86	0		
	Lolium perenne	1	1		
	Poa trivialis	6	57		
	Trifolium repens	1	11		
5. Crediton, Devon	Agrostis stolonifera	1	2	5	5
	Cynosurus cristatus	13	20	-	-
	Dactylis glomerata	17	5	22	15
	Holcus lanatus	4	0	-	-
	Lolium perenne	37	56	55	57
	Poa annua	20	3	12	12
	Trifolium repens	8	14	6	11

DISCUSSION

Asulam has given excellent and very persistent control of established docks. This includes residual activity against emerging seedlings up to at least 8 months after spraying. Asulam is however rather slow in action and has in most cases taken up to 7 months to produce its optimum effect. At this time, in the orchard experiments, the effect of the standard compounds - MCPB and aminotriazole is rapidly falling off. The figures in Table 3 are somewhat misleading since the counts include dock plants showing the typical asulam-treated appearance - stunted plants with small twisted pink shoots, but with a root system which is still apparently healthy, though seldom regenerating. Seedlings emerging in asulam-treated plots the following spring often show this pink colouration and usually die quite quickly. The orchard dock control figures are calculated on percentage ground cover and therefore give a very much more favourable picture. Experimental results suggest that an autumn application of asulam followed by a further application or light cultivation in the spring, would be suitable to control a heavy infestation of established docks in any habitat. The $2\frac{1}{4}$ and 3 lb/ac doses of asulam give good dock control but the higher doses are more persistent and give better residual activity.

Six weeks after spraying the grass swards showed considerable chlorosis - particularly of Poa and Agrostis spp. Five months after treatment (March) the appearance of the sward was much improved and the bare patches left by the removal of docks had started to be colonised by Poa annua, Poa trivialis, and broad leaved weeds such as creeping buttercup, dandelion etc. As a result of this, the sward 7 months after spraying was completely recovered but with the advantage of very few docks and, at some sites, an increase in desirable grass species.

Of the individual grass species Holcus lanatus was particularly susceptible, and Lolium perenne was particularly resistant. Dactylis glomerata was scorched by asulam at 3 lb/ac. The Poa spp. were severely damaged but because of their ability to germinate from seed so readily they were able to recolonise any ground becoming bare as a result of the spray treatment.

Acknowledgments

The authors acknowledge advice given by Mr H. J. Terry during the course of this work and in preparing this paper. Thanks are also due to Mr P. C. Moring for his assistance in field assessments.

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Research Summary

HERBICIDES ON BRACKEN (*Pteridium aquilinum* (L) Kuhn): TRIALS WITH DICAMBA AND PICLORAM

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Previous trials with dicamba (Hodgson 1964) and picloram (Lawson 1964) had given promising results in the control of bracken. In 1963 trials were laid down to evaluate these chemicals further. In 1964 granular formulations of both became available and these were tested as pre-emergence treatments.

MATERIALS

Dicamba (a) an aqueous solution containing 280 g/l. a.e. as the sodium salt (b) granules containing 10% technical acid.

Picloram (a) an aqueous solution containing 173 g/l. a.e. as the potassium salt (b) granules containing 7.2% of the active ingredient.

SITES

Charlbury, Oxon. A level plateau 600 ft above sea level. The bracken fronds attaining an average height of 5-6 ft to give a dense and uniform canopy. The number of fronds per unit area is not high (14 per yd^2 in 1966). There is a layer of litter 6-9 in. deep and the area is virtually free from other plant species. This site is never grased by farm animals.

Leebotwood, Salop. A moderate N.W. slope 1200 ft above sea level. The average height of the bracken is 2 ft or less. The number of fronds per unit area is relatively high (29 per yd^2 in 1966). A less uniform distribution of the fronds gives a more broken canopy. The litter layer is relatively shallow and there is an almost complete cover of grass, the two main species being *Holcus mollis* and *Deschampsia flexuosa*. Cattle and sheep have access to the area.

RESULTS WITH DICAMBA

Post emergence spray applications. (Late July, late August and mid-September 1963, at 2,4 and 8 lb/ac a.e., at both sites)
Doses of 4 and 8 lb/ac reduced the bracken severely in the season after spraying. After three years the mid-August application of 4 lb/ac and all applications of 8 lb/ac were still providing excellent control at both sites.

Pre-emergence spray applications. (Early May 1964, at 2, 4 and 8 lb/ac a.e. at both sites)
Doses of 4 and 8 lb/ac applied just before the fronds emerged have given a high degree of control for three seasons (just over 2 years) at each site. At Charlbury the dose of 2 lb/ac has also remained effective but has failed to do so at Leebotwood. It should be noted that these treatments, applied in the absence of a canopy of fronds, severely damaged the *H. mollis* and *D. flexuosa*.

Treatments with granules. (Early November and mid-December 1964, late March and early May 1965, at 2 lb/ac a.e., at Leebotwood)
Regardless of the time of application these treatments resulted in approximately an 85% reduction in the frond cover for one season, but allowed considerable

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regrowth in the second. Treatment with granules, unlike the liquid formulation had no apparent effect on the grass species.

RESULTS WITH PICLORAM

Post emergence spray applications. (Mid-July and late August 1963, at 0.7, 1.4 and 2.9 lb/ac a.e., at both sites)
In the year after spraying, the highest dose completely suppressed the bracken at Leebotwood and reduced the frond cover by over 80% at Charlbury. 1.4 lb/ac reduced the frond cover by 95% at Leebotwood but was less effective at Charlbury. 0.7 lb/ac was ineffective at both sites. By the third year, these plots at Leebotwood which had been treated with 2.9 lb/ac in mid-July were still almost free from fronds, but in all other treatments, at both sites, considerable regrowth had occurred.

Pre-emergence spray applications. (Early May 1964, at 0.7, 1.4 and 2.9 lb/ac a.e. at both sites)
The highest dose achieved an almost complete suppression of the bracken at each site in the first season and during the third season the treatment was still very effective (80% reduction in ground cover). The two lower doses were less effective.

Treatments with granules. (Early November and mid-December 1964, late March and early May 1965. 2 lb/ac a.e. at Leebotwood)
These treatments resulted in an almost complete suppression of the fronds in the first season. In the following season there was some regrowth, but the canopy was still reduced by 90% or more. The time at which the treatments were made had no apparent effect.

These trials have indicated that doses of 2-4 lb/ac of either chemical are capable of giving a high degree of control for at least three years. The treatments were at least as effective when applied before the fronds had emerged and application at this time of the year, especially with granules, has obvious practical advantages.

Only liquid formulations of dicamba, applied in the absence of a frond canopy, appeared to damage *H. mollis* and *D. flexuosa*.

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