TABLE IV. THE EFFECT OF BARBAN AND BARBAN/MCPA MIXTURES ON A. FATUA AT SHILLINGFORD, OXON.

Number of spikelets expressed as a percentage reduction of controls (mean of 3 replicates).

Date of spraying:		25.4.60.	
Stage of growth) Wheat No. of leaves) *A. fatua*		4-5 1-3 (54 per cent)	
Treatment		'above'(1)	'total'(2)
4 oz barban/ac)	without MCPA	100	60
8 oz barban/ac)		66	25
12 oz barban/ac)		53	36
4 oz barban/ac)	with MCPA at 1½ lb/ac	8	-19*
8 oz barban/ac)		49	19
12 oz barban/ac)		75	24
Control plots. 39 spikelets/sq yd 'above' the crop. 114 spikelets/sq yd 'total' count.			

TABLE V. THE EFFECT OF BARBAN ON A. FATUA AT BRETFORD, NR. EVESHAM

Numbers of spikelets expressed as a percentage reduction of controls (mean of 3 replicates).

Date of spraying:	6.5.60. (T_1)	16.5.60. (T_2)	24.5.60. (T_3)
Stage of growth) Barley No. of leaves) *A. fatua*	3-4 1-3(90%)	5-5½ 3-5 (66%)	5½-6 3-5 (79%)
Treatment:	Total(2)	Total(2)	Total(2)
4 oz barban/ac	43	-2*	37
8 oz barban/ac	73	29	52
12 oz barban/ac	80	52	37
Control plots: 115 spikelets/sq yd total count.			

* The negative sign indicates that there was an increase over control.

(1) These figures show the number of spikelets 'above' the crop, expressed as a percentage reduction from the number above the crop on the controls.

(2) These figures refer to the total number of spikelets.

Regrowth, however, occurred fairly rapidly from secondary tillers. These generally produced numbers of small panicles, many of which never rose above the crop. Thus although the 'apparent' control was often good, the actual reduction as measured by the 'estimated' number of spikelets was also often poor, e.g. at Shillingford where 4 oz barban gave a 100 per cent reduction of the panicles above the crop there were in fact 45 spikelets/sq yd still present.

Conversely, if total panicle counts had been used as the criterion, rather than numbers of spikelets, the degree of control could have appeared to be much less than was in fact the case, e.g. for the same treatment at Shillingford counts based on the total number of panicles would have shown a reduction of only 45 per cent whereas in fact the reduction in spikelet numbers was 60 per cent.

The main objects of weed control are of course two fold, firstly to reduce the competitive powers of the weed, and secondly to reduce the amount of viable weed seed produced. Barban satisfies the first of these, for it can reduce the competitive ability of the oats, at least temporarily. If the crop can take advantage of this reduced competition, i.e. soil conditions are right, etc., and the degree of infestation is relatively high, quite large increases in yield can result, as is shown in some of this season's N.A.A.S. trials (Evans, 1960). Unfortunately, the reduction in the amount of viable seed produced is very variable as is shown in these experiments. Thus, although barban treatments may give yield increases which more than compensate for the cost of application and materials, it seems unlikely that the wild oat population in ensuing years will be greatly reduced.

Acknowledgements

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REFERENCES

BROWN, D. A. (1958) 4-chloro-2-butyl N-(3-chlorophenyl) carbamate (S.847) for the control of wild oats. Proc. North Central Weed Control Conf, 15, 97

CORNS, W. G. (1958) Foliage sprays of 4-chloro-2-butynyl N-(3-chlorophenyl) carbamate (S.847) for selective control of wild oats in cereals and flax. Proc. North Central Weed Control Conf, 15, 98-99

EVANS, S. A. (1960) The control of wild oats with barban and 2,3-dichloroallyl diisopropylthiocarbamate: A summary of N.A.A.S. experiments, 1960. Proc. 5th British Weed Control Conf.

HOFFMAN, O. L. HOPKINS, T. R. AND PULLEN J. W. (1958) Wild oat control with 4-chloro-2-butynyl N-3-(chlorophenyl) carbamate (S.847). Proc. 12th Meeting of the Western Section, National Weed Committee, Canada, 3-6.

HOLLY, K. (1960) Pot experiments with new herbicides for the control of wild oats. Proc. 5th British Weed Control Conf.

HOLROYD, J. (1959) Unpublished.

PFEIFFER, R. K., BALNER, C., AND HOLMES, H. M. (1960) Factors affecting the selectivity of barban for the control of *Avena fatua* in wheat and barley. Proc. 5th British Weed Control Conf.

SOME PRELIMINARY EXPERIMENTS WITH 2,3-DICHLOROALLYL DIISOPROPYLTHIOLCARBAMATE

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Summary: During 1960, three experiments on spring wheat and five on spring barley were laid down with 2,3-dichloroallyl diisopropylthiolcarbamate. At two of the sites the wild oat populations were relatively large and at three of the others light to moderate. The dose range generally used was 0, 0.5, 1 and 2 lb/ac. Discs or harrows were used to incorporate the herbicide into the seed-bed immediately after application. The time interval between application and drilling varied from 1-20 days. The optimum dose for wild oat control was between 1 and 2 lb/ac. The numbers of A. fatua spikelets where reduced by 85 percent - 99 per cent on four sites by 2 lb/ac and on two sites by 1 lb/ac. The 2 lb/ac treatment slightly reduced the density of barley drilled within 4 days of treatment, wheat was reduced more severely both in stand and vigour. It was however only slightly affected by the 1 lb/ac treatment. The increase in barley yield due to the removal of wild oat competition at the two sites when the wild oat population was high (100 and 50 panicles per sq yd) was 10 cwt/ac (74 per cent) and 3.3 cwt/ac (21 per cent) respectively.

INTRODUCTION

2,3-dichloroallyl diisopropylthiolcarbamate is a soil-acting herbicide which has been tested on a fairly wide scale in Canada and the U.S.A. fornthe control of wild oats. It has proved very successful when applied at a rate of 1.5 lb/ac and incorporated into the soil prior to drilling. As it is relatively volatile the incorporation must be carried out very soon after application, preferably the same day. In Canada and the United States, crops of barley and flax have proved relatively resistant to 1.5 lb/ac, although wheat has shown less resistance (Hannah) 1959). During 1960 the Weed Research Organisation laid down eight experiments with this herbicide on fields which were reported to have been heavily infested with wild oat during the previous year. On three of the fields however very few wild oat appeared.

METHODS AND MATERIALS

2,3-dichloroallyl diisopropylthiolcarbamate has a very low solubility in water and a commercially formulated emulsifiable concentrate* was used. It was applied by means of an Oxford Precision Sprayer at a volume rate of 20 gal/ac to plots which were 6 x 4 yd. Treated plots alternated with control plots. The dose range was 0.5, 1 and 2 lb/ac except at Brackley where it was 0.4, 0.8 and 1.6 lb/ac. There were five replicates and paths of 2 yd width between each replicate. The treated plots were randomised in each replicate. Applications were generally made to a roughly prepared seed bed and incorporated immediately afterwards with either discs or spring timed harrows.

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*"Avadex" containing 40 per cent w/v active ingredient, Monsanto Chemical Co.

Details of sites

Experiment at Harwell, Berks. This experiment was treated on the 11th April when the air temperature was 51 °F. The soil which was a light loam with some chalk over green-sand had been worked down to a good seed bed. The top 2 in was moist and friable but the soil below was wet and sticky. After treatment the area was harrowed twice with spring tined harrows to a depth of 2-3 ins. After cultivation the soil was 'closed' and the maximum diameter of the soil clods 1½-2 ins. Three days later Proctor barley was drilled and the area rolled and harrowed. Due to the dry spring, the crop emerged in two fairly distinct phases, but evened up before harvest. The infestation of A.fatua was heavy, producing over 100 panicles/sq yd.

Experiment at Bretford, Nr. Evesham. Here a heavy silty loam had been worked down to a very rough seed bed when sprayed on 11th March, it was then very wet below 3-4 in. After treatment the area was cultivated twice with heavy discs to a depth of 4-5 in. The texture of the soil after cultivation was rather open with clods of up to 4-5 in. diameter. The air temperature was 50°F. Heavy rain followed immediately after the cultivation. Carlsberg barley was drilled on the 31.3.60 and harrowed afterwards. The population of A. fatua was moderate, giving 21 panicles/sq yd, and uneven in distribution.

Two experiments at Lewknor, Oxon. These experiments were in adjacent fields and both were treated on the 17th March. The soil, a silty loam, wet underneath but only damp on the surface, was essentially the same on both sites. Immediately after application of the treatment it was cultivated once each way with spring tined harrows. This left the soil surface 'closed' with a good tilth and a few clods of up to 2-3 in. diameter. The depth of cultivation was 2-3 in. The air temperature was 40°F. The day after treatment one site was harrowed again before being drilled with Koga II spring wheat. Afterwards it was harrowed twice and rolled. The other site was harrowed twice more before being drilled four days later (21st March) with Proctor barley. Subsequently it also was harrowed twice and rolled. Very few wild oats came up on either site.

Experiment at Brackley, Northants. This site was treated on the 8th March with 0.4, 0.8 and 1.6 lb/ac of the herbicide. The soil was heavy and lumpy having been disced once after ploughing. There was a fairly general infestation of Agropyron repens, the rhizomes of which tended to hold the clods together. As a result post-treatment cultivations with discs (twice), to a depth of 3-4 in left the soil surface open with clods of up to 4-5 in. The air temperature was 34°F. Nine days later (17th March) the area was disced again, dragged once and then drilled with Rika barley. After drilling it was harrowed twice. A. fatua was moderately dense, giving rise to 55 panicles/sq yd.

Experiment at Didcot, Berks. The spray applications were made at this site on the 10th March to a lightish, slightly chalky soil over 'green sand'. It was a little lumpy on the surface and wet underneath after being in kale the previous season. The air temperature was 54°F. Immediately after treatment the area was harrowed twice. This left the soil surface moderately open with clods of up to 2-3 in. Rain followed immediately afterwards. Four days later the area was harrowed twice again, drilled with Atle wheat and then given two further harrowings and a final rolling. This was another site with very few wild oats which produced only 1½ panicles/sq yd. They were nearly all A. fatua with a very occasional plant of A. ludoviciana. The distribution was patchy.

Experiment at Stagsden, Beds. The treatments were applied at this site on the 7th April to a heavy lumpy soil which had been harrowed once with spring tines after ploughing. After spraying the area was harrowed once again. This left the soil surface very open with large clods up to 8-9 in. diameter. The air temperature was 63°F. The area was drilled ten days later (17th April) with Proctor barley, harrowed twice and rolled. A dry spell of weather followed the drilling and the crop was very slow to emerge, and uneven. The population of A. fatua was light, giving 6 panicles/sq yd.

Experiment at Wytham, Berks. The soil on this site had already been worked down to a fairly fine tilth before the treatments were applied on the 21st March. The air temperature was 50°F. Immediately after treatment the area was disced twice. This resulted in a soil surface which was 'closed' with lumps of up to 1½ in. diameter. The soil was over gravel but moderately heavy with a fairly high proportion of clay. The experiment was drilled with Jufy spring wheat the following day, harrowed and rolled. No wild oats appeared on this site but observations were made of the growth of the crop, and its density was assessed.

Assessments

The assessments were made on a 2 yd strip down the centre of each plot. Shortly after emergence, when the crop had 2-4 leaves, counts were made of the number of crop plants in ten one-square foot quadrats/strip. In some of the trials the vigour of the crop was also scored at the same time.

During the latter part of July all the A. fatua panicles in the assessed area of each plot were counted and classified in the following manner:-

(i) position above or below the crop
(ii) size a) small 1-10 spikelets
b) medium 10-30 "
c) large 30 or more spikelets.

(iii) stage of growth a) fully expanded.
b) just emerging from the sheath.
c) still within the sheath.

For the purpose of calculating the numbers of spikelets the small panicles were assumed to have a mean of 5 spikelets, the medium 20 and the large 40. A rough comparison of the mean yields of grain from the treated and untreated plots was obtained at Harwell and Brackley. In each replicate the treated and untreated plots were opposite one another and only separated by a 2 yd path. Thus by ignoring the untreated path it was possible to harvest a strip 38 yd long, with a combine harvester, from the centre of each row of treated or untreated plots.

RESULTS

Table I shows the effect of the treatments on the density and the vigour of the crop. The 0.5 lb/ac treatment had little or no effect at any of the sites but 1 lb/ac reduced the vigour of the two spring wheats (at Lewknor and Wytham) which were sown on the day after application. The 2 lb/ac treatment had little or no effect on barley provided there was an interval of nine days or more before drilling. If the interval was only three or four days as at Harwell and Lewknor there was some reduction in crop density. Wheat, on the other hand, was severely reduced both in density and vigour by the 2 lb/ac treatment, the maximum interval between spraying and drilling being four days. When damage occurred the symptons shown by the two crops were rather different. The effect on the barley was much more 'all or nothing'. There were one or two trapped leaves in the very early stages of growth but in general the plants seemed either to emerge and grow fairly normally or not emerge at all. In the later stages of development no damage was visible. The symptons on wheat were much more apparent. There was a reduction in plant density and, shortly after emergence, many of the plants were stunted and their leaves trapped or tubular. Damaged plants were slow to recover and matured later than the rest of the crop. The 2 lb/ac treatment visibly reduced the yield in all three of the wheat trials.

Table II shows the counts of the wild oat spikelets on the treated plots as a percentage reduction from the counts on the controls. Unfortunately only the sites at Harwell and Brackley had wild oats present in any quantity but at both of these the 1 lb/ac treatment was sufficient to reduce the number of spikelets by 85 per cent or more. At Harwell 2 lb/ac gave almost complete eradication. The incorporation of the chemical at Stagsden was very poor due to the lumpy nature of the soil and this probably accounts for the poor control given by the 0.5 and 1 lb/ac treatments. At Didcot where the control was also not very good, the wild oat population was small and variable in density.

TABLE I. THE EFFECT OF 2,3-DICHLOROALLYL DIISOPROPYLTHIOLCARBAMATE ON CROP DENSITY

(Density as percentage of control)

Site	Crop	Variety	No. of days spraying to drilling	Method of incorporation	Control density plants/ sq ft	0.5 lb/ac	1.0 lb/ac	2 lb/ac
Harwell	Barley	Proctor	3	harrows	19	97	114	72
Brackley	"	Rika	9	discs	8	121*	111*	103*
Bretford	"	Carlsberg	20	discs	26	96	103	111
Stagsden	"	Proctor	10	harrows	15	96	94	99
Lewknor	"	Proctor	4	harrows	17	98	102	88
Lewknor	Wheat	Koga II	1	harrows	18	101	101	57
Didcot	"	Atle	4	harrows	19	97	95	63
Wytham	"	Jufy	1	discs	21	99	89	70

* Dose was 0.4, 0.8 and 1.6 lb/ac

The yields of grain which were taken from the untreated and treated plots at Harwell and Brackley emphasised the competitive effect of the wild oat which has always been suspected but never satisfactorily proved. Thus at Harwell where the wild oat population was reduced by at least 97 per cent from a control density of 3,174 spikelets or 102/panicles sq yd, the yield increase was 10 cwt/ac or a little over 70 per cent. At Brackley where the wild oat population was about half that at Harwell, and the control was not quite so good, the increase was over 3 cwt/ac or 21 per cent.

TABLE II. THE EFFECT OF 2,3-DICHLOROALLYL DIISOPROPYLTHIOLCARBAMATE ON THE PRODUCTION OF SPIKELETS BY A. FATUA AND ON CROP YIELD

(Assessment of total spikelets and of spikelets above the crop expressed as percentage reduction from their respective controls.)

Site	Assessment	Control density		per cent reduction in spikelets			Yield of crop in cwt/ac	
		Spikelets/ sq yd	Panicles/ sq yd	0.5 lb/ac	1 lb/ac	2 lb/ac	Control	Treated +
Harwell	Spikelets above crop	2,670	67	97	99	99.8	13.6	23.9
	Total spikelets	3,174	102	97	99	99.8		
Brackley	Spikelets above crop	1,445	36	81*	86*	96*	15.2	18.5
	Total spikelets	1,707	55	78	85	96		
Bretford	Spikelets above crop	129	3	47	85	92	-	-
	Total spikelets	359	21	41	75	85		
Stagsden	Spikelets above crop	126	3	45	42	84	-	-
	Total spikelets	260	6	51	46	86		
Didcot	Spikelets above crop	20	0.5	36	53	66	-	-
	Total spikelets	36	1.5	27	60	74		

* Dose was 0.4, 0.8 and 1.6 lb/ac.
+ This is the mean of all 3 doses

DISCUSSION

Many factors may influence the toxicity of a herbicide incorporated into the soil, particularly when it is volatile. These include the soil type, the method of incorporation as it influences efficiency and depth, the time interval between spraying and drilling, the depth of sowing in relation to the depth of incorporation and the weather conditions. In these experiments the soils ranged from a light calcareous loam to a heavy clay, the cultivations from light harrowing (1-2 in. in depth) to heavy discing (4-5 in. in depth) and the interval between spraying and drilling from one to twenty days. To achieve the most satisfactory incorporation it may be necessary to match up the method of cultivation with the soil type and its condition.

At Harwell a double light harrowing was sufficient to incorporate the herbicide into a light and easily worked soil to a depth of 2-3 in. The resulting soil surface was closed and the 0.5 lb/ac treatment gave a 97 per cent control of wild oat. Harrows were used at Stagsden but as the soil was heavy and lumpy, the incorporation was poor and the soil surface left open. The result was only 51 per cent control with the same dose. At Brackley the soil was also heavy and lumpy, but the herbicide was disced in so that although the soil surface was not closed the incorporation was a little deeper (3-4 in.). Here as little as 0.4 lb/ac gave a control of 78 per cent. The weather conditions also probably influenced the effectiveness of the herbicide at these two sites for whereas the soil was relatively warm at Stagsden (air temperature 63°F) when the treatments were applied, it was cold at Brackley (air temperature 34°F). Thus the vapour loss at Brackley was probably less, before subsequent cultivations, drilling and rolling closed the soil surface eight days later. At Bretford discs were also used to incorporate the herbicide relatively deeply (4-5 in.) into a heavy soil, but the cultivations left the soil surface open. The air temperature was 50°F and there was a delay of twenty days before drilling and rolling was completed an and the soil surface closed. Thus the 0.5 lb/ac treatment gave poor control (45 per cent) and the 1 lb/ac only moderate (75 per cent). If the soil is cultivated too deeply it seems likely that excessive dilution will also reduce the effectiveness of the herbicide.

The time interval between spraying and drilling directly effects the amount of crop damage although any factor which influences the persistence of the herbicide in the soil must be important. Thus Proctor barley at Harwell and Lewknor drilled after time intervals of three and four days respectively was slightly reduced in density by the 2 lb/ac treatment, whereas it was unaffected at Stagsden (time interval ten days). Similarly at Brackley and Bretford, the barley varieties Rika and Carlsberg (Time intervals nine and twenty days respectively) were also unaffected although this may have been due to a difference in varietal susceptibility.

The depth of sowing of a crop in relation to the depth of incorporation of the herbicide may also influence its susceptibility. It was noticeable in the experiment at Wytham that the wheat plants which had accidentally been sown deeper were damaged less than those sown more shallowly, Perhaps wheat but not wild oat can grow through a contaminated layer of soil. Wheat seemed to be generally more susceptible than barley. At Didcot the 2 lb/ac treatment reduced the crop density to 63 per cent of control whereas at Harwell and Lewknor the reductions were only to 72 per cent and 88 per cent respectively. A true comparison can only be made under the same conditions i.e. on the same site, but the effect certainly persisted much longer on the wheat than the barley as has already been mentioned. However considering the wide range of conditions over which the herbicide was used, its effectiveness on wild oat was surprisingly consistent.

It was very noticeable that the effect of the herbicide on wild oat as on barley was very much 'all nor nothing'. If a plant was not killed early in development it seemed to grow almost normally. This fact is illustrated by the similarity between the figures for control based on the numbers of spikelets 'above' the crop and those based on the total number of spikelets (Table II). Treatments did not appreciably alter the proportion of small panicles to large panicles. Thus vigorous crop competition was not essential for successful control. This means that the herbicide should prove useful for the control of A. fatua not only in competitive crops such as spring barley and possibly spring wheat but also in other less competitive crops such as beet, field beans and peas. Preliminary experiments have already indicated that these crops are relatively resistant.

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REFERENCE

HANNAH, L. H. (1959). Avadex, a selective wild oat herbicide. Proc. of the 16th Nth. Central Weed Control Conference 50.

THE CONTROL OF WILD OATS (AVENA FATUA) WITH BARBAN AND 2,3- DICHLOROALLYL DI-ISOPROPYLTHIOLCARBAMATE

(A Summary of N.A.A.S. Experiments 1960)

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Summary: Fourteen experiments with barban and six with 2,3-dichloroallyl di-isopropylthiolcarbamate for the control of Avena fatua, carried out by the N.A.A.S. in 1960, are reported. Barban was applied post-emergence at two doses and at two dates, with and without MCPA applied at the second date to spring barley, spring wheat and winter wheat, at two doses and at two dates on peas and at three doses on a single occasion on spring beans. 2,3-dichloroallyl di-isopropylthiolcarbamate was applied at four doses pre-sowing, on spring barley. The effect of treatments on the crop was assessed by scoring for vigour and/or height measurements; yields were assessed in seven barban experiments and three experiments with 2,3-dichloroallyl di-isopropylthiolcarbamate. The control of wild oats was assessed by panicle counts, or occasionally by scoring for density of panicles at harvest time.

INTRODUCTION

Barban (4-chloro-2-butynyl-N-(3-chlorophenylcarbamate) and 2,3-dichloroallyl di-isopropylthiolcarbamate (hereafter referred to as X) were investigated by the Weed Research Organisation in 1960 for the selective control of wild oats in cereals (Holroyd 1960). The experiments reported in this paper, carried out by the N.A.A.S., were designed to corroborate the work of the Weed Research Organisation.

METHODS AND MATERIALS

Barban * and X * were each investigated in a separate series of experiments.

Barban

The experiments were carried out on barley (Proctor, Rika and Freja), spring wheat (Jufy I), winter wheat (Cappelle and Hybrid 46), drying peas and beans all infested with the common wild oat (Avena fatua). The standard design embodied barban at 4 and 8 oz/ac applied at approximately the 1½ to 2 - and the 4 - leaf stages of the wild oats, with and without MCPA at 24 oz/ac applied on the second occasion. Three exceptions to these treatments were at Watlington where mecocrop at 40 oz/ac replaced MCPA, at Blandford where the MCPA was applied along with the barban on each occasion and not only at the time of the second spraying and at Warmington where there was one date of application only. The treatments on peas were barban at 4 and 8 oz/ac applied when the wild oats were at approximately the 1½ to 2-leaf and 4-leaf stages, and the treatments on the beans were barban at 8, 12 and 16 oz/ac when the wild oats were at approximately the 2-leaf stage.

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*Barban as "Carbyne" and X as "Avadex".

The layouts were randomised block experiments with threefold replication in the cereal and bean experiments and fourfold replication in the pea experiments. The plot sizes in the cereal experiments were 1/100 to 1/400 ac with the exception of Watlington where plots were 1/22 ac. Barban was applied at 10-20 gal/ac by a Vehicle-mounted sprayer at Watlington and by an Oxford Precision Sprayer at the other sites. Details of each site are given in Table I.

2,3-dichloroallyl di-isopropylthiolcarbamate

The experiments were carried out on barley (Rika and Proctor) and treatments were applied to the soil, at either ¾, 1, 1½ and 3 lb/ac or 1½, 2, 3 and 6 lb/ac, before sowing the crop. The layout was in each case a randomised block with two control plots per block and three replicates. The plot size was approximately 1/140 ac with the exception of Watlington where plots were 1/22 ac. The volume rate used was 15 or 20 gal/ac. The chemical was applied to the soil surface and in every case was incorporated into the soil on the day of spraying by at least one stroke of the harrow or cultivator. Details of the experiments are given in Table II.

RESULTS

Barban

Crop

The effect of the treatments on the crop during the growing season are summarised in Table III and yields recorded in seven experiments are shown in Table IV. In four of the seven experiments on barley, no visible effect of the treatments was seen on the crop. In the remainder of the barley experiments and in the spring wheat experiment some of the treatments checked the crop, later applications and lower doses being generally less harmful than earlier applications and higher doses. The use of MCPA or mecoprop had little influence on the visible effect of barban on spring wheat or barley. Yields from all treatments in one trial on Rika were similar to the yield from the control plots but in the second harvested barley trial (Proctor) treatments depressed yield, particularly those applied early. On Jufy I spring wheat, treatments led to improved yields.

On winter wheat all treatments visibly checked the crop to some extent, the later treatments being more harmful than early treatments. The use of MCPA had little influence on the effect of early treatments with barban and 4 oz of barban at the later spraying, but with 8 oz barban at the later date it increased the damage. Table IV shows that the only depressed yields with barban were from late applications combined with MCPA.

Neither pea experiment was harvested but there was no visible sign of damage to the crop. Yields from the bean experiment showed the yield to be nearly trebled by all treatments.

Wild Oats

The control of wild oats (*Avena fatua*) achieved is summarised in Table V which is based on counts of all panicles, or scoring for panicle density at harvest time. Earlier applications when the wild oats were at about the 2-leaf stage have in nearly every case given a better control than later applications at the 4 to 5-leaf stage. The higher dose has usually given better control of wild oats than the lower dose at the early date of application but results are variable in this respect from the later applications. The addition of MCPA or mecoprop has had little influence on the earlier applications of barban but when included with the later spraying has, particularly with the higher dose, had adverse effects. Some of the variability in results can be explained by the markedly uneven infestation of wild oats at sites 3, 4, and 10 and inadequate method of assessment as at sites 2, 6 and 13. The control of wild oats from 8, 12 and 16 oz of barban on spring beans was 58, 67 and 79 per cent respectively.

2,3-dichloroallyl di-isopropylthiolcarbamate

Crop

The effect of the treatments on the crop during the growing season are summarised in Table VI and yields, recorded in three experiments are shown in Table VII. In no instance did ¾ or 1 lb/ac appear to cause appreciable harm to the crop. At doses higher than 1 lb/ac the crop response was variable. During the growing season 1½ lb/ac affected the crop in half the experiments, and higher doses tended to increase the incidence and intensity of the damage. Slight reduction in crop density was not reflected in reduction in yield (reduction in wild oat competition was probably compensatory) but reduction in plant density in the order of 25 per cent or more was accompanied by reduced yields in the experiments where yields were taken. The evidence available does not suggest that the interval between spraying and sowing, the soil condition at the time of spraying, or crop variety have had any marked influence on results on the crop.

Wild Oats

The control of wild oats achieved is summarised in Table VIII which is based on counts of all panicles at harvest time. The control of wild oats was variable, 1½ lb/ac in every experiment but one gave a 80 - 100 per cent control by harvest time. Increasing the dose above 1½ lb generally did not improve results. The condition of the soil at the time of spraying does not appear to have had any marked effect.

DISCUSSION

Barban

Part of the variability in the results on the control of wild oats may be due to uneven infestation of wild oats over the experimental area or to inadequate method of assessment. It is obvious however, that the stage of growth of wild oat when sprayed is very important and the wide range of stages of growth of wild oat that occurred at any one time and place in the spring of 1960 may also have contributed to the variable results.

The mean percentage reduction in wild oat panicles from a dose of 4 oz barban applied early was 66 (Table V). In only two experiments was the control greater than 90 per cent from this dose, which is rather surprising to the author in view of the apparently good control seen at several cereal sites. This suggests that treatment had reduced the straw length of the surviving wild oat so that the panicles did not appear above the level of the crop and were not readily seen. This was the case at site 8 on spring wheat where the wild oat panicles above the crop in the control plots were 70 per cent of the total, but only approximately 30 per cent of the total where 4 oz of barban had been applied early with or

TABLE I.

Site	1 Baldock		2 Warmington	3 Blandford	
N.A.A.S. Region	East		East Midland	South West	
Crop	Barley		Barley	Barley	
Variety	Rika		Rika	Rika	
Treatments	4 & 8 oz early & later + 24 oz MCPA		4 & 8 oz ± 24 oz MCPA	4 & 8 oz early & later + 24 oz MCPA *	
Vol(gal per ac)	10		10	10	
Dates of spraying	25/4	23/5	20/5	27/4	25/5
Stage growth of crop No. leaves on main stem	2.9	well tillered	4½	2½	4 to 5
Height (in.)	6½	-	8½	4	10
Stage growth W. Oats No. leaves on main stem	2.1	well tillered	3.8	1½ to 2	3 to 4
Height (in.)	3 to 4	13	-	3	7
Density (per sq ft)	2.6	6.2	3.3	-	-
Density of other weeds per sq ft	7	26	-	-	-

Note: Where figures for stages of growth are given to one decimal place they are the result of random replicated samples; otherwise the assessment is the result of casual observation

* MCPA was applied along with the barban at both times of application

\- A blank indicates that information is not available.

DETAILS OF EXPERIMENTS WITH BARBAN

4 Aldborne		5 Ovingham		6 Taunton		7 Redcar	
South West		North		South West		North	
Barley Proctor		Barley Proctor		Barley Proctor		Barley Freja	
4 & 8 oz early & later + 24 oz MCPA		4 & 8 oz early & later + 24 oz MCPA		4 & 8 oz early & later + 24 oz MCPA		4 & 8 oz early & later + 24 oz MCPA	
10		10		10		10	
21/4	25/5	27/4	24/5	9/5	23/5	4/5	30/5
1.8	4.5	2.4	4.3	5.1	-	1.2	3.8
-	-	3	9 to 12	4½	10	2	7
1½ to 2	-	2.1	3.4	1 to 6	-	1.3	3.7
2	-	1½	8	-	-	1 to 1½	6
1.2	-	15.1	-	-	-	16.3	14.4
-	-	5	10	-	7	5	5

TABLE I.

Site	8 Watlington		9 March		10 Takeley	
N.A.A.S. Region	South East		East		East	
Crop Variety	Spring wheat Jufy I		Winter wheat Cappelle		Winter wheat Cappelle	
Treatments	4 & 8 oz early and later ± 40 oz mecoprop		4 & 8 oz early and later ± 24 oz MCPA		4 & 8 oz early and later ± 24 oz MCPA	
Vol (gal per ac)	20		10		10	
Dates of spraying	25/4	9/5	23/2	23/3	8/3	28/3
Stage of growth of crop No. leaves on main stem	2½	3½	3 to 3½	4½	3	5 to 6
Height (in.)	5½	9	-	4 to 6	-	6.3
Stage growth wild oats No. leaves on main stem	2.1	2.8	1½ to 3	4	1 to 3	4
Height (in.)	3 to 4	2 to 5	-	3 to 6	2 to 3½	1 to 3½
Density (per sq ft)	9.8	14.2	-	7.8	-	3.5
Density of other weeds per sq ft	-	4.8	-	22	-	8½

(Contd.)

11 Papworth	12 Debenham	13 Takeley	14 Britwell
East	East	East	South East
Winter wheat Hybrid 46	Peas -	Peas -	Spring beans -
4 & 8 oz early and later ± 24 oz MCPA	4 & 8 oz early and later	4 & 8 oz early and later	8, 12 & 16 oz
10	10	10	20
19/2 22/3	29/4 25/5	11/4 4/5	22/4
3½ 4 to 5 - 5 to 7	2 to 3 6.6 2 to 3 8	¾ 3.6 1½ 2 to 3	1 to 2 2 to 3
2½ 3½ - 3½ - 8.3	1.5 4.7 2½ to 4 9 15.3 10.9	1.1 2.7 1 to 3½ 3½ 3.1 1.9	1½ to 3 3 to 4 -
- 4.8	- -	- -	-

TABLE II.

Site	15 Baldock	16 Haverhill	17 Warmington
N.A.A.S. Region	East	East	East Midland
Crop Variety	Barley Rika	Barley Rika	Barley Rika
Date of spraying	15/3	14/3	7/4
Date of sowing	21/3	1/4	11/4
Treatments (as lb/ac)	1½, 2, 3 & 6	1½, 2, 3 & 6	¾, 1, 1½ & 3
Cultivations	-/2 cultivated 15/3 pitchpole once after spraying 21/3 harrow & roll after drilling	14/3 harrowed once (duckfoot) 1/4 harrowed once after drilling	Harrowed twice before 7/4 Harrowed after spraying & once more on 8/4
Condition of soil when sprayed	Fairly fine tilth, moist	Very rough, moist	Fine and dry
Soil type	-	heavy	-

DETAILS OF EXPERIMENTS WITH X

18 Blandford	19 Swindon	20 Watlington
South West	South West	South East
Barley Rika	Barley Proctor	Barley Proctor
21/3	22/3	18/3
22/3	22/3	21/3
$\frac{3}{4}$, 1, $1\frac{1}{2}$ & 3	$\frac{3}{4}$, 1, $1\frac{1}{2}$ & 3	$\frac{3}{4}$, 1, $1\frac{1}{2}$ & 3
15/3 plough 21/3 cultivated once 22/3 cultivated once, harrowed	21/3 harrowed 22/3 & cultivated 23/3 harrowed after drilling	18/3 cultivated once before and after spraying
Freshly ploughed furrow, moist	Loose, fine tilth	Rough, drying on surface but wet and cold below
medium loam over chalk	light loam over chalk	heavy

TABLE III. EFFECT OF TREATMENTS WITH BARBAN ON VIGOUR AND/OR HEIGHT OF CROP DURING GROWING SEASON (TREATMENT MEANS)

(Vigour by score 0 to 10 where 0 = crop dead and 10 = maximum growth; height in inches)

Site	1		5	6	8	9		10		11	
Variety of Crop	Rika		Proctor	Proctor	Jufy I	Cappello		Cappelle		Hybrid 46	
Date of assessment	15/6		at harvest	15/7	20/6	18/5		26/5		23/5	
Type of assessment	ht	vigour	ht	-	vigour	ht	vigour	ht	vigour	ht	vigour
Barban @ 4 oz (applied early)	33.0	9.7	28	Crop apparently not affected except that 8 oz barban, early, checked crop	9.0	27.3	9.7	27.7	9.8	27.7	9.2
" " 8 oz (applied early)	31.7	8.7	25		9.0	27.3	9.5	25.3	8.7	23.7	7.8
" " 4 oz + MCPA (applied early)	33.0	10.0	28		9.2	27.3	9.7	28.0	9.7	27.3	9.2
" " 8 oz " " (applied early)	29.7	7.0	26		8.7	28.3	9.5	25.0	9.0	23.7	7.7
Barban @ 4 oz (applied late)	33.3	10.0	28		9.7	26.3	9.2	27.7	9.3	22.0	7.0
" " 8 oz (applied late)	33.0	9.3	28		9.0	24.0	7.2	24.0	8.0	20.7	5.0
" " 4 oz + MCPA (applied late)	32.7	9.0	28		9.7	24.3	7.2	27.7	9.8	25.3	8.3
" " 8 oz " " (applied late)	30.0	8.8	23		9.2	20.0	5.2	22.0	7.3	9.7	3.3
MCPA	32.7	9.7	28		9.3	29.0	9.8	26.7	9.3	30.3	10.0
Control	33.2	9.5	28		9.8	28.0	10.0	27.9	9.9	29.7	10.0

In the remaining experiments - 2 & 3 (Rika), 4 (Proctor), 7 (Freja), 12 & 13 (Peas and 14 (Spring Beans) - little or no effect on crops was seen.

(78178)

TABLE IV. MEAN YIELD OF CROPS TREATED WITH BARBAN AS PER CENT OF CONTROL

Site		1	6	8	9	10	11	14
Variety		Rika	Proctor	Jufy I	Cappelle	Cappelle	Hybrid 46	Spring Beans
Barban 4 oz	applied early	94	67	126	126	119	104	Barban 8 oz 263
" 8 oz		106	64	115	126	105	113	" 12 oz 275
" 4 oz + MCPA		96	84	130 ⌿	149	103	114	" 16 oz 293
" 8 oz + MCPA		104	64	121 ⌿	149	98	102	Control 100
" 4 oz	applied later	99	93	103	121	100	98	
" 8 oz		102	92	117	116	98	102	
" 4 oz + MCPA		96	88	104 ⌿	106	93	102	
" 8 oz + MCPA		91	85	108 ⌿	84	94	59	
MCPA		95	99	108	82	116	123	
Control		100	100	100	100	100	100	
Control Yield (cwt/ac)		26.7	20.5	19.0	38.1	33.5	28.6	6.5
Assessed		as harvested	at 15 per cent moisture	at 15 per cent moisture	as harvested	as harvested	as harvested	at 15 per cent moisture

⌿ Mecoprop used instead of MCPA

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TABLE V. PER CENT REDUCTION IN TOTAL NUMBER OF WILD OAT

Site		1	2	3	4	5	6
Crop		Barley	Barley	Barley	Barley	Barley	Barley
			*				*
Barban at 4oz	early	47	-	38	47	60	+20
" " 8oz	early	83	-	+179	52	85	0
" " 4oz + MCPA	early	24	-	42 †	60	68	+10
" " 8oz + MCPA	early	96	-	+ 71 †	43	89	0
" " 4oz	later	+37	72	+171	38	25	0
" " 8oz	later	32	94	+58	38	45	+50
" " 4 oz + MCPA	later	+59	40	+108	46	29	+20
" " 8oz + MCPA	later	8	37	+316	65	13	10
MCPA alone		+86	13	+208	68	18	+30
Mean density of wild oats in control plots (per sq yd)		19.25	approx	24.0	13.8	approx 100	-

\+ A plus sign indicated an increase in panicles of wild oats

* Figures based on assessments by scoring to an original scale of 0 to 10, where 0 = no wild oats and 10 = maximum density

† MCPA applied at same time at barban

‡ Mecoprop used instead of MCPA

PANICLES AT HARVEST TIME AFTER TREATMENT WITH BARBAN

7	8	9	10	11	12	13	14	Mean excl. expts 2, 6, 12, 13 & 14
Barley	Spring wheat	Wntr wheat	Wntr wheat	Wntr wheat	Peas	Peas *	Spring beans	
65	64	91	77	96	73	19	-	66
74	92	96	81	58	80	34	58	49
65	69 ‡	93	53	87	-	-	-	62
75	91 ‡	98	81	+2	-	-	-	55
9	12	69	45	+36	17	13	-	+5
12	30	50	75	+54	0	34	-	19
+1	+8 ‡	29	23	+82	-	-	-	+15
30	9 ‡	+174	23	+963	0	-	-	+144
9	15	+92	53	4	-	-	-	+24
16.8	81.9	41.4	27.0	19.4	112	-	123.6	

TABLE VI. THE EFFECTS ON THE CROP DURING THE GROWING SEASON OF THE TREATMENT WITH X

Site	15	16	17	18	19	20
Method of assessment	Score 0-10 for crop vigour	Crop density: plants per ft drill length	Crop density: tillers per ft drill length	-	-	Plants per sq yd
Date of assessment	24/5	9/5	18/5	11/4	-	25/4
¾ lb/ac	-	-	9.3	Thinning of crop noted at 1½ to 3 lb per acre	No effect noticed	260
1 "	-	-	10.0			237
1½ "	9.7	12.0	7.7			184
2 "	9.0	12.1	-			-
3 "	7.7	12.7	11.7			138
6 "	3.7	4.1	-			-
Control	10.0	16.6	11.0			274

TABLE VII. MEAN YIELD OF CROPS TREATED WITH X AS PERCENTAGE OF CONTROL

Site	15	16	20
Assessment	as harvested	as harvested	85 per cent dry matter
Variety	Rika	Rika	Proctor
¾ lb/ac	-	-	102
1 " "	-	-	101
1½ "	98	112	80
2 "	102	98	-
3 "	87	125	81
6 "	66	63	-
Control as cwt/ac	30	20	28

TABLE VIII. PERCENTAGE REDUCTION IN THE NUMBER OF WILD OAT PANICLES AT HARVEST TIME AFTER TREATMENT WITH X.

Site	15	16	17*	18	19	20
¾ lb/ac	-	-	(85)	35	45	72
1 "	-	-	(69)	46	45	85
1½ "	100	93	(81)	81	60	92
2 "	96	97	-	-	-	-
3 "	100	96	(91)	72	55	95
6 "	100	92	-	-	-	-
No. panicles in control plots (mean/sq yd)	8.6	12.8	approx 30	43.0	1.1	5.1

* Figures based on assessments by scoring to an original of scale 0 - 10 where 0 = no wild oats and 10 = maximum density (= approx 30 panicles per sq yd).

water at one site) and an untreated plot left between them. Spraying was done with an Oxford Precision Sprayer using Allman "O" jets. Three rows of 100 pea seeds, variety Big Ben, were sown on each of the plots at intervals of approximately 0,2,6, 10 and 14 days after spraying. Due to delayed germination caused by propham, two series of pea counts were made on each trial at 2-4 week intervals.

RESULTS

Results are presented in Table I.

TABLE I. EMERGENCE COUNTS EXPRESSED AS PERCENTAGES OF UNTREATED CONTROLS

Trial 1 - Peaty loam soil, worked down with heavy harrows the day before chemical application which was made on 21 March. No cultivations before drilling.

Interval between spraying and drilling	Dose of propham			
	3 lb		6 lb	
Days	1st Count	2nd Count	1st Count	2nd Count
0	89	100	64	95
2	95	96	44	80
6	103	100	89	102
10	103	102	96	99
14	96	97	95	96

Trial 2 - Peaty loam soil, worked down with heavy harrows on 20 March. Chemical application made on 4 April. Light-harrowed and cross-harrowed immediately afterwards.

Interval between spraying and drilling	Dose of propham			
	3 lb		6 lb	
Days	1st Count	2nd Count	1st Count	2nd Count
0	96	97	88	95
2	105	100	93	98
6	104	102	91	92
10	101	101	95	96
16	107	104	102	100

Trial 3 - Organic loam soil, harrowed on 21 March. Chemical application made on 23 April. Light-harrowed immediately afterwards.

Interval between spraying and drilling	Dose of propham			
	3 lb		6 lb	
Days	1st Count	2nd Count	1st Count	2nd Count
0	102	103	98	102
2	102	104	93	97
6	101	102	100	103
9	102	102	101	105

Trial 4 - Clay-loam soil, harrowed before chemical application on 4th April, and whole area rotovated afterwards.

Interval between spraying and drilling	Dose of propham 4 lb	
Days	1st Count	2nd Count
0	81	89
2	90	95
6	91	96
10	97	98
14	101	106
18	106	106

DISCUSSION

It is evident that pre-sowing applications of propham can either delay emergence or reduce the pea plant population. Repeat counts made on trials in 1958 where germination was effected by propham did not reveal delayed germination but pea kill. Soil conditions in 1958 were inclined to be cold and wet and it is possible that under these adverse conditions the peas did not survive the initial setback. In 1959 much better growing conditions prevailed, which allowed the peas to overcome initial damage and make healthy growth subsequently.

The results of these trials confirm that the longer the interval between propham application and sowing, the smaller the risk to pea germination. Previous work has indicated that best wild oat kill results when propham is applied 1-2 weeks before drilling (Proctor and Armsby 1960; Murant 1960) and it has been recommended that peas should be sown 4-14 days after an application of 3 lb/ac (Armsby, 1958). In the light of the present trials, and in order to further reduce the danger of pea damage, it is advised that an interval of 6-14 days should elapse between spray application and sowing.

PART II: STUDIES ON POST-EMERGENCE APPLICATIONS OF "NEW" CHEMICALS

METHODS AND MATERIALS

A completely randomised block layout with two-fold replication was used at each of the four sites, and all herbicides were applied by means of an Oxford Precision Sprayer. The spray volume used throughout was equivalent to 50 gal/ac, using Allman "0" jets, except that in 1960 "000" jets set at an angle of 45°* were employed for barban, which was applied in 20 gal/ac of water. Individual plot size was approximately 0.005 ac.

The chemicals, each tested at two rates (see tables II, III and IV), were:

1959: atrazine, 50 per cent wettable powder; maleic hydrazide (25 per cent triethanolamine salt solution); fenac (18 per cent sodium salt

* In all other experiments the jets were directed vertically downwards.

solution); dalapon (85 per cent sodium salt soluble powder); dalapon 85 per cent sodium salt soluble powder) plus dinoseb (18.5 per cent alkanolamine salt solution); dalapon (85 per cent sodium salt soluble powder) plus MCPB (40 per cent sodium salt solution); amiben (24 per cent triethylamine salt solution).

1960: barban† (12 per cent emulsifiable concentrate); atrazine (50 per cent wettable powder); amiben (24 per cent triethylamine salt solution).

The following are the site details (1959: Trials A and B; 1960 Trials C and D).

	<u>Trial A</u>	<u>Trial B</u>
Site	Stonea, Cambs.	Shelton, Beds.
Soil type	Loam	Silty loam
Wild oat population/ sq yd	<1‡	25
Variety of pea	Zelka	Harrison's Glory
Date of sowing	17 March	20 March
Date of emergence	8 April	7 April
Date of herbicide applications	7 May	8 May
Weather conditions at time of applications	Sunny, no wind Air temp. 62°F.	Sunny, little wind Air temp. 65°F.
Average size of plants at time of applications		
Peas	4-5 in. high	4-5 in. high
Wild oats	3-leaf stage, tillering	3-leaf stage, tillering
Broad-leaved weeds	Seedling to 2-leaf stage	Seedling to 2-leaf stage

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† Included at three times of application in Trial C only.

‡ The number of wild oats that emerged at this site was very much less than expected.

		Trial C	Trial D
Site		Kimbolton, Hunts.	Whittlesey, Peterborough
Soil type		Clay loam	Peaty loam
Wild oat population/ sq yd		68	17
Variety of pea		Big Ben	Big Ben
Date of sowing		2 March	11 March
Date of pea emergence		24 March	31 March
Date of herbicide applications	Early	8 April	8 April
	Inter	19 April	12 April
	Late	28 April	-
Weather conditions at time of applications	Early	Sunny, little wind Air temp. 55°F.	Sunny, little wind Air temp. 55°F.
	Inter	Warm but windy Air temp. 55°F.	Cold and windy Air temp. 48°F.
	Late	Some wind Air temp. 50°F.	-
Average size of plants at time of applications			
Peas	Early	1 in. high, starting to unfold	1 in. high, starting to unfold
	Inter	2 in. high, unfolded	1-1½ in. high, unfolding
	Late	3-4 in. high	-
Wild oats	Early	1-1¼-leaf stage, still emerging	1-leaf stage, still emerging
	Inter	1-2-leaf stage, some still emerging	1-1½-leaf stage
	Late	1-3-leaf stage, starting to tiller	-
Broad-leaved weeds	Early	Seedling stage	Seedling stage
	Inter	Seedling to 2-leaf stage	Seedling stage
	Late	2-3-leaf stage	-

RESULTS

1959 Trials

Assessments were limited to making periodic notes on the appearance of the peas and weeds. On Trial A the almost complete absence of wild oats allowed the effect of treatments on broad-leaved weeds to be recorded, whilst on Trial B the dominating wild oats made any assessment of broad-leaved weed control virtually impossible. Results are summarised in Table II.

TABLE II. VISUAL ASSESSMENT OF TREATMENTS, 1959 TRIALS

Chemical	Dose (lb/ac)	Trial A		Trial B	
		Peas	Broad-leaved weeds*	Peas	Wild oats
Atrazine	1	Marginal chlorosis of lower leaves	Good weed control excepting mayweed and wild oats	No effect	No control
	2	Some scorch of lower leaves	Good weed control, mayweed slightly checked	No drastic effect, perhaps fewer pods	No control
Maleic hydrazide	5	Peas stunted and very pale. Low yield.	Mayweed controlled, other weeds stunted.	Severe stunting and loss of colour. Yield reduced.	Very good control
	10	Severe stunting and loss of colour. No yield.	"	Very severe stunting. No pods produced.	Complete control
Fenac	2	Severe stunting and distortion	No effect	Very stunted	Wild oats greener and more vigorous
	4	Peas severely distorted	Slight check to weeds	Severely stunted and retarded	"
Dalapon	1.5	Loss of bloom. Yield appeared unaffected.	No effect	No effect	Wild oats appeared less vigorous
	3	"	"	"	"
Dalapon + amine dinoseb	1 + 1	Loss of bloom	Good control	No effect	No effect
	2 + 2	"	Very good control	"	Wild oats appeared to be more sparse

* Broad-leaved weeds present on Trial A included black bindweed (Polygonum convolvulus), redshank (Polygonum persicaria), fathen (Chenopodium album), scentless mayweed (Matricaria maritima ssp. inodora), hempnettle (Galeopsis tetrahit), chickweed (Stellaria media), wild radish (Raphanus raphanistrum), shepherd's purse (Capsella bursa-pastoris), speedwell (Veronica spp.), knotgrass (Polygonum aviculare), white campion (Melandrium album) and charlock (Sinapis arvensis).

TABLE II (CONT)

Chemical	Dose (lb/ac)	Trial A		Trial B	
		Peas	Broad-leaved weeds*	Peas	Wild oats
Dalapon + MCPB	1 + 2	Loss of bloom	No effect	No effect	Slight reduction in vigour
	2 + 4	"	Black bindweed checked	"	"
Amiben	4	No effect	No effect	No effect	No effect
	8	Slightly stunted	Black bindweed controlled	"	"

1960 Trials

Trial C

The wild oat stand was uniformly dense at this site, and five scorings at weekly intervals were made for loss of pea vigour and wild oat control, after applications had been made. Weights of wild oat plants were obtained from one square yard per plot prior to harvesting, and wild oat panicles were weighed separately for comparison against total weight of heads plus straw (Table III). The whole of each plot was harvested for yield determination (Table IV).

TABLE III. YIELDS OF WILD OAT PLANTS (STRAW + HEADS) IN CWT/AC, 1960 TRIALS

Time of Application	Untreated	Atrazine		Amiben		Barban			
		1 lb	2 lb	4 lb	8 lb	0.5 lb	0.75 lb	1.0 lb	Mean
Early		78.3	12.2	124.2	(±12.1) 108.0	25.7	35.1	31.1	(±7.0) 30.6
Inter.						14.9	14.9	18.9	16.2
Late						54.0	39.2	29.7	41.0
Mean	(±8.5) 114.1	78.3	(±12.1) 12.2	124.2	108.0	31.5	(±7.0) 29.7	26.6	29.3

S.E. per plot as per cent of general mean = 31.4 (14 d.f.)

Sig. differences in cwt/ac	P = 0.05	P = 0.01
Between treatments in body of table	36.6	50.8
" means of barban treatments	21.1	29.3
" untreated and treatments in body of table	31.7	44.0
" untreated and means of barban treatments	23.6	32.8

* Broad-leaved weeds present on Trial A included black bindweed (*Polygonum convolvulus*), redshank (*Polygonum persicaria*), fathen (*Chenopodium album*), scentless mayweed (*Matricaria maritima ssp. inodora*), hempnettle (*Galeopsis tetrahit*), chickweed (*Stellaria media*), wild radish (*Raphanus raphanistrum*), shepherd's purse (*Capsella bursa-pastoris*), speedwell (*Veronica spp.*), knotgrass (*Polygonum aviculare*), white campion (*Melandrium album*) and charlock (*Sinapis arvensis*)

TABLE IV. YIELDS OF THRESHED PEAS IN CWT/AC, 1960 TRIALS

Time of Application	Untreated	Atrazine		Amiben		Barban			
		1 lb	2 lb	4 lb	8 lb	0.5 lb	0.75 lb	1.0 lb	Mean
Early		11.9	12.0	8.9	(±1.6) 7.8	18.3	18.6	18.3	(±0.9) 18.4
Inter.						16.3	17.0	14.0	15.8
Late						12.5	16.7	17.3	15.5
Mean	(±1.1) 8.6	11.9	(±1.6) 12.0	8.9	7.8	15.7	(±0.9) 17.4	16.5	16.6

S.E. per plot as per cent of general mean = 16.6 (14 d.f.)

Sig. differences in cwt/ac

	P = 0.05	P = 0.01
Between treatments in body of table	4.9	6.8
" means of barban treatments	2.8	3.9
" untreated and treatments in body of table	4.2	5.9
" untreated and means of barban treatments	3.2	4.4

Effects on Peas - The series of assessments for loss of pea vigour are not presented in this paper; in any case scorings on a particular date are not comparable since recording did not begin until all applications had been made. Results indicated, however, little or no pea damage by the three doses of barban at the first (early) time of application. Considerable pea damage in the form of schorching of the lower leaves and loss of foliage colour was caused by the second (intermediate) application and became more pronounced with increasing dose. The third (late) application of barban also resulted in pea damage, but not to the extent of the intermediate application, and was again more severe with the higher doses.

These results are reflected in the yields obtained (Table IV), which show that early application of barban led to significantly more peas than the late application. The difference between the early and intermediate applications also approached significance at P = 0.05. Differences in yield between doses of barban did not reach significance except that 1 lb applied late resulted in a higher yield than 0.5 lb, presumably because of the inferior wild oat control achieved by the latter treatment (Table III). Despite crop damage, barban at all doses and times of application significantly outyielded the untreated controls, by reducing wild oat competition.

The high dose of atrazine led to considerable loss of pea vigour and some plants succumbed. This effect was less noticeable with 1 lb. Amiben at both doses caused the peas to lose colour. Yields from both doses of these two herbicides were not significantly different from the untreated controls, although the higher yields from the atrazine treatments (Table IV) followed the significant effect of this herbicide on the wild oat population, particularly at the higher (2 lb) dose (Table III).

Effects on Wild Oats - Weights of whole wild oat plants and heads were recorded to determine if certain treatments, whether or not reducing the population, had the effect of inhibiting flowering and seed production. In general, however, all weights of heads and whole plants were approximately proportional to those from the untreated controls. By comparison with no treatment, all applications of atrazine and barban significantly reduced wild oat competition in terms of weight of straw. The difference between the amiben applications and untreated controls was not significant. Lower wild oat straw weights were given by the intermediate application of barban, compared with the early and late (significant) applications. Differences between doses were not significant.

Effects on Broad-leaved Weeds - Barban, at all doses and times of application, had little effect on broad-leaved weeds. Both doses of atrazine gave a complete kill and amiben also gave very good results in this respect.

Trial D

Visual scorings indicated that neither atrazine nor amiben had any lasting effects on peas, wild oats or broad-leaved weeds on this soil type. Barban-treated plots showed some pea chlorosis at 1 lb, but lower doses caused no visual damage. Broad-leaved weeds were only slightly affected by barban, but wild oats appeared stunted with blackened tips a few days after applications. By June wild oats were virtually non-existent on the barban plots, with little difference between doses. The extreme unevenness of wild oats at this site did not make pea and wild oat yield assessments worth while.

Discussion

No chemical treatments used post-emergence in 1959 showed promise for the control of wild oats in peas at any time or dose tested. Only maleic hydrazide gave satisfactory wild oat control, but with a drastic effect on the peas.

As amiben and atrazine function mainly through the plant's root system and as a result of observations made on pre-emergence applications of these herbicides it was decided to apply them in the 1960 trials soon after pea emergence when the wild oats were small and vulnerable. It was also considered that this time of application might result in less pea damage by these chemicals. In the event amiben caused less pea damage when used post-emergence at Trial C in 1960, compared with the pre-emergence application, but gave no control of wild oats. On the other hand the high dose of atrazine led to an excellent wild oat kill but produced more pea damage than the pre-emergence application (Reynolds and Armsby, 1960). On the basis of the 1960 trials neither amiben nor atrazine would appear to warrant further tests as post-emergence treatments for use in peas.

At Trial C all three rates of barban at the first (early) time of application resulted in an almost complete kill of wild oats that had emerged at that time; the peas were just beginning to unfold and suffered little visual damage. All rates of the second application also gave an equivalent control of all wild oats that had emerged; however, the peas had unfolded by this time and sustained more damage, in proportion to dose. It appeared that the yield depression caused by pea injury far outweighed the degree of wild oat control achieved. By the time of the third application, wild oats had become fairly well established and were tillering. Kills were not so good although they improved with increasing dose. Pea damage was less marked, possibly due to the fact that the plants were stronger and more established. The higher doses were only justified on the last application, when wild oats had commenced to tiller, and required larger doses to secure adequate control. It is possible that two applications of, say, 0.25-0.375 lb/ac, made at the time of the first and third applications at Trial C would have given virtually complete wild oat control with minimum pea damage. Further trials with lower doses and two times of application would seem to be warranted.

It is not known if better wild oat kills were secured with barban by setting the sprayer jets at an angle of 45°, but is seems reasonable to assume that better coverage is obtained by this means. More trials are needed to study the effect of temperature and other conditions at the time of application of barban in relation to pea damage, but from these limited trials it appears that peas are less vulnerable immediately after emergence when the leaves have not unfolded, and again later on when they are larger and well-established.

Acknowledgments

We wish to acknowledge the assistance given in this work by Messrs. R. Q. Robinson and J. W. Flint. Thanks are also due to the co-operating farmers for the provision of sites and other facilities, and to the following firms for supplying chemicals: Baywood Chemicals Ltd.; Bugges Insecticides Ltd.; Dow Agrochemicals Ltd.; Fisons Pest Control Ltd.; A. H. Marks & Co. Ltd.; May & Baker Ltd. Statistical analysis of results was kindly undertaken by the Rothamsted Experimental Station.

REFERENCES

ARMSBY, W. A. (1958) Chemical control of wild oats in peas. Misc. Pubn. Pea-growing Res Org Ltd. No. 5.

GREGORY, P., REYNOLDS, J. D. and PROCTOR, J. M. (1955) Preliminary experiments on chemical control of wild oats in peas. Proc Brit Weed Control Conf, 1954, 177-184.

HOLMES, H. M., GREGORY, P. and PROCTOR, J. M. (1957) Experiments with TCA for the control of wild oats in peas: progress report, 1955. ibid, 1956, 65-68.

MURANT, A. F. (1960) Control of wild oats (*Avena fatua*) in sugar beet, 1955-58. ibid, 1958, 162-167.

PROCTOR, J. M. and ARMSBY, W. A. (1957) Further experiments on the control of wild oats in peas: progress report, 1956. ibid, 1956, 69-78.

PROCTOR, J. M. and ARMSBY, W. A. (1960) Control of wild oats in peas: progress report, 1957-58. ibid, 1958, 156-161.

REYNOLDS, J. D. and ARMSBY, W. A. (1960) Residual herbicide experiments on peas, 1959-60. Tech. Memo. Pea-growing Res Org Ltd. No. 5.

Presentation by Mr. J. Holroyd of preceding four papers

The methods used for the assessment of wild oat in the various trials reported differ considerably. In the N.A.A.S. trials, only total oat panicles were counted; in the WRO experiments the panicles were counted and classified according to size and maturity; and in the P.G.R.O. experiments, panicles and straw were weighed. One of the effects of barban is to reduce panicle size and the amount of seed produced, thus the method of assessment used in the N.A.A.S. trials underestimated the effectiveness of barban. The W.R.O. methods probably gave the best measure of the amount of seed produced and those of the P.G.R.O. a more accurate estimate of the effect of the treatments on the competitive powers of the oat.

Many of the differences between the two herbicides are due to the different methods and time of application used for each. To summarise these differences. (a) Barban is a post-emergence herbicide which must be applied when the main flush of wild oat has between 1 and 2½ leaves. (b) Crop competition with the wild oat must be vigorous to achieve a good control with barban. (c) Considerable yield increases can result from the use of barban in crops with moderately heavy infestations of wild oat, provided that there is little or no check to the crop itself; although the reduction in actual wild oat seed produced may not be very great. (d) The farmer has to be educated not only to recognise wild oat in the seedling stage but also to be able to judge when the main flush has between 1 and 2½ leaves. (e) The thiolcarbamate (X) is a soil acting herbicide which needs to be incorporated into the soil, the shallower and more efficiently the better; although as is shown in these papers good control of wild oat can be achieved in spite of relatively poor incorporation, as long as the soil clods are not too large. (f) X can cause crop damage, particularly of wheat, although it may be possible to overcome this by delaying drilling, increasing the seeding rate or modifying the method of incorporation. (g) However it has the advantage that the timing of the application need not be precias as long as the soil conditions are reasonably good and the incorporation is immediately after spraying. (h) Finally there is the psychological problem of persuading the farmer to spray before he sees his weed - this is particularly difficult as he can always persuade himself that "this is not going to be a wild oat year".

POT EXPERIMENTS WITH NEW HERBICIDES FOR THE CONTROL OF WILD OATS

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Summary: A series of experiments investigated the influence of a variety of factors on the efficiency of barban and 2,3-dichloroallyl diisopropylthiolcarbamate for the control of wild oats in cereals. With barban these factors included spray volume, site of spray deposition, stage of growth, depth of sowing and light intensity. The first three were particularly important. With 2,3-dichloroallyl diisopropylthiolcarbamate some variation in toxicity with soil type and environmental conditions was found, and an appreciable degree of persistance noted. Experiments on the feasibility of undersowing grass-clover mixtures in crops treated with these herbicides suggested that it might be possible with barban but not with the thiolcarbamate. A preliminary experiment indicated the possibility of some risk from spraying a post-emergence herbicide onto a crop treated with the thiolcarbamate.

INTRODUCTION

During the past two years two herbicides have been discovered in the United States and put forward as having potentialities for the selective control of wild oat in cereal crops. One was 4-chloro-2-butynyl-N-(3-chlorophenyl) carbamate (barban), used as a post-emergence spray (see Hoffman et al, 1960, which includes bibliography of earlier references). The other was 2,3-dichloroallyl diisopropylthiolcarbamate, used as a pre-sowing soil-incorporated treatment (Deming et al., 1959, Hannah, 1959). These two compounds were included in the Unit's programme of pot experiments to evaluate potential killers of wild oats (Holly, 1956). The present paper summarises the results of many experiments designed to investigate the influence of several factors on the activity of these two herbicides.

METHODS AND MATERIALS

A medium loam was used for the experiments with pre-sowing treatments. Incorporation was simulated by placing the appropriate amount of soil for the depth of incorporation required into a rectangular tin, spraying the herbicide on the surface, allowing a short time for drying, and then mixing the bulk of soil by pouring at least three times through a funnel. A definite number of seeds was then sown at the appropriate depth in this soil, in a suitable sized pot. After treatment the pots were kept in randomised blocks on the greenhouse bench and watered only by sub-surface irrigation to avoid leaching.

Plants for the post-emergence treatments were generally grown in a 2:1 soil-sand mixture. In the winter they were raised in the greenhouse; at other

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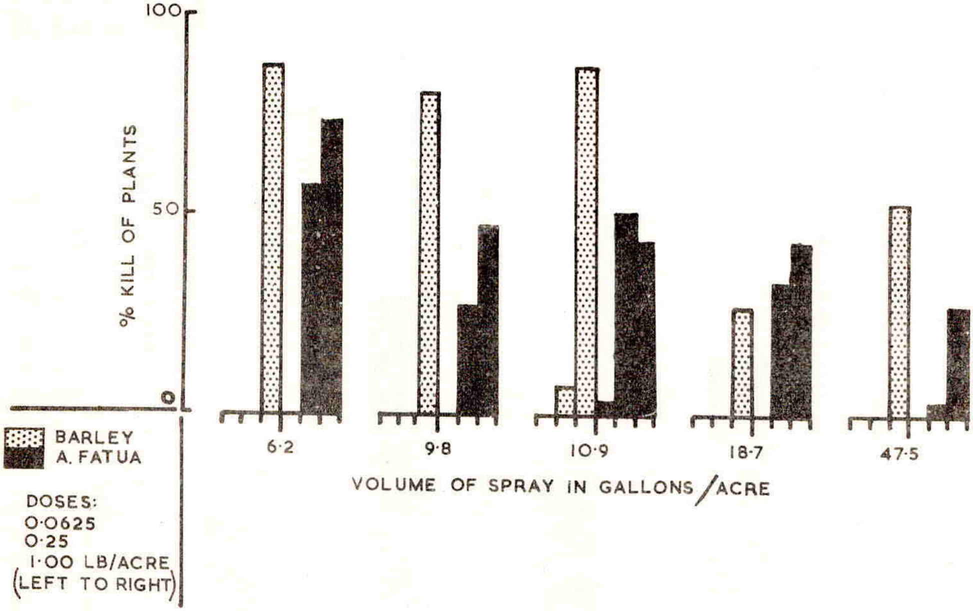

Fig. 2. Percentage kill of barley and A.fatua by barban at various volume rates.

Depth of sowing

Hoffman (unpublished information) suggested that depth of sowing influenced the recovery of wheat and barley but not of A.fatua, from treatment with barban. He indicated that this might be connected with the length of the translocation path from the soil surface to the growing point of the plant. A detailed investigation was made therefore of the depth of the growing point below the soil surface in relation to sowing depth of these plants. This culminated in an experiment to determine the response of plants sown at various depths and subsequently treated with barban. At the time of spraying there were only very slight differences in growth of plants from the various depths, namely ½, 1 and 2 inches. A.fatua was at the 1½-leaf stage while the cereals had 2-2½ leaves. There was a trend for the deepest sown Atle wheat and Rika barley to retain less spray than the shallow sown. There was no such trend with A.fatua or Proctor barley. The effect on the plants was assessed by measurement of fresh weight above ground level 2½ weeks after spraying. Even at the highest dose of 1 lb/ac there was no large effect on Rika barley. This dose caused a very considerable reduction in growth of the Proctor barley and A.fatua which was the same at all sowing depths. Atle wheat germinating from ½ and 1 inch was reduced in growth by about the same amount as the Proctor

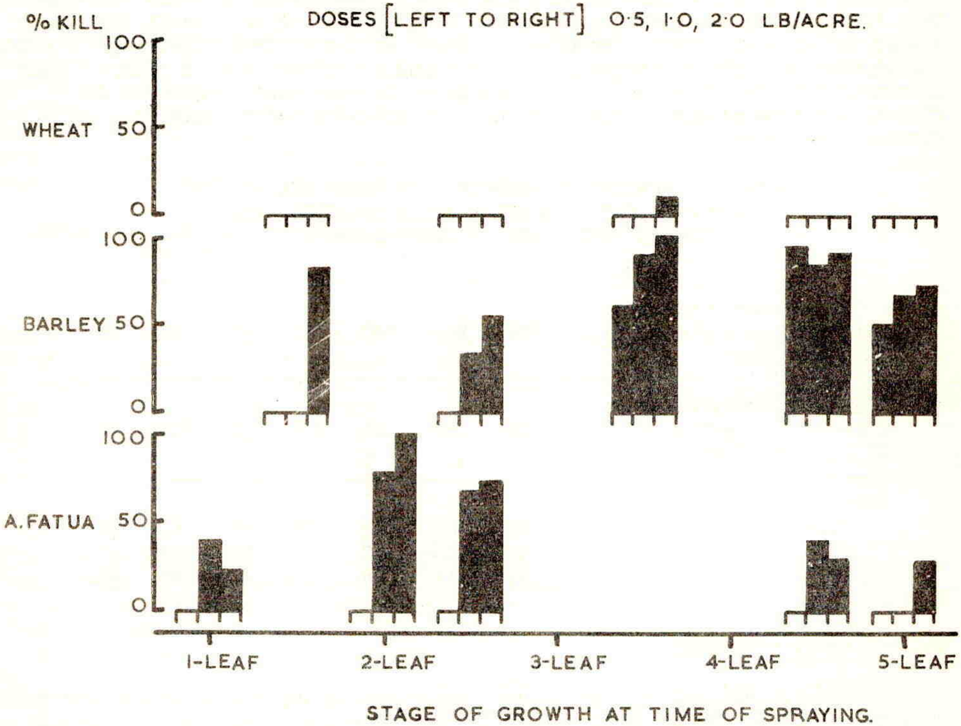

Fig. 3. Percentage kill of wheat, barley and A.fatua treated with barban at various stages of growth.

(55-70 per cent) but at a sowing depth of 2 inches there was only 30 per cent reduction. These results were not readily explicable in terms of the depth of the growing point as measured in this experiment.

Crop competition

Various suggestions have been made that competition from a vigorous crop increases the control of A.fatua by barban. Accordingly an experiment was conducted to determine whether light intensity, one of the major factors involved in competition, influenced susceptibility of A.fatua to barban. Light was reduced to 24 per cent and 50 per cent of full daylight by the use of perforated metal screens placed over the pots from the time of seedling emergence to spraying, at the 1½-1¾ leaf stage, and from spraying to final assessment 4 weeks later. There was an appreciable increase in spray retention, particularly on the leaf blades, by plants in full daylight prior to spraying compared with those receiving only 24 per cent light. This difference was almost proportional to the difference in dry weight of shoots between the two sets of plants.

Visual observation indicated some differences in leaf characteristics of plants receiving 2,3-dichloroallyl diisopropylthiolcarbamate prior to sowing, as compared with control plants. Therefore wheat which had received 0.31 and 0.47 lb/ac of this herbicide as a pre-sowing incorporation treatment was sprayed with 2,4-D or dinoseb or tartrazine for retention measurement at the 2-leaf stage. This preliminary experiment indicated a slight increase in spray retention and in damage from dinoseb where there had been pretreatment with the thiolcarbamate.

Experiments on other species indicate most dicots to be resistant to this herbicide. Sugar beet, kale, peas, field bean, maize, lucerne, white clover, red clover all withstood up to 2 lb/ac incorporated in the soil immediately prior to sowing. Dicotyledonous weeds such as Stellaria media and Brassica alba also appeared resistant. Most grasses tested were susceptible and may be roughly ranked in the following order of decreasing resistance: Poa annua, cocksfoot, Alopecurus myosuroides, timothy, Avena fatua, Italian ryegrass.

DISCUSSION

The experiments described have demonstrated that both barban and 2,3-dichloroallyl diisopropylthiolcarbamate have potentially useful selectivity between wild oats and cereal crops. However they also indicate that successful use will depend on compliance with restrictions regarding many of the conditions of the application.

With barban, barley was often as susceptible as A.fatua (as in Figure 2) but this was because the variety Proctor was used. This variety is particularly susceptible as is shown by Pfeiffer et al (1960); Rika showed a much higher resistance when included in one experiment. Differences in spray retention between wheat, barley and A.fatua do not favour the selective action required; on the contrary selectivity should be much greater if equal doses could be deposited on crop and wild oat plants. Reducing the spray volume increases retention and ultimate effect on both barley and A.fatua; thus low volume application should give greater economy of herbicide. The results indicate that an application method which increased retention by the leaf sheath and at the bases of the leaf blades would improve the control of A.fatua. The importance of stage of growth of both crop and weed at the time of spraying was verified, and the very short period of maximum susceptibility of A.fatua is an obvious practical disadvantage of this herbicide. Selectivity in Proctor barley cannot be improved by deep drilling, though some increased safety was imparted to wheat by sowing 2 inches deep. This would however be unacceptable agriculturally.

The results of the experiments with 2,3-dichloroallyl diisopropylthiolcarbamate indicate that, as with most soil-acting herbicides, the environment may be particularly important. Thus there appear to be variations in performance with changes in soil type and perhaps with temperature. On the other hand there was not the major change in resistance between Proctor and Rika barley that occurs with barban. The period of persistence of toxic residues in the soil is a major advantage in that control of wild oats germinating some time after drilling of the crop can be expected. It is a disadvantage insofar as cultivated grasses are susceptible and undersowing of treated crops is precluded, whereas this is probably possible with barban. The safety of applying post-emergence herbicides to crops treated with 2,3-dichloroallyl diisopropylthiolcarbamate requires further investigation. Promising indications were obtained that this herbicide would be worth experimenting with for the control of *Avena* spp. in dicotyledonous crops such as beet, peas and beans.

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REFERENCES

DEMING, J. M., WILSON, C. L., HAMM, P. C. and D'AMICO, J. J. (1959) Introductory studies of an effective wild oat control chemical. Proc 16th North Central Weed Control Conference and 10th Western Canadian Weed Control Conference 49-50.

HANNAH, L. H. (1959) Avadex, a selective wild oat herbicide. Proc 16th North Central Weed Control Conference and 10th Western Canadian Weed Control Conference 50.

HOFFMAN, O. L., PULLEN, J. W., EPPERLY, J. R. and HOPKINS, T. R. (1960) Factors affecting the activity of 4-chloro-2-butynyl N-(3-chlorophenyl) carbamate as a selective herbicide. Weeds 8, 198-203.

HOLLY, K. (1956) The effects of some newer herbicides on annual grass weeds. Proc 3rd British Weed Control Conference 235-245.

PFEIFFER, R. K., BAKER, C. and HOLMES, H. M. (1960) Factors affecting the selectivity of barban for the control of *Avena fatua* in wheat and barley. Proc 5th British Weed Control Conference.

Discussion on preceding nine papers on wild oats

Mr. G. B. Lush. I deprecate as much as anyone the reading of papers from the floor but, unfortunately, peculiar circumstances have made it impossible for us to contribute to this session in the usual way. We regret this enormously and are extremely grateful to the Chairman and Session Organiser for allowing us the opportunity of recording a very few words on our work this year on the control of wild oats with 2,3-dichloroallyl di-isopropylthiolcarbamate (X). We have in the past season carried out an extensive series of both replicated and farmer trials, distributed throughout the wild oat problem areas, the trials lying in the territory to the east of a line drawn between Yorkshire and Devonshire. In the replicated trials, 'X' was applied at a range of doses from ¾ to 3 lb/ac and investigations included method of incorporation, effect of soil type, timing, varietal susceptibility and persistence in the soil. In this season we have concentrated on spring barley, in order that we might have available sufficient wealth of information of performance under U.K. conditions to enable us to market for this crop in 1961. At the same time, more limited work in spring wheat, sugar beet and peas indicates the potential use of 'X' in these crops. The results of this programme of work show quite clearly that 'X', used as we propose to recommend it, in spring barley at 1½ lb active ingredient per acre well incorporated into the soil before drilling, will give an extremely good control of both *Avena fatua* and *Avena ludoviciana*. I entirely agree with Dr. Sanders when, earlier in this Conference, he made the point that 90 per cent control of wild oats was insufficient. In our trials the poorest results we have had, have been of that order and in every case we have been able to explain the failure in terms of incorrect application. In the main, our control of wild oats has varied between 95 per cent and 98 per cent with the occasional 100 per cent. It has been notable that the wild oats that do emerge from treated plots, i.e. the odd 2-5 per cent, grow to the same height as in the untreated plots and can readily been seen and rogued. Provided the recommended technique is employed, there is negligible hazard to barley with considerable latitude in application. All the commonly grown barley varieties included in our trials were found to be equally resistant. This is, of course, including Proctor, which occurred in 97 per cent of our farmer trials. Removal of wild oats by the use of 'X' in these trials has given increases in barley yield of up to 50 per cent. The following of applications of 'X' by post emergence sprays of MCPA, 2,4-D and mecoprop has been carried out without any deleterious effect on the crop or on wild oat control.

Miss J. M. Thurston. The results of my experiments on competition between the crop and wild oats in pots and in naturally infested fields agree well with the results obtained by Miss Holmes and Dr. Pfeiffer using cultivated oats. The number of wild oat seeds per plant can be reduced considerably by increasing competition from the crop. This can be done by any method which does not also benefit the wild oats e.g. by increasing the sowing-rate, by sowing early to ensure that the crop is well established by the time the wild oats germinate, or by changing to a more vigorous and free-tillering variety. Additions of nitrogenous fertilizer does not increase competition from the crop as it also increases the vigour of the wild oat plants. Wild oats are most susceptible to competition in the early seedling stage, when their leaves are small and narrow and there is not so much food-reserve available from the smaller seed of wild oats compared with the seed of a cultivated cereal. The young seedlings of wild oats have a higher nett assimilation rate than corresponding crop plants or older wild oat plants; this enables them to grow faster than the crop plants and catch them up in size. Overshadowing by the crop can prevent them from taking advantage of this difference.

It is possible that the sensitivity of young wild oat plants to barban applied at the $1\frac{1}{2}$-$2\frac{1}{2}$ leaf stage, decreasing as the plants get older and bigger, is connected in some way with the physiological activity of the seedling, and this would seem to be worth investigation.

It might also be worth considering whether the sensitivity of wild oats to 2,3-dichloroallyl di-isopropylthiolcarbamate is connected with the depth at which the wild oat seeds are buried in the soil and the effect of this on the part of the plant which penetrated the treated layer of soil. If the seeds are more than 3 to 4 in. below the surface of the soil it is the first leaf, and not the coleoptile, which appears at the surface and perhaps this is more sensitive than the coleoptile to the herbicide. The crop, on the other hand, is sown at such a depth that the emerging shoot is protected by its coleoptile. Wild oats can emerge from seeds buries at 6 to 9 in. below the soil and often do so. The seeds are commonly mixed with the soil down to or below the depth to which it was ploughed.

Mr. R. W. E. Ball. We carried out some field experiments, in 1959, with barban, and one of these was in a crop of Koga II spring wheat. The results confirmed the observation of Mr. Holroyd that this variety is sensitive to barban after the 2-3 leaf stage. In our experiment it appeared to be as susceptible as Proctor at doses of 8 oz/ac and above. I should like to ask Dr. Pfeiffer whether spring wheats show as great a variation in varietal susceptibility as do the spring barleys.

Dr. R. K. Pfeiffer. In the majority of our experiments we had Koga II and we encountered no difficulty. Our own spring wheat variety trials failed due to drought but N.I.A.B. should in future have information on this.

Regarding crop competition, Miss Holmes and I have submitted a paper on this matter to the Editor of the new Weed Research Journal. This is a study of the competition between oats and barley as influenced by fertiliser and seed rate. We confirm observations that nitrogen does not help, for wild oats and barley benefit to the same degree, but increase in barley seed-rate led to a reduction of the oats. Additional reduction was produced by barban.

Mr. J. Holroyd. When Koga II was sprayed at the 3-leaf stage in our field trial there was no depression in yield but there was a reduction when it was sprayed at the 5-leaf stage.

Mr. T. E. Miller. March was mentioned specifically, but March in Yorkshire is not the same as March in the South. This is very important if it is a matter of spraying at exactly the right stage.

Dr. R. K. Pfeiffer. So far as the effect during March is concerned, we do not understand it yet. A lot more work is needed on this and trials have actually started.

Professor A. H. Bunting. Have you followed the pattern of development of tillers during this period, and the effect of treatment thereon, for this may be critical in determining ultimate yield?

Dr. R. K. Pfeiffer. We observed the effect for the first time this year; we did not expect it and therefore unfortunately did not take the necessary observations. We have to start from the beginning to study the problem.

Mr. A. L. Abel. Dr. Dubrovin of Spencer Chemical Co. is now engaged on detailed study of that particular point, and in due course this will appear in the American Journal 'Weeds'.

With the subject we are dealing with it is important we do not have too many unnamed off-spring. It is desirable to have a family and christian name for herbicides - barban has been christened and its name is 'Carbyne'. Could we please have a name for the thiolcarbamate?

Mr. G. B. Lush. Before long we shall be able to produce the appropriate name.

Mr. R. F. Norman. To what depth should 'X' be incorporated into the soil and how is this depth to be measured? Is it as a loose or firm tilth and how critical is this factor? There is little indication as to whether it is possible to use other herbicides, for example MCPA or mecoprop, on crops growing in land treated with 'X'. It would appear from Dr. Holly's work that materials such as DNCC and dinoseb might well cause scorch to crops growing in land treated with 'X'. It is possible to provide more information on this matter?

Dr. L. H. Hannah. When we say incorporate in the top 1 to 2 in. we mean stirring not more than the top 1 or 2 in. of soil, whether firm or loose. We maintain that the closer to the surface we keep the herbicide the better wild oat control will be. I did not have time to present information from the U.S.A. on concentrating the chemical, with a special piece of equipment, about ½ in. below the surface in loose soil. This gave an excellent control of wild oat; Chenopodium and Amaranthus were also controlled.

About the use of MCPA, we could cite experience in Canada this year in which many thousands of acres of flax, barley and wheat were treated. About 95 per cent of the crops that were treated with 'X' were also treated with 2,4-D and there was no injury.

Mr. G. B. Lush. When 'X' application to barley was followed by post emergence application of MCPA, 2,4-D or mecoprop, no deleterious effect occurred.

Mr. G. A. Toulson. Towards the end of his paper, Dr. Holly dealt with the effect of barban on species other than the cereals and appeared to give the impression that this herbicide does not adversely affect grasses, clovers, etc. I suggest that this statement requires qualifying. In a particular trial conducted in Wales, in the absence of wild oats, barley varieties were sprayed with barban (11 oz/ac) at two stages during early development. The barley had been undersown with a general purpose seed mixture at the time of drilling the crop and grasses and clover were in their first and second true leaf stage respectively, at the time of spraying. The application of barban at both stages considerably reduced the stand of grasses, but the clovers remained unharmed.

Dr. K. Holly. I should point out that in my paper I was dealing with the susceptibility of grasses and legumes sown into soil treated with barban, i.e. visualising the situation where the crop was sprayed very early for wild oat control and the 'seeds mixture' drilled subsequently. The results of differences between the two fields both as to the herbicides that can be used and as to the way in which they must be applied. In industrial weed control, many times herbicides are used which are taken up through the roots. Now the root system of aquatic plants is hard to get at. In addition the water environment of submerged aquatic weeds differs considerably from the atmosphere in which terrestrial plants are growing, and consequently the techniques of application must be different. The problems involved will form the background of the first part of my discussion.

In the control of emergent graminaceous weeds, systemic herbicides, transported from the leaves to the root system, have been widely investigated and they are already used in practice. Among these products dalapon takes an outstanding position. TCP (trichloropropionic acid) is much less active (Kramer, 1960). Expressed in molecular concentration the general herbicidal activity of dichlorobutyric acid seems to be about the same as that of dalapon, although it seems to be less effective against Sparganium racemosum. For practical applications the price of the commercial formulations and their availability may determine which of them will be used.

For an optimal effect dalapon, as most other herbicides, must be applied at a rather high relative air humidity (not less than 70 per cent), in low to medium volumes of water and in rather small droplets. A wetting of all leaves is necessary, so in dense vegetation a penetrating air stream or the use of a high pressure spray gun is needed. The effect of wetting agents on the effect of dalapon is partly a controversial topic. Most investigators agree that wetting agents generally increase the initial kill and die-back of the vegetation. This may be important because of an earlier decay, but it is not clear whether the final effect is also improved. Of course the proportions of the leaf area above and in the water must effect the dosage required for an effective treatment. However in our experiments in the Netherlands Glyceria maxima, Phragmites and Typha have been successfully controlled by 15 kg/ha (16.5 lb/ac) of dalapon under varying conditions of water table and treated leaf area.

Aminotriazole is another chemical effective against emergent ditch weeds. At sufficiently high rates of application (about 10 lb/ac) the activity of this herbicide is sufficient to make it of practical importance. In mixtures with dalapon, amino triazole is given the function of "assisting herbicide". We have found that a mixture of 10 lb of dalapon and 2 lb of amino triazole/ac has the same herbicidal activity as 15 lb of dalapon alone. In the mixture, amino triazole considerably speeds the effect of the application and the rate of decomposition of the dead organic material. After spring applications, the results may be clean or more or less clogged watercourses during the summer. The importance of the way of formulating amino triazole, in particular the addition of ammonium thiocyanate, is under study in several countries. It seems to me too early to come to general conclusions as to the effect of this addition on the rate of chemical to be applied and the initial and final kill of the vegetation. After the publicity amino triazole has received in the U.S.A. as a result of residue determinations in food products and subsequent governmental action on contaminated cranberries, the chemical is the subject of great public suspicion. There are indications, however, that a reconsideration of the available toxicological data in some countries may lead to official recommendation of its use in aquatic weed control.

In the control of broad leaved emergent weeds no special difficulties are met. Generally speaking satisfactory control is obtained with the auxin herbicides MCPA and 2,4-D at twice the doses used in cereals and grass-lands. In mixed vegetation we prefer the amine salt of 2, 4-D to MCPA, because of its activity against a broader range of weeds. Against the typical low peat vegetation, where Stratiotes aloides and Sium species are the main weeds, the cheaper MCPA is acting as well. As a rule two applications are required against Stratiotes. In early spring this is a submerged weed, the rosettes of which become floating and partly emergent in early summer, often covering the whole surface of the ditches. As the herbicide is only effective when sprayed on the emerged parts of the leaves and not all rosettes always emerge at the same time, a second treatment about three weeks after the first may be necessary for a complete control.

In most cases grasslike and broad-leaved weeds may be satisfactorily controlled by one single spraying of a mixture of dalapon, an auxin type herbicide and amino triazole. In the Netherlands we have good experimental results with a combination of about 7½ lb of dalapon, 2 lb of 2,4-D-amine salt and 2 lb of amino triazole.

Next to the stage of development of the weeds, the time of spraying has to be based on the specific maintenance requirements of the watercourses. In Holland spraying in the middle of May has the advantage that the treated weeds decay rather quickly. Thus watercourses sprayed at that time remain clean until at least the beginning of August. Then some regrowth may start from some not completely killed rhizomes of Glyceria maxima and Phragmites. This new vegetation may, however, be definitely killed by a second treatment with a lower dose, e.g. two thirds of the first application. If the first spraying is postponed until the middle of June or later, one single treatment will generally give a satisfactory control, but the treated ditch will not be clean during the summer because the dead lignified plant material decays too slowly and obstructs the flow of the water.

The vegetation of temporarily dry ditches is usually very similar to the emergent vegetation dealt with before. For the control of weeds under these circumstances, however, in addition to the herbicides mentioned other products have to be considered. First of all TCA, a grass-herbicide, cheaper in use than dalapon and successfully applied in e.g. temporarily dry fish ponds. TCA is only effective through the roots whereas dalapon effects the plant both through the roots and leaves. So for temporarily dry water ways that may become refilled with water at any unexpected moment, TCA is not to be recommended instead of dalapon. In Germany and the Netherlands commercial mixture of TCA, amino triazole and auxin herbicides are being studied. In my opinion mixtures of dalapon, amino triazole and auxin herbicide as mentioned earlier are more important, however.

If a ditch is free of water for considerable time periods and without of deep-rooted plants, e.g. due to treatments with dalapon and auxins, applications of total herbicides of low solubility with long residual action become attractive. A long residual effect against germinating plants can only be expected, however, if the chemicals can penetrate in the top-layer of the ditch bottom. Therefore, some rain is required, but not so much that the ditch bottom will be again covered with flowing water. In experiments, good results were obtained with monuron and diuron, with mixtures of monuron and diuron with amino triazole and with simazin plus amino triazole. In the Netherlands monuron and diuron are used for these applications on a practical scale.

The exceptionally dry summer of 1959 caused the drying up of watercourses carrying large volumes of water under normal weather conditions. This actually offered opportunities for chemical weed control, but unfortunately could not be taken advantage of. Sufficient experience was not available then to justify large-scale practical recommendations. In future, however, such opportunities may be better utilized.

Passing on to the control of submerged weeds, in these plants the interrelations between leaves, stems and roots may be in many respects different from those in land plants. In Ceratophyllum, which has no roots at all, it is clear that water and minerals may only be taken up by the leaves and stems. In other submerged weeds the only function of the roots might be to attach the plants in the ditch bottom.

As there is no transpiration stream, an intensive transport of water through the xylem is not probable. Consequently herbicides that act on land plants after absorption by the roots and subsequent translocation by the transpiration stream to the shoot system should be of no value in the control of submerged weeds. It appears, however, that some of these products, as e.g. monuron, diuron and simazine, although they are poorly or not at all absorbed by the leaves of land plants, act quite well on submerged leaves through absorption from the surrounding water. Here we must realise, that the anatomy of the leaves of submerged water weeds is different from that of most land plants. In contrast to the leaves of submerged aquatics the leaves of land plants generally have morphological features which restrict transpiration and uptake of chemicals as e.g. a pronounced cuticule, sunken stomata and a waxlayer. As these are wanting in submerged weeds, the uptake of substances dissolved in the water will be much easier than in immersed (normal) leaves of land plants.

In treating submerged weeds with herbicides we have to consider the concentration of the product in the water and not the dose to be applied to the treated area. This goes for stagnant as well as for flowing water. In the latter case, however, where the time of exposure is limited, the concentrations to be applied must be much higher than in stagnant water. This is particularly true for the application of contact herbicides. Here it can be said, that above a certain threshold value, typical for each chemical, the concentration as well as the time of exposure determined the effect. In flowing water the continuously occurring dilution of the herbicide limits optimal effects to a certain distance from the place of injection.

In systemic herbicides, as monuron, simazine and auxin herbicides probably a different relationship exists between concentration and time of exposure. Although our insight in this point is far from complete it has been established for auxins (Blackman, 1956), monuron (Tedd, priv. comm.) and simazine (Van Steekelenburg, priv. comm.) that after short time exposures a loss of the chemicals from the treated plant parts can be observed if the plants are returned to untreated water. Because of this submerged plants may completely recover from temporary growth inhibitions. However, this does not mean that plants treated with the same chemicals in very high concentrations will also recover. A trend in the investigations in our institute is the study of such treatments with concentrations of 30 - 1000 ppm with short exposure times.

It is too early to say, however, whether the investigations will lead to any practical method of control.

One way to achieve a higher concentration of chemical near the leaves and stems of submerged plants is by using pellets, which sink to the ditch bottom or settle on the vegetation. In completely stagnant water in this way a rather high concentration can be achieved in the water-layer close to the ditch-bottom and in various cases with this method positive results are mentioned, especially with pellets containing esters of 2, 4-D or 2,4,5-TP. On the basis of surface area treated the doses to be applied are very high, viz. 10 to 20 times those for land plants. But here we must realise that in land plants after an application of e.g. only 1 lb /ac of MCPA in 50 gal of water the herbicide is taken up from an initial concentration of the spray of about 2000 ppm, which concentration even rises during drying-up.

Dusts have also been investigated for the control of submerged weeds. When using dusts the leaves may be covered by many small particles from which the herbicide diffuses into the leaves, a situation more or less similar to that in sprayed land plants. The formulation of the product and particularly those factors that determine the tendency of the dusts to become attached to the submerged vegetation are probably of great importance. As far as I know the method has not yet led to extensive practical applications, and where dusts were applied apparently the doses of active ingredient used were similar to those where the products were formulated as pellets.

After these general considerations some comments can be given on specific products. In the irrigation districts of the western United States contact herbicides are generally used, in the first place aromatic solvents, nowadays also acrolein., The last named product has been introduced to you at the 4th British Weed Control Conference (Van Overbeek, 1958). The application difficulties of this very unpleasant product seem to have been sufficiently mastered to allow safe handling. Its most important advantages seems to be that acrolein is flowing much more evenly through the submerged vegetation than any other product and that in a short time the plants desintegrate to small pieces, which do not have to be removed. In Western Europe the very high toxicity of the product for all organic life in the water prevents its application in most cases. The same goes for aromatic solvents.

Although I understand that diquat may also be of some use in the control of submerged weeds, its use is apparently unsufficiently studied to allow practical recommendations.

It must be emphasized that on submerged weeds the effect of contact herbicides is a kind of chemical mowing, without any effect on roots and rhizomes in the bottom, so regrowth takes place.

Attention continues to be drawn to copper sulphate, used as algicide. The product has also some value against some dicotyledonous weeds too, as has been shown e.g. by Chancellor et al (1958).

From the auxin herbicides studied, 2,4,5-TP has to be specially mentioned. The chemical is recommended for use in the control of submerged weeds in the PGBE formulation commonly used in applications against terrestrial weeds. In stagnant water or where the flow of water can be prevented for some days the product is effective against weeds like Myriophyllum and Elodea (Dow 1959). The toxicity of the product to fish will be discussed later.

A group of lower plants which I should like to mention briefly are the filamentous algae. In some parts of the Netherlands occasionally they are very harmful, because such growths of algae are so tough and felty that they cannot be removed by machines. Filamentous algae do not occur in some ditches in polders north of Amsterdam. This absence is caused by an intensive treatment of the ditch banks with monuron, a herbicide to which filamentous algae are more sensitive than submerged weeds. The practice of killing all vegetation on ditch banks is certainly not recommended by us, because it exposes the banks to erosion. The only reason that I mention this is that the treatment causes the ditches to be practically free from algae. At Wageningen we have discontinued our investigations on the control of filamentous algae because we have observed in preliminary tests that these organisms are much more susceptible to herbicides than Elodea canadensis, which is our most common and serious submerged weed and one of the major test weeds in the experiments.

The use of chemicals in weed control on ditch banks is no problem on its own. In Holland we prefer a closed vegetation with grasses and this can be easily achieved by spraying auxin herbicides. This is also an important measure for the general farm sanitation, because ditch banks are as a rule important sources of weed seeds for the farm.

In several countries studies are made on growth inhibition of grasses in order to cut down mowing costs. A treatment with 4 - 6 lb/ac of maleic hydrazide combined with an auxin herbicide in order to prevent domination of broadleaf weeds proved to be successful, but generally was insufficiently reliable. The fact is, that the margin between growth inhibition and partial kill has proved to be very narrow and besides grasses most important for a closed sward are the most susceptible. Also with high doses of 2,4,5-TP growth inhibition may be obtained. Also treatments for inhibiting grass growth are rather expensive. Therefore at the moment in my experience spraying auxin herbicides is the most suitable. It results in a good and valuable sward, that can easily be mowed mechanically or by hand.

Control of water weeds means interfering in a natural succession of plant growth. The removal of the emergent vegetation, as can take place with chemicals, will inevitably result in a stronger development of the submerged plants. This is the reason that in our opinion the study of the control of submerged weeds and algae deserves highest priority.

In my opening remarks I mentioned that there are several consequences of the application of herbicides in watercourses. From all problems indicated I should like to discuss in some detail only one, viz. the influence of the chemicals on the water as the environment of fish life. The presence of waterplants may be either beneficial or troublesome to fish. The determining factor is to what intensity the plant growth is developed. Only few plants, like Lemna and Azolla, are always considered to be harmful for fishes. For all other waterplants, waterweed control can be looked upon from the viewpoint of fisheries, as selective checking of plant growth favourable to the maintenance or improvement of water environments required for optimal fish life. In this respect control of aquatic weeds is more or less comparable to control of grassland weeds; a selective checking of many plants is there preferred to a complete eradication, because of the function of dicotyledonous plants in determining the herbage value of the sward. From the point of view of fisheries a careful maintenance of waterways is highly desirable. This explains the interest of fishery specialists for simplified methods of maintaining waterways. The urgency of improved vegetation control is well illustrated by Hofstede (1960) who states that in Holland in 1957 in 30 per cent of all cases of severe death of fish exceptional growth of Lemna or other plants could be established as the probable cause.

In checking aquatic vegetation the maintenance of the ditch profile is of great importance. In many ditches dredging is so long postponed that the removal of all material means a strong interference in the biological environment. Due to mechanical cleaning the parts of most water plants present in the ditch bottom are removed (rhizomes, and other hibernating organs). In practice a complete removal seldom occurs and then quite soon regrowth starts.

Those waterways of major importance for the drainage conditions in a district are usually regularly cleaned. From spring to autumn the conditions in these waterways, where the plant-growth is frequently mowed or cut down near the bottom, are quite different from those in the uncleaned smaller ditches. This means, that various types of environment are available, each with its specific importance for adult fishes, fish-brood and fish-food organisms. In most cases exuberant plant-growth means decrease and consequently loss of environment suited to fish-life. On the other hand a great quantity of intensively decaying plant material may result in oxygen shortage and other toxicity phenomena in the water.

Taking into consideration all aspects mentioned, the use of herbicides in waterways may not result in an undesirable influence upon the water environment for fish. Preceeding any approval, products must be investigated as to their possible toxic action on fish species in any stage of development, on fish-food and on other organisms of importance in the food-chains in water.

The available time does not allow me to discuss all problems in detail. Therefore, I shall restrict myself to some comments.

In the first place a comment on the method of assessing toxicity to fishes and fish-brood. In reading publications on this topic (Alabaster, 1956, 1958; Bandt, 1959; Davis and Hardcastle, 1959; Edson, 1958) one observes a diversity in methodology which leads us to express the desirability of having a more standardized technique. Considering the work carried out already, it should be possible to come to an agreement on the methodology of one or some toxicity determinations, the results of which could also be used for an international exchange of data. In aquarium experiments fishes are usually exposed for several days to definite concentrations of herbicides. In our opinion it should also be recommended to investigate the effect of short temporary exposures to higher concentrations.

Secondly a comment on the way of interpreting the results of the determinations. Generally speaking in toxicity studies concentrations of herbicides are being investigated, calculated to be present after field applications in waterways of a specific not too great depth. In Holland, until now, we have accepted the standard that a tenfold concentration of the calculated one shall not influence test animals. Of course somewhere a line must be drawn but still a discussion on this factor seems desirable. In Austria Neururer and Slanina (1960) accept a safety quotient of 20. Only if the relation between the lowest tolerated concentration by fish and fish-food and the concentration calculated to be present after practical applications exceeds 20, Neururer and Slanina approve the application.

Finally a comment on the importance of the formulation of the herbicide in these toxicity studies. Although from a scientific point of view insight into the toxicity of the active ingredient is necessary, from data available it appears that the formulated products also have to be investigated. It is known, that the addition to the product of a wetting agent increases the toxicity of dalapon. In other cases we must believe that concentrating active substances in solvents and applying the products as emulsions greatly influences their toxicity.

According to Edson (1958) there is a general correlation, although not a precise one, between toxicity of pesticides to fish and toxicity to mammals, influenced in some cases by the water stability of the chemical. The correlation is too weak, however, to be of decisive importance in the discussion on the approval of herbicides for water weed control. We can roughly state, that herbicides easily soluble in lipoidal material are more toxic to fish than those soluble in water. In auxin herbicides, therefore, application of ester formulations has to be avoided at places inhabited by fish. Considering the recent interest in 2,4,5-TP, mentioned previously, from the point of view of fish toxicity the investigation of salt formulations is very interesting. With the commonly used PGBE-ester formulation apparently some fish toxicity has been observed.

It might be useful to mention briefly what determinations have been carried out in the Netherlands before the conclusion was drawn that of the several herbicides considered only dalapon, amino triazole and salts of MCPA and 2,4-D do not have detrimental influences on the water environment. The investigations, which are based on spraying in 10 cm deep water, are not finished yet, the results will probably be published some time in the future. In these investigations the following aspects have so far been considered:

1. the influence of the chemicals on some fish-species and fish-food organisms;
2. the influence on bacteria, of importance in the purification of surface waters;
3. the influence on the biological oxygen demand, the B.O.D.-5, indicating the biological oxygen consumption of organic material in water, determined after 5 days of incubation at 20°C;
4. the influence on some soil protozoa, occurring in silt from water purification installations.

As to these effects dalapon, amino triazole and salts of MCPA and 2,4-D were considered sufficiently safe to allow temporary approval in aquatic weed control. From these chemicals amino triazole has not been officially cleared because of insufficient data concerning the public-health aspects connected to application of the product.

In the meantime with the chemicals mentioned and also others, further research is planned and is to be carried out on differences in susceptibility between adult fish, young fish and fish-brood, on the influence of water composition, on the toxicity and on the persistence of the chemicals in the water environment. About this last aspect hardly any data are available and more research is certainly required.

I hope to have covered in my discussion the main aspects of the use of herbicides in aquatic weed control. In most European countries this practice will take its place next to mechanical ditch cleaning, the two methods supplementing each other.

REFERENCES

ALABASTER, J.S.(1956): The toxicity of certain weedkillers to trout. Proc. 3rd British Weed Control Conf. 2,807.

ALABASTER, J.S.(1958): Toxicity of weedkillers, algicides and fungicides to trout. Proc. 4th British Weed Control Conf. 84-85.

BANDT, H.J.(1959): Chemische Pflanzenbekampfungsmittel und Fische. Deutsche Fischerei Zeitung No. 8.

BLACKMAN, G.E.(1956): in The Chemistry and mode of action of plant growth substances, p.253-59. (Wain, R.L. and Wightman, F., Eds. Butterworths Scientific Publications, London, England, 312 pp.)

CHANCELLOR, R.J., A.V. COOMBES and H.S. FOSTER (1958): Control of aquatic weeds by copper sulphate. Proc 4th British Weed Control Conf. 80-84

DAVIS, J.T. and W.S. HARDCASTLE (1959): Biological Assay of Herbicides for Fish Toxicity. Weeds - 7, 397-404

DOW (1959): Kuron, for aquatic weed control. Down to Earth 15, 16

EDSON, E.F.(1958): The risks of pesticides to fish. World Crops 10(8), 281-283

HOFSTEDE, A.E.(1960): Bestrijding van overmatige waterplantenvegetatie. Visserij-Nieuws 13,2-6

KRAMER, D.(1960): Uber den Einsatz von Herbiziden zur chemischen Entkrautung von Ent- und Bewasserungsgraben. Wasserwirtschaft-Wassertechnik 10, 33-38

NEURURER, H. and K. SLANINA (1960): Chemische Bekampfung unerwunschter Teichpflanzen mit besonderer Berucksichtigung der Fischtoxizitat von Herbiziden. Pflanzenschutzberichte Vienna 34, 139-162

OVERBEEK, J. VAN (1958): New herbicide for aquatic weed control. Proc 4th British Weed Control Conf. 259-261

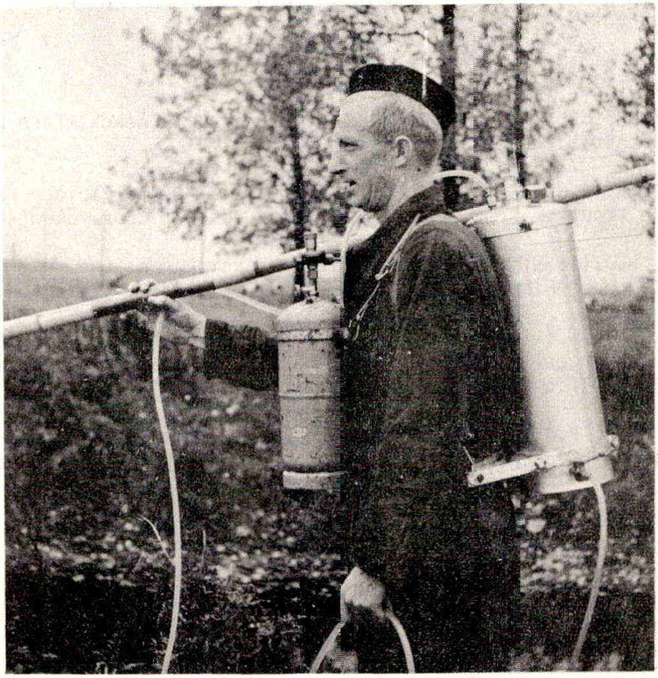

FIG. 1. PROPANE KNAPSACK SPRAYER

In front: 4 lb steel propane bottle ("Primus") with stopcock and pressure regulating valve.
At back: 16 l liquid pressure tank in carrying harness. High pressure spraying tube of PVC leading to nozzles.

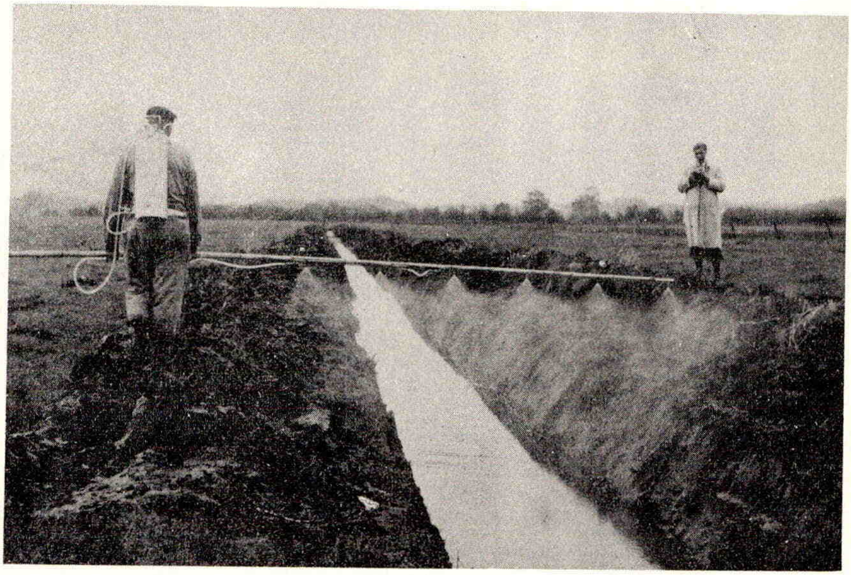

FIG. 2. PROPANE KNAPSACK SPRAYER

Combined carry-and sprayboom composed of three sections like an anglers rod, with 6 nozzles and a working width of 3 m. For use in and along watercourses with water level only slightly below the land surface.

FIG. 3. FROPANE KNAPSACK SPRAYER

Hinged spray boom with 3 nozzles and working width of 1.5 m for use in ditches with a low water level.

RESULTS OF SOME PRELIMINARY EXPERIMENTS ON THE USE OF PELLETED HERBICIDES FOR CONTROLLING SUBMERGED WATER PLANTS.

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Summary: In the experiments detailed in this report no useful effect on submerged vegetation was obtained using a variety of relatively insoluble pelleted herbicides in small plots (20 sq yd) in flowing to nearly static water.

INTRODUCTION

The development in recent years of a new technique in North America (Grigsby et al. 1956 and Grigsby, 1957) for the control of submerged water plants had aroused considerable interest in this country. In general terms the technique is to apply herbicides in relatively insoluble form as granules. These are applied where feasible, on to ice in winter by means of a fertilizer spreader, (the pellets sinking when the ice melts), or by hand, by pellet distributors or by aircraft. Applications in winter or early spring are reputed to ensure control of submerged plants throughout the growing season of the year of application and in some instances for up to eighteen months. Some of the pellets are thought to act through the roots of submerged plants (Grigsby and Smith, 1958). An experiment in 1959 carried out by the National Agricultural Advisory Service (Proctor, 1960) showed great promise in that 2,4-D ethyl hexyl ester on clay pellets* gave excellent control of a number of submerged plants. Control continued into the following year. It was therefore decided to test as many pelleted formulations as were available of chemicals suitable for this purpose to see if the technique was suitable for use in this country. If satisfactory the technique would allow localised treatment of submerged weeds in flowing water without pollution of the water, because it was believed that release would be so slow that the concentration of chemicals would not be appreciable in the water.

The experiments reported here were carried out mostly in 1960, but details of several earlier ones have also been included. The sites treated in 1960 were selected to give as wide a range as possible not only of conditions, but also of the species of plants present.

METHODS AND MATERIALS

Experiments on ditches were laid out with treated and untreated lengths alternating. Plots were usually 20 sq yd in area (of water surface). Treatments were never replicated because of limitations of the sites. All treatments were broadcast as evenly as possible by hand. Each experiment is treated separately because of the great variability between sites.

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* Supplied by Reasor Hill Corp.

Supplier	Ingredients of pellets	Common Name or Number	Conc. of Act. Ingredient (as percentage)
American Chemical Paint Co.	2,4-D butoxy ethanol ester in granulated (8/15 mesh) attaclay.	ACP-M-518C	10 a e w/w.
" " "	2,4,5-TP butoxy ethanol ester in granulated (8/15 mesh) attaclay	ACP-M-518G	10 a e w/w.
" " "	2,3,6-trichlorophenylacetic acid in granulated (8/15 mesh) attaclay	ACP-M-816	10 a e w/w.
Borax Consolidated Ltd.	2,3,6-TBA in granulated sodium borates	Benzabor Sample No. 952	4 a e w/w.
" " "	Methoxypropazine in granulated sodium borates.	EH 592 Sample No. 953	2.5 w/w.
" " "	2,4-D in granulated sodium borates.	DB granular Sample No. 995	7.5 a e w/w.
Chipman Chemical Co.	Telvar 'W' (80% monuron), Borax (decahydrate) and Neobor (pentahydrated borax)	Monax granules	5 w/w. 81.5 w/w. 11.5 w/w.
" " "	Telvar 'W' (80% monuron), Borax (decahydrate), Sodium chlorate and 2,4-D-sodium.	Chlorea granules	3 w/w. 37.5 w/w. 38 w/w. 1.25 a e w/w
Fisons Pest Control Ltd.	Monuron pellets	CP/36/56	25 w/w.
J.R. Geigy, S.A.	Simazine on sand	-	2 w/w.
Plant Protection Ltd.	Fenuron pellets	YF 3356	50 w/w.
Reasor-Hill Corp.	2,4-D iso-octyl (2-ethyl hexyl) ester and inert ingredients (clay).	Weed Rhap 20	20 a e w/w.
" " "	2,4-D and 2,4,5-T mixed iso-octyl (2-ethyl hexyl) esters inert ingredients (clay)	-	10 a e w/w. 2,4-D and 10 a e w/w. 2,4,5-T.

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Supplier	Ingredients of pellets	Common Name or Number	Conc. of Act. Ingredient (as percentage)
Shell Research Ltd.	2,4-D acid bound in resin pellets	-	70 a e w/w.
Shell Research Ltd.	2,4-D acid bound in resin pellets	-	80 a e w/w.
" " "	2,6-dichlorobenzonitrile granulated.	Batch No. B4/60.	2.5 w/w.

RESULTS

(Note: All doses are as lb a e or a i /ac)

1. Experiment No. H/39/55. Location: Hingham, Norfolk.

Plants present: Sparganium sp. (bur-reed) floating leaves only.

Date of treatment: 10.9.55.

Treatments: Fenuron pellets 50 per cent were applied at 12, 24 and 48 lb/ac on to 1/50 acre plots.

Site: Margin of a shallow lake of clear water about 1½ feet deep. Trial area shaded, no water flow apart from wind movement.

Assessment: 10 months after treatment.

Results: No effects apparent.

2. Experiment No. H/39/55. Location: Hingham, Norfolk.

Plants present: Carex spp. and a little Sparganium sp.

Date of treatment: 18.5.56.

Treatment: Monuron pellets containing 50 per cent monuron, applied at 25 lb/ac

Site: As above.

Assessment: 24.5.57.

Results: Very effective treatment, complete suppression of Carex and Sparganium.

3. Experiment No. W/20/57. Location: Oxford.

Plants Present: Elodea canadensis (Canadian pond-weed), Callitriche stagnalis (Starwort), Myriophyllium spicatum (spiked water-milfoil) Hottonia palustris (water violet) and Utricularia vulgaris (greater bladderwort).

Date of treatment: 12.7.57.

Treatments: 4 lb/ac simazine pellets (2 per cent w/w).

Site: Narrow drainage channel, water clear and about 2 ft deep; treated area shaded; little flow of water.

Assessments: Many visits were made during 1957 and 1958.

Results: No apparent effects.

4. Experiment No. W/26/57. Location: Spalding, Lincs.

Plants Present: Alisma plantago-aquatica (water plantain,) Sparganium ramosum (bur-reed), Myosotis sp. (forget-me-not), Glyceria fluitans (flote-grass), Callitriche obtusangula (Starwort), Juncus spp. (rushes), Polygonum hydropiper (water pepper), and several algae including Chara spp. and Entermorpha intestinalis.

Date of treatment: 16.8.57.

Treatments: Simazine on sand (2 per cent a i) at 2, 10 and 20 lb/ac of water surface.

Site: Small drainage ditch 6 ft wide and water 1½ - 2 ft deep. Water clear and flowing, unshaded.

Assessments: 25.10.57 and 12.6.58.

Results: Although counts indicated some reduction in the number of shoots of Alisma and Sparganium on the treated plots, the plots were not distinguishable from untreated lengths of the ditch.

5. Experiment No. W/9/59. Location: Oxford.

Plants present: Mainly Elodea canadensis (Canadian pond-weed), with a few plants of Callitriche sp. (Starwort), Sparganium ramosum (bur-reed), Nasturtium officinale (watercress), Hottonia palustris (water violet), Equisetum fluviatile (water horsetail), Glyceria maxima (reed-grass) and Myriophyllum spicatum (spiked water-milfoil).

Date of treatment: 23.6.59.

Treatments: 2,4-D (ethyl hexylester) on clay granules at 5, 10 and 20 lb/ac, simazine on sand (2 per cent) at 2 and 4 lb/ac, 'Monax' granules (4 per cent monuron on sodium borates) and 'Chlorea' granules (2,4-D 1 per cent sod. chlorate 38 per cent and monuron 2.4 per cent) both to give 25 lb/ac of monuron.

Site: A three foot wide drainage ditch, partly shaded. Water clear, flowing, 1 ft over deep mud.

Assessments: Several visits were made in 1959 and 1960.

Results: No effects apparent.

6. Experiment No. W/3/60. Location: Chatteris, Cambs.

Plants present: Hottonia palustris (water violet), Myriophyllum sp. (water-milfoil) Carex sp. (sedge), Sparganium sp. (bur-reed), Callitriche sp. (Starwort), Phragmites communis (reed) Alisma plantago-aquatica (water plantain) Juncus bulbosus (bulbous rush) Hippuris vulgaris (mare's tail) Ranunculus trichlophyllu (crowfoot) and the algae Chara and Spirogyra.

Dates of treatment: 17.3.60 and 19.4.60.

Treatments: (1) 17.3.60, 20 lb/ac 2,4-D (ethyl hexyl ester) on clay and 20 lb/ac equal mixture of ethyl hexyl esters of 2,4-D and 2,4,5-T. (2) 19.4.60, 20 lb/ac (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) (methoxy propazine) 2½ per cent on sodium borates, 2,3,6-TBA 4 per cent on sodium borates at 4 lb/ac, butoxy ethanol ester of 2,4,5-TP (10 per cent on granulated 8/15 mesh attaclay) at 20 lb/ac.

Site: Drainage ditch 6 ft wide, water muddy, 1-2 ft deep over mud, unshaded, flowing slightly, pH 7.8.
Assessments: 19.4.60, 20.5.60 and 20.9.60.
Results: No effects apparent on plots treated at either date.

7. Experiment No. W/5/60. Location: Oxford.
Plants present: Hottonia palustria (water violet), Sparganium ramosum (bur-reed), Carex riparia (Great pond sedge), Myriophyllum spicatum (spiked water milfoil) and Elodea canadensis (Canadian pondweed).
Date of treatment: 28.3.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, 2,4-D acid resin-bonded pellets (70 per cent w/w) at 20 lb/ac, butoxy ethanol ester on granulated 8/15 mesh attaclay of 2,4,5-TP and 2,4-D each at 20 lb/ac and 2,3,6-trichlorophenylacetic acid 10 per cent on attaclay at 20 lb/ac.
Site: Drainage channel, partially shaded, water clear, about 2-3 ft over mud, slight flow, pH 7.8.
Assessments: Several visits during 1960.
Results: No useful effect from any treatment, although some treatments, notably 2,4-D butoxyethanol ester on attaclay, produced a number of deformities of leaves of Hottonia and slight twisting of the flower stems, but there was no effect on the subsequent flowering of this species.

8. Experiment No. W/7/60. Location: Dymchurch, Kent.
Plants present: Ranunculus sp. (crowfoot), Callitriche sp. (starwort) Elodea canadensis (Canadian pondweed) Potamageton crispus (curled pondweed) Phragmites communis (reed), Sparganium ramosum (bur-reed), Potamogeton pectinatus (fennel-leaved pond-weed).
Date of treatment: 26.4.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, butoxyethanol esters of 2,4-D and 2,4,5-TP each 10 per cent on 8/15 mesh attaclay each applied at 20 lb/ac, 2,4-D acid resin-bonded as pellets (80 per cent) at 20 lb/ac, 2,3,6-trichlorophenylacetic acid 10 per cent on 8/15 mesh attaclay at 20 lb/ac, (2-methoxy-4,6-dis-isopropylamino-s-triazine) (methoxypropazine) 2½ per cent on sodium borates at 10 lb/ac 2,3,6-TBA 4 per cent on sodium borates at 4 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac (a i).
Site: Drainage channel 12 ft wide, 2-3 ft deep, water clear and flowing over deep mud, slightly shaded, pH 6.4.
Assessments: 23.5.60, 23.8.60.
Results: No effects apparent.

9. Experiment No. W/8/60. Location: ,Pikefish stream, Nr. Marden.

Plants present: Sparganium ramosum (bur-reed), Callitriche sp.Kent. (starwort), Phalaris arundinacea (Reed-grass), Potamogeton natans (broad-leaved pond-weed), Lemna minor (duckweed), Hydrocharis morsus-ranae (frogbit) and Equisetum fluviatile (water horsetail).

Date of treatment: 27.4.60.

Treatments: 2,3,6-TBA (4 per cent w/w) on sodium borates at 4 lb/ac (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) (methoxypropazine) 2½ per cent w/w) on sodium borates at 10 lb/ac (a i) butoxy ethanol esters of 2,4-D and 2,4,5-TP 10 per cent on 8/15 mesh attaclay granules and 2,3,6-trichlorophenylacetic acid 10 per cent on 8/15 mesh attaclay granules all applied at 20 lb/ac, 2,4-D acid in resin-bonded granules (80 per cent) at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac and 2,6-dichlorobenzontrile 2½ per cent granules at 10 lb/ac (a i).

Site: Drainage channel, 10 ft wide, banks of clay, water 2-3 ft deep, clear and flowing over deep mud, no shade, pH of water 6.4.

Assessments: 23.5.60 and 23.8.60.

Results: No effects apparent.

10. Experiment No. W/9/60. Location: Oxford.

Plants present: Ranunculus sp. (crowfoot), Sparganium ramosum, (bur-reed), Elodea canadensis (Canadian pondweed) Callitriche sp. (starwort) and Polygonum amphibium (Amphibious bistort).

Date of treatment: 30.4.60.

Treatments: 2,4-D acid 80 per cent resin-bonded in pellets at 20 lb/ac 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 10 per cent on clay pellets at 20 lb/ac, (2-methoxy-4-6-bis (isopropylamino)-s-triazine (methoxypropazine) 2½ per cent on sodium borates at 10 lb/ac.

Site: Newly dredged, narrow drainage channel, 6 ft wide, water 1-2 ft deep, unshaded, slight water movement, water clear, pH of water 7.8.

Assessments: Several visits during summer, 1960.

Results: No effects apparent.

11. Experiment No. W/12/60. Location: Southery, Norfolk.

Plants present: Phragmites communis (reed) Callitriche spp. (starwort), Apium nodiflorum (fool's watercress) Veronica sp. (Speedwell) Sparganium ramosum (bur-reed) Solanum dulcamara (bitter-sweet), Agrostis stolonifera (Fiorin) Berula erecta (narrow-leaved water parsnip), Epilobium hirsutum (Great hairy willow-herb), Lycopus europaeus (Gipsy-wort), Rumex sp. (dock) and Phalaris arundinacea (reed-grass).

Date of treatment: 25.5.60.

Treatments: 2,4-D (2-ethyl hexylester) 20 per cent on clay pellets on 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, 2,4-D (70 per cent) resin-bonded in pellets, 2,4-D (7½ per cent) on sodium borates at 20 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.

Site: Overgrown drainage channel with steep tall sides, 8 ft wide at the bottom, mostly 2-3 in. of static water over deep mud, in places wet mud only, partly shaded.
Assessments: 17.8.60 and 9.9.60.
Results: No effects apparent.

12. Experiment No. W/10/60. Location: Cowbit, Lincs.
Plants present: Alisma plantago-aquatica (water plantain), Myriophyllum alterniflorum (alternate-flowered water milfoil) Veronica sp. (speedwell), Elodea canadensis (Canadian pondweed) Callitriche sp. (starwort) Ceratophyllum demersum (hornwort) Hippuris vulgaris (mare's tail), Sparganium ramosum (bur-reed), Ranunculus aquatilis (water crowfoot) Glyceria maxima (reed-grass) and Glyceria fluitans (flote-grass), Hottonia palustris (water violet) Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (fennel-leaved pondweed).
Date of treatment: 4.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay granules at 20 lb/ac, 2,4-D acid (70 per cent) resin-bonded as pellets, methoxypropazine (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) 2½ per cent on sodium borates at 10 lb/ac, and 2-6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Drainage ditch, 8 ft wide, water 1-2 ft over deep mud, no water flow, clear, unshaded.
Assessment: 18.8.60.
Results: When treated little could be seen of submerged plants because the ditch had recently been cleared out, but when assessed several plots were filled with dense Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (Fennel-leaved pondweed) and no effects were noticeable on the others.

13. Experiment No. W/13/60. Location: Stretham, Cambs.
Plants present: Glyceria maxima (reed grass), Phalaris arundinacea (reed grass), Callitriche sp. (starwort), Elodea canadensis (Canadian pondweed), Lemna minor (duckweed), Lemna trisulca (Ivy duckweed), Ranunculus sp. (crowfoot), Potamogeton crispus (curled pondweed), Nasturtium officinale (watercress) Veronica catenata (speedwell) Alisma plantago-aquatica (water plantain) and Potamogeton densus (opposite-leaved pond-weed).
Date of treatment: 25.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent in clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent in clay pellets at 20 lb/ac, 2,4-D acid (80 per cent) resin-bonded as pellets at 20 lb/ac. 2,4-D (7½ per cent) on sodium borates at 20 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Narrow steep-sided drainage channel, water 6 ft across and one foot deep and densely filled with submerged plants. No water flow.
Assessments: 18.8.60.
Results: No effects apparent.

DISCUSSION

Before discussing the reasons for the almost complete lack of effects in these experiments, the mode of action of these pellets should be considered. Grigsby and Smith (1958) summarising four seasons' work concluded (a) that the mode of action appears to be by destroying the root system of rooted submerged and emergent plants, (b) that date of application is important: early spring is best because summer applications are slow in acting although they too will ultimately destroy rooted weeds, (c) that the depth of water appears to have no effect upon the amount of herbicide required to give control, (d) 40 - 70 lb/ac 2,4-D will control Myriophyllum, Ceratophyllum and Potamogeton species for 2-4 years, (e) only compounds of the general group of phenoxyacetic acid compounds were effective. The fact that the depth of water is immaterial, in conjunction with the mention in an earlier report (Grigsby et al. 1956) that 'the boundaries of the plots were as well marked by absence of vegetation as though a mechanical shield had been placed on the bottom', appears to indicate most definitely that the effects are not due to the formation of a chemical solution in the water as a whole, especially so because the test plots of 50 x 50 ft were in a 20 acre lagoon which varied from 3 to 8 ft in depth. In addition, the destruction of the root system appears to indicate that the chemical is taken up by the roots from the surface of the mud where concentrations may be locally appreciable, although in view of the time taken for the effects to occur it may be that very small quantities of chemical are continuously taken up over a long period from low concentrations.

The experiments carried out in 1960 included species of the same genera mentioned in the North American work and some of the pellets were of similar formulations. It appears therefore that other factors such as environmental conditions or the doses applied might be the significant ones. The dose of 2,4-D formulations was standardised at 20 lb/ac because of the excellent result obtained in 1959 (Proctor, 1960) with 30 lb/ac 2,4-D pellets (supplied by Reasor Hill Corp.) and also because of useful results at 20 lb/ac elsewhere (Younger, 1959). The excellent result in 1959 mentioned above was obtained in a dammed off length of ditch which might indicate, despite evidence quoted above, that the action was by the formation of a solution throughout the water becuase the same formulation when applied to an undammed ditch on the same farm in 1960 (Expt. No. W/3/60) showed no effects. However, in Experiment No. W/12/60 at Southery in Norfolk where the water was only 2-3 in. deep and in places only wet mud, thus ruling out water movement, the results with the same formulation were again equally ineffective.

Apart then from the possible influence of unrecorded factors such as temperature, rate of plant growth etc. there appears to be no immediately obvious reason for the absence of effects. The useful result of unformulated monuron pellets in Experiment No. H/39/55 is equally unrelatable to the factors discussed above. It is therefore necessary to carry out experiments under controlled conditions to elucidate the factors influencing the action of pelleted herbicides.

Acknowledgments:

Grateful acknowledgment is made to the River Boards and Internal Drainage Boards who found such a variety of sites for these experiments and who kept them undisturbed. Thanks are due to Amchem Products Inc., Borax Consolidated Ltd., Chipman Chemical Co., Fisons Pest Control Ltd., J.R. Geigy S.A., Plant Protection Ltd., Reasor-Hill Corp. and to Shell Chemical Co. for supplying the pelleted herbicides.

REFERENCES

GRIGSBY, B.H., HAMILTON, R.H. and SMITH, J. (1956) A new approach to the Control of Certain Aquatic Vegetation. Proc 13th N. Central Weed Control Conf, 30-31.

GRIGSBY, B.H. (1957) Further Observations on the Use of Pelleted Herbicides for the control of Aquatic Weeds. Proc. 14th N.Central Weed Control Conf, 32.

GRIGSBY, B.H. and SMITH, J. (1958). Application of Granular Herbicides for the Control of Submerged Weeds. Proc. 15th N.Central Weed Control Conf, 40-1.

PROCTOR, J.M. (1960) Proc. 5th British Weed Control Conf.

YOUNGER, R.R. (1959) Progress Report on the Use of Kuron, 2,4-D and 2,4,5-TP Granules as Aquatic Herbicides. Proc. 13th N.East.Weed Control Conf, 322-8.

Site: Overgrown drainage channel with steep tall sides, 8 ft wide at the bottom, mostly 2-3 in. of static water over deep mud, in places wet mud only, partly shaded.
Assessments: 17.8.60 and 9.9.60.
Results: No effects apparent.

12. Experiment No. W/10/60. Location: Cowbit, Lincs.
Plants present: Alisma plantago-aquatica (water plantain), Myriophyllum alterniflorum (alternate-flowered water milfoil) Veronica sp. (speedwell), Elodea canadensis (Canadian pondweed) Callitriche sp. (starwort) Ceratophyllum demersum (hornwort) Hippuris vulgaris (mare's tail), Sparganium ramosum (bur-reed), Ranunculus aquatilis (water crowfoot) Glyceria maxima (reed-grass) and Glyceria fluitans (flote-grass), Hottonia palustris (water violet) Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (fennel-leaved pondweed).
Date of treatment: 4.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay granules at 20 lb/ac, 2,4-D acid (70 per cent) resin-bonded as pellets, methoxypropazine (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) 2½ per cent on sodium borates at 10 lb/ac, and 2-6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Drainage ditch, 8 ft wide, water 1-2 ft over deep mud, no water flow, clear, unshaded.
Assessment: 18.8.60.
Results: When treated little could be seen of submerged plants because the ditch had recently been cleared out, but when assessed several plots were filled with dense Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (Fennel-leaved pondweed) and no effects were noticeable on the others.

13. Experiment No. W/13/60. Location: Stretham, Cambs.
Plants present: Glyceria maxima (reed grass), Phalaris arundinacea (reed grass), Callitriche sp. (starwort), Elodea canadensis (Canadian pondweed), Lemna minor (duckweed), Lemna trisulca (Ivy duckweed), Ranunculus sp. (crowfoot), Potamogeton crispus (curled pondweed), Nasturtium officinale (watercress) Veronica catenata (speedwell) Alisma plantago-aquatica (water plantain) and Potamogeton densus (opposite-leaved pond-weed).
Date of treatment: 25.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent in clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent in clay pellets at 20 lb/ac, 2,4-D acid (80 per cent) resin-bonded as pellets at 20 lb/ac. 2,4-D (7½ per cent) on sodium borates at 20 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Narrow steep-sided drainage channel, water 6 ft across and one foot deep and densely filled with submerged plants. No water flow.
Assessments: 18.8.60.
Results: No effects apparent.

DISCUSSION

Before discussing the reasons for the almost complete lack of effects in these experiments, the mode of action of these pellets should be considered. Grigsby and Smith (1958) summarising four seasons' work concluded (a) that the mode of action appears to be by destroying the root system of rooted submerged and emergent plants, (b) that date of application is important: early spring is best because summer applications are slow in acting although they too will ultimately destroy rooted weeds, (c) that the depth of water appears to have no effect upon the amount of herbicide required to give control, (d) 40 - 70 lb/ac 2,4-D will control *Myriophyllum*, *Ceratophyllum* and *Potamogeton* species for 2-4 years, (e) only compounds of the general group of phenoxyacetic acid compounds were effective. The fact that the depth of water is immaterial, in conjunction with the mention in an earlier report (Grigsby *et al.* 1956) that 'the boundaries of the plots were as well marked by absence of vegetation as though a mechanical shield had been placed on the bottom', appears to indicate most definitely that the effects are not due to the formation of a chemical

EXPERIMENTS ON THE CHEMICAL CONTROL OF EMERGENT WATER PLANTS

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Summary: This paper describes experiments carried out on the use of chemicals, mainly dalapon (as the sodium salt), for controlling emergent water plants. Details of the effects in each experiment are given as assessed in the year after spraying. All important water plants are considered and some of less importance are also noted and included in the table of susceptibilities given at the end which is a summary of all work known to the author that has been carried out in the British Isles. The results show in general that dalapon at doses in the range of 10 - 40 lb gives satisfactory control of important emergent water weeds, although occasional failures are apparently liable to occur.

INTRODUCTION

Investigations into the use of 2,4-D have shown that useful effects on emergent water weeds in general cannot be obtained with this chemical (Dadd 1953). However, the advent of dalapon, specific to certain monocotyledons and particularly grasses, provided a possibly suitable chemical treatment because most large emergent water plants are grasses or are closely allied to them. Since the discovery of dalapon a great number of experiments have been reported, mainly from North America, on the uses of this chemical for controlling emergent water weeds. To test these uses under the conditions existing in this country and on the water plants occurring here, a number of experiments have been laid down: they are summarised in this report. More recently a recommendation (Eipper and Brumstead 1959) on the use of amino triazole for the same purpose led to the inclusion of this chemical in three experiments. A few other chemicals have also been investigated and are included.

A great number of foreign reports list only a limited number of water plants in each experiment so that information is available for only a few species. The practice adopted in the experiments detailed in this report has been to make notes on the susceptibilities of every plant present and although most of these are not included in the assessment data under each experiment they are included in the tentative table of susceptibilities at the end. In addition attention has been paid where possible to the changes occurring in the composition of the vegetation. This is of particular importance because the use of a selective chemical on a stand of mixed species could possibly result in a different problem of equal importance to the original; but perhaps less easy to solve.

METHODS, MATERIALS AND RESULTS

Because of the variability of stands of water plants it has not been possible to lay out proper replicated experiments as is usual in herbicide work. Most of these experiments are therefore observation plots which were replicated where possible. This limits the presentation of data: each experiment has here been treated separately.

All references to dalapon refer to "Dowpon"[x] and references to amino triazole with ammonium thiocyanate to "Weedazol TL"*. Technical amino triazole refers to unformulated chemical (98 per cent). The use of additional wetting agents are mentioned when appropriate in the text.

Note: All doses are given in lb a e /ac or a i /ac.

H/38/55: Hingham, Norfolk.

Plants present: Sparganium ramosum (bur-reed) Typha latifolia (great reedmace, cat's-tail), Typha angustifolia (lesser reedmace), Carex pseudocyperus (cyperus sedge), Iris pseudacorus (yellow Flag) and Phragmites communis (reed).

Object: A preliminary experiment to discover the most suitable chemicals for further investigation.

Dates of spraying and treatments: (i) 9/9/55. dalapon (sodium salt) at 20 and 40 lb/ac, ammonium sulphamate at 20, 40 and 60 lb/ac, 2,4-D (butyl ester) at 1, 2 and 4 lb/ac as an oil emulsion, monuron (as a wettable powder and as a dust) at 25, 50 and 100 lb/ac, sodium arsenite to give 7½ and 15 parts per million of arsenic trioxide.

(ii) 18/5/56, dalapon (sodium salt) at 2½, 10 and 20 lb/ac and sodium arsenite at 5 and 10 ppm of As_2O_3,

Spraying data: Spraying was carried out by a multiple jet assembly ("boomjet") or a handlance attached to a Land-Rover mounted sprayer or by a knapsack sprayer. Dusts were applied by hand. Volume rate varied from 16 gal/ac by the "boomjet" to 150 gal/ac by the handlance. Rain fell towards the end of the applications, but water-soluble treatments had been completed several hours before it started. Plots were 1/200 acre in area (1 replicate).

Site: The area varied greatly from standing water 1 - 2 ft deep to bare mud.

Assessments were made in the year following each spraying.

Results: Dalapon at 20 and 40 lb in 150 gal/ac gave a more or less complete clearance of Sparganium, Carex and Typha. Iris, however, was resistant although reduced in numbers and deformed. A little Sparganium regrew later in the following year. To confirm the effects on Iris, one further plot was sprayed in 1956 with 20 lb/ac. In the following year a considerable reduction had occurred and survivors were stunted and deformed. Other plots principally of Carex spp were treated with dalapon at 2½, 10 and 20 lb/ac in 1956, but these showed inconsistent results in 1957. Ammonium sulphamate at 20, 40 and 60 lb/ac also gave good initial clearance of the plots, but regrowth occurred and after ten months little overall effect was visible. 2,4-D (butyl ester)

* supplied by Messrs. A. H. Marks & Co.

[x] supplied by Dow Agrochemicals Limited.

at 1, 2 and 4 lb/ac in 16 gal/ac gave good control of Sparganium but Iris was resistant. Carex showed variable results and Typha augustifolia and Phragmites were unaffected. Monuron both as a dust and as a wettable powder at 25, 50 and 100 lb/ac gave complete control of Sparganium, Carex and Typha latifolia, but not of Iris. The effects were, however, very slow to appear and were complete only after ten months. Sodium arsenite at 7½ and 15 ppm gave variable results on Sparganium but no effects were apparent on Phragmites, Potamogeton sp. or Iris. Carex spp. were, however, killed by 5 and 10 ppm applied on other plots in 1956.

These results showed the possible usefulness of dalapon and monuron, but because monuron is a danger to trees (Baumgartner 1955), is slow to act and is an expensive treatment, it was decided in later experiments to concentrate on dalapon.

H/39/55: Gorehanbury

The results of experiment H/38/55 were confirmed in part by this one sprayed in September 1955. Dalapon at 20 and 40 lb/ac in 150 gal/ac gave effective control of Carex sp. and Schoenoplectus lacustris (bulrush), while 2,4-D (butyl ester) as an oil emulsion at 2 and 4 lb/ac did not. Other plants controlled by dalapon were Sparganium sp. and Glyceria fluitans (flote-grass). Equisetum fluviatile (water horsetail) was resistant to dalapon.

The results of these two experiments gave rise in 1958 and 1959 to a series of experiments using mainly dalapon to determine the susceptibilities of as wide a range of water plants as possible.

W/5/58: Oxford

Plants present: Glyceria maxima (reed-grass) the only plant.

Date of spraying: 1/9/58.

Treatments: Dalapon (sodium salt) at 5, 10 and 20 lb/ac (2 replicates).

Spraying data: Applied with an Oxford Precision Sprayer at 20 gal/ac.

Site: Deep alluvial mud on river bank, no surface water.

Assessments: Shoot counts in 8 sq yd/2 plots.

Results:

TABLE I. GLYCERIA MAXIMA (SHOOT COUNTS)

Date of assessment	6/4/59		28/4/59		17/6/59	
Treatment	Shoot counts	percent reduct cf. control	Shoot counts	percent reduct cf. control	Shoot counts	percent reduct cf. control
Dalapon 5 lb/ac	111	90.8	350	66.9	718	29.7
" 10 "	16	98.7	68	93.6	838	17.9
" 20 "	3	99.8	12	98.9	173	83.1
Controls	1208		1058		1021	

(prespray controls 1360)

(78178)

The considerable regrowth of Glyceria occurring on 5 and 10 lb/ac plots between the second and third assessment is characteristic of the effect of dalapon on certain grasses: a dormancy is induced which may disappear later on. In June 1960 (two years after spraying) counts were made of the commonest invading plants. Urtica dioica (stinging nettle) averaged 98 shoots per treated plot and controls averaged 4; Epilobium hirsutum (Great hairy willow-herb) averaged 54 on treated plots with one on controls and Equisetum palustro (Marsh horse-tail) averaged 13 and 1 shoot on controls. These figures show the great increase of other species once the dominance of Glyceria is broken. Invading species that occurred less frequently were Cirsium arvense (creeping thistle), Poa trivialis Rumex conglomeratus (sharp dock), Galium aparine (cleavers) and Cardamine pratensis (lady's smock).

W/7/58: Oxford

Plants present: Phragmites communis (reed)

Date of spraying: 12/9/58, resprayed 11/9/59

Treatments: Dalapon (sodium salt) at 2½, 5, 10, 20 and 40 lb/ac.

Spraying data: Sprayed with an Oxford Precision Sprayer, 20 gal/ac.

Sites: Waterlogged field.

Results: Counts in June and September of the following year showed little useful effect by any dose (40 lb/ac gave 65 per cent reductions of average control plots in September). 10, 20 and 40 lb/ac plots were resprayed with the same doses on 11/9/59 and counts in the following August showed no increased effects. The poor results after repeated large doses are at variance with results obtained elsewhere.

W/14/58: North Hinksey, Oxford

Plants present: Sparganium ramosum (bur-reed), Phragmites communis (reed), Carex spp. (sedges) and Iris pseudacorus (yellow flag)

Date of spraying: 16/9/58

Treatments: Dalapon (sodium salt) at 10, 20 and 40 lb/ac in 100 gal/ac with 1 per cent "Teepol" added (1 replicate)

Spraying data: Sprayed with an adjustable hollow cone nozzle on a hand-lance attached to a Land-Rover mounted sprayer.

Site: A ditch with shallow (c. 1 ft deep) water, more or less static, covering deep mud.

Assessments: 12/5/59 and 21/7/59.

Results: All doses of dalapon gave excellent clearance of the vegetation, On the control area the water surface was hardly visible at all but on treated plots with the exception of a few small shoots the ditch was clear. It is of interest that no invasion by other plants occurred and even Callitriche sp. which had been present originally had not increased.

W/15/58: Oxford.

Plants present: Schoenoplectus lacustris (bulfush), Sparganium ramosum (reed-grass), Carex spp. (sedges) Iris pseudacorus (yellow flag) and many others.

Date of spraying: 16/6/58, resprayed 27/8/59.

Treatments: Dalapon (sodium salt) at 5, 10, 20 and 40 lb/ac in 100 gal/ac with 1 per cent "Teepol" added. (2 replicates with controls at both ends of each treated plot).

Spraying data: Sprayed with an adjustable hollow-cone nozzle on a handlance attached to a Land-Rover mounted sprayer.

Site: Water-logged bank of drainage channel.

Assessments: A number of assessments were made both in 1959 a year after the first spraying and in 1960, the year following the respraying.

Results:

TABLE II. THE RESPONSE OF EMERGENT SPECIES TO A SINGLE TREATMENT WITH DALAPON AS MEASURED BY SHOOT COUNTS IN THE YEAR FOLLOWING TREATMENT

(2 replicates. 10 sq yd/plot)

Sprayed 16/9/58, assessed 17/6/59

Treatment:	Schoenoplectus lacustris (bulrush)		Sparganium ramosum (bur-reed)		Phragmites communis (reed)	
Treatment:	Shoot totals	percent reduct cf. controls	Shoot totals	percent reduct cf. controls	Shoot totals	percent reduct cf. controls
Dalapon 5 lb/ac	326	-61.4	54	60.0	9	88.3
Adjacent controls	202		135		77	
Dalapon 10 lb/ac	264	21.2	104	37.3	36	18.2
Adjacent controls	335		166		44	
Dalapon 20 lb/ac	203	59.2	83	46.8	2	89.5
Adjacent controls	497		156		19	
Dalapon 40 lb/ac	65	85.8	37	78.1	6	80.6
Adjacent controls	459		169		31	

TABLE II. (Continued)

Treatment:	Glyceria maxima (reed-grass) shoot totals	Glyceria maxima (reed-grass) percent reduct cf. controls	Carex spp. (sedges) shoot totals	Carex spp. (sedges) percent reduct cf. controls	Iris pseudacorus (yellow flag) shoot totals	Iris pseudacorus (yellow flag) percent reduct cf. controls
Dalapon 5 lb/ac	70	65.5	23	63.5	310	24.0
adjacent controls	203		63		408	
Dalapon 10 lb/ac	33	83.7	18	77.8	240	32.8
adjacent controls	203		81		357	
Dalapon 20 lb/ac	11	95.1	15	79.5	165	54.8
adjacent controls	225		73		365	
Dalapon 40 lb/ac	21	90.7	13	81.7	69	86.3
adjacent controls	227		71		503	

Selected plots were resprayed on 28/8/59. The plots that originally received 20 and 40 lb/ac were resprayed with either 20 or 40 lb/ac to give four treatments. The average effect of these double doses (20 + 20, 20 + 40. 40 + 20 and 40 + 40) as counted in the following year are shown in Table III. Of the two plots that originally received 5 lb/ac one was treated with amino triazole (technical) at 20 lb/ac and the other with amino triazole with ammonium thiocyanate also at 20 lb/ac. To all these resprays 1 per cent "Teepol" was added.

TABLE III. THE EFFECT OF DOUBLE APPLICATIONS OF DALAPON ON DENSITY OF EMERGENT WEEDS

(Average counts from doses of 20 + 20, 20 + 40, 40 + 20 and 40 + 40)

Shoot counts in 40 sq yd/plot

Plant	Treated Plots	Untreated plots	percent reduction cf. controls
Schoenoplectus lacustris (bulrush)	105	1023	98.7
Sparganium ramosum (bur-reed)	374	747	49.9
Phragmites communis (reed)	21	167	87.4
Glyceria maxima (reed-grass)	25	246	89.8
Carex spp. (Sedges)	113	67	80.6
Iris pseudacorus (Yellow flag)	206	1102	81.3

TABLE III. (Contd.)

Plant	Treated Plots	Untreated Plots	Percent reduction of Controls
	Shoot counts in 40 sq yd/plot Shoot counts in 40 sq yd/plot		
	Plant counts in 40 sq yd/plot		
<u>Caltha palustris</u> (Marsh marigold)	224	156	-43.6
	Shoot counts in 10 random sq yd quadrat/plots		
<u>Mentha aquatica</u> (Water mint)	2321	718	-223.3
<u>Equisetum fluviatile</u> (Water horsetail)	2432	696	-249.4
<u>Oenanthe fistulosa</u> (Water dropwort)	988	448	-120.5
<u>Ranunculus repens</u> (Creeping buttercup)	291	144	-102.1

This table shows that the large water weeds have all been usefully reduced in numbers with the possible exception of Sparganium. Conversely the plants that are resistant to dalapon treatments, which in this experiment are all small herbs, have increased in number. Amino triazole treatments gave promising clearance of large plants and controlled a greater number of species than dalapon, notably <u>Mentha aquatica</u>. Additional plots in this experiment with a cover mainly of <u>Glyceria maxima</u>, <u>Sparganium</u> ramosum and Iris pseudacorus were sprayed on August 27th 1959 with 2-chloro-4-ethyl amino-6-isopropylamino-s-triazine (atrazine) and isodiazine at 4 lb/ac in 100 gal/ac. Assessment in 1960 showed no apparent effect with either.

W/26/59: Oxford

In 1959 three sets of observation plots were laid down, (W26, 28 and 29/59) (W/26/59) was a test to confirm the susceptibility of <u>Schoenoplectus lacustris</u> to dalapon. Small stands of the plant were sprayed with 20 and 40 lb/ac of dalapon in 100 gal/ac with ¼ per cent "Teepol" added. Assessment in 1960 showed about 90 per cent kill with both doses.

W/28/59

This was on <u>Glyceria maxima</u> and was to obtain confirmatory evidence on the susceptibility of this grass to dalapon and also to test out amino triazole with ammonium thiocyanate added. Plots were sprayed with dalapon at 40 lb/ac and amino triazole at 20 lb/ac in 20 gal/ac on 11/10/59. An assessment in May 1960 showed virtually no regrowth, but by July all plots were almost indistinguishable from the controls except for a slight reduction in height. It is evident that the induced dormancy mentioned under W/5/58 above has, in this instance, not persisted at all although the dalapon dose was higher.

W/29/59: Oxford

This was on several water plants comparing the effects of dalapon and amino triazole with ammonium thiocyanate added. Dalapon was applied at 20 and 40 lb/ac and amino triazole at 20 lb/ac in 100 and 200 gal/ac with 0.25 per cent "Teepol" added on 11/9/59. Assessed on 3/6/60 dalapon at 20 lb/ac had given very good control of Glyceria maxima. Amino triazole had given good control of Sparganium ramosum and Schoenoplectus lacustris, but on one of the three plots of the latter there was only about 50 per cent kill.

In 1960 observation plots were laid down on Iris pseudacorus. Iris appears to be one of the more resistant water plants and when it was reported (Watson and Leasure 1959) that O-(2,4-dichlorophenyl) O-methyl isopropylphosphoroamidothioate was toxic to cultivated Iris in North America, it appeared that this compound merited investigation.. It was sprayed onto Iris pseudacorus at 9½, 60 and 90 lb/ac in 106, 40 and 60 gal/ac respectively on 17/5/60. Assessment of the plots on 2/9/60 showed no apparent effect at any dose.

DISCUSSION

The results obtained from W/15/58 indicate the useful selectivity of dalapon and the change in the composition of the vegetation that has taken place. This shift in populations of different species was beneficial as far as the maintenance of water-courses is concerned. The resistant species that increased in abundance cannot be regarded as undesirable. They are small and unlikely to impede water flow and may in fact be useful in holding mud and preventing it eroding. A rather different change in flora, however, occurred on the river bank in experiment no. W/5/58. The reduction of Glyceria maxima allowed a number of plants to colonise the area, of these the new dominant species i.e. Urtica dioica and Epilobium hirsutum cannot be considered desirable. A third type of result was seen in a shallow ditch in experiment no. W/14/58 where a mixed stand of water weeds was cleared and remained clear for at least 10 months after spraying. All the experiments fall into one of these three categories. In some it would be difficult to forecast what the change would be: these are the areas where all species present are susceptible. Where there are mixed susceptible and resistant plants, the resistant species are likely to spread over the area.

On the whole there is comparatively good agreement of results between the effects of dalapon on a species in one experiment and the effects on the same species in another, but there are occasional results that do not conform to the general picture. These exceptions may be due to a number of factors and it will take a long time to investigate them on water plants. The primary purpose behind the experiments detailed above was to collect as much information on as many species as possible so that a table could be drawn up of their approximate susceptibilities to dalapon. This has been done and is given in Table IV.

TABLE IV. TENTATIVE LIST OF THE SUSCEPTIBILITY OF WATER PLANTS TO DALAPON

(Treatments have varied between 10 and 40 lb/ac and as a number of gradings of small plants are based upon only one or two observations no definite dose of dalapon is given).

S = susceptible
MS = useful results can be obtained in the dose range 10-40 lb/ac
MR = no useful results obtained
R = unaffected.

When more than one grading is given, they show the variations obtained from several experiments.

Alisma plantago-aquatica (Water plantain)	R
Apium nodiflorum (Fool's watercress)	R
Butomus umbellatus (Flowering rush)	R
Callitriche sp. (Starwort)	R
Caltha palustris (Marsh marigold)	R
Carex pseudocyperus (Cyprus sedge)	S
Carex spp. (sedges)	S-MS-MR
Dipsacus fullonum ssp. sylvestris (Wild teasel)	R
Epilobium hirsutum (Great hairy willow herb)	R
Equisetum fluviatile (Water horsetail)	R
Filipendula ulmaria (Meadow sweet)	R
Galium palustre (Marsh bedstraw)	R
Glyceria fluitans (Flote-grass)	S-MS
Glyceria maxima (Reed-grass)	S-MS-MR
Hydrocharis morsus-ranae (Frog-bit)	R
Impatiens capensis (Orange balsam)	R
Iris pseudacorus (Yellow flag)	MS-MR
Juncus effusus (Soft rush)	S
Lemna gibba (Gibbous duckweed)	R
Lemna minor (Duckweed)	R
Lysimachia vulgaris (Yellow loosestrife)	R
Lythrum salicaria (Purple loosestrife)	R
Mentha aquatica (Water mint)	R
Menyanthes trifoliata (Buckbean)	R
Myosotis palustris ssp palustris (Water forget-me-not)	R
Nasturtium officinale (Watercress)	R
Nuphar lutea (Yellow water-lily)	R
Oenanthe fistulosa (Water dropwort)	R
Oenanthe fluviatilis	R
Phalaris arundinacea (Reed-grass)	MS
Phragmites communis (Reed)	S-MS-MR
Polygonum amphibium (Amphibious bistort)	R
Polygonum hydropiper (Water pepper)	R
Potamogeton natans (Broad-leaves pond-weed)	R
Ranunculus lingua (Great spearwort)	R
Ranunculus repens (Creeping buttercup)	R
Rumex conglomeratus (Sharp dock)	R
Rumex hydrolapathum (Great water dock)	R
Sagittaria sagittifolia (Arrow-head)	R
Schoenoplectus lacustris (Bullrush)	S-MS
Scrophularia nodosa (Figwort)	R
Scutellaria galericulata (Skull-cap)	R
Sium latifolium (Water parsnip)	R

Solanum dulcamara (Bittersweet)	R
Sparaganium ramosum (burreed)	S-MS-MR
Stachys palustris (Marsh woundwort)	R
Stellaria paulustris (March stitchwort)	R
Typha augustifolia (Lesser reedmace)	S
Typha latifolia (Great reedmace)	S
Veronica catenata (Speedwell)	R

Most of these gradings are derived from experiments carried out by the Weed Research Organisation, but a few are from experiments by Borax Consolidated Ltd., Dow Agrochemicals Ltd., and the Kent River Board.

Although three-quarters of the species in Table IV are resistant, most of the resistant plants are small dicotyledons, while the majority of the large water plants are to varying degrees susceptible. All plants with surface floating leaves that have been tested are apparently resistant. All submerged plants are apparently resistant to sprayed applications of up to at least 40 lb/ac.

Acknowledgements

Thanks are due to all those individuals and organisations who found or provided sites for experimental purposes: also to those who helped in the spraying and assessment of these experiments, often under unfavourable conditions.

REFERENCES

BAUMGARTNER, L. L. (1955). A case History of a Misapplication of CMU for Aquatic Weed Control. Proc. 9th Ntheast Weed Control Conf. 559-62.

DADD, C. V. (1953). Weed Control in Farm Ditches. Proc Brit Weed Control Conf. 400-406, 409-411.

EIPPER, A. W. AND BRUMSTEAD, H. B. (1959). How to Control Weeds and Algae in Farm Ponds. Ext. Bull. Cornell State Univ No. 1014 pp.32.

WATSON, A. J. AND LEASURE, J. K. (1959). Zytron, a Promising Material for Crabgrass Control. Down to Earth. 15, (3). 2-5.

CHEMICAL CONTROL OF WEEDS IN FARM DYKES 1959 and 1960

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National Agricultural Advisory Service Eastern Region

Summary: Acrolein gave a rapid kill of broad leaved species in stagnant water but application was difficult and control of some species was short-lived. Acrolein might have value where the rapid killing and collapse of vegetation was required in emergency conditions. Atrazine, and to a lesser extent, simazine, appeared to have some value for the control of vegetation in marshy-bottomed dykes. Good results were produced by 2,4-D pellets. Some excellent control was obtained of a wide range of broad leaved species and Sparganium in near-stagnant water. Pellets appeared to be a very suitable formulation for dyke work.

INTRODUCTION

The N.A.A.S. Eastern Region Crop Husbandry Department became interested in the work following the success reported by the Shell group in U.S.A. with acrolein (Van Overbeek 1958). The Department's co-operation was sought by the A.R.C. Unit of Experimental Agronomy for field scale trials with this material and the opportunity was taken of testing other new materials. The work was carried out in 1959 and 1960.

METHODS AND MATERIALS

Chemicals were tested in single lengths in any one farm dyke, dams being used to separate plots in some cases. The wide variation in the distribution of species encountered in most dykes made replication and critical control impossible This was not wholly unsatisfactory since large effects only were being sought.

The materials tested were acrolein (liquid), simazine, atrazine, trietazine (each as a 50 per cent wettable powder) "Chlorea", "Monax" (pelletted herbicide mixtures containing monuron) and 2,4-D pellets (several formulations). Fuller details are given in the Table I. Most of the work was carried out near Manea, Cambs. Consultations were held with the Ouse River Board to ensure that fishing interests would not be affected by any of the chemicals used.

Note: All doses are in terms of a e or a i.

RESULTS

Acrolein

The 1959 work was predominantly with acrolein. This very volatile liquid was injected into the dykes by a special hand operated apparatus (Stovell 1960) and immediately stirred in by hand. The latter operation was laborious but essential to prevent complete loss of the chemical into the air. Water flow was in no circumstances sufficient to allow it to be used as in the U.S.A. where it is mixed at weirs and allowed to flow down stream in a weed killing blanket. By comparison with the United States experience, fairly high rates were used since temperatures were considerably lower. Acrolein is highly toxic to fish but is rapidly inactivated.

TABLE I. DETAILS OF

(NOTE - Lack of mention may imply that the species was not present
In the interests of brevity, weed species are referred to
more than one species of any genus is involved)

Chemical	Composition	Supplier	Dose	Date Applied
Acrolein	Acrolein	Shell Chem. Co.	15, 30 & 60 ppm	26. 5. 59.
Simazine	50 per cent wettable powder	Fisons Pest Control Limited	20 lb ac	"
Atrazine	"	"	"	"
	"	"	"	"
Trietazine	"	"	"	"

(78178)

where the chemical was tested.
by their generic name after their first mention, except where

Dyke Condition	Species markedly affected	Notes
c. 9 in. of water-plots contained within dams. Water temperature 53°F.	Alisma plantago-aquatica, Hippuris vulgaris, Sparganium ramosum, Callitriche sp., Myriophyllum spicata, Elodea canadensis, Potamogeton crispus, Ranunculus aquatilis, Nasturtium officinale, Chara and other algae (all seriously affected within 4 days.)	Glyceria maxima, Phragmites communis, Carex sp. and Typha latifolia were resistant. Regrowth of Alisma was evident within 4 weeks and the dyke was completely choked with a variety of species within a year. Differences between rates not very marked.
Marshy bottomed	Alisma, Callitriche sp., Berula erecta, Epilobium hirsutum, Hippuris, Hottonia palustris, Ranunculus scleratus, Juncus spp., brambles, Glyceria, Agrostis stolonifera, Galium palustre and Lysimachia vulgaris	Practical control for 16 months
Marshy bottomed	As simazine but also Typha latifolia	" " " "
c. 9 in. water - dam at lower end of plot	None	-
Marshy bottomed.	None	-

TABLE I.

Chemical	Composition	Supplier	Dose	Date Applied
"Chlorea"	Pelleted mixture of sodium chlorate, borate, 2,4-D and monuron ⁕	Chipman Chem. Co.	2 cwt/ac, equiv. to about 10 lb ac monuron	26. 5. 59
"Monax"	Pelleted mixture of borates and monuron ≁	-	" "	" "
2,4-D ("Weed Rhap 20")	20 per cent 2,4-D clay based pellets ⁕⁕	Reasor-Hill Corp.	30 lb/ac	"
2,4-D	75 and 80 per cent 2,4-D resin bonded pellets.	Shell Chem. Co.		31. 5. 60 8. 8. 60 18. 8. 60 26. 5. 59 From 8. 6. 59 to 20. 5. 60

⁕ Telver 'W' (80 per cent monuron 3 per cent; powdered Borax (decahydrate) cent; 2,4-D Sodium salt .125 percent.

≁ Telver 'W' (80 per cent monuron) 5 per cent; Borax (decahydrate) 81.5 per

⁕⁕ 2,4-D iso-octyl (2-ethyl hexyl) ester 30.12 per cent and 69.88 per cent inert

(Contd.)

Dyke Condition	Species markedly affected	Notes
Marshy bottomed.	Typha, Alisma and Agrostis stolonifera.	Control for 16 months. Lower rate of 2/3 cwt was unsatisfactory
Marshy bottomed.	None	Some check to Typha.
c. 9 in. of water	None	-
c. 9in. of water - dam at upper end of plot.	Alisma and Sparganium (apparently affected most readily) Callitriche, Nasturtium, Ranunculus aquatilis, Potamogeton crispus, Hippuris, Myriophyllum and Oenanthe sp., Elodea least affected	Where applied in May '59 Alisma and Sparganium were still well controlled (86 per cent and 100 per cent respectively) 12 months later. Submerged species did not completely recolonize until about 12 months after application. No evidence of differences between formulations which were not compared directly until 1960, most of which tests failed through absence of dams.
6 in. of water within dams		
6-18 in. of water within dams, long dyke.		
6-18 in. of water, long stagnant dyke.		
Marshy bottomed	None	
Various standing water dykes with no dams.	None	

37.5 per cent; Sodium carbonate dense, 20.25 per cent; Sodium chlorate 38 per cent; powdered glue 2 per cent; Neobor (pentahydrated) Borax 11.5 per cent

ingredients (clay) = 20 per cent a e w/w 2,4-D

Where dams were employed, acrolein applied on 26th May at 15, 30 and 60 ppm gave, within four days, an excellent kill of most of the leaves of a wide range of broad leaved species and Sparganium ramosum. Regrowth of Alisma plantago-aquatica and Sparganium ramosum was fairly rapid so that the plots required to be roded in the normal manner in the autumn. Where short plots without dams were treated control was poor. This was thought to be due to dilution of the chemical.

Simazine, Atrazine and Trietazine

These were applied on 26th May, 1959 at 20 lb/ac. In marshy-bottomed dykes atrazine was more rapid in its action than simazine. Both gave a complete top kill of a wide range of species and a good control was still evident 16 months later. Typha latifolia was well controlled by atrazine but not by the other two triazines. Trietazine was not effective in marshy conditions. Only atrazine was tested in standing water where it was found to be ineffective.

"Monax" and "Chlorea"

These pelleted "Complete" weedkiller mixtures were applied at up to 2 cwt/ac (giving 10 lb monuron/ac besides other chemicals). Applied on 26th May "Chlorea" gave a very good control (for at least 16 months) of Typha latifolia in a marshy bottomed dyke while "Monax" was less satisfactory. "Monax" was quite ineffective in standing water.

Pelleted 2,4-D

All were tested at 30 lb/ac. No real comparison was made between them, the main reason for using the different formulations being their availability. All were described as being slow release formulations and it was thought that the chemical might be taken up directly by the roots with negligible release into the water and consequently no risk in water use.

The first applications were made on 26th May, 1959 in a marshy dyke and in standing water with a dam at one end of the plot. Although effects were slow in comparison with acrolein the water application gave a very good control of Alisma and Sparganium and markedly reduced the growth of submerged species. In marshy conditions the treatment was ineffective. Several further applications were made in standing water, without dams to control water flow, with no apparent effect on the weeds. At the time this was thought to be due to the lateness of application.

Due to the first excellent results in standing water more extensive testing was planned for 1960. The plan was to compare monthly applications beginning in mid March (2 dykes) and study the effects of the material in contrasting dyke conditions (3 widespread sites). By 20th May only very minor effects of treatment could be discerned and the only possible explanation seemed to lie in the loss of the chemical in the water. Work elsewhere (Chancellor 1960) with 2,4-D pellets, without dams, was reported to be equally unpromising. A comparison was then made in dammed plots of two types of 2,4-D pellets and a spray application, on 31st May. All treatments were very effective, the spray being slightly quicker and affecting Carex sp. in addition to the species controlled by the pellet formulations. It was subsequently observed in a non-dammed dyke that a late May application caused distortion of Alisma to a gradually reducing extent for 150 yd "downstream" and only 20 yd upstream from the treated area, the rate of water flow being imperceptible.

On 8th August 2,4-D pellets were applied, at Manea, in a ½ mile of Alisma-infested dyke which was sealed off at the pipes under bridges. Nevertheless an appreciable water flow was observed ten days later, following heavy rains. Effects on Alisma were very apparent at that date and by 20th September it was clear that a very good control had been obtained of both Alisma and Sparganium, although it was thought that earlier application would have been better. Samples of water were taken from this dyke on 18th and 23rd August and tested for presence of 2,4-D by the Went pea test. These showed a slight but positive reaction. No reaction was observed on a sample taken on 29th August.

On 18th August about a ½ mile of dyke was treated with 2,4-D pellets at Wormegay in Norfolk. The dyke was blind at one end and constricted at the other so that water flow could be expected to be very limited. A Went pea test on a water sample taken on 29th August was more clearly positive than any obtained at Manea. On that date it was clear that the Callitriche sp. was markedly affected, the leaves being curled though still fairly green. By 20th September practically all the Callitriche was dead and Alisma and Sparganium were dead or dying. Only Potamogeton natans appeared to be unaffected.

Both long stretches of dyke were treated at the request of the farmers.

Details of species controlled by the different treatments are given in Table I.

DISCUSSION

The maintenance of free water-flow in dykes is directly related to weed growth. Weed clearance is laborious and costly and during the time of maximum growth, dykes may be so clogged that there may be a danger of flooding should heavy storms occur. The general problems of chemical control have, however, been fully discussed previously (Dadd 1953). The particular value of acrolein would seem to be its ability to give a rapid kill of aquatic vegetation but the difficulty of applying it and the danger to fish suggest that it is unlikely to be used on a wide scale. In any case it would require to be handled by a trained operator. Acrolein compares unfavourably with 2,4-D pellets so far as persistency of control is concerned. While those chemicals giving total weed control may have an occasional place on the farm, the rates necessary are heavy and a danger to crops could arise when dykes were dragged out. Of those tested, atrazine would seem most effective. 2,4-D pellets were, by comparison, with acrolein, rather slow acting. Circumstantial evidence suggests that 2,4-D acted directly through water solution and not through the roots as had been supposed. This raises the question whether it would not be better to apply 2,4-D as a spray which would be more effective on emerged species than the pellet formulation. Sprays so far have not been accepted for this work due largely to a lack of suitable equipment, the difficulties of access, danger of drift onto adjoining crops and the general dangers to other water users of 2,4-D in solution. Pellets applied by hand are very convenient by comparison. It is possible that the slowness of the 2,4-D release from the pellets might greatly reduce the danger from this chemical to other users of the water as its concentration in the water would be very low by comparison although present over a long period. On the other hand quick release would give better control where there was appreciable water movement.

It is obvious that careful investigation of the risks of water contamination must be made before the material can be recommended for farm use, particularly in areas where dyke water is used for irrigation. On a cost basis (approx 2s 0d per chain 4 ft wide) 2,4-D pellets compete very favourably with other methods of control, especially since some species may be controlled for 16 months or more.

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Grateful thanks are due to the farmers in whose dykes the work was done; also for advice received from the Great Ouse River Board. Thanks are also due to the suppliers of the chemical formulations.

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REFERENCES

CHANCELLOR R. J. (1960) Results of some Preliminary Experiments on the use of Pelleted Herbicides for controlling submerged Water Plants. Proc 5th Brit Weed Control Conf.

DADD C. V. (1953) Weed Control in Farm Ditches. Proc 1st Brit Weed Control Conf. 400-406

STOVELL F. R. (1960) A progress Report on the Development of Aquatic Weed Control. Proc. 5th Brit. Weed Control Conf.

VAN OVERBEEK J. (1958) New Herbicide for Aquatic Weed Control. Proc. 4th Brit. Weed Control Conf. 259-261

A PROGRESS REPORT ON THE DEVELOPMENT OF AQUATIC WEED CONTROL

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Summary: The report describes five trials with an acrolein formulation (EF 1015) and three trials with 2,4-D pellets for the control of submerged aquatic weeds, carried out during 1959 and 1960. A method of using EF 1015 in static water is described and the danger to fish is discussed. This is thought to be inversely proportional to the opportunities for the fish to move to untreated waters. Resin-based 2,4-D pellets of very low toxicity to fish are described. Their use is effective in static and slow moving water but may provide hazards, which are at present being investigated, if this is used for crop irrigation.

INTRODUCTION

The River Boards and other authorities are already well equipped with weed cutting boats for dealing with the problem of aquatic weeds in navigable channels but the small water courses, which are of vital importance in land drainage, present a more difficult task, the major part of which must be carried out by hand. The figure of £850,000 has been mentioned (Spalding 1958) as spent by water boards alone annually, on hand clearing ditches, so bearing in mind the advance in chemical weed control over the last decade, it was only natural that those concerned with the control of aquatic weeds should turn to chemicals for assistance in this work. Emergent species may be tackled relatively easily by means of a spray application to the aerial shoots, but the principal restriction to water flow is caused by submerged weeds. The majority of these submerged species are relatively simple organisms and susceptible to chemicals used for terrestrial weed control. The problem lies in the method of treatment and the selection of most suitable material. Two possible candidate materials have been considered, the acrolein based herbicide (F.98) (Van Overbeek 1958) and a granular formulation based on 2,4-D. The acrolein based herbicide seemed promising because of its rapid action and particular effectiveness against algae while the granules seemed to offer a simple method of application.

PART I. ACROLEIN HERBICIDE FORMULATION EF.1015

Results from the U.S.A. indicated that, in stagnant water, five ppm was sufficient at 70°F to control weeds and that the dose must be doubled for each 10° fall in temperature. Trials to confirm this for the lower temperatures usually obtaining in the United Kingdom were carried out in 1959 and are reported elsewhere (Proctor 1960). In these trials acrolein (F.98) was injected beneath the surface in small doses of 5 - 10 ml at intervals calculated to produce the required concentration. The doses were accurately measured and introduced by a special metering device, the operator carrying a small can of acrolein on his back. The water was agitated to ensure adequate mixing of the herbicide.

The results from the initial trials were variable. The control was less satisfactory where the shallowness of the stream, or the quantity of emerged weeds made agitation difficult. Further work was carried out on the formulation to improve the rapidity with which was dispersed in the water, this was given the number EF.1015. On the applicator the flexible outlet was changed for a semi-rigid one terminating in a fan jet to assist further in dispersing the toxicant. The connections to the drum were also improved.

These modifications were tested but owing to the advancing season application was difficult due to the presence of flowering heads of *Alisma*. The results of this trial were disappointing, but it was decided to repeat the work.

METHODS, MATERIALS AND RESULTS

A series of plots were treated at Stalham, Norfolk, on August 26th 1959.

Water Temperature: 67 - 68°F.

Site: Dyke 12 ft wide 15 in. deep. Dammed to prevent movement.

Treatments: Acrolein at 10, 7½ and 5 ppm.

Plot lengths: 30 to 50 yd half plots only agitated

Weeds Present: *Myriophyllum* sp. *Callitriche* sp. *Chara* sp. algae, *Lemna minor*, *Lemna trisulca*, *Elodea canadensis*, *Potamogeton natans* and *Alisma plantago-aquatica*.

Weeds mainly submerged, some flowering heads of *Alisma* present.

Observations:

Treatment 26.8.60	5 ppm	7½ ppm	10 ppm
4.9.60	All effect much slower. *Lemna* and algea still present, but both brown. Agitated and unagitated plots the same	Good control but not so much collapse as 10 ppm. Some *Alisma* still emerged.	No weeds above surface but plenty of dead weeds collapsing beneath the water which was clearing. Agitated and unagitated plots equal.
16.9.60	Water now clear. No weeds above surface. Decomposing weeds below surface.	Some patches of algae 2-3" diameter present. Pinkish-white in appearance. Patches possibly larger in unagitated plot. Dead weeds visible under water.	Water still clear. Few decomposed weeds visible.
19.10.60	Some leaves of *Alisma* being produced.	Algae patches disappeared. Plot weed free.	Still clear of all growth.

No significant difference could be seen between the plots agitated and those not agitated except for 7½ ppm plot on September 16th. Some difficulty was experienced in treating this plot owing to emerged heads of *Alisma*.

A further trial with improved apparatus was laid down at Stalham on July 11th 1960.

Water Temperature: 60°F

Site: Dyke 12 ft wide 9 in. deep. No damming and possibly slight flow occurred.

Weeds present: Myriophyllum sp., Alisma plantago-aquatica, Callitriche sp., Elodea canadensis, Lemna minor, Sparganium sp. and Potamogeton natans.

Treatments: Acrolein 10 ppm

Observations:

	I	II	III
Treatment 11.7.60	From one side with agitation	From one side without agitation	5 ppm from each side without agitation.
Observations 3.8.60	Some Callitriche still present but over 90 per cent weed control. Bottom clearly visible.	Some Potamogeton still present but control over 90 per cent	Myriophyllum, Potamogeton, and Callitriche disintegrating. Bottom clearly visible.

By August 3rd any differences between the effects of these treatments would have evened out and the slight variations recorded are likely to be due to the distribution of the original weed population.

At the same time another plot 6 in. deep was treated without agitation in a smaller dyke. This showed 90 per cent control of species present, Potamageton natans, Callitriche sp. and Lemna minor.

Two further bankside applications were made in 1960 with the co-operation of the Essex River Board.

Site: Tillingham 22 ft wide average depth 18 in.

Water Temperature: 60°F

Weeds: Potamogeton pectinatus, Enteromorpha intestinalis

Treatments: 10 ppm acrolein, water agitated and static.

Observations:

Treatment 22.7.60	(i) agitated	(ii) not agitated
3.8.60	Weeds dying, but not disintegrated. Algae well controlled	Not quite as good as (i) but since it was upstream (i) may have had the benefit of some of (ii)'s treatment. Algae well controlled.
15.8.60	Weeds now disintegrating. Some algae present having drifted down from upstream.	No difference now between plots.

Site: Marsh House. A much narrow stream 6 ft wide varying from 6 in. to 12. depth.
Water: Temperature 67°F

Weed: pure stand of Potamogeton pectinatus Very thick

Treatment: 15.9.60 10 ppm acrolein, agitated and not agitated.

Application was made about noon with very little water flow but 12 hours of rain fell from 6 p.m. onwards and the rate of flow increased rapidly.

Observations 5.10.60: About 50 per cent kill of foliage obtained. The surfaces of the plants were scorched but thick clumps were not penetrated. This poor result is probably due to the short exposure of acrolein due to rain.

To examine the effect in large masses of water, part of the lake at Hamptworth, Hants was treated from a punt. The acrolein (EF 1015) was released in a steady flow controlled by a constant head device. The boat traversed a series of parallel courses 15 ft apart marked by canes in the lake bed. The application was made on 21.6.60 in water of an average depth of 3 ft and a temperature of 65°F. One half of an acre was treated.

Weeds Present: Potamogeton pectinatus, Elodea canadensis. The weeds were growing up to the surface of the water.

Observations, July 6th; Weed growth had collapsed and sunk in the treated water, the bottom being visible in bright sunlight. No dead fish were found though a local bailiff had kept a constant watch.

DISCUSSION

As a result of these trials it was confirmed that a 10 ppm concentrate of acrolein in water at a temperature of 60°F controlled Callitriche sp., Chara sp., Elodea canadensis, Myriophyllum sp., Potamageton pectinatus, Potamageton natans. (submerged species) Alisma plantago-aquatica, large plants of Hippuris vulgaris and Sparganium sp. (emerged species).

In general the reaction of weeds to acrolein was fairly rapid. Stems of emerged plants rotted below water and subsequently collapsed. The leaves of Alisma bronzed, all the floating leaves of Potamogeton natans became brown, while Chara turned almost completely straw coloured in one or two days. Callitriche sp. browned much more quickly. Other submerged species showed no obvious signs of dying although they disintegrated completely by the end of 14 days. The effect of acrolein is to kill back the stems and foliage and its action, which has been described as a "chemical cutting", is extremely effective, because it is so complete. If necessary treatment can easily be repeated.

The most widely published property of acrolein is its irritant vapour which, while this makes the chemical difficult to use, has the advantage that its presence can be detected in very small quantities, far smaller than would constitute any toxic hazard. Similarly, though very toxic to fish (LD 50 for Harlequins being 0.14 ppm for 24 hours) (Alabaster 1960) if they can escape they will. In experiments in a dammed dyke thought to be free of fish an occasional eel was found killed, yet where about 1/8th of the area of a lake was treated at one time, no dead fish were seen though it was known to be well stocked with fish. The weed control indicated that very little movement of the acrolein occurred outside the treated water.

A simple test for the presence of acrolein is the rapid discolouring of potassium permanganate. Two drops of an 0.5 per cent solution of potassium permanganate in 10 ml of water are decolourised in less than one minute where more than 1 of acrolein is present. However, this test needs to be interpreted with care as decaying organic matter also causes the discolouration of the water. Cases have occurred where the reaction was negative to acrolein a few days after application yet later became increasingly positive due to the presence of organic matter in the water.

Thus it appears that given special circumstances, which must include the absence of fish or adequate opportunity for their escape, acrolein provides a rapid and effective means of clearing water channels of submerged weeds and algae in a manner least likely to cause blockages to pump inlets and sluices. While normally all traces of chemical are broken down within 48 hours, it can easily be detected both in the air and in the water by means of a simple test. This product should only be applied by trained operators.

PART II. GRANULAR 2, 4-D FORMULATIONS

The investigation of granulated weedkillers followed reports of their successful use in the U.S.A. (Grigsby and Smith 1958). Two formulations were tested, one clay, the other in a resin compound to produce a slow release of toxicants.

METHODS, MATERIALS AND RESULTS

Site: Stalham

Materials: 6 per cent 2, 4-D clay pellets. 80 per cent resin-based 2, 4-D pellets

Treatments: Clay pellets applied 26th August, 1959 to give 30 lb.ae/ac. Resin pellets applied 4th September to give 30 lb ae/ac.

Weeds present: *Myriophyllum sp.*, *Alisma plantago-aquatica*, *Callitriche sp.*, *Chara sp.*, *Elodea canadensis*, *Lemna minor* and *Algae*.

Observations:

Treatments	Clay Pellets	Resin Pellets
16.9.59	Most weeds turning brown. *Potamogeton* and *Alisma* showing greatest effect.	Slight browning of weeds on plots treated with resin pellets.
19.10.59	Some regrowth of *Callitriche*	No regrowth. All weeds dead

The question of formulation was re-considered before work started in 1960. From field observations, it was decided that a granular formulation should have the following characteristics.

1. Good carrying properties to enable application to be made to wide water channels and in moderate wind speeds.

2. Freedom from dust to avoid possible damage to susceptible crops.

3. Slow release of toxicant into the water or mud, so that the concentration which might escape is as low as possible and so that some degree of persistence can be obtained.

While clay pellets could be produced to meet requirement 1, they failed requirement 2 as they rapidly became dusty when the bags were handled. A suitable resin-based formulation EF 1223 was produced which appeared to fulfil all three requirements. This formulation also possessed the additional advantage that when tested by the Freshwater Fish Laboratory it was 6½ times safer than clay pellets to fish, which themselves did not present a hazard. The product contains 80 per cent 2, 4-D and the pellets are uniform, free from dust and about 3 mm in diameter, when applied at 20 lb ae/ac the pellets are less than 3 in. apart. This high concentration would enable the operator to treat 13/8th of a mile of dyke 6 ft wide with a single 28 lb pack of product, using a fiddle drill to distribute the granules.

Further applications were made at Stalham on 11th July, 1960, Three areas were treated with 2,4-D resin pellets.

Dose	Weeds	Observations
20 lb a e/ac.	_Myriophyllum sp._, _Potamageton sp._, _Callitriche sp._, _Sparganium sp._	3rd August. Partial control Some Myriophyllum persisting.
30 lb a e/ac.	_Myriophyllum sp._, _Sparganium sp._, _Potamogeton sp._, _Callitriche sp._,	Good control of all species.
30 lb a e/ac	_Potamageton sp._, _Callitriche sp._, _Elodea canadensis._	Some Callitriche and Potamogeton persisting.

A further site at Ashby Folville, Leics. was treated on 2nd August.

Weeds Present: _Callitriche sp._, _Alisma plantago-aquatica_, _Potamogeton natans_, _Lemna minor_.

Observations: 11th September. Considerable flow had occurred yet 80 per cent of weeds had been controlled. There was no effect on Lemna minor though this may have come down from upstream.

DISCUSSION

Rainfall during the season of 1960 was much higher than in 1959, and it appeared that the water flow through the dyke was affecting action of the chemicals. American workers had hinted that no 2,4-D was released into the water and Chancellor could find no trace of 2,4-D in water that had stood over pellets for 8 days yet the same formulations of pellets failed to work under conditions of flowing water in 1960 (Chancellor). It is possible that the action of the water on the pellets may be affected by its pH but it appears that the main route for the toxicant is through the leaves and not via the mud and roots as was originally supposed. Thus the action of the pellets was to produce a local solution of 2,4-D. Assuming immediate release of all the chemical, with no loss by absorption or by breakdown, the strength of a solution in a dyke only 6 in. deep would be approximately 14.5 ppm. In practice the release only occurs slowly and there will be losses by absorption and breakdown so that the concentration will be considerably lower. However, more work must be done on the rates of release and absorption to determine the risk from using this water for irrigation, though on a farm it would be possible to damp up ditches temporarily for treatment to prevent any escape of contaminated water. It appears that while 2,4-D pellets show considerable promise for the treatment of some species of aquatic weeds in stagnant water, the likelihood of the method working in flowing waters is much less, decreasing with increasing rate of flow. In all cases use of the water must be borne in mind.

Acknowledgements

The Author would like to thank Mr. J. M. Proctor for his assistance and encouragement with this work, and Mr. R. J. Chancellor for his advice and help in identifying weed species, in addition to those farmers and River Boards who permitted the work to be carried out in their dykes and lakes.

REFERENCES

ALABASTER, J. S. (1960) Private Communication
CHANCELLOR R. J. (1960) Private Communication
GRIGSBY H, SMITH, J. (1958) 15th North Eastern Weed Control Conference
PROCTOR J. M. (1960) Proc 5th British Weed Control Conference
SPALDING, J. B. (1958) 4th British Weed Control Conference
VAN OVERBREEK, J. (1958) Proc 4th British Weed Control Conference 259-261.

Discussion of papers on water weeds.

Mr. G. B. Lush It would seem to me that one of the problems of this type of weed control is the fate of the weedkiller further down the watercourse. I would be interested to hear what experiences any of the speakers have had on what happens further downstream where a farmer wishes to irrigate his land or to use the water for cattle. What precautions should be taken?

Mr. J. Proctor This is a very important aspect. We have no information ourselves. It must be investigated before we can use certain of these herbicides on a large scale.

Mr. Spalding (Chairman) In quite a number of sites where weeds are present, there is no 'downstream', in fact the water is stagnat. For instance, the Romney Marsh is dammed up during the summer and it is only in the event of a sudden flood that there is downstream movement of water.

Mr. G. B. Lush In was the Fenland areas, where Mr. Proctor has been operating, that I was thinking about in particular.

Dr. van der Weij In Holland we have very strict regulations for the use of herbicides in waterways. For example, we prohibit the use of herbicides in waterways flowing through horticultural districts where the water might be used for making up sprays or for overhead irrigation. These aspects are discussed more fully in my paper but there is not time to discuss them here in detail.

Mr. R. E. Longmate When spraying waterways with weedkillers, would it not be an advantage if some colouring agent could be added to such chemicals as dalapon? It would then be possible to see just where the chemical has gone? Is a colouring agent added in Holland and if so which is the agent used?

Dr. van der Weij In Holland we have never had any need for such a thing. It is important to use good equipment and we have no difficulty when using such equipment.

Dr. K. Holly We have seen in Mr. Chancellor's paper that many very important emergent weeds can be controlled by the use of dalapon, leaving a population of small resistant herbs. Are these populations of small herbs successful in preventing re-invasion by the weeds that have been controlled? Do we know what the ideal bank-side vegetation should be for keeping out emergent weeds on the borders of waterways? Should one aim to improve the grass population or something else?

Mr. R. J. Chancellor There is no precise answer. The ultimate vegetation is not known, as our experiments have been under way for only two or three years. The grasses are reduced by the use of dalapon and small herbs and dicotyledonous weeds take their place, but whether they persist as a stable community or not is unknown.

Dr. van der Weij In canals used for navigation it may be important to have a border of weeds to maintain the ditch/banks and in that case it might be better simply to check their growth. We would leave about 1 m of weeds along the banks under these circumstances.

Mr. Spalding (Chairman) From an engineering point of view the vegetation should be all roots and no top growth.

Dr. J. K. Leasure We are doing a considerable amount of work on the control of aquatic weeds. We use dalapon for the emergent weed. For the control of submerged weeds, in ponds of up to 100 acres, silvex (2,4,5-TP) is now widely used. We have had good results up to 2 years later. We have found that slightly acid or neutral waters give the best results.

Mr. J. R. Sterry Dr. Leasure says that he is using dalapon, but other people are using other things! Regarding the use of dyes with spray materials, we have known applicators demand dye materials, both oil-soluble and water-soluble, but after the first day of spraying the applicators have gone home covered in red and the demand has subsided. Have any of the speakers found any difference in rates of application of chemicals needed for emergent water weeds that are growing on dry land, or for example the ditch bank, and for those with their roots actually in the water?

Dr. van der Weij We have no conclusive results but we got the impression that on marshy soils and under water Glyceria is more susceptible to dalapon treatment.

Mr. Chancellor When I started this work, from reading the literature it appeared that weeds growing in water were less susceptible: but our results show no conclusive evidence either way.

Dr van der Zweep There is one general observation I would make. When Glyceria is growing in willow plantations, our general experience has been that it is easier to control in this situation than when it is growing in water. The willow is used for dam protection.

Mr. J. Proctor Where we have used dalapon at 15 lb/ac on reeds (Phragmites) we apparently have obtained better control than some people are getting in water. We have obtained an excellent control for at least 2 years.

Dr. van der Weij I might add something that I believe I omitted from my lecture and that is the effect of volume of spray on the efficiency of dalapon. In past years rather high doses of dalapon were used - 40 to 50 lb/ac. We have now found that 15 lb/ac is satisfactory.

Formerly in Holland it was considered advisable to spray at 1,000 l/ha or about 100 gal/ac but now we never use more than 30 gal/ac. This is because we are using a wetting agent and the higher volumes result in run-off. The film on the leaves should not be too thick. Where vegetation is dense it is necessary to use more water and also a high pressure in order that the spray will penetrate into the vegetation. There is another important matter, namely the time of application; you may be applying dalapon too early in the year. You will kill parts above the soil but will get regrowth from the treated rhizomes and it might be that this is one of the causes of your inconsistent results. I have got the impression that you do not know the best way to spray.

Mr M. V. Grant I wonder whether any of the speakers have any advice to give on the control of Equisetum in clay-lined lakes. We are finding in Oxfordshire the weed is causing the lining to break up and resulting in excessive loss of the water.

Dr. van der Weij Equisetum can be controlled by low doses of MCPA but you will have to repeat the treatment several times to get rid of the weed entirely.

SESSION X

CHAIRMAN - Dr. E. K. WOODFORD

NEW HERBICIDES AND TECHNIQUES

AN ASSESSMENT OF THE NEW HERBICIDE 2,6-DICHLOROBENZONITRILE

G. E. Barnsley

"Shell" Research Ltd., Woodstock Agricultural Research Centre

Summary: Initial screening work was carried out in the laboratory, glasshouse and field in 1959 and 1960 to define the spectrum of activity of 2,6-dichlorobenzonitrile, the herbicidal properties of which were independently discovered at the Woodstock Agricultural Research Centre in the U.K. and by Phillips Duphar in the Netherlands.

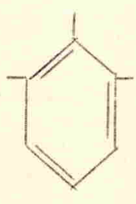
The compound's outstanding biological feature is its very high toxicity to seeds and to buds generally, and it shows, by virtue of this activity, considerable promise for the control of a wide range of annual and perennial weeds, including grasses and broad leaved species. Several important woody crops showed considerable tolerance of the compound, but otherwise 2,6-DBN has no wide selectivity. Its use in herbaceous crops will depend on the exploitation of its relatively short persistence and low water solubility. Persistence was substantially influenced by method of application and by the formulation used. Incorporation into the soil by cultivation, drenching by irrigation, or rain fall after spraying increased the persistence, and 2,6-DBN was more persistent when applied as a granule than as a spray.

INTRODUCTION

The herbicidal activity of 2,6-dichlorobenzonitrile has been recorded by Koopman (1960), Hagood (1959), and Alley (1960). Prior to these publications the present author and colleagues, investigating the phytotoxic properties of aromatic nitriles, independently discovered this highly active compound, and a detailed paper is in the press (Barnsley and Rosher) recording two years study of some of its more important properties. However, no account has yet been published of the compound's general spectrum of herbicidal activity and this is attempted in the present paper. Exploratory screening experiments are described to illustrate the potential scope of this new herbicide and factors which seem likely to influence its performance significantly.

METHODS AND MATERIALS

2,6-Dichlorobenzonitrile (2,6-DNB) has the structure.



The pure material is a white crystalline solid with a M.P. of 142°C, a vapour pressure of 5×10^{-4} mm Hg at 25°C (determined by Effusometer) and a water solubility of approximately 20 ppm at 25°C. The compound is appreciably volatile, and the 'half life' of a fine deposit on glass with an air flow of 0.5 l/min in an oven of volume 100 l was two days 40°C and fourteen days at 25°C. Its acute oral toxicity to rats is >1000 mg/Kg.

The material used in the present experiments contained not less than 95 per cent of 2,6-DBN. Doses quoted are of 100 per cent 2,6-DBN.

Laboratory experiments

In the seed germination experiment no. 1/59, 2,6-DBN was applied in acetone to 11 cm diameter germination pads in petri dishes. After allowing the solvent to evaporate 15 ml of distilled water were added, 50 seeds placed on each pad, and the dishes incubated at 25°C. The length of shoots was measured after five days.

The exposure of crop seeds to the vapour of 2,6-DBN in experiment no. 4/49, was carried out in two 10 l bell jars each containing uniform volumes of the various seeds separately contained in open petri dishes. Air was drawn through each jar at 0.5 l/min via a 9 in. length of 2 in. diameter glass tubing containing cotton wool, half of which was impregnated either with 10 gm of 6 per cent dust of 2,6-DBN or filler alone. The remainder of the cotton wool served as a filter to prevent solid particles passing out of the tube. The jars were held at 20°C for twenty days, a sample of each crop seed removed, washed in running tap water for one hour and then germinated in pots in the glasshouse.

Glasshouse experiments

In the *Salvinia* experiment no. 6/60, five plants each bearing four fronds were placed in nutrient medium with varying concentrations of 2,6-DBN. After four days, two plants from each treatment were washed in distilled water and placed in fresh culture medium free from 2,6-DBN. They were kept for ten days for an estimate of recovery to be made.

In the remaining glasshouse experiments 2,6-DBN and simazine were used as aqueous suspensions derived from a 50 per cent wettable powder. Compounds were applied either by a micrologarithmic sprayer in a volume corresponding to 50 gal/ac or as a drench at the rate of 15 ml or 30 ml per 3½ in. or 5 in. diameter pot respectively.

In all glasshouse tests, seeds were germinated and plants raised in 3½ in. or 5 in. polyvinyl pots with sterile John Innes No. 1 potting medium, except in experiment no. 3/60 in which the pre-emergence tests were carried out in 3 in. x 9 in. x 14 in. polyvinyl seed trays. The pre and post-emergence toxicity of 2,6-DBN to the crop test plants was estimated by determining the fresh weight of shoots seven to ten days after treatment, and also by germination counts in experiment no. 2/59.

The rhizomes of *Agropyron repens* and *Aegopodium podagraria* used in the glasshouse experiments, nos. 7/59 and 8/59, were obtained from dormant pure stands in a weed garden. Five sections with 1 - 3 buds on each were cut and planted 2 - 3 in. deep in John Innes No. 1 potting medium in 5 in. pots which were then transferred to the glasshouse and the compounds applied. Subsequent growth was recorded as fresh weight of shoots of Agropyron, or dry weight of roots and rhizomes in the case of Aegopodium.

In the persistence experiment no. 12/60, air dry John Innes potting medium in 5 in. pots was sprayed with 2,6-DBN and kept in the glasshouse until the appropriate time when 50 mustard seeds were sown on the surface of the soil, covered with ¼ in. of fine silver sand, and then watered by subirrigation as required until the end of the experiment.

Field experiments

All experiments were conducted at Woodstock in Kent on a Brick Earth Loam soil in 1959 and 1960. 2,6-DBN and simazine were sprayed as aqueous suspensions derived from a 50 per cent wettable powder, and the nitrile was also applied in the form of a 2½ per cent granule in experiment nos. 13/60 and 14/60. Spraying was carried out with an Oxford precision Knapsack Sprayer at the volume of 50 or 100 gal/ac. Treatments were applied to single plots only, and these were separated by discards of the same size.

Experiment no. 5/59 (potato sprout inhibition)

One cwt quantities of tubers (var. Bintje) were spread out and dusted with 100 gm of filler containing 0.25 to 5.0 gm of either 2,6-DBN or 2,3,5,6-tetrachloro-1-nitrobenzene (TCNB). The potatoes were then stored in hessian sacks in a farm building from November until January, when a 10 lb sample of tubers was obtained from each sack and the fresh weight of sprouts recorded.

Experiment no. 9/59 (herbaceous crops treated pre-emergence)

All the test crops were drilled except ryegrass which was broadcast. The plot size per dose level was 1/100 ac. Spraying was carried out as soon as possible after sowing on 4.7.59., and followed by an overhead application of about ¼ in. of water from a line irrigator. Emergence was assessed by counts of seedlings in 3 x 12 ft rows of French bean and sweet corn, 9 x 12 in. random row lengths in radish, oat, rice and sugar beet, and in 10 x 6 in. x 6 in. quadrat areas in ryegrass.

To assess the long term persistence of 2,6-DBN this experimental area was ploughed to a depth of 7 in. in March 1960 and drilled with Blenda oats. The yields subsequently obtained were based on total weight of sheaves from 1/300 ac plots i.e. from the centre one third of the original sprayed plot.

Experiment no. 10/60 (herbaceous crops treated post-emergence)

Tomatoes, leeks, celeriac, sweet corn, and cabbage were established by transplanting and the remaining crops by drilling seeds in situ. Plots 1/80 ac in size were sprayed on 13.7.59., when the crops were at the stages of growth indicated in Table XII, and then watered by overhead irrigation as in the previous experiment. All crops except the onions and leeks were weed-free when sprayed and were subsequently kept clean by hand weeding until harvested. The first weeding in the onions and leeks, one month after spraying was timed to obtain an estimate of post-emergence weed control. Yields of the various crops were estimated by recording the total number and fresh weight of plants, either in part or whole, on 1/135 ac plots.

Experiment no. 13/60 (gooseberries)

Plots 1/135 ac in size, with six eight year old bushes (varieties Careless or Leveller) were treated on 28.4.60. Sprays containing simazine or 2,6-DBN were applied over and between bushes, and the granule formulation of the nitrile uniformly over the plot. Weed cover at the time of spraying was about 75 per cent, and the dominate species were Stellaria media, Cirsium arvense, Poa annua, and Veronica sp. No subsequent hand weeding was carried out, but one series of plots was rotovated once to a depth of approximately 3 in. the day after application of the chemicals. Weed cover was estimated nine weeks after treatment by means of a 50 x 50 cm^2 grid quadrat. Yield of fruit per plot (i.e. six bushes) was recorded.

Experiment no. 14/60 (blackcurrants)

Plots 1/135 ac in size with six, three year old bushes (two of each of the varieties Baldwin Hilltop, Boskoop Giant, and Wellington XXX) were treated on 28.4.60. Sprays containing 2,6-DBN were applied either over and between bushes, or under and between bushes. The 2,6-DBN granules were spread uniformly over the plots. These were weed free when treated, and were subsequently kept clean by hand weeding as required. One such weeding 13 weeks after treatment was timed to obtain an estimate of weed control. Yield of fruit per plot (i.e. six bushes) was recorded.

Determination of 2,6-DBN and simazine residues in soil

In the gooseberry and blackcurrant experiments soil samples were taken on all plots by means of 1.5 in. diameter corer, sufficient cores being taken to obtain 2 - 3 lb of soil per treatment. The soil samples were transferred to sealed tins and placed in a cold store until analysed.

The method for 2,6-DBN was to dry the soil by admixture with anhydrous sodium sulphate, extraction for two hours with redistilled n-hexane, followed by determination of the 2,6-DBN in the extracts by gas-liquid chromatography.

The method for simazine involved a modification of the one used by Birchfield and Storres (1956) for the determination of chloranilino triazines.

RESULTS

The toxicity of 2,6-DBN to seeds

The results in Tables I and II indicate that the toxicity of the compound to germinating seeds was of a very high order both in vitro and in soil; the margin of selectivity, however, being relatively narrow. 2,6-DBN was presumably imbibed in the solid phase and in solution in both experiments. In marked contrast, when unimbibed seeds were exposed to the vapour of 2,6-DBN considerable selectivity was observed (Table IV) the dicotyledon species being notably more tolerant then the monocotyledons.

Field data on the toxicity of 2,6-DBN to weed seeds, not presented here, have been obtained on some 30 species, both temperate and tropical. These results resemble those given for the cultivated species (Table IX) in that no wide range in selective toxicity was found. More than half the weeds succumbed to 1.0 lb/ac or less and none survived a dose of 3.0 lb/ac.

The toxicity of 2,6-DBN to other bud producing organs

The results in Tables V, VI, VII, and VIII indicate the high activity of 2,6-DBN in killing or inhibiting buds. Appreciable effects were obtained at very low dose levels e.g. 1.0 gm/ton and 1.0 ppm severely inhibited bud development in potatoes and *Salvinia* respectively.

As was expected from this activity as a bud inhibitor 2,6-DBN proved highly toxic to herbaceous perennial weeds (Tables VII and VIII) which propogate from bud producing organs such as stolons, rhizomes and tubers, when the compound was applied around the organs in the early stages of bud growth.

In the experiment with *Aegopodium podagraria* (Table VIII) not only was 2,6-DBN more toxic than simazine, but it killed the rhizome even at the lowest dose of 2.0 lb/ac while simazine failed to do so at the highest level of 16.0 lb/ac judging by healthy buds that were present on the rhizomes when these were examined four months after treatment.

A wide range of similar herbaceous perennial weeds has been found to be susceptible, including such important species as *Agrostis stolonifera*, *Pteridium aquilinum*, *Epilobium angustifolium*, and *Cirsium arvense*.

The toxicity of 2,6-DBN to plants

The compound was found to be generally less toxic to plants than to seeds (Table III) and bud producing organs, the level of toxicity being predominantly influenced by the age and morphology of the plant and whether applied to leaves or roots. Woody species appeared to be more tolerant than herbaceous plants, sensitivity to 2,6-DBN decreased rapidly with increasing maturity, and the compound evidently penetrated roots more readily than leaves. However, in experiments not reported here it was found that 2,6-DBN vapour readily enters leaves.

Seedling herbaceous plants wilt within a few hours of treatment when in active growth. Days later laminae become abnormally dark green in the interveinal areas whereas, leaf veins, petioles and stem become brown, spongy and necrotic frequently producing exudates. Root and shoot growth is rapidly inhibited and meristems also become grossly discoloured and necrotic.

In more mature herbaceous and woody plants symptoms are slower to appear, less acute or absent altogether. Additional effects such as acceleration of anthocyanin pigmentation in or abcission of leaves have been observed.

Crop plants (post-emergence)

The results of a field screen carried out in July - September 1959 are presented in Table XII. Carrot, sugar beet, and cabbage proved highly sensitive to 2,6-DBN and were severely damaged by 2 lb/ac or less. Leeks, onions, celeriac, tomato and sweet corn appeared to tolerate 3 lb/ac, a dose which gave useful post-emergence control of the weeds present in this experiment (Table X).

In the field screening tests carried out in soft fruit in 1960 (Tables XVII and XVIII) gooseberries and blackcurrants appeared to tolerate about

4.0 lb/ac of 2,6-DBN but the results also showed that formulation, method of application and subsequent soil cultivation influenced the tolerance level. Although fruit yield appeared to be depressed in some instances no other growth abnormalities were observed.

Weeds (post-emergence)

Applied as a soil drench 2,6-DBN was highly toxic to a wide range of seedling broad leaved weeds treated soon after emergence (Table XIII) and none of the 20 species survived a dose of 1.5 lb/ac. In the field, sprays required much higher doses to achieve comparable weed control. In experiment no. 9/59 (Table 10) 3.0 lb/ac followed by ½ in. of rainfall was highly effective, but 8.0 lb/ac in experiment no. 13/60 applied in drought was ineffective. In the latter experiment the granule form of 2,6-DBN was strikingly more effective than the spray, and this result is clearly attributable to the greater persistence of 2,6-DBN (Table XIX).

The persistence of 2,6-DBN

As might be expected from its appreciable vapour pressure 2,6-DBN is highly volatile. More than 20 experiments have been conducted, to determine the influence of volatility on the persistence and hence the herbicidal activity of 2,6-DBN using biological and chemical methods of assessment. Both methods have shown that when 2,6-DBN is sprayed onto soil without further incorporation by cultivation or rainfall, it has a 'half-life' of about two days under temperate conditions, (Table XIV) and a few hours in the tropics. In the U.K. the 'half life' can fall to <1day in the summer (Tables XV, XIX) and in the winter can extend to 5 - 10 days. The main difference between experiment nos. 13/60 and 14/60 was the presence of a substantial weed cover in the former. Comparison of spray residues in the two experiments suggests that the presence of such a soil cover, in the absence of rainfall soon after spraying, effectively reduces the soil residue of 2,6-DBN. The penetration of this canopy by the granule was observed in experiment no. 13/60 and this factor was no doubt partly responsible for the greater persistence and herbicidal activity obtained with this formulation.

If spraying was followed by a light overhead irrigation (Table IX) or cultivation (Table XV) persistence was greater. When temperatures were low and cultivation followed immediately, the persistence of 2,6-DBN was dramatically extended, and a 'half life' 50 days or more obtained. However, the results obtained in experiment no. 9/59 with oats, a sensitive indicator crop, (Table XI) suggest that the persistence of appreciable residues of 2,6-DBN for a year is unlikely with normal doses.

DISCUSSION

The toxicity of 2,6-DBN to germinating seeds is its outstanding biological characteristic and is of a very high order. In the case of oats (var.Blenda), a sensitive species, the LD 50 in petri dish germination is about 0.1 mg/kg of imbibed seed fresh weight. Such high toxicity is rare in the entire pesticide field, and indicates 2,6-DBN to be an exceedingly potent biocide.

Our work has indicated that 2,6-DBN is probably taken up by seeds both in aqueous solution and as a vapour, and suggests the possibility that lethal amounts of the herbicide can be absorbed onto or into dormant seed, or vegetative organs such as tubers and rhizomes. The most obvious potential of 2,6-DBN lies in exploiting these properties, which considered in the light of the relatively short persistence of the compound might provide a means of cleaning land of both annual and perennial weeds before cropping. 2,6-DBN could be the first economic, safe, wide spectrum phytosterilant, and find use in the U.K. in a chemical winter fallow, possibly the most logical and the cheapest time to fallow land.

Although 2,6-DBN shows some selective toxicity to seeds in vitro and in soil, we do not yet have any indication that this may be of a biochemical or physiological kind. The higher apparent tolerance of larger seeds, at least in soil, is likely to be due in part to greater planting depth resulting in a lower effective dose reaching the seed. If the compound penetrates into or is absorbed onto seeds, the dose per seed would be related to the ratio of seed volume/seed surface area. Assuming equal ease of penetration it might be that the larger seeds take up a lower dose on a weight or volume basis.

The effectiveness of 2,6-DBN applied post-emergence was of a lower order, and more variable. Conditions favouring uptake by roots, the predominant mode of entry, may be expected to give best results. No wide margin of selectivity was found in herbaceous abnuals. Where differences in depth of rooting and/or age of crop and weeds exist, as in experiment no. 10/59, useful selectivity may be obtained. In general it would seem that the post-emergence use of 2,6-DBN in herbaceous field crops may be limited, technically by the narrow margin of selectivity and economically by the rather high doses required for effective weed control.

The tolerance of 'woody' crops is, however, of a much higher order, and the prospects for 2,6-DBN in these appear promising. Preliminary tests indicate that in addition to gooseberries and blackcurrants reported here, apple, plum, citrus, cacao, vine, and numerous ornamental species appear to tolerate upwards of 4.0 lb/ac 2,6-DBN. However, it is considered that tests over several seasons are required with such crops, before safe rates of application can be determined.

The appreciable volatility of 2,6-DBN at normal temperatures is a highly significant factor influencing its penetration into and persistence on leaves, distribution and persistence in soil, and the effectiveness of different formulations. Since in practice 2,6-DBN is most active when applied to the soil and taken up by roots, its persistence in the soil largely determines the effective as distinct from the applied dose, and hence the herbicidal effect obtained and the subsequent permissible freedom of cropping. The indications are that relative to such compounds as simazine 2,6-DBN possesses a short persistence, and land should be safe to crop within a few weeks or months depending on the method of use. Because of its low water solubility and high rate of loss from soil surfaces the persistence of 2,6-DBN is increased rather than decreased by overhead irrigation, rainfall, or cultivation after spraying. From a large number of experiments not reported here it appears that the rate of loss by volatilisation can be decreased by a factor of four by cultivation.

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REFERENCES

ALLEY, H. P., (1960) Western Weed Control Conference, Denver, February 1960.

BARNSLEY, G. E., ROSHER, P. H., Weed Research, 1 (in press).

BIRCHFIELD, H. P., STORRES, E. E., (1956) Contribs. Boyce Thompson Inst. 18, 319.

HAGOOD, (1959) West Canadian and N. Central Weed Control Conference Winnipeg, December 1959.

KOOPMAN, H., and DAAMS, J., (1960) Nature, 186, 89 - 90.

TABLE I. THE TOXICITY OF 2,6-DBN TO CROP SEEDS GERMINATING IN VITRO

(Lab. Exp. no. 1/59)

Concentration ppm	Length of shoot after five days at 25°C							
	mm				Percent reduction in length			
	M	L	B	O	M	L	B	O
2,500	4	3	2	0	83	96	95	100
1.000	6	5	3	0	75	93	92	100
0.500	10	7	7	0	58	90	82	100
0.250	14	30	18	4	42	58	57	71
0.100	24	53	23	6	0	25	45	57
0.050	27	67	31	5	-13	6	26	64
0.025	26	67	37	7	- 8	6	12	50
0.000	24	71	42	14	-	-	-	-

M = Mustard L = Linseed B = Barley O = Oats

TABLE II. THE TOXICITY OF 2,6-DBN TO CROP SEEDS GERMINATING IN STERILISED JOHN INNES COMPOST AT 20°C

(Glasshouse Exp. no. 2/59)

Crop	Dose reducing emergence by 50 per cent lb/ac	Reduction in fresh wt/ shoot of surviving plants at LD 50 per cent
Sweet corn	1.2	86
Peas	0.6	75
Mustard	0.3	3
Linseed	0.5	20
Barley	0.7	10
Wheat	0.5	32
Ryegrass	0.3	-
Oats	0.3	-

TABLE III. THE SPECTRUM OF PHYTOTOXICITY OF 2,6-DBN

(Glass house Exp. no. 3/60)

50 per cent Growth Inhibition Dose lb/ac																							
Seeds								Plants															
Pre-emergence								Post-emergence															
Soil spray								Foliar spray								Soil drench							
O	RG	SC	P	SB	L	K	M	O	RG	SC	P	SB	L	K	M	O	RG	SC	P	SB	L	K	M
< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.4	1.2	5.6	8.3	3.8	> 10.0	> 10.0	> 10.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.5	2.1

O = Oats, RG = perennial ryegrass, SC = Sweet corn, P = peas, SB = Sugar beet, L = Linseed, K = Kale, M = Mustard

TABLE IV. THE TOXICITY OF 2,6-DBN IN THE VAPOUR PHASE TO DORMANT UNIMBIBED SEEDS EXPOSED FOR 20 days

(Lab. Exp. no. 4/59)

Seed	Germination per cent			Inhibition of germination per cent	Seedling shoot fresh wt (gm)		
	Control		Treated		Control		Treated
Oats	75	**	0	100	0.15		-
Mustard	96	N.S.	94	2	0.14	N.S.	0.13
Barley	90	**	69	23	0.26	*	0.15
Per. ryegrass	73	*	6	83	0.01		-
Peas	99	N.S.	97	2	0.65	N.S.	0.69
Sunflower	84	N.S.	92	9	1.38	N.S.	1.39

N.S. = not significant
* = significant at 5 per cent level
** = significant at 1 per cent level

TABLE V. THE RELATIVE INHIBITION OF SPROUTING IN STORED POTATOES DUSTED WITH 2,6-DBN AND 2,3,5,6-TETRACHLORO-1-NITROBENZENE (TNCB)

(Field Exp. no. 5/59)

Material applied	Dose gm/ton of tubers	Fresh wt of sprouts (2) per 20 lb tubers (gm)
2,6-dichlorobenzonitrile	5 50 100	7 0 0
TCNB (1)	5 50 100	46 27 9
Blank dust formulation	0	42
Control	0	41

(1) Dosage recommended commercially 140 gm/ton.
(2) After three months storage.

TABLE VI. THE TOXICITY OF 2,6-DBN TO SALVINIA AURICULATA WHEN INCLUDED IN THE AQUEOUS NUTRIENT MEDIUM

(Glasshouse Exp. no. 6/60)

Concentration of 2,6-DBN in nutrient ppm	0.0	0.1	0.5	1.0	5.0	10.0	20.0
Frond number minus 4 (= original inoculum) after 13 days in nutrient with 2,6-DBN	68	43	6	0	0	0	0
Frond number of 2 plants, 4 days in nutrient with 2,6-DBN, followed by 10 days in pure nutrient	22	28	5	0	0	0	0
Bud development	++	++	+	+	-	-	-

++ Normal Bud development
\+ small deformed buds
\- no buds

TABLE VII. THE TOXICITY OF 2,6-DBN AND APPLIED AS A SOIL DRENCH TO THE BUDDED RHIZOME SECTIONS OF AGROPYRON REPENS

(Glasshouse Exp. no. 7/59)

Compound	Dose lb/ac	Shoot fesh wt gm/3 x 5 in. pots			Reduction in shoot wt per cent		
		A 1st cut	B 2nd cut	C 3rd cut	A 1st cut	B 2nd cut	C 3rd cut
2,6-dichloro-benzonitrile	0.1	37.3	34.7	24.7	9	-14	- 2
	0.2	21.0	18.3	21.5	48	40	11
	0.4	5.2	0.2	0.0	87	99	100
	0.8	1.8	0.0	0.0	96	100	100
Control	0.0	40.7	30.3	24.3	-	-	-

A, B, C, 4, 8, 14 weeks after spraying

TABLE VIII. THE RELATIVE TOXICITY OF 2,6-DBN AND SIMAZINE APPLIED AS SOIL DRENCHES TO BUDDED RHIZOME SECTIONS OF AEGOPODIUM PODAGRARIA

(Glasshouse Exp. no. 8/59)

Compound	Dose lb/ac	Dry wt* of roots and rhizomes gm/3 x 5 in. pots	Reduction in dry wt* roots and rhizomes, per cent
Simazine	2	11.1	75
	4	14.6	67
	6	13.4	70
	8	5.9	88
	12	3.7	92
	16	4.6	90
2,6-dichloro-benzonitrile	2	3.3	93
	4	4.4	91
	6	0.8	98
	8	0.5	99
	12	1.0	98
	16	2.7	94
	0	45.0	-

* harvested four months after treatment.

TABLE IX. THE TOXICITY OF 2,6-DBN TO CROP SEEDS IN THE FIELD SOWN UP TO 45 DAYS AFTER SPRAYING

(Field Exp. no. 9/59)

Initial Dose lb/ac	Period between spraying and sowing (days)	Reduction in germination per cent							
		French Bean	Radish	Sweet corn	Rice	Rye Grass	Oats	Carrot	Sugar Beet
0.5	0	28	43	21	-	100	68	100	100
	36	-	0	0	0	6	5	18	0
	45	0	0	0	-	0	0	4	0
1.0	0	15	77	27	-	100	83	100	100
	36	-	0	0	0	37	15	85	15
	45	0	0	0	-	0	0	48	0
2.0	0	63	84	63	-	100	100	100	100
	36	-	0	0	0	20	57	88	42
	45	0	0	0	-	0	0	70	16
3.0	0	61	100	69	-	100	100	100	100
	36	-	0	11	0	51	67	96	75
	45	0	0	0	-	0	0	100	63
6.0	0	100	100	66	-	100	100	100	100
	36	-	0	14	0	48	95	100	100
	45	0	0	0	-	0	37	100	96
8.0	0	100	100	66	-	100	100	100	100
	36	-	5	31	6	42	100	100	100
	45	0	0	0	-	15	81	100	100
12.0	0	100	100	83	-	100	100	100	100
	36	-	0	31	17	100	100	100	100
	45	0	0	0	-	53	89	100	100
16.0	0	100	100	100	-	100	100	100	100
	36	-	31	72	38	100	100	100	100
	45	0		0		58	91	100	100

- indicates not sown

TABLE X. WEED CONTROL ACHIEVED IN ONIONS AND LEEKS WITH 2,6-DBN APPLIED POST-EMERGENCE TO CROPS AND WEEDS

(Field Exp. no. 9/59)

Principal weeds	Dose lb/ac	Reduction in hoeing time per cent
Chenopodium album)	0.5	11
Solanum dulcamara)	1.0	41
Urtica urens)	2.0	68
Stellaria media)	3.0	87
	6.0	100

TABLE XI. THE YIELD OF BLENDA OATS SOWN 8 MONTHS AFTER APPLICATION OF 2,6-DBN TO THE SOIL

(Field Exp. no. 9/59)

Dose of 2,6-DBN applied July 1959 lb/ac	Yield of straw and grain in 1960 tons/ac	
	Treated plot	Adjacent discards (mean)
0.5	3.8	4.2
1.0	4.5	4.5
2.0	4.2	4.9
3.0	5.4	5.6
6.0	4.3	5.2
8.0	5.2	5.3
12.0	3.9	5.6
16.0	4.7	5.7

TABLE XIII. SUSCEPTIBILITY OF SEEDLING WEEDS TO 2,6-DBN (POST-EMERGENCE DRENCH APPLICATION IN POT EXPERIMENT)

(Glasshouse Exp. no. 11/59

Weed species	Dose lb/ac				
	0.25	0.5	1.0	1.5	3.0
Matricaria maritima	B	A	A	A	A
Polygonum persicaria	B	A	A	A	A
Veronica spp.	A	A	A	A	A
Geranium molle	D	D	A	A	A
Capsella bursa-pastoris	D	C	A	A	A
Achillea millefolium	A	A	A	A	A
Plantago media	A	A	A	A	A
Sonchus oleraceus	A	A	A	A	A
Prunella vulgaris	C	B	A	A	A
Taraxacum officinale	A	A	A	A	A
Chrysanthemum leucanthemum	C	A	A	A	A
Urtica urens	D	A	A	A	A
Chenopodium album	A	A	A	A	A
Sinapsis arvensis	C	C	A	A	A
Papaver rhoeas	C	C	A	A	A
Stellaria media	C	B	A	A	A
Polygonum convolvulus	C	C	C	B	A
Plantago major	A	A	A	A	A
Galium aparine	A	A	A	A	A
Raphanus raphanistrum	D	C	C	A	A

Abbreviations: A = Virtually 100 per cent kill.
B = 100 per cent kill, but unlikely to recover.
C = 100 per cent kill, but likely to recover.
D = No significant growth inhibition.

TABLE XII. THE EFFECT OF 2,6-DBN.

(Field Exp.

Crop and stage of growth when sprayed	Percentage reduction in no. plants harvested										
	Dose of 2,6-DBN lb/ac										
	0	½	1	2	3	6	8	12	16	0	½
Leeks - 6 - 8 in.	-	15	3	9	6	9	9	12	16	7.3	6.5
Onions - 4 - 6 in.	-	8	0	6	0	5	40	36	78	8.1	8.6
Celeriac - 4 - 6 in.	-	0	0	0	0	0	20	33	60	6.8	8.0
Tomatoes - first truss set	-	0	0	0	0	0	0	0	0	16.3	19.0
Sugar beet - 4 - 6 in.	-	7	21	30	6	33	75	85	100	30.0	26.6
Carrots - 2 - 3 in.	-	30	41	66	100	100	100	100	100	14.0	8.4
Sweet corn - 18 - 24 ins.	-	0	0	0	0	0	0	33	77	20.2	19.3
Cabbage 6 - 8 in.	-	0	0	0	6	29	35	41	65	27.0	26.5
French bean - in flower	-	0	0	0	0	0	0	0	0	3.4	3.2

* French bean, tomato - fruit only
Celeriac, sugar beet, carrots - whole plants
Onions, leeks, sweet corn, cabbage - stem and leaf only

APPLIED POST-EMERGENCE ON CROP YIELDS

no. 10/59)

Yield*															
Dose of 2,6-DBN lb/ac															
tons/ac							Percentage reduction								
1	2	3	6	8	12	16	0	½	1	2	3	6	8	12	16
8.7	7.8	6.7	6.0	6.5	6.2	5.7	-	7	-10	8	15	10	9	15	14
11.5	9.9	12.4	7.3	3.1	5.1	1.8	-	3	-16	7	-23	-20	37	20	73
7.8	6.8	7.3	5.7	4.4	4.5	2.5	-	-18	-16	-1	- 8	16	31	33	63
19.5	16.8	16.8	12.9	13.6	9.9	12.0	-	-17	-20	-3	- 3	21	16	39	26
30.4	28.0	30.9	15.1	9.9	5.6	0.0	-	11	0	7	0	13	67	81	100
11.1	4.6	0.5	0.0	0.0	0.0	0.0	-	23	26	71	96	100	100	100	100
19.1	20.2	21.6	18.2	15.7	7.7	4.5	-	4	5	0	- 7	10	22	38	78
24.3	18.4	17.3	13.2	11.1	7.8	2.7	-	2	11	32	36	50	59	71	89
3.2	2.4	2.3	2.2	2.2	1.6	0.9	-	7	7	31	33	36	36	52	73

TABLE XIV. THE PERSISTENCE OF 2,6-DBN IN JOHN INNES POTTING MEDIUM MEASURED BY GERMINATION OF MUSTARD SEED

(Glasshouse Exp. no. 12/60)

Dose lb/ac	Fresh weight of emerged seedlings in 2 x 5 in pots					Reduction in fresh wt emerged seedlings per cent				
	Delay in sowing after spraying (days)									
	0	2	4	8	16	0	2	4	8	16
0.0625	0.4	15.5	15.2	21.3	19.5	98	13	13	- 7	12
0.125	0.2	4.3	9.2	27.3	27.6	99	77	47	-63	-23
0.250	0.0	0.7	0.6	18.7	25.7	100	96	66	6	-14
0.500	0.0	0.0	0.0	4.5	14.3	100	100	100	77	43
1.000	0.0	0.0	0.0	0.2	5.6	100	100	100	99	75
0.0	22.6	17.8	17.5	19.9	22.5					

TABLE XV. THE INFLUENCE OF FORMULATION AND POST TREATMENT CULTIVATION ON THE PERSISTENCE OF 2,6-DBN IN SOIL

(Field Exp. no. 13/60)

Compound	Dose lb/ac	Formulation	Soil Cultivation	Residue ppm in dry soil (0-3 in.) after (days)			
				1	15	29	65
2,6-DBN	4.0	50 per cent w.p.	-	0.3	0.2	0.1	0.1
	4.0		+	0.3	0.2	0.3	0.3
	8.0		-	0.3	0.2	0.1	0.1
	8.0		+	1.1	0.9	0.9	0.9
2,6-DBN	4.0	granule	-	2.0	0.3	0.6	0.1
	4.0		+	2.7	2.1	0.5	0.4
	8.0		-	7.3	0.3	.0.6	0.2
	8.0		+	8.5	5.1	2.3	2.3
Simazine	4.0	50 per cent w.p.	-	-	2.7	3.6	1.4
	4.0		+	-	3.2	4.1	2.6
	8.0		-	-	5.1	5.6	2.1
	8.0		+	-	6.2	6.6	6.2

TABLE XVI. THE EFFECT OF SIMAZINE AND 2,6-DBN ON WEED COVER TREATED POST-EMERGENCE IN GOOSEBERRIES 9 WEEKS AFTER SPRAYING (VARIETIES LEVELLER AND CARELESS)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Percentage reduction in weed cover	
			Uncultivated	Cultivated (1 day after spraying)
2,6-DBN	spray	4.0	0	60
2,6-DBN	granule	4.0	36	99
Simazine	spray	4.0	94	94
2,6-DBN	spray	8.0	0	90
2,6-DBN	granule	8.0	73	100
Simazine	spray	8.0	98	100

TABLE XVII. THE EFFECT OF 2,6-DBN AND SIMAZINE ON THE YIELD OF GOOSEBERRIES (VARIETY LEVELLER)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Mean fruit yield (oz per bush)			
			Uncultivated		Cultivated (1 day after spraying)	
			Treated	Untreated	Treated	Untreated
2,6-DBN	spray	4.0	28	30	21	25
Simazine	spray	4.0	19		16	
2,6-DBN	granule	4.0	29		30	

TABLE XVIII. THE EFFECT OF 2,6-DBN AND SIMAZINE ON THE YIELD OF GOOSEBERRIES (VARIETY CARELESS)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Mean fruit yield (oz per bush)			
			Uncultivated		Cultivated (1 day after spraying)	
			Treated	Untreated	Treated	Untreated
2,6-DBN	spray	8.0	8.7	9.3	7.5	7.0
Simazine	spray	8.0	11.0		5.0	
2,6-DBN	granule	8.0	8.6		10.0	

TABLE XIX. THE INFLUENCE OF FORMULATION ON THE PERSISTENCE OF 2,6-DBN IN SOIL

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Residue (ppm in dry soil) 0 - 3 in. after			
		1 day	6 days	15 days	49 days
spray	2.0	0.6	0.3	0.3	0.2
granule	2.0	0.7	0.7	0.3	0.3
spray	4.0	1.4	0.8	0.8	0.2
granule	4.0	5.2	3.0	1.1	0.2
spray	8.0	2.2	0.8	1.0	0.6
granule	8.0	8.8	4.5	3.0	1.3

TABLE XX. THE EFFECT OF 2,6-DBN ON THE TIME REQUIRED TO HAND HOE WEEDS IN BLACKCURRANTS 13 WEEKS AFTER APPLICATION

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Per cent reduction in hoeing time	
		Overall spray	Soil only treated
Spray	2.0	42	61
Granule	2.0	-	73
Spray	4.0	83	81
Granule	4.0	-	85
Spray	8.0	89	92
Granule	8.0	-	94

TABLE XXI. THE EFFECT OF 2,6-DBN ON THE YIELD OF BLACKCURRANTS

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Per cent reduction in hoeing time	
		Overall spray	Soil only treated
Spray	2.0	25.0	25.7
Granule	2.0	-	26.3
Spray	4.0	25.2	18.3
Granule	4.0	-	18.7
Spray	8.0	21.3	25.0
Granule	8.0	-	18.5
	0	25.3	