Research Summary

SOME ECOLOGICAL OBSERVATIONS ON THE USE OF PARAQUAT AND DIQUAT AS AQUATIC HERBICIDES

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Summary Effects on aquatic invertebrates, dissolved oxygen and the fate of active material were recorded in three experiments where the herbicides diquat or paraquat were used. Some invertebrates died as a result of treatment at one site, but no evidence was obtained in any of the experiments of any major direct effects on any group. At another site there was some indication that the increased amount of organic debris may have favoured detritus feeding invertebrates. At one site where all the weed in a lake was killed by a single application of paraquat, severe deoxygenation occurred. Preliminary studies of this effect and of the subsequent reoxygenation of the lake are discussed. No severe deoxygenation occurred at another site where partial treatment of the water body was carried out at different times. Captive trout in cages died where there was severe deoxygenation but free living coarse fish and trout were generally unaffected. Analysis of water, weed and mud at intervals after application of the active material showed that the herbicide was removed from the water by absorption into the weed. With the breakdown of the weed the residues became incorporated into the bottom mud. At one site, 36% of the applied herbicide was found in the top 2 inches of the bottom mud, $5\frac{1}{2}$ months after application.

INTRODUCTION

The effectiveness of both paraquat and diquat as herbicides for a range of submerged weeds has already been established (Weed Control Handbook, 4th edition, 1965). The experiments summarized below were designed for the study of the ecological effects of the use of these two compounds under field conditions. Two of the experiments were made in lakes and a third in a series of drainage channels under conditions of minimum water flow during the summer.

EXPERIMENTAL SITES AND METHODS

Site 1. Pannel Sewer, Nr. Winchelsea, Sussex

Four side channels of the main Pannel Sewer, each approximately 5 ft wide, 3 ft deep and 200 ft long, were used. On 27.7.64 paraquat ion at 1 mg/l was applied to one channel, diquat ion at 1 mg/l to another, in the third weed was cut and removed mechanically and the fourth was left as an untreated control. Before treatment the channels carried a dense vegetation, principally of *Callitriche* sp., *Ranunculus aquatilis agg.*, *Elodea canadensis*, *Potamogeton natans*, *Hydrocharis morsus-ranae* and *Hottonia palustris*. In addition, surface blankets of filamentous algae were present and *Phragmites communis* and *Sparganiun erectum* occurred along the edges. Satisfactory control of the submerged weed was obtained for the herbicide and mechanical treatments. Faunal and other samples were taken from four equally spaced positions in each channel on the day of application and 16, 29 and 358 days after application. Faunal samples were taken by making roughly standard subsurface sweeps with a hand net (Newman 1965).

Site 2. Oxton Lake, Nottinghamshire

In a joint experiment, effects on weed and aquatic invertebrates were recorded by the Nature Conservancy, residue analyses of paraquat ion in water, weed and mud were made by Jealotts Hill Research Station and a range of physicochemical effects were studied by the Water Pollution Research Laboratory. Paraquat ion at 0.5 mg/l was applied to a lake approximately 1 acre in area of average depth 3 ft, and another rather larger lake of 4.5 acres and average depth 3 ft, upstream of the treated lake, was used as a control. Both lakes carried a fairly uniform dense growth of *Elodea canadensis* with some scattered *Myriophyllum spicatum*, *Potamogeton crispus* and emergent *Polygonum amphibium*. Before treatment a surface scum of *Entomorphora intestinalis* and other filamentous algae was skimmed off the lake to which paraquat was applied. Both lakes contained numerous roach and perch, together with some introduced trout. In addition, 10 captive trout in cages were placed in both the treated and the untreated lakes. Paraquat was applied uniformly over the surface of the treated lake on 1.6.65 and resulted in a 100% kill of submerged vegetation together with quite severe effects on *P. amphibium*. Faunal samples were taken by making a standard number of net sweeps from the bank at 22 marked collecting sites, and the frequency of occurrence of each group of animals was recorded for each site 4 days before and at 9 and 151 days after treatment. Samples of water, weed and mud were taken from 6 sampling stations in the treated lake and 2 in the control lake before the date of treatment and at 2, 4, [illegible], 16 and 32 days after treatment. A mud sample was also taken from the treated lake $5\frac{1}{2}$ months after treatment. Dissolved oxygen measurements were made over different periods of time 5 days before and at 5, 8, 9, 32 and 37 days after treatment, using the lead/silver electrolytic cell technique (Mackereth 1963), standardized by chemical determination by the Winkler method.

Site 3. Ivy Farm Lake, Chichester, Surrey.

Diquat was applied on three different occasions (so that ultimately the whole area had been treated) to different areas of a 50 acre lake whose depth varied from 3-6 ft. The aggregate amount of diquat ion applied was 0.1 mg/l, although this concentration would not have been reached in the water body as a whole at any one time. *Ranunculus aquatilis agg.* was the principal submerged species present and good control was obtained over the whole area of the lake after the final application. Faunal samples were taken by the same method as at the Pannel Sewer site. Dissolved oxygen determinations were made by the same method as at Oxton on 11 occasions during the course of the experiment.

RESULTS

Aquatic Invertebrates

Considerable difficulties are posed in the collection of quantitative records of the aquatic fauna in that the sampling method used is to some extent selective in its catch. The sudden change from thick weed conditions to almost clear water after herbicide application introduces additional difficulties in sampling techniques and in the interpretation of the results. Under these circumstances one can only expect to detect major effects on population and frequency of occurrence of aquatic invertebrates. With these reservations in mind the samples taken at the 3 sites did not show any major direct effects of the herbicidal treatments.

At the Pannel Sewer (Newman 1965) there were some indications of an increase in detritus feeding *Diptera* late in the season, occurring to a greater extent in the herbicide treated channels than in the mechanically or untreated channels. This may be related to the increased food supply provided by the decaying weed. At this site there were no important differences in the recorded catches at the time of treatment and 1 year afterwards.

At Oxton where a severe deoxygenation of the water occurred within 4 days of treatment, dead animals in the groups Hirudinea, Isopoda, Odonata, Coleoptera, Trichoptera, Gastropoda and Lamellibranchiata were recorded 9 days after treatment.

Dissolved Oxygen

At Oxton there was a severe deoxygenation of the water within 4 days of treatment resulting in the death of all ten of the caged trout. Free living fish in the lake came to the surface in distress and some large roach died. There were no records of deaths amongst the caged trout or free living fish in the control lake at this time. Whilst the dissolved oxygen concentration remained at a low level up to 32 days after treatment (Fig. 1) no effects were recorded on the free living fish 8 days after treatment or thereafter. Thirty-seven days after treatment an increase in the dissolved oxygen concentration was recorded, associated with a bloom of Volvox.

At Chichester, where limited areas of the water body were treated at any one time, there was no evidence of severe deoxygenation following treatment (Fig. 2). At this site there was a less dense infestation of weed growth than at Oxton, in addition the lake was larger and more exposed so that there were greater chances for mixing and reoxygenation by wind and wave action. However, it is reasonable to suppose that sequential treatments of parts of a body of water would be a practicable method of avoiding severe deoxygenation, especially where critical dissolved oxygen conditions are likely to exist, as in the lake at Oxton.

Fate of the Applied Herbicide

Analysis of paraquat ion residues in water, weed and mud at Oxton showed that the herbicide disappeared exponentially from the water. The initial concentration of paraquat was reduced by 50% in 2 days and residues in the water were non-detectable by 16 days after treatment. Analysis of weed samples 4 days after treatment showed residues of approximately 25 mg/kg, suggesting that absorption by the weed was the main route of removal of paraquat from the water. Analysis of mud residues $5\frac{1}{2}$ months after treatment showed that 36% of the applied paraquat was accountable for in the mud, of which 70% was found in the top inch. The persistence of bipyridyl residues in pond muds is being further investigated. Since such muds are often largely organic, the residues may be more rapidly available to bacterial degradation than in sites where firmer adsorption to clay minerals can occur.

References

MACKERETH, F.J.H. (1964) An improved galvanic cell for determination of oxygen concentrations in fluids. J. sci. Inst. 41, 38-41.

NEWMAN, J.F. (1965) Methods of assessing wild life hazards. Proc. 3rd British Insecticide and Fungicides Conference 342-351.

Figure 1.

Oxton Lake - dissolved oxygen concentrations in early afternoon.
(combined I.C.I. & Water Pollution Research Laboratory data)

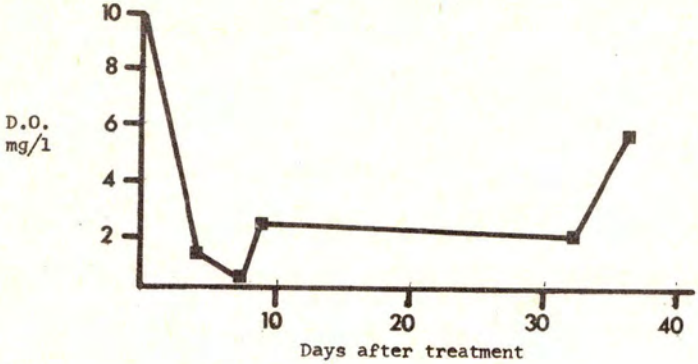
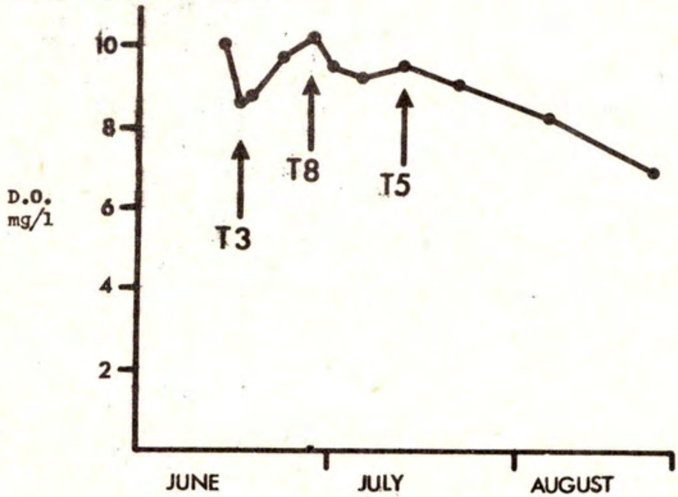


Figure 2.

Chichester - dissolved oxygen concentrations in early afternoon.



T3 =	application	of	3	galls	of	20%	diquat	ion	
T8 =	"	"	8	"	"	"	"	"	
T5 =	"	"	5	"	"	"	"	"	

Research Summary

OBSERVATIONS ON THE USE OF DIQUAT FOR THE CONTROL OF WATER WEEDS

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INTRODUCTION

During 1965 a series of forty observation plots were established to study the use of diquat as an aquatic herbicide in both static and flowing water.

METHOD AND MATERIALS

Injection of the diquat used throughout at 1 p.p.m. diquat cation, equivalent to 2 gallons of formulation per acre/foot depth was achieved by (i) application of measured "shots" from a boat, or in the case of moving water, from a bridge or single point of entry, (ii) slow drip-release from a container, supported on an inflated rubber tube and pulled from side to side of a pond, (iii) injection via a handlance nozzle held below the surface of the water, either from a bridge or the bankside.

Surface spraying was achieved by normal jet or multi-jet boom application, either from a mechanical sprayer in a boat, or from the bankside of a water-course or pond.

Treatments were made over the period May to September and a final assessment made towards the end of October. The method of assessment was based upon $\frac{\text{COVER x VIGOUR}}{100}$ and results over all sites were averaged to give figures for the control of individual species as shown in the Table. (Cover - 100% = complete coverage
0% = no cover
(Vigour - 100% = completely healthy
0% = dead growth

RESULTS

The Table compares the control of different species in static and flowing water with both surface and injection methods of application of diquat. It was also noted that the green algae Cladophora was effectively controlled in several trials, but Spirogyra was not efficiently killed by either method of treatment. Duckweed (Lemna trisulca) was controlled by surface spray in several trials, reinfestation from sources up-stream being apparent in all cases where water-flow was involved.

DISCUSSION

Weed identification

Difficulty was sometimes experienced in determining the overall weed population due to a number of reasons, e.g. water depth, discolouration of water, or weeds at a lower level being masked by floating, or vegetation existing at a higher level. It appears that efforts should be made to accurately record all weeds by "bottom" dragging, or by breaking-up surface weeds to facilitate a clearer examination. In a few cases, poor weed control was achieved against susceptible weeds growing in static water over 3 ft. depth. This might be due to insufficient light at these levels to promote adequate chemical activity within the vegetation.

Flowing water

Where cessation of flow cannot be achieved for 24 hours, treatment so far has been confined to a maximum flow of 1 ft. per second. It is vitally important that sufficient exposure of the weed growth to diquat is achieved. This calls for accurately timed injection, calibrated to provide such contact for at least a minimum of 30 minutes. Spot-injections appear capable of providing up to 12 ft. width of diffusion, but work to date is being restricted to streams up to 24 ft. width based upon two injection points. To assist with the accuracy of chemical injection, tables similar to those used by Leonard and Greenland (1) have been compiled in order to establish the necessary rate of chemical release to give sufficient concentration over a desired period of exposure.

Fish

In only one trial was any damage to fish experienced. This concerned a lake in which fish were present in large numbers, and evidence suggests that the water was low in oxygen from the onset. It would appear that caution is necessary, particularly in land-locked water, to establish the oxygen level before insertion of diquat. Although the chemical itself has proved harmless to fish when used at 1 ppm. diquat cation, the deoxygenizing effect of decaying vegetation arising from the destruction of aquatic plant life, may well act as a factor tipping the balance against fish survival, especially in hot weather. The problem is more particularly associated with static, rather than flowing water. In such circumstances, partial treatment of ponds with intervals between application has so far proved satisfactory.

Timing of application

In static water June to July treatments appear to be better but in moving water where the basic need was to remove submerged vegetation to facilitate high winter-flow the trials to date suggest that August/September produces high standards of control.

Reference

(1) LEONARD, W.F. and GREENLAND, A.R. (1965) Control of aquatic weeds. Proc. 18th New Zealand Weed and Pest Control Conference 1965, 95-104.

Control of water weeds in October 1965 following applications of diquat at 1 p.p.m.

TYPE	Weed Species	Static water: Surface spray % control at Final Assessment	Static water: Injection % control at Final Assessment	Just discernible flow: Surface spray % control at Final Assessment	Just discernible flow: Injection % control at Final Assessment
Submerged weeds	Myriophyllium spicatum	90	70	95	100
	Ceratophyllum demersum	-	100	100	-
	Elodea canadensis	85	80	95	70
	Potamogeton crispus	75	95	90	100
	Potamogeton berchtoldii	-	90	-	-
Emergent weeds	Sparganium ramosum	50	-	35	-
	Iris pseudacorus	-	-	30	-
	Typha latifolia	50	-	-	-
	Carex riparia	65	-	-	-
	Equisetum fluviatile	85	-	-	-
	Sagittaria sagittifolia	-	-	100	-
	Rumex hydrolapathum	100	-	-	-
	Alisma plantago-aquatica	-	-	90	100
Floating weeds	Lemna trisclca	*	*	*	*
	Nuphar lutea	60	65	*	40
	Polygonum amphibium	-	-	90	-
	Ranunculus aquatilis	-	100	-	-
	Callitriche stagnalis	100	100	-	-
	Potamogeton natans	85	80	55	10
	Utricularia vulgaris	100	-	-	-

* Re-appearance. - No such species existed at time of application.

AQUATIC WEED CONTROL IN SWEDEN

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This paper deals with Swedish investigations intended to illustrate methods of controlling vegetation in waterways and in particular open ditches by chemical means. The investigations comprise vegetation control as well as the listing of ditch vegetation, the determination of the damming effect of the vegetation on the water flow in open ditches and the testing of the toxic effect of the herbicides on fish, crayfish and chickens.

The increase of vegetation in waterways is probably mainly caused by an increase in the release of nutrient-rich sewage water from individual farms, factories and communities of different sizes. A secondary reason is that the cutting of the vegetation which used to be carried out is increasingly neglected owing to lack of labour and high wages.

The vegetation very rapidly returns after so-called vegetation cleaning with an excavator where accumulated mud and plants are lifted up from the ditch-bed and many plant roots are cut off. When manual or mechanical cutting (with a cutter boat) is carried out the result is relatively short-lived and measures must be taken annually.

The listing of ditch vegetation in 98 km of open ditches in the south of Sweden (Table I) shows that the occurrence of vegetation is greater in open ditches in farming land than in ditches in forest regions. In the latter there is a dominance of different sedge varieties, while in the former there is a greater occurrence of broad-leaved vegetation. This fact is apparently caused by more favourable nutritional conditions in the ditches in farming land. The data show that half of the ditches in farming districts and more than a third of the ditches in forest regions are in acute need of vegetation control. In these the vegetation covers more than a third of the area of the ditch.

Calculations are carried out in order to determine the damming influence of the vegetation on water flow. These data show that flow resistance is proportional to the density of the vegetation, expressed as the sum of stalk diameters per m^2, which is why dense stands of thick stalked vegetation (T. latifolia and S. ramosum) have the greatest damming effect on the water flow. A calculation of the change in the water flow, after the vegetation control treatment, has been carried out in the ditches investigated and shows that it would increase by 500-600% (T. latifolia and S. ramosum) and 100-200% (S. lacustris and P. communis) with the same slope and water depth. The vegetation consequently has a high damming effect on the water flow. During periods of intensive rainfall this causes flooding or an abnormally high water level in the ditches with deterioration in the conditions for crop husbandry in the surrounding fields.

The trials with chemical control of emerged vegetation show that:

1. Aminotriazole (with sesquicarbonate) gives good control at 15 kg/ha without regard to the composition of the vegetation.
2. A mixture of dichloropropionic acid + 2,4-D + 2,4,5-T (17+2+1 kg/ha) gives good control of all species except E. limosum. The control of Carex spp. in the trials was very uneven with in many cases a good regrowth in the year after the first treatment. A second treatment, however, gave a good final result in most cases.
3. Aminotriazole (with thiocyanate) which has been tested to a considerably lesser extent should be usable in the same way and at the same rates (15 kg/ha) as aminotriazole with sesquicarbonate.

Table 1

Ditch vegetation in the south of Sweden

	% of total vegetation in	
	farm land	forest regions
Carex spp.	30.7	49.0
Grasses, not specified	15.2	10.3
Sparganium spp.	7.2	3.7
Filipendula ulmaria	6.5	3.0
Juncus spp.	5.5	9.6
Equisetum limosum	4.9	4.5
Galium spp.	4.0	0.4
Typha latifolia	3.7	0.2
Iris pseudacorus	3.0	0.1
Lythrum salicaria	2.8	0.1
Alisma plantago aquatica	2.5	5.2
Veronica spp.	2.0	0.8
Epilobium palustre	2.0	0.2
Phragmites communis	1.5	1.9
Bidens tripartita	1.4	--
Sium latifolia	1.2	--
Scirpus lacustris	1.1	2.6
Weeds, not specified	4.8	8.4

4. Dichloropropionic acid has a selective effect. Grasses and sedges can be controlled with 15-20 kg/ha, while broad-leaved plants are resistant. The control of *Carex* spp. was good the year after treatments, but after two years the *Carex* spp. showed relatively good regrowth.

5. Dichlorobutyric acid gives results comparable with dichloropropionic acid. This chemical is also selective, with good control of grasses and sedges (15-20 kg/ha), while the broad-leaved plants are resistant.

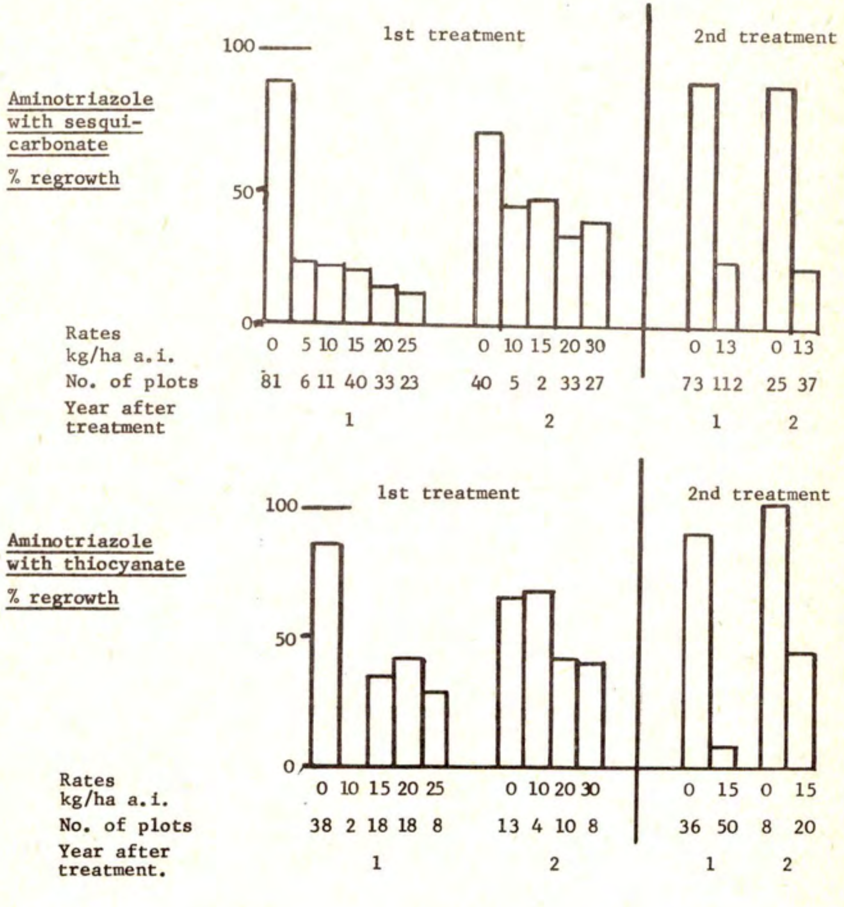
6. The chemicals 2,4-D (ester) and 2,4-D + 2,4,5-T (ester) have a selective effect on broad-leaved plants (5-10 kg/ha). Grasses and sedges are resistant.

The trial results show that one treatment seldom gives 100% control, and thus a second complementary treatment at the same dose must always be allowed for, preferably in the year after the first treatment (Fig. 1). Trials with different volume rates, from 200-1,000 l/ha, show that within these limits the volume rate does not influence the result of the treatment.

The influence of the time of the treatment on the control has been studied in some trials. The plots were treated from the end of June to the end of September and during this period no noticeable influence of the time factor on the control was observed. Certain species had a tendency towards a "greater" resistance at early (e.g. *Glyceria* spp.) or late (e.g. *Caltha palustris* and *Lysimachia vulgaris*) treatments. This resistance probably depended on whether the species in question had an early or late development. Experience shows that the vegetation should be green and fully developed with large herbicide absorbent leaf areas when the treatment takes place. The influence of the weather at the time of treatment on the control

Fig. 1

Regrowth of emergent weeds after treatment with aminotriazole with sesquicarbonate and with thiocyanate



has not been subjected to a systematic investigation. However, routine observations show that variations in air temperature between 13° and 25°C were not generally noticeable in the results of the treatments.

In order to obtain experience of the practical applications of the trial results, to interest ditching companies in the control of vegetation on a practical scale and to study the economics of vegetation control, about 200 km of the ditches and rivers in Uppland were sprayed. The herbicide chosen for the treatment was aminotriazole (with sesquicarbonate) at 15 kg/ha. The volume rate was 600 l/ha. The treatments were carried out with a motor driven knapsack sprayer. The results from the spraying were very good, which is seen by the fact that only a quarter of the total length was considered in need of another treatment in the following year.

Trials with the chemical control of floating and submerged vegetation were on the whole without result. The herbicides tested in these trials were either granules or liquids. The treatments with granular herbicides had not the intended effect showing some results only with granular 2,4-D and 2,4,5-TP against Stratiotes aloides and Myriophyllum spicatum. The liquid herbicides which were applied by means of spraying the water surface had a good killing effect during the year of treatment on Elodea canadensis with 0.5 p.p.m. paraquat and 1.0 p.p.m. 2,4,5-TP. Lemna spp. were controlled with 0.5-1.0 p.p.m. diquat. Both weeds showed regrowth the next year even where 10 p.p.m. paraquat and 2,4,5-TP had been used during the first year. Aminotriazole and 2,4,5-TP applied at 15 kg/ha gave good control of Nuphar luteum.

The toxic effect of the herbicides on fish, crayfish and chickens was tested. During the test time, 96 hours, the crayfish and the small fish of different species were placed in glass aquaria with the different chemicals at several concentrations. The tests were carried out partly in humic and partly in alkaline water from different lakes at water temperatures of about 10°C and 20°C. It was considered best and most informative to rate the preparations in toxicity tests according to the quantity of commercial products.

Table 2

Results from the toxicity tests on fish and crayfish

Active ingredients	Amount of a.i. in commercial product used	No damage with	Damage with
2,4-D-ester	500 g/l	1 mg/l*	10 mg/l*
2,4-D + 2,4,5-T ester	650 g/l	1 mg/l	10 mg/l
Dalapon	850 g/l	100 mg/l	1000 mg/l
Aminotriazole	500 g/l	100 mg/l	1000 mg/l
Dalapon + 2,4-D + 2,4,5-T	290 g/l	10 mg/l	100 mg/l

* commercial product.

In the tests with chickens the chemicals were mixed into the dry chicken-food. The chickens had to eat the prepared food from their first day of life until they were eight weeks old.

Table 3

Results from the toxicity tests on chickens

Active ingredients	Amount of a.i. in commercial product used	Food with 1000 mg/kg commercial product	
		Mortality	Growth in % of untreated
2,4-D-ester	500 g/l	Normal	99
2,4-D + 2,4,5-T-ester	650 g/l	Normal	97
Dalapon	850 g/l	Normal	100
Aminotriazole	500 g/l	Normal	101
Dalapon + 2,4-D + 2,4,5-T	290 g/l	Normal	98

As seen from these results aminotriazole, dalapon and dalapon + 2,4-D + 2,4,5-T can be used at the quantities recommended for the control of vegetation without any risk of injury to fish, crayfish and birds. Neither do grazing cattle, which obtain drinking water from sprayed waterways, run any risk as they presumably have a considerably greater power of resistance than chickens which have been seen to tolerate relatively large quantities of the herbicides mentioned.

SOME STUDIES OF THE PERSISTENCE OF 2,4-D IN NATURAL SURFACE WATERS IN BRITAIN

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Summary The rate of disappearance of an oil soluble amine of 2,4-D was studied in water and water plus bottom mud taken from a small static pond. For a few days immediately after treatment there appeared to be little or no breakdown, but this was followed by a period of more rapid degradation. When 2,4-D was added for a second time breakdown was rapid and immediate. These results suggest that, as in the case of soils, breakdown is due to micro-biological activity.

INTRODUCTION

The use of herbicides in foliar sprays for the control of emergent weeds in British rivers and drainage channels is increasing. Although the amount of herbicide entering the water from such sprays is likely to be small very dilute solutions of some can cause damage to irrigated crops. As water from these water courses is being used increasingly for irrigation it is necessary to know how long these herbicides persist in a phytotoxic form in order to assess the risk to irrigated crops.

The herbicides most commonly used are dalapon, maleic hydrazide and 2,4-D; of these 2,4-D appears to offer the most hazard because many of the irrigated crops are susceptible to very low doses. It was therefore chosen as the first to receive attention.

Audus (1949) demonstrated biological breakdown of 2,4-D in soil and found that in some situations it occurs rapidly (fifteen days in a garden loam). Faust and Aly (1964) have reported work on the persistence of 2,4-D in natural water in America and have demonstrated a similar adaptation of micro-organisms in the bottom mud to the presence of 2,4-D, as was reported by Audus (1949) in his work on soils. This was not shown to occur in water alone. The rate of breakdown varied with formulation. Butyl and propyl esters were oxidized biologically in water seeded with settled sewage in seven to nine days but the sodium salt had not been broken down completely by this treatment after 120 days.

A series of experiments designed to study the rate of breakdown of 2,4-D in some of the different natural surface waters in Britain e.g. ponds, sluggish drainage channels and fast flowing streams, was started in January 1966. This report presents the results of the first in this series.

METHODS

The initial experiments were concerned with 2,4-D in water and bottom mud collected in December 1965 from a stagnant pond about two feet deep and frequented by domestic ducks and geese. The water was collected from the bank of the pond before the mud was stirred up and two separate covered plastic containers, holding about 120 litres each were used to store it at room temperature (varying between 5° and 15°C). Ten litres of water from each of the plastic containers were put in earthenware jars, bottom mud being added where appropriate. These were then placed in a greenhouse with a minimum air temperature of 10°C and a day length of 10 hours, a week before treatment and remained there for the whole period of the experiment.

On 13th January the required quantity of an oil soluble 2,4-D amine was added to jars containing water and water plus mud to give a concentration in each of 0.5 ppm 2,4-D a.e. Other jars received no herbicide and were included as controls. Water samples (80 ml each) were taken from both the treated and untreated jars 4 and 11 days after treatment and the 2,4-D concentration determined by means of the sorghum root bio-assay technique described by Parker (1964).

On 8th February, 26 days after the original treatment, the same formulation of 2,4-D amine was added to both the treated and untreated jars. The 2,4-D concentration was determined in the same way as before from water samples taken on the day of treatment and 7, 13 and 21 days afterwards.

RESULTS

The results of the first phase of the experiment are given in Figure 1 and show that within 11 days the concentration of 2,4-D dropped to the lowest level that can be determined reliably by the bio-assay method used (0.1 ppm). There is also some suggestion that breakdown was slower during the first four days after treatment than it was between the 4th and 11th days but it was not possible to establish this with certainty from the data obtained in this phase of the experiment.

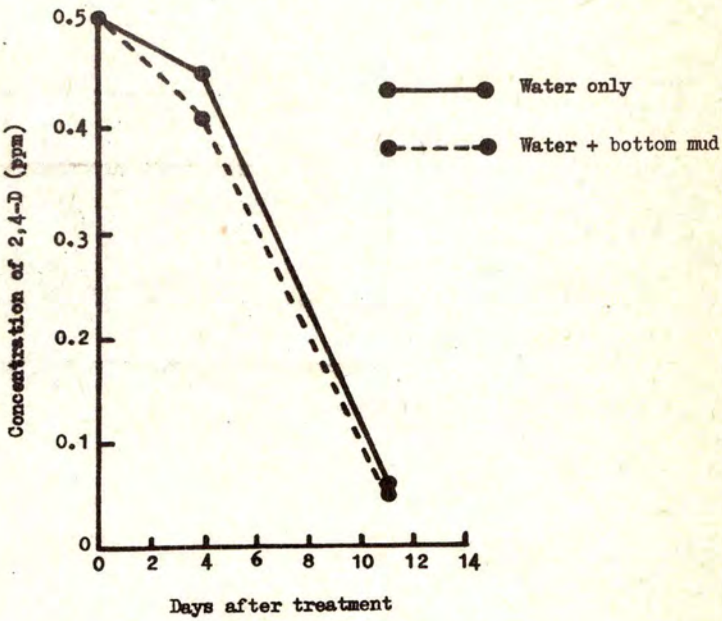

Fig. 1. The breakdown of 2,4-D in pond water with and without bottom mud

The results of the re-treatment of the water in the second phase of the experiment are shown in Figure 2 and demonstrate the immediate breakdown of 2,4-D in the water which had been previously treated with 2,4-D at 0.5 ppm and the pronounced delay in breakdown in the previously untreated samples. The presence of mud had little effect on the breakdown of 2,4-D and therefore the mean of the concentrations in the presence and absence of mud has been used in the figure to simplify the presentation of the data.

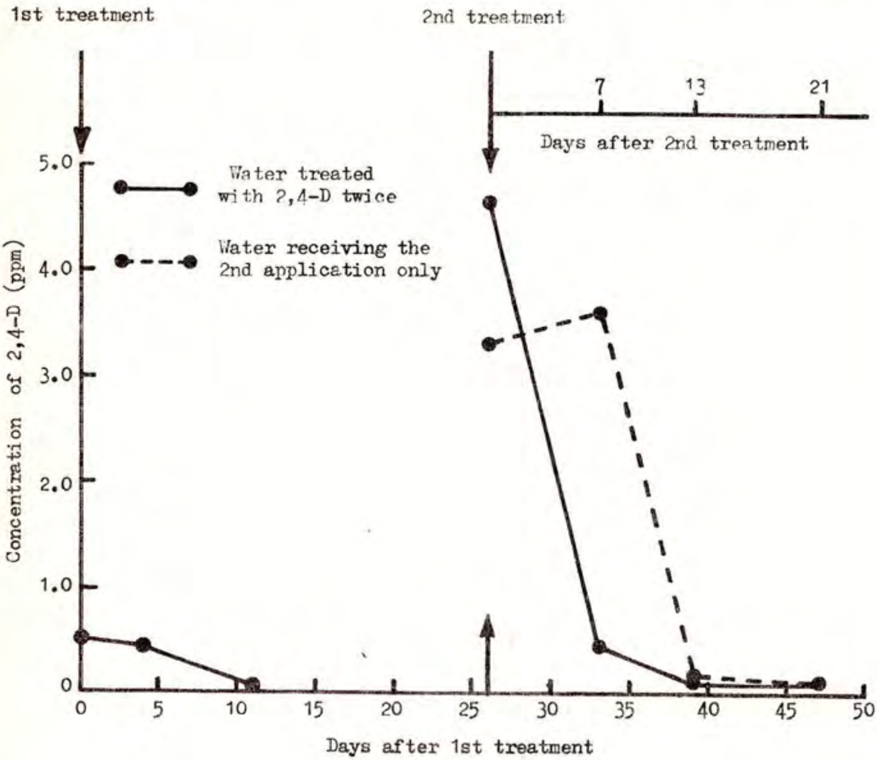

Fig. 2. The rate of breakdown of 2,4-D in pond water previously treated with 2,4-D compared with rate of breakdown in previously untreated water.

DISCUSSION

The delay in breakdown of 2,4-D in the water treated for the first time and the immediate and rapid breakdown in water that had previously received a low concentration of the same herbicide form a pattern similar to that of 2,4-D degradation in soils reviewed by Audus (1960) and it is thought to indicate a similar adaptation of micro-organisms to the presence of 2,4-D. If this is the case then one point of particular practical interest is the very low concentration required to bring about this adaptation to a degree that is sufficient to cause rapid breakdown of subsequent concentrations ten times as great as the original. One of the requirements of a herbicide in most aquatic situations is that it should break down rapidly and these results suggest that the use of very small non-toxic doses as pre-treatments may be a possible technique for increasing the rate of breakdown in the field. However, it must be stressed that these are preliminary results applicable to one set of conditions only and that they cannot yet be applied to other situations where environmental factors may differ.

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FURTHER PROGRESS WITH THE AERIAL APPLICATION OF AQUEOUS SOLUTIONS OF DALAPON TO DRAINAGE DITCHES

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The project for the development of an accurate drift-free system for applying herbicides to narrow targets from the air without additives, was first described at the 7th British Weed Control Conference (Little et al. 1964). The results of the first field trial, were fully reported more recently (Robson et al. 1966).

This work has shown that by using certain spray nozzles developed originally for industrial purposes and selected for their ability to deliver a coarse spray in a narrow swath, accurate, relatively drift-free applications are possible from a helicopter at fifteen feet altitude. It also indicated that neither the method of application nor the lower volume of spray per acre (35 gal as compared with the usual recommendation of 100 gal for ground applications) reduced the effect of dalapon on Phragmites communis.

The Weed Research Organisation (WRO) and the Tropical Pesticide Research Unit (TPRU) have continued to collaborate on this project and on 2nd September, 1965 a further trial was put down at Littleport, near Ely, with the co-operation of the Littleport and Downham Drainage Commission, to compare the effect on Phragmites communis of dalapon applied from the air at three different volumes (10, 20 and 30 gal/acre) and, because there had been signs that lower doses might be effective, at two doses (10 and 20 lb/acre).

A Bell 47 helicopter was used flying at 20 miles/hour at an altitude of 10 feet in a 12 miles/hour wind. The spray volume/acre was altered by fitting different nozzles with the appropriate delivery and droplet characteristics previously selected in tests by TPRU.

In December 1965 the top-growth was cut and removed by the drainage authority.

RESULTS

As this experiment has been planned to compare the different volumes and doses of dalapon no attempt was made to measure the degree of drift in the field. However it was noted that the only visible damage to adjacent crops (wheat and sugar beet) occurred in the very few instances when the spray swath missed the target due to pilot error.

The assessment of the difference between treatments will be based on estimates of regrowth made annually over a period of at least three years. The first of these assessments was completed in mid-June 1966 and the results, obtained from presence or absence records of 100 six inch square quadrats per plot, are given in Table 1.

Table 1.

Comparison of the effect of two doses dalapon applied in three volumes from the air on the re-growth of Phragmites communis.

Spray volume gal/ac	Dalapon lb/ac	Mean reduction of shoot re-growth as percentage of control
30	20	87.7
30	10	92.5
20	20	96.7
20	10	89
10	20	89
10	10	97.9

Although the object of the experiment is to obtain a comparison of the effects of dalapon at various doses and in various volumes, these intermediate results do not allow such comparisons to be made at this stage because all treatments have suppressed regrowth in the first year. However, it is interesting that 10 lb/ac dalapon in only 10 gal/ac water, an application in both respects less than that usually recommended, has at this site given an effect as good as that obtained from the recommended dose (20 lb/ac). It will be necessary to wait for the results of assessments in subsequent years to see whether the treatments continue to be equally effective.

Acknowledgments

The assistance and funds provided by the Tropical Pesticide Research Unit and the co-operation of the Littleport and Downham Drainage Commission is gratefully acknowledged.

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THE USE OF HERBICIDES AS INVERT EMULSIONS FOR AQUATIC WEED CONTROL

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SUMMARY

Results obtained from aerial application of 2,4-D and dalapon as invert emulsions at low volumes suggest that a more rapid kill of emergent water-weeds can be obtained at a significantly lower dose than is now used for commercial application. Properly formulated and applied, invert emulsions enable applications to be made with minimum water contamination and negligible drift. Preliminary results indicate that submerged species present different problems and these are discussed.

INTRODUCTION

The control of aquatic weeds has posed a number of problems from the question of access to the weeds themselves to the possible contamination of the water in which they are growing. A number of different approaches have been employed to overcome the question of access, the simplest being to bathe the plants in a toxic solution but depending on the persistence of the chemical, this raises problems of contamination. Any aqueous solutions "running off" into water are immediately dispersed and are of no further value in controlling weeds while still presenting a contamination problem. Granular materials have been used in an attempt to provide a system which could easily be applied by land equipment, or even aircraft, and would localise active material to a zone where it would be absorbed by the plants, and excesses absorbed by the mud. However, only limited success was achieved under U.K. conditions (Stovell, 1960). Application from aircraft was a natural development yet conventional materials introduced fresh problems in controlling drift and accuracy of application which have occupied other workers. The development of a practical system of consistently producing uniform invert emulsions (Morrow 1962) appeared to offer the possibility of considerably reducing drift (Phillips, 1963). Ford 1966 has discussed the spray characteristics of such formulations. The system also presents the chemical in a physical state which is not miscible with water and will remain for a considerable time as discrete droplets which preferentially attach themselves onto plant cuticles. This work was first carried out with inverts which floated (Robison P.E., 1965) and later for the control of <u>Phragmites communis</u> in Italy (Vavasori A. 1965), both instances showing considerable economies in materials applied. The work reported here was carried out in the Sudan and in the U.K. In the Sudan, a policy of chemical control of water hyacinth (<u>Eichornia crassipes</u>) is carried out using mist blowers mounted on launches. This work is confined to the upper reaches of the Nile since an area of about 300 miles in length along the river is closed to chemical treatments because of cotton crops in the region. Work in the U.K. was in two parts, that on emerged and on submerged weeds.

METHODS AND MATERIALS

Experiments in the Sudan were conducted at two sites, Malakal and Kosti, in February 1964 to confirm that Robison's work could be repeated using formulations capable of producing invert emulsions with a wider water to oil ratio.

In both cases a formulation * capable of "flash" inversion containing 2 lb. 2,4-D a.e./gal as an oil soluble amine with emulsifiers in a light high aromatic solvent was used. To provide a comparison, the material normally used, a diethylamine salt of 2,4-D containing 7.2 lb. a.e./gal, was applied by conventional spraying equipment from the air using a Cessna at 4 lb. a.i./ac.

At Malakal, application was from a Piper P.A. 18.A. equipped with a Bifluid spraying system. The equipment had a fan driven Simplex water pump with a chain drive to a gear pump for the oil phase. Forty-five mixing chamber nozzle bodies Type III were mounted on the boom and fitted with 0940 E jets.

Water : oil ratios were set from 6:1 to 7:1 and applied with a swath width of 33 ft. at air speeds from 75 - 90 miles per hour to give doses of 1.54, 1.75 and 3.5 lbs. a.e./ac. Wind speeds were constant within 2 m.p.h. for each plot, but increased steadily from 5 to 15 m.p.h. as is usual in that locality as the morning progressed.

The volume of application varied with the dose being 5.7 gal/ac, 6.6 gal/ac and 13 gal/ac respectively. These rates were obtained by flying the appropriate number of passes to give the required dosage.

The three plots selected at Malakal comprised water hyacinth (Eichornia cressipes) trapped in islands of papyrus grass to ensure they would be available up to one month after spraying for evaluation and comparison with the surrounding conventional application. Observations were made at three days and three weeks after treatment.

Applications at Kosti were by a Bell 47 G fitted with an electrically driven bifluid rig. The boom had twenty-five Type III nozzles and 0940 E jets. Water:oil ratios were set at 7:1 and the spray applied at 25 m.p.h. and 50 m.p.h. respectively, giving application rates of 1.5 and 1.0 lb. a.e./ac in 8, 6 and 4 gal/ac. in a single application. The area treated was a large mass of floating hyacinth.

Experiments in England were on emerged and submerged weed. The emerged trial was carried out in August 1964 in Kent and application was made by a Piper P.A.18 A with equipment similar to that used at Malakal, except that the Type III mixing chambers were replaced by a manifold mixing chamber. The jets were the same. The formulation used here was a "blank" invert oil + (a light oil containing an emulsifier complex, but no herbicide). The rate of application was 3.5 gal/ac on the first plot and 7 gal/ac on the second plot by flying over it twice. The water: oil ratio applied was 10:1 and the herbicide used was 85% sodium dalapon dissolved in the water phase, the concentration being adjusted to give respectively $7\frac{1}{2}$ and 15 lb sodium dalapon/ac on the two plots.

The plots selected formed a part of the Selby Arm Sewer in Romney Marsh which had not previously been treated and were each about three-quarters of a mile long. Application was at an average speed of 80 m.p.h. and this necessitated cutting off spray and realigning aircraft on some of the sharper bends. Occasionally this procedure was repeated more than once. Application was made from a height of about 4 ft. above the reeds and the swath width was 30 ft. wide.

* Referred to as Fx 11 in some earlier work.

\+ Referred to as Fx 0258 earlier.

The weeds present were principally Phragmites communis, Typha latifolia Sparganium ramosum.

Observations were made three weeks later and in June 1965. It was not possible to spray an exact control plot of the conventional commercial treatment, though there was several miles of such a treatment with 21 lb. sodium dalapon and 4 lb. 2,4-D a.e./ac in close proximity to the trial.

A second series of trials was carried out on a much smaller scale for the control of submerged aquatic weeds using a bifluid knapsack with one and two Type III mixing bodies and fitted with 1421, and later 1418, jets. The plot size varied slightly with location, but averaged 2 yds. wide and 10 yds. long with a minimum of 5 yds. discard between plots. The material used was an oil-soluble amine of 2,4-D containing 2 lb. a.e./gal formulated in a high density oil to be capable of "flash" inversion to produce an invert emulsion which would sink in water. Sites were located in Essex and Berkshire in ditches with negligible flow.

Main species present were:-

Essex: Callitriche spp., Myriophyllum spp., Elodea canadensis.
Berks: (i) Alisma plantago-aquatica, Polygonum hydropiper, Callitriche spp.
(ii) (iii): Potomogeton natans, Elodea canadensis, Callitriche spp., Nymphaea spp.

Doses ranged from 1, 1½ & 2 lbs. a.e./ac in Essex and Berks. (i) (ii) to 2, 3 & 4 lbs a.e./ac in Berks (iii).

RESULTS

Malakal The aerial application of the invert gave a marked response on the leaves of the hyacinth within 24 hours and was visible earlier than on the conventional application. The kill at three weeks was 90% or more at doses of 1.75 lbs. or over. A 50% control was obtained with 1.5 lb. a.e. and new growth was starting to shoot. The control in the commercial comparison was a 90%/95% kill.

Kosti It was not possible to assess the Kosti trial with any accuracy because the floating mass broke up, probably because of the death of some of the plants at the higher rate applied. A large number of affected plants in the area which were re-shooting would probably indicate that the lower rates were insufficient.

Kent All top growth was dead within three weeks in the autumn of 1964, but no estimate of ultimate kill was possible. The overall speed of this die-back was particularly noticeable and emphasised the very sharp cut off at each edge of the swath. In June 1965 there was no growth of Phragmites or Typha on the 15 lbs./ac plot. Some weak re-growth, estimated by independent observers at less than 5%, consisted of Phragmites and some Sparganium on the 7½ lb. plot. The best of the conventional treatments showed not less than 5% Phragmites re-growth.

Essex and Berks (i) Complete control recorded for emerged weeds Alisma and P. hydropiper. Submerged weeds showed only 50% kill at 2 lb. dose, only the outside of Myriophyllum clumps being affected.

Berks (ii) 60% control Callitriche at 2 lbs., 50% control of Elodea. Nymphaea reacting strongly, but impossible to estimate long term effect. No effect on P.natans.

Berks (iii) 85% control of Callitriche, 75% control of E. canadensis. P. natans 30% kill at the 4 lb. dose

DISCUSSION

It was noticeable from all trials that by using invert system a rapid kill was obtained with a significantly lower rate of active material than is used in practice. The reasons for this increased activity have been ascribed to-

i) The oil being outside the droplets. These adhere readily and firmly to any waxy cuticle. Even where this is slightly wet, the impact is usually sufficient to produce adhesion.

ii) The size of the droplet combined with its low spreading characteristics produces and maintains a steep concentration gradient encouraging movement of the material into the translocation stream.

iii) The drops do not disperse in water, but float until they attach themselves to any emergent plant growth.

The low percentage of kill recorded for the 1.5 lbs. a.e./ac rate at Malakal was almost certainly due to the rather scattered cover obtained with the low volume of application used in this treatment when sprayed through 0940 E nozzles. This was particularly noticeable at Kosti since the rotor wash from a helicopter does not break up the droplets to the same extent as the slipstream from a fixed wing aircraft. These nozzles were employed to obtain maximum drift control in view of the total ban on the spraying of any growth regulating herbicide in this area of the Sudan because of the possible damage to the cotton crop. Subsequent experience has indicated that adequate control of drift can be obtained with 1429 E nozzles on fixed wing aircraft and 1418 E nozzles on rotary wing aircraft, the degree of cover being vastly improved.

While rooted emerged aquatics such as Phragmites, Typha, Nymphaea appear to translocate herbicides very well given suitable growth conditions, this does not appear to be true of floating aquatic weeds such as hyacinths. Preliminary results from work with the invert formulated to sink for the control of submerged aquatics indicates a very low degree of translocation of 2,4-D in the control of mats of Callitriche and Myriophyllum. These trials for submerged weeds were not designed to differentiate between cover and weight of active ingredient per acre and this has resulted in a preliminary finding that a minimum of 4 lbs. a.e./ac was required to produce an 80% control. The earlier work with pellets was at doses with five to ten times more acid per acre, so this method of seeking penetration through the leaf is of interest. The effect of equal volumes of less concentrated applications will be investigated in future work. It is, of course, inevitable with an invert system where the toxicant is included in the oil phase that only limited alterations can be made over acceptable alterations in phase ratio, i.e. in the range from 7:1 to 15:1 without altering the concentration of active ingredient in the original oil formulation. The encouraging results on rooted emerged aquatic weeds are now subject of large scale development work for commercial application by aircraft. Helicopters appear to be the ideal vehicle in this respect. The system appears to offer advantages of aerial access to waterways between cropped areas which are too small for boats while enabling spray application to be made without risk of crop damage.

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THE PERSISTENCE OF SOME NEW HERBICIDES IN THE SOIL

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Summary A simple bioassay method was used to follow the loss in phytotoxicity of herbicide-treated soil samples which were aged in the greenhouse. Sixty two herbicides were studied in a five-year series of experiments, and were categorised according to the time taken for the freshweight reduction of the assay species to fall to 50% and 20% relative to the controls. These results are discussed in terms of 1) the relationship between the phytotoxicities of the samples and the concentrations of herbicide remaining and 2) the relationship between herbicide persistence in the greenhouse and in the field. Some possible improvements to the technique are suggested.

INTRODUCTION

When the potentialities of a new soil-acting herbicide are being examined one of the most important properties which must receive attention is the persistence of the compound, both in the plant and in the soil. The persistence of a herbicide in the soil will very often determine the duration of weed control which is obtained in the treated crop, and may also affect the safety of succeeding crops. Potential persistence must therefore be examined as early as possible in the evaluation of each new soil-acting herbicide. Detailed information on this property is seldom included in the manufacturers' literature. In addition little comparative data on the persistence of a wide range of herbicides has been published.

At this early stage a simple test is needed. Soil and environmental conditions must be standardised as far as possible so that results from a series of tests may be compared. New herbicides may be available initially only in small quantities. These requirements favour a laboratory or greenhouse technique rather than a field study.

These considerations led the A.R.C. Unit of Experimental Agronomy, and later the Weed Research Organisation, to adopt a greenhouse technique using simple biological assays to assess the potential persistence of new soil-acting herbicides. The technique is in many ways similar to that used by Sheets and others (Sheets and Crafts, 1957; Sheets and Shaw, 1963) to examine the persistence of herbicides in the soil under greenhouse conditions.

METHODS AND MATERIALS

Treatment method

Tin plate containers either 5 x 6.5 in. or 5.3 x 7.5 in. were filled to a depth of 2.0 to 2.3 in. with slightly moist sieved topsoil. The soil used for new herbicides tested from 1963 onwards (approximately half the total number of experiments) was a sandy loam taken from a field at Begbroke Hill Farm, having an organic matter content of about 3%, a clay content of about 13% and a pH near to neutral. Soils for the earlier experiments came from two other sources and had organic matter contents between 4.8 and 7%, clay contents of 20 to 37% and pH values from 5.0 to 7.8.

The herbicides were generally applied as water-based sprays in the formulations supplied by the manufacturers or, if unformulated, in a suitable solvent such as a mixture of water and acetone. They were sprayed onto the soil surface from laboratory sprayers embodying a single 'Teejet' fan nozzle moving at constant speed above a spray bench. Each treatment was replicated twice. Unless stated otherwise the herbicide deposits were incorporated into the full depth of the soil within an hour of application; in the case of volatile materials this interval was reduced to a few minutes.

After mixing, the soil samples were replaced in their containers and transferred to the greenhouse bench where they - and appropriate untreated control samples - were kept moist by light overhead watering at suitable intervals. Greenhouse air temperatures were in the range 10 to 25°C, and exceeded these limits only occasionally. No attempt was made to shield the soil samples from sunlight.

Assay method

At intervals after treatment the soil samples were permitted to dry out. Each was then removed from its container, thoroughly mixed, sub-sampled and replaced. The containers of soil were returned to the greenhouse after sampling.

The sub-samples were put into 2.5 in. diameter plastic pots, moistened, and then planted with a fixed number (usually 10 or 12) of dry, or in later experiments pre-germinated, seeds of an appropriate assay species. In earlier experiments in the series the seeds were covered with 30 ml of treated soil; later 20 ml of fine sharp sand was used instead. In early experiments a single assay pot was filled from each of the two replicate containers. Later the number of assay pots was increased to two. The assay species were selected partly because they were among the most sensitive species to the herbicide in question, and partly for ease of handling.

The bioassay pots stood in the greenhouse in foil dishes, so that any herbicide leached through by watering would be drawn back again as the pot dried out. After approximately three weeks the above-ground parts of the assay plants were cut off and their fresh weights were recorded. The mean freshweight per pot was then expressed as a percentage of the control mean, and plotted against the time from herbicide application until sub-sampling.

The sensitivity of the assay species was established initially either from an assay immediately after spraying, or from the selectivity test with which each persistence trial was associated. The intervals between persistence assays depended on the herbicide being examined. Certain of the carbamate experiments were assayed every 2 or 3 weeks. With more persistent herbicides the intervals, especially near the end of a trial, were in excess of 16 weeks.

Herbicides

The following 62 herbicides were studied:

Carbamates

propham chlorpropham
BiPC (1-methylprop-2-ynyl N-(3-chlorophenyl)carbamate)
UC 22463 (3,4-dichlorobenzyl-N-methylcarbamate + 2,3-dichlorobenzyl-N-methylcarbamate)
M&B 9057 (methyl 4-aminobenzenesulphonylcarbamate)

Thiocarbamates

EPTC di-allate
PEBC (S-propyl N-butyl-N-ethylthiolcarbamate)
R-1910 (ethyl N,N-diisobutylthiolcarbamate)
R-4572 (S-ethyl N,N-hexamethylene(thiolcarbamate))

Anilines

trifluralin
benefin (N-butyl-N-ethyl-α,α,α-trifluoro-2,6-dinitro-p-toluidine)
SD 11831 (2,6-dinitro-N,N-dipropyl-4-(methylsulphonyl)-aniline)

Amides

diphenamid
CP 31393 (α-chloro-N-isopropylacetanilide)
CP 31675 (α-chloro-6-t-butyl-o-acetotoluidide)
CP 32179 (6-t-butyl-o-bromoacetotoluidide)
CP 45592 (6-methyl-N-methoxymethyl-2-t-butyl-α-bromoacetanilide)

Substituted ureas

diuron fenuron linuron monolinuron chloroxuron cycluron
metobromuron (N'-(4-bromophenyl)-N-methoxy-N-methylurea)
C 6313 (N'-(4-bromo-3-chlorophenyl)-N-methoxy-N-methylurea)
fluometuron (N'-(3-trifluoromethylphenyl)-N,N-dimethylurea)
difenoxuron (N'-4-(4-methoxyphenoxy)phenyl-N,N-dimethylurea)

Chlorotriazines

simazine atrazine propazine
GS 13529 (2-chloro-4-ethylamino-6-t-butylamino-1,3,5-triazine)
WL 8535 (2-chloro-4-isopropylamino-6-(N-phosphorodiamido-N-ethyl)amino-1,3,5-triazine)

Alkylthiotriazines

simetryne ametryne prometryne desmetryne
GS 11349 (4-ethylamino-2-methylthio-6-n-propylamino-1,3,5-triazine)
GS 11357 (4-methylamino-2-methylthio-6-n-propylamino-1,3,5-triazine)
GS 14253 (4-ethylamino-2-methylthio-6-sec.butylamino-1,3,5-triazine)
GS 14260 (4-ethylamino-2-methylthio-6-t-butylamino-1,3,5-triazine)
GS 16065 (4-ethylamino-2-ethylthio-6-isopropylamino-1,3,5-triazine)

Benzonitriles

dichlobenil
chlorthiamid (2,6-dichlorothiobenzamide)
PH 40-25 (N-hydroxymethyl-2,6-dichlorothiobenzamide)

Methoxytriazines

simeton atraton prometon

Diazines

isocil bromacil pyrazon
lenacil (3-cyclohexyl-6,7-dihydro-1H-cyclopentapyrimidine-2,4-(3H,5H)dione)

Other groups and miscellaneous

endothal
WL 9385 (2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine)
nitrofen (2,4-dichlorophenyl 4-nitrophenyl ether)
CP 13936 (methylthio-2-nitrobenzene)
medinoterb (2,4-dinitro-3-methyl-6-t-butylphenol)
BV-201 (1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone)
BV-207 (1-(3-chloro-4-methylphenyl)-3-methyl-2-pyrrolidinone)
PH 40-21 (3,4,6-trichlorobenzo-1-thia-2,7-diazole)
D-263 (1,1-dimethyl-4,6-diisopropyl-5-indanyl ethyl ketone +
1,1-dimethyl-4,6-diisopropyl-7-indanyl ethyl ketone)
'Daxtron' (2,3,5-trichloro-4-pyridinol)

RESULTS

Two figures were derived from the graphs relating the weight of the bioassay plants to the age of the soil samples. These were the time taken for the growth inhibition to fall to 50%, and to 20%. The figures were then assigned to categories which are defined as follows:

A = less than 4.5 weeks;
B = 4.5 to 25 weeks;
C = 25 to 60 weeks;
D = greater than 60 weeks.

The results are presented in this form in Table 1. A blank entry indicates that at no time were the assay plants depressed by the specified amount.

The capital letters showing the persistence categories are followed by a lower-case letter indicating the sensitivity of the assay species. The assay sensitivities are defined by the degree of inhibition produced by each herbicide dose at the start of the persistence period. The sensitivities are graded as follows:

- h = highly sensitive; all plants killed in phytotoxicity assay at start of experiment.
- m = moderately sensitive; some survival in initial phytotoxicity assay, but freshweight reduction of more than 50%.
- l = low sensitivity; freshweight reduction of less than 50% in initial assay.
- x = no initial data available.

Also shown in Table 1 are abbreviations for the assay species, as follows:

IRG = Italian ryegrass	TN = turnip
PRG = perennial ryegrass	KL = kale
WC = white clover	TIM = timothy

The results for atrazine and CP 31675 are each derived from 3 separate experiments. Those for di-allate, EPTC, trifluralin, linuron, diuron, isocil, simazine, atraton, simeton, prometon, simetryne, prometryne and nitrofen come from 2 separate experiments each. These are all reported individually. The results for the remaining compounds come from single experiments.

Table 1.

A categorisation of herbicides according to their persistence in soil as shown by the time taken for their activity to decrease below levels giving 50% and 20% inhibition of a test species

Herbicide	Dose (lb/ac)	Assay Species	Persistence category 50%	Persistence category 20%
Ureas				
diuron	0.25	TN	Cx	Cx
	0.5	IRG	Bm	Cm
	1.0	TN	Cx	Cx
	2.0	IRG	Dm	Dm
	4.0	TN	Cx	Cx
linuron	0.33	IRG	-	Al
	0.5	IRG	-	Am
	1.0	IRG	+	Cm
	2.0	IRG	Cm	Cm
	3.0	IRG	Dm	Dm
monolinuron	0.33	TN	Bm	Bm
	1.0	TN	Bh	Ch
	3.0	TN	Ch	Dh
metobromuron	0.33	TN	Bm	Bm
	1.0	TN	Bh	Bh
	3.0	TN	Ch	Ch
fenuron	0.5	IRG	Am	Bm
C 6313	0.33	TN	Bx	Bx
	1.0	TN	Bx	Bx
	3.0	TN	Bx	Cx
fluometuron	0.25	TN	Bx	Cx
	1.0	TN	Cx	Cx
	4.0	TN	Cx	Cx
chloroxuron	1.0	TN	Bx	Bx
	4.0	TN	Cx	Cx
	10.0	TN	Cx	Cx
difenoxuron	0.25	TN	Bx	Bx
	1.0	TN	Bx	Bx
	4.0	TN	Bx	Bx
cycluron	0.125	IRG	-	Bl
	0.5	IRG	Bm	Bm
	2.0	IRG	Cm	Cm

+ = data unsatisfactory

Table 1 (Continued)

Herbicide	Dose (lb/ac)	Assay Species	Persistence category 50%	20%
Chlorotriazines				
simazine	0.25	IRG	Cm	Dm
	0.25	IRG	Bm	Bm
	1.0	IRG	Dm	Dm
	1.0	IRG	Dm	Dm
	4.0	IRG	Dh	Dh
	4.0	IRG	Dh	Dh
atrazine	0.11	TN	Bx	Bx
	0.25	IRG	Bh	Ch
	0.25	IRG	Bm	Bm
	0.33	TN	Cx	Cx
	1.0	IRG	Dh	Dh
	1.0	IRG	Dm	Dm
	1.0	TN	Dx	Dx
	4.0	IRG	Dh	Dh
	4.0	IRG	Dh	Dh
propazine	0.25	IRG	-	Bm
	1.0	IRG	Cm	Dm
	4.0	IRG	Dh	Dh
GS 13529	0.33	TN	Cx	Dx
	1.0	TN	Dx	Dx
	3.0	TN	Dx	Dx
WL 8535	0.33	TN	Bx	Cx
	1.0	TN	Dx	Dx
	3.0	TN	Dx	Dx
Methoxytriazines				
simeton	1.0	IRG	Dm	Dm
	4.0	IRG	Dh	Dh
atraton	0.25	IRG	Bm	+
	1.0	IRG	Dm	Dm
	1.0	IRG	Dm	Dm
	4.0	IRG	Dh	Dh
	4.0	IRG	Dh	Dh
prometon	0.25	IRG	Bm	Dm
	1.0	IRG	Dm	Dm
	1.0	IRG	Dm	Dm
	4.0	IRG	Dm	Dm
	4.0	IRG	Dh	Dh
Diazines				
isocil	0.06	IRG	Am	Bm
	0.17	IRG	Dm	Dm
	0.17	IRG	Cm	Dm
	0.5	IRG	Dh	Dh
	0.5	IRG	Dm	Dm
	1.5	IRG	Dh	Dh
bromacil	0.06	IRG	-	Bl
	0.17	IRG	Bm	Dm
	0.5	IRG	Dm	Dm
lenacil	0.33	IRG	Am	Cm
	1.0	IRG	Bm	Cm
	3.0	IRG	Dm	Dm
pyrazon	1.0	IRG	Bm	Bm
	3.0	IRG	Cm	Cm

Herbicide	Dose (lb/ac)	Assay Species	Persistence category 50%	20%
Alkylthiotriazines				
simetryne	0.25	IRG	-	Al
	1.0	IRG	Bm	+
	1.0	IRG	Am	Bm
	4.0	IRG	Cm	Cm
	4.0	IRG	Dm	Dm
ametryne	1.0	IRG	Bm	Cm
	4.0	IRG	Dm	Dm
prometryne	0.33	TN	Bx	Bx
	1.0	IRG	+	Dm
	1.0	TN	Bx	Bx
	3.0	TN	Cx	Cx
	4.0	IRG	Dm	Dm
desmetryne	1.0	IRG	+	+
	4.0	IRG	Dh	Dh
GS 11349	0.33	TN	Bx	Bx
	1.0	TN	Bx	Bx
	3.0	TN	Bx	Bx
GS 11357	0.33	TN	Bx	Bx
	1.0	TN	Bx	Bx
	3.0	TN	Bx	Bx
GS 14253	0.33	TN	Bx	Bx
	1.0	TN	Bx	Bx
	3.0	TN	Bx	Bx
GS 14260	1.0	PRG	Am	Bm
	4.0	PRG	Bm	Cm
GS 16065	0.25	PRG	Am	Bm
	1.0	PRG	Bm	Cm
	4.0	PRG	Ch	Ch
Amides				
CP 31393	1.0	PRG	-	Al
	3.0	PRG	Am	Bm
	9.0	PRG	Am	Bm
CP 31675	0.33	IRG	Bm	Bm
	0.33	IRG	Bh	Bh
	0.33	PRG	Bh	Bh
	1.0	IRG	Bh	Ch
	1.0	IRG	Bh	Bh
	1.0	PRG	Bh	Bh
	3.0	IRG	Bh	Ch
	3.0	IRG	Ch	Ch
	3.0	PRG	Bh	Bh
CP 32179	3.0	IRG	Bm	Bm
CP 45592	0.67	PRG	Am	Bm
	2.0	PRG	Bm	Bm
	6.0	PRG	Bh	Bh
diphenamid	0.5	IRG	Bm	Cm
	2.0	IRG	Ch	Ch
	8.0	IRG	Ch	Ch

+ = data unsatisfactory

Table 1 (Continued)

Herbicide	Dose (lb/ac)	Assay Species	Persistence category 50%	20%
Carbamates				
propham	0.56	IRG	Am	Am
	1.69	IRG	Ah	Ah
	5.06	IRG	Ah	Ah
chlorpropham	0.56	IRG	Am	Am
	1.69	IRG	Am	Am
BiPC	0.56	IRG	Am	Am
	1.69	IRG	Bm	Bm
UC 22463	1.0*	WC	Bh	Bh
	3.0*	WC	Bh	Bh
	9.0*	WC	Bh	Bh
M&B 9057	0.5	KL	Am	Am
	2.0	KL	Ah	Ah
	8.0	KL	Bh	Bh
Miscellaneous				
WL 9385	0.33	TN	Bx	Bx
	1.0	TN	Bx	Bx
	3.0	TN	Dx	Dx
nitrofen	1.0	IRG	-	Bl
	1.0*	TIM	Bh	Bh
	3.0	IRG	-	Bl
	3.0*	TIM	Bh	Bh
	9.0	IRG	Cm	Dm
	9.0*	TIM	Bh	Bh
CP 13936	6.0	TN	Bm	Bm
medinoterb	0.86*	WC	-	Bm
	2.57*	WC	Bh	Bh
endothal	1.69	IRG	-	Al
	5.06	IRG	Am	Am
	15.19	IRG	Am	Am
BV-201	1.0	TN	Bx	Bx
	3.0	TN	Cx	Cx
	9.0	TN	Cx	Cx
BV-207	1.0	TN	Bx	Bx
	3.0	TN	Bx	Cx
	9.0	TN	Cx	Cx
PH 40-21	0.7	PRG	Bm	Bm
	1.0	PRG	Bm	Bm
	3.0	PRG	Dm	Dm
	9.0	PRG	Dh	Dh
D-263	0.5	PRG	-	Bm
	1.5	PRG	Bm	Bm
	4.0	PRG	Bh	Ch
'Daxtron'	0.1	PRG	Bm	Cm
	0.4	PRG	Cm	Cm
	1.6	PRG	Ch	Ch

Herbicide	Dose (lb/ac)	Assay Species	Persistence category 50%	20%
Thiocarbamates				
EPTC	0.125	IRG	Am	Am
	0.5	IRG	Bh	Bh
	0.5	IRG	Ah	Bh
	2.0	IRG	Bh	Ch
	2.0	IRG	Bh	Bh
	8.0	IRG	Bh	Bh
PEBC	0.5	IRG	Am	Am
	2.0	IRG	Ah	Bh
	8.0	IRG	Ah	Bh
R-1910	0.5	IRG	Bm	Bm
	2.0	IRG	Bm	Cm
	8.0	IRG	Ch	Ch
R-4572	0.5	IRG	-	Al
	2.0	IRG	Am	Bm
	8.0	IRG	Am	Bm
di-allate	0.125	IRG	Am	Am
	0.5	IRG	Am	Bm
	0.5	IRG	Bh	Bh
	2.0	IRG	Ch	Ch
	8.0	IRG	Ch	Ch
Anilines				
trifluralin	0.33	PRG	Bm	Cm
	0.33	IRG	Bm	Bm
	1.0	PRG	Ch	Ch
	1.0	IRG	Ch	Dh
	3.0	PRG	Ch	Ch
	3.0	IRG	Dh	Dh
benefin	0.33	PRG	-	Bl
	1.0	PRG	Bm	Cm
	3.0	PRG	Ch	Ch
SD 11831	0.33	PRG	-	Bl
	1.0	PRG	Cm	Cm
	3.0	PRG	Cm	Cm
Banzonitriles				
dichlobenil	0.17	IRG	Am	Bm
	0.5	IRG	Bh	Bh
	1.5	IRG	Ch	Ch
chlorthiamid	0.36	PRG	Bh	Bh
	1.44	PRG	Ch	Ch
PH 40-25	0.42	PRG	Am	Bm
	1.68	PRG	Dm	Cm

* = applied as surface spray, and incorporated only at time of assay

DISCUSSION

The normal purpose of herbicide bioassays in persistence experiments is to show the concentration of herbicide present. This is deduced from the observed phytotoxic response of the assay species by reference to artificially-prepared standards of known concentration. In the experiments reported here there were no such standards; the bioassays showed only the phytotoxicity of soil samples at different times after treatment. The observed effects are therefore a result of the interplay of two factors: 1) the persistence of the herbicide in the soil, and 2) the sensitivity of the assay species. Direct comparisons of herbicide persistence are possible only where the assay sensitivities are the same. Since this was not so in most of the experiments reported in Table 1 some caution is needed in comparing results for one herbicide with results for another. An example of the way in which phytotoxicity data can be misleading in the absence of sensitivity data is given in Table 2.

Table 2

Initial toxicity of pyrazon and lenacil to Italian ryegrass, compared with the time required for growth inhibition to fall to 50% and 20%

Herbicide	Dose (lb/ac)	Initial freshwt. as % of control	Time to 50% (weeks)	Time to 20% (weeks)
pyrazon	0.33	81	-	-
	1.0	30	8	25
	3.0	10	50	55
lenacil	0.33	10	4	35
	1.0	2	15	30
	3.0	1	70	80

When pyrazon and lenacil are compared on a pound-per-acre basis it is lenacil which appears the more persistent. But if compared at doses which are equally toxic to the assay species initially (pyrazon 3 lb/ac vs. lenacil 0.33 lb/ac) it is pyrazon which appears more persistent. Nevertheless, from a practical point of view it should be borne in mind that the assay species were chosen from those most susceptible in pre-emergence selectivity trials in the greenhouse. By the time the reduction in freshweight had fallen below 20% it is unlikely that any herbicide residue in the soil would be of agricultural importance.

Herbicide dosage must also be considered in interpreting the results in Table 1. Each of the persistence experiments was associated with a greenhouse selectivity experiment. Of the three doses which were generally used the lowest often had little effect on the weeds, while the highest often caused unacceptable depressions in the vigour of the crops. It is the middle dose or doses which most often showed the selectivity pattern characteristic of the normal field dose, and it is the persistence data for these which should be given most weight in anticipating the persistence of a new herbicide in the field. Where only two doses are shown it is the lower which is usually the more important.

Throughout the series of experiments the soil samples were kept warm and reasonably moist in the greenhouse. These conditions are known to favour the breakdown of herbicides in the soil by micro-organisms (Burnside et al, 1963, Sheets and Harris, 1965) and will not be inimical to less important causes of loss such as chemical breakdown or, for some herbicides, volatilisation. Yet examination of the results in Table 1 for those herbicides which are now well established shows a generally longer persistence than would be expected from subsequent field performance. For example, when Clay (unpublished) studied the persistence of simazine in the field at Begbroke a dose of 1 lb/ac fell to a concentration approximating to the limits of detection for a ryegrass bioassay after 11 months under dry conditions, after 6 months under natural rainfall, and after 3.5 months under irrigation. In both greenhouse experiments simazine at 1 lb/ac was still giving substantial inhibition of ryegrass after approximately 16 months. This sort of comparison suggests that, despite attempts to achieve the contrary, the persistence obtained in the greenhouse was often near to the maximum which would be expected in the field. It is not possible to say whether this is due to differences in microbial activity, or whether it is because dissipation by leaching was prevented under greenhouse conditions.

Rather than place too much emphasis on the meanings of categories A, B, C and D in weeks it is perhaps more helpful, therefore, to consider their implications in the light of what has been written above, in terms of selective weed control in a typical annual crop.

Category A implies a herbicide treatment with very little residual effect.
Category B implies a herbicide treatment which may continue to produce residual effects until the crop is nearing maturity.
Category C implies a herbicide treatment which may continue to produce residual effects after the crop is harvested, and could damage sensitive crops which follow later in the same season.
Category D implies a herbicide treatment which may continue to produce residual effects for some time into the following season, and could damage crops planted at that time.

In this way the simple greenhouse technique which has been described can be used as a guide to the potential persistence or a new soil-acting herbicide under field conditions.

In conclusion some improvements can be suggested to the present technique. The original persistence figures were converted to categories for presentation in Table 1 because of the variability of the original data. Part of this variability could be due to inadequate control of temperature in the present experiments, since McCormick and Hiltbold (1966) have shown a twofold increase in the rate of disappearance of simazine and a threefold increase in the rate of disappearance of diuron with a temperature rise of 10 C°. From the results of Sheets and Crafts (1957), who showed the rate of dissipation of substituted urea herbicides to be slower when the soil samples were permitted to dry out than when they were kept continuously moist, it appears that variability in the trials reported here might be further reduced if the samples were watered to a constant weight, rather than being sprinkled when visual inspection suggested this to be necessary.

In the present experiments it often took more than a year to discover the limits of the phytotoxic life of a new herbicide in the soil. It is most desirable that an indication of the potential persistence of a new herbicide should be obtained as early as possible in its evaluation. Therefore there is a case for adopting some standard method of accelerating the rate of breakdown, provided each experiment includes a reference herbicide of which the persistence is known under various field conditions. McCormick and Hiltbold have achieved large increases in the rate of herbicide breakdown by adding glucose to the soil. If this procedure was adopted as routine it should be possible to get an estimate of persistence in a shorter time, although there is some evidence from preliminary experiments by the present authors that when the soil is treated in this way there can be an accumulation of phytotoxicity in the absence of any herbicide, so that biological assays may not always be possible. However work is continuing on such an accelerated breakdown test.

Acknowledgments

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Research Summary

SOME STUDIES ON THE FATE OF PICLORAM AND DICAMBA IN SOILS UNDERLYING BRACKEN

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INTRODUCTION

Hodgson and Donaldson (1966) have reported separately on field trials in which dicamba and picloram showed promise for the control of Pteridium aquilinum (L.) Kuhn. (bracken). The following associated studies were conducted to determine the dangers which might arise from the herbicides either (a) leaching into the ground water, or (b) persisting in the bracken litter or underlying soil.

METHODS AND MATERIALS

(i) Two preliminary experiments were carried out in which various soils were placed in 10 in. diameter cylindrical glazed pots. Dicamba-sodium and picloram-potassium were each sprayed at 4 lb/ac a.e. on to the surface. The pots were then placed in a greenhouse for 4 weeks, and watered regularly. The amount of herbicide remaining in various layers of soil from these pots was then determined by bio-assay using the dwarf bean as a test plant.

(ii) Samples of bracken litter and soil were collected from plots at several sites where dicamba and picloram had been applied up to 3 years earlier. The samples were usually taken from the upper 4-8 in. and included organic and mineral layers. These samples were dried, mixed and assayed for herbicide residues as above.

(iii) For further elucidation of certain aspects, some more detailed studies were made including (a) more complex assays with dwarf bean in bracken litter variously steam sterilised and/or treated with hydrated lime, and (b) short-term persistence studies using the sorghum root-growth assay (Parker, 1964).

RESULTS

Picloram

The first two experiments in pots showed (a) that 4 in. of overhead watering carried 50% of the herbicide through a 5 in. layer of bracken litter, and (b) that there was no detectable degradation of picloram in bracken litter over a 4-week period at 15°C.

The first bio-assays on samples from one field experiment did not give precise results, owing to uneven growth of the bean plants, but did show that residues in the top 4-6 in. from an initial application of 4 lb/ac were very approximately 0.2 lb/ac after 4 months and 0.1 lb/ac after 12 months. Tests on soils from a second site showed residues of 0.1 lb/ac after 12 months and 0.01 lb/ac after 2 years. After 3 years, they did not appear to have declined any further, and still caused severe distortion of the bean plants.

Greenhouse studies showed that small amounts were degraded in the soil. This loss was arrested by steam sterilisation, or by raising the pH to 7.5, and is

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considered to be due to microbial, possibly fungal, action; but the rate of degradation was estimated to be less than 0.001 lb/ac in. of soil, per week.

Dicamba

The initial experiments in pots showed some leaching through a 5 in. layer of bracken litter, but less than 50% of the dicamba was recovered, and substantial breakdown had apparently also occurred. The bio-assay method gave erratic results in the early experiments, but the cause of this was eventually traced and the following conclusions have been drawn:-

(i) Breakdown of dicamba in bracken litter at pH4 can be extremely rapid. For instance, at 25°C., 50% of an initial 1.25 lb/ac in. dose was lost in 4 days. At lower initial doses, the absolute rate of loss was smaller, but the percentage loss was greater.

(ii) Raising the pH to 7.5 by addition of $Ca(OH)_2$ reduced the rate of loss very substantially and allowed the bean to be used as a bio-assay plant.

(iii) The loss was also arrested by low temperatures and by steam sterilisation, and was believed to be due to microbial action.

(iv) Initial rates of loss in the field were not precisely assessed, but appeared to be comparable to those of picloram.

(v) After 12 months, residues from 4 and 8 lb/ac applied in the field, were no longer detectable by the bean bio-assay in unmodified litter, but when lime was added, damage was caused consistent with a residue of about 0.01 lb/ac in. After 3 years the residue had been reduced further but was still detectable. It is supposed that small amounts of dicamba are adsorbed on to bracken litter in such a way as to resist microbial attack for extended periods.

CONCLUSIONS

Initial disappearance of picloram from surface layers of treated soil is moderately rapid, presumably due to leaching. Degradation of picloram in the soil has been demonstrated, but is slow, and small residues persist in the upper soil layers for at least 3 years. The fate of picloram leached into the ground is not known, but would be cause for concern if large areas of bracken were to be treated.

Dicamba is subject to very rapid microbial breakdown in bracken soils at pH 4, but small residues can persist for at least 3 years, which become active when the soil pH is raised. These are a possible danger to susceptible species such as clover. Breakdown of dicamba is much slower at pH 7.5.

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PRE-TREATMENT OF SOIL WITH MCPA AS A FACTOR AFFECTING PERSISTENCE OF A SUBSEQUENT APPLICATION.

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Summary Details are given of two experiments in each of which the disappearance of detectable residues of MCPA was observed, following application to soil which had (a) received field applications of MCPA, or (b) had not previously been treated with MCPA.

In the first experiment, soil taken from plots which had received 7 previous applications of MCPA-sodium/potassium at 3 lb/ac a.e., during a 3½ year period as a soil treatment, showed a marked increase in ability to break down MCPA, compared with soil from adjacent plots that had not previously been treated with MCPA.

In the second experiment, there was no apparent difference in the disappearance rate of MCPA from field plots which had received 11 treatments of 2 Ib/ac a.e. MCPA-sodium on barley during 14 consecutive years of cropping, compared with adjacent plots which had never received MCPA. In this experiment a residue from MCPA at 10 lb/ac was barely detectable 13 days after spraying. It is possible that heavy rainfall shortly after spraying may have contributed to this exceptionally rapid disappearance.

INTRODUCTION

There is considerable evidence that disappearance of MCPA from soil is correlated with conditions favourable to the growth of micro-organisms (Audus, 1951; 1960; Brownbridge, 1956; De Rose and Newman, 1948). The following bacteria isolated from soil have been shown to decompose MCPA:- Flavobacterium peregrinum and two Achromobacter strains (Steenson and Walker, 1956; 1957; 1958), Mycoplana sp. (Walker and Newman, 1956), Achromobacter sp., Bell, 1958; Stanier, 1947; Stapp and Wetter, 1953), Flavobacterium aquatile and Corynebacterium sp. (Jensen and Petersen, 1952).

It has been shown by Brownbridge (1956), that under conditions of soil perfusion *in vitro*, 80% of an initial concentration of 100 ppm MCPA could be detoxified within 85.7 ± 23.1 days, but that subsequent applications could be detoxified to the same extent within 8.3 ± 0.79 days.

Briefly reported work at Rothamsted (Anon, 1956), showed that successive doses of MCPA (and 2,4-D) in the field increased the subsequent rate of disappearance, until 50 ppm disappeared in 4 to 6 days, and that the postulated adaptation of the soil micro-flora responsible for this accelerated breakdown could be induced by an initial dose providing 1 ppm in the soil. Further, this 'enriched' state has been shown to persist without further addition of herbicide for at least six months in the field in the case of MCPA and 2,4-D (Anon, 1956), and for one year in stored moist soil for 2,4-D (Brownbridge, 1956).

The most acceptable theory of the mechanism of enrichment postulates the synthesis of adaptive enzymes by the cells of certain responsive strains or species of bacteria (Cohn and Monod, 1953).

While the work described above clearly indicates the probability that repeated practical use of MCPA in field crops is likely to lead to accelerated breakdown compared with that in hitherto untreated soil, no work has been published which demonstrates that this does, in fact, occur. The practical significance of the work of Brownbridge is also open to doubt in view of the much higher concentrations used, compared with the 1 to 2 ppmw more commonly occurring in practical field treatments (equivalent to c. 1-2 lb of chemical in the top 3 in. of soil per acre). The opportunity was therefore taken to study the rate of breakdown of MCPA in the plots of two long-term field experiments in which soil was available, which (a) had been regularly treated with MCPA for a number of years, and (b) had never received MCPA.

METHODS, MATERIALS AND RESULTS

Experiment 1

This took the form of a subsidiary investigation on plots of a long-term herbicide experiment which has been in existence since 1963 at the A.R.C. Weed Research Organisation.

The object was to investigate the breakdown of MCPA applied to soil taken from plots: (a) which had received a total of seven applications of MCPA-sodium/potassium at 3 lb/ac a.e. on bare soil, i.e. in each spring and autumn during the period 1963-65, and in the spring of 1966, and (b) which had not received any MCPA since prior to 1960. The soil is a coarse, sandy loam.

Forty 6 in. deep, 1 in. diameter soil cores were taken from each of the pre-treated plots (size 10 x 5 yd) and from the untreated control plots on 4th July, 1966, the last application of MCPA having been on 1st June, 1966. The cores from each plot were bulked.

The moist soil was sieved through a 0.125 in. sieve, thoroughly mixed, and 100 ml samples placed in pots and sprayed with MCPA-potassium at 3 lb /ac a.e. at a volume rate of 25 gal/ac using the W.R.O. pot sprayer.

Some pots were removed immediately after spraying and stored at -3°F. The remainder were placed in foil dishes in the greenhouse in random positions and watered from beneath, each pot receiving the same amount of water.

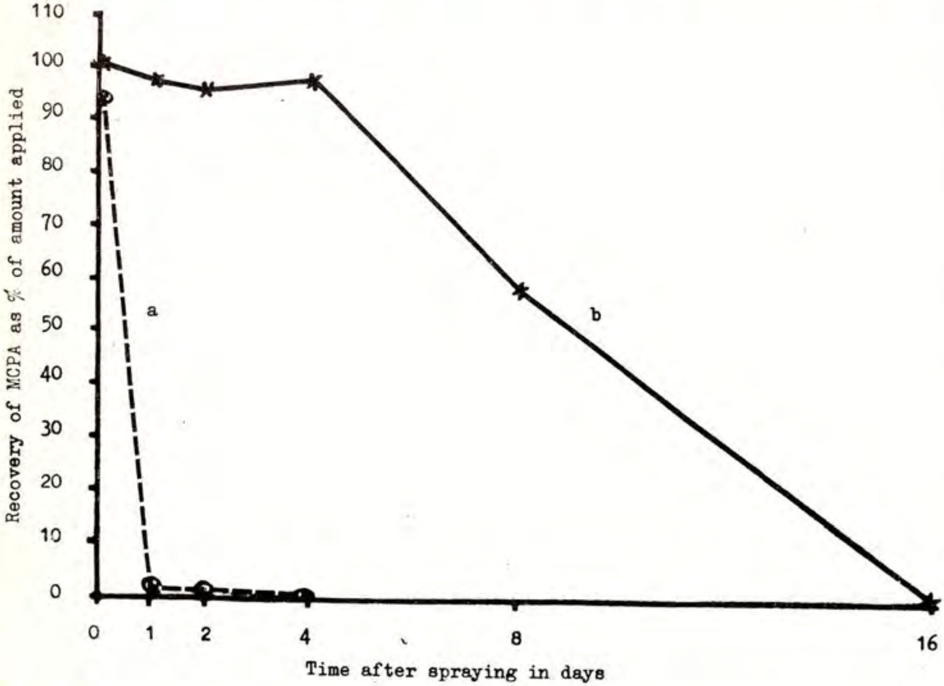
Pots were removed at random at intervals of 1, 2, 4, 8, 16 and 32 days after spraying, and the soil deep-frozen until required for MCPA estimation. The samples were then thawed, air-dried at room temperature for 6 days and sieved through a 0.125 in. sieve. The air-dry samples were shaken in a tin to disperse the herbicide residue as evenly as possible through the soil.

The temperature of the greenhouse varied from 15 to 25°C throughout the experimental period.

MCPA was determined by a rapid bio-assay method (Parker, 1964), using the root inhibition of sorghum in Petri dishes. All assays were run in comparison with a specially prepared standard or calibration set. The resultant recovery data are presented in Fig. 1.

Fig. 1

Disappearance of MCPA, from (a) soil previously treated with MCPA 7 times (broken line) and, (b) soil which had not previously received MCPA treatment (solid line):



Breakdown of MCPA in soil which had received pre-treatment (enriched soil), was much accelerated as compared with breakdown in soil that had not previously been treated (control soil).

There was a definite lag phase for the control soil, which as far as can be ascertained from the available results, was of the same duration as the time taken for complete disappearance of MCPA from the enriched soil. The breakdown times should not be taken as absolute as some MCPA may have been lost, particularly from the enriched soil, during the process of air-drying which took about 6 days. However, in a previous investigation in 1964, adding an aqueous solution of MCPA to air-dry control soil to bring the latter up to 12% moisture, and then air-drying the resulting mixture did not lead to any loss, though the samples which had to be air-dried in the present experiment were for the most part at about 25% moisture. There is no doubt attached to the initial recovery figure for enriched soil, as the sample was only moist at the time of spraying and only took 2 days to dry.

Some MCPA may also have been lost during the four-day period of the bio-assay, though this would be compensated for to a certain extent by the incorporation of standard series containing known amounts of MCPA which would themselves be subject to breakdown.

Experiment 2

This experiment was undertaken at Bridgets Experimental Husbandry Farm, Martyr Worthy, Hampshire, on plots of the long-term herbicide experiment that was in existence between 1950 and 1965.

The object was to investigate the breakdown of MCPA applied to bare soil on plots: (a) which had received MCPA-sodium at 2 lb/ac a.e. every year that cereals had been grown since 1951, a total of 11 applications, i.e. in 1951-56, 58-59, and 61-64, and (b) which had not received any herbicide since before 1951. There was threefold replication of plots in the original experiment. Within each plot two replicates, each of four sub-plots, were laid down. The area of each sub-plot was 4 yd^2 and of the main plots 1080 yd^2.

MCPA-sodium/potassium was applied to the sub-plots as an aqueous solution on 7th July, 1965, at 2, 4.5 and 10.1 lb/ac a.e. with an Oxford Precision Sprayer. The fourth sub-plot was unsprayed. The soil had been previously ploughed and worked to a seedbed.

Soil samples were taken from each sprayed sub-plot one hour after spraying, and at intervals of 7, 13 and 28 days thereafter. For the first sampling date, five 2.25 in. diameter cores were taken from each sub-plot to a depth of 2 in., but this was altered to 4 in. for subsequent samples because 0.9 in. of rain fell the day after spraying and it was thought that leaching below the first sampling depth might have occurred. Deeper sampling was not practical because of the flinty nature of the soil. Cores for the two replicates of sub-plots on each main plot were bulked, making one sample from each main plot per treatment, i.e. 6 samples for each rate of MCPA.

Control soil was taken with a spade, samples from each main plot being kept separate. Accurate sampling of the chalky clay soil was difficult due to the presence of flints. Weeds were kept to a minimum by hand-hoeing during the period of soil-sampling.

The samples were stored at $0^{\circ}F$ until required for MCPA estimation. They were then thawed, sieved through a 0.25 in. mesh sieve and air-dried at room temperature for 10 days. The air-dry samples were shaken in a tin to disperse the herbicide residue as evenly as possible through the soil.

The technique for determining MCPA was as for Experiment 1, and the results are summarised in Table 1.

The disappearance of all doses from the Martyr Worthy soil was much more rapid than had been expected, and as a result, the sampling intervals proved too great to provide a critical comparison of relative disappearance rate from the previously treated and untreated soil. There is, however, no indication of any marked difference and if there was a lag phase it could not be detected. Unfortunately the samples taken 7 days after spraying on the 10.1 lb/ac plots were discarded. Possible loss of MCPA during the air-drying process was not determined.

The initial recovery rates varied considerably between the two lower doses and the highest dose, and the reason for this is unknown. The problem of variation between the amount applied and the actual initial recovery from sprayed experimental field plots is currently under review at the Weed Research Organisation.

Table 1

Recovery of MCPA from plots with eleven previous MCPA treatments (a) and from plots with no previous MCPA treatment (b).

Recovery of MCPA as % of applied dose.

Days between spraying and field sampling	Applied dose lb/ac 2		4.5		10.1	
	(a)	(b)	(a)	(b)	(a)	(b)
0	59	66	57	59	85	92
7	0	0	8	8	-	-
13	0	0	0	0	1	1
28	0	0	0	0	0	0

DISCUSSION

The first experiment convincingly demonstrated the phenomenon of enrichment as having taken place in the field, but the second experiment failed to do this in view of the unexpectedly rapid disappearance of MCPA and hence the inadequate number of samples taken during the breakdown period. No direct comparison of breakdown rates between the two experiments is useful because of the widely differing conditions.

The scattered literature on the persistence of MCPA in soil (Anon, 1958; De Rose and Newman, 1948; Anon, 1949) gives results ranging from 4 to 10 weeks for doses from 2 to 20 lb/ac and covering a number of different soil types and conditions (the Weed Control Handbook* gives 2 - 3 months for a dose of 2 lb/ac). The disappearance rate experienced at Martyr Worthy would appear to be exceptional. If it is typical of this particular soil, then clearly any enhanced breakdown rate due to enrichment would be of little practical importance. Leaching of the bulk of the applied MCPA to a depth greater than 4 in. as a result of heavy rainfall after application (0.9 in. the day after spraying and 0.7 in. 4 days after spraying) is a further possibility. No record can be found in the literature of work on the leaching of MCPA in soil. Further investigations are obviously needed.

There is evidence from persistence data obtained from the long-term experiment at the Weed Research Organisation (to be published at a later date) that enrichment on the MCPA-treated plots involved in Experiment 1 is lasting at least six months in the field.

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* 3rd ed. published by Blackwell Scientific Publications, Oxford.

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WEED CONTROL EXPERIMENTS ON UMBELLIFEROUS CROPS IN NORTHERN IRELAND

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Summary Experiments are described in which pre- and post-emergence herbicides were applied to carrots, parsnips and parsley. Pre-emergence treatments involved applications of linuron and prometryne to each crop, trifluralin to carrots and parsley, chloroxuron, a mixture of linuron and chlorpropham and 1-(3,4-dichlorophenyl)-3-methyl-2- pyrrolidinone (BV 201) to carrots only. Post-emergence treatments involved applications of linuron and prometryne to each crop, T.V.O. to carrots and solan to parsley. T.V.O. reduced the yield of carrots but no other treatment significantly affected yield in any crop. The results show that linuron and prometryne provide an adequate weed control when applied either before or after crop emergence. Pre- and post-emergence applications of these herbicides can be combined without detrimental effects. Trifluralin and BV 201 at 3.0 lb/ac were similar in effect to linuron at 1.0 lb/ac. Chloroxuron failed to give an adequate weed control. CDAA, CDEC, prometryne, linuron, monolinuron and cycluron + BIPC were applied as pre-planting treatments to self blanching celery and post-planting treatments included prometryne, linuron, chlorpropham and chlorpropham + linuron. CDAA and CDEC reduced yield. Post-planting applications of prometryne, linuron, monolinuron and chlorpropham + linuron were all shown to be satisfactory treatments for this crop under Loughgall conditions.

INTRODUCTION

The use of linuron and prometryne in carrots is now an established practice. Results with these herbicides have been described by Stephens (1962) in Scotland and by Roberts and Wilson (1964) in England when their effect on parsley and parsnips was also described. This paper describes experiments on carrots, parsnips, parsley and celery which were conducted during 1964 and 1965 with these and several other herbicides on light/medium loam and peat soils under Northern Ireland conditions.

METHOD AND MATERIALS

The experiments were conducted in Co. Armagh on light/medium loam and peat soils. Except where otherwise stated pre- and post-emergence treatments were applied in a factorial arrangement with three or four replicates. The plot size was 12 yd^2 with the exception of the 1964 parsnip experiment where it was 6 yd^2. All treatments were applied in a water volume of 50 gal/ac. Weed control was assessed either by counting weeds in each of three 1 ft. quadrats thrown at random per plot or by scores on a scale from 0-5 where 0 = weeds absent and 5 = weeds dominant. The total marketable yield of carrots and parsnips were recorded. The yield of celery before trimming but with the roots removed was recorded. The yield of parsley was not recorded as this was sown as an overwintering crop and unusually wet conditions the following spring affected the growth of the crop and prevented harvest. Weed scores and counts and crop yields are presented in the tables. Statistical significance is indicated, where appropriate, by the standard error of the difference between two treatment means.

RESULTS

Weed Control in Carrots

Experiment 1

This experiment examined all combinations of pre- and post-emergence herbicide treatments to carrots on a light/medium loam soil in 1964. Weed control and yield data are shown in Table 1 from which it can be seen that pre-emergence treatment with linuron at 1.0 lb/ac gave a significantly better weed control than prometryne at the same dose. There were no significant differences between post-emergence treatments except that linuron gave a significantly better control of Stellaria media (chickweed) than the other herbicides. Weed competition reduced carrot yield on unsprayed plots and the post-emergence application of linuron gave a significantly higher yield than T.V.O. and prometryne.

Table 1.

Weed control and yield of carrots (var. St. Valery) following pre- and post-emergence herbicide treatments

	Senecio vulgaris Count/yd^2	Chenopodium album Count/yd^2	Stellaria media Count/yd^2	Capsella bursa-pastoris Count/yd^2	Total weed Count/yd^2	Log x	Total marketable yield lbs/60 ft^2
Pre-emergence herbicide							
1. No herbicide	1.4007	1.2138	2.3754	1.4052	393.00	2.5899	10.83
2. Linuron 1.0 lb/ac	0.7039	0.2575	1.0172	0.0838	113.25	1.9982	35.17
3. Prometryne 1.0 lb/ac	0.9713	0.5424	1.2966	0.9382	146.08	2.1238	34.04
S.E.	0.1383	0.1669	0.1505	0.1386	-	0.0606	3.11
Post-emergence herbicide							
1. T.V.O. 50 gls/ac	0.8266	0.5669	1.6182	0.8266	212.00	2.2429	21.29
2. Linuron 0.75 lb/ac	1.1222	0.8312	1.3553	0.8710	199.00	2.1792	32.46
3. Prometryne 0.75 lb/ac	1.1270	0.6155	1.7157	0.7295	240.87	2.2897	26.29
S.E.	0.1383	N.S.	0.1505	N.S.	-	N.S.	3.11
CV%	33.13	60.98	31.52	42.01	-	6.62	28.59
Unsprayed control	2.5829	1.0264	2.4450	1.0281	388.40	2.5829	4.75

Log x transformation used for statistical analysis of weed counts.

Experiment 2

This experiment was designed to assess the effect of pre- and post-emergence applications of linuron on the growth and yield of carrots in 1964. From Table 2 it is evident that pre-emergence treatment with linuron at doses up to 2.0 lb/ac does not significantly affect yield or growth. Post-emergence applications gave significantly higher yields than the no herbicide treatment but the 1.0 lb/ac dose reduced yield slightly compared with 0.5 lb/ac.

Table 2.

Yield of foliage and roots following pre- and post-emergence applications of linuron to carrots (var. Chantenay Red Core)

	Total marketable yield carrots lbs/60 ft^2	Wt. of foliage lbs/60 ft^2
Pre-emergence herbicide		
1. Linuron 1.0 lb/ac	26.64	14.96
2. Linuron 1.5 "	28.35	15.37
3. Linuron 2.0 "	25.62	13.25
S.E.	N.S.	N.S.
Post-emergence herbicide		
1. No herbicide	21.66	12.12
2. Linuron 0.5 lb/ac	31.17	15.92
3. Linuron 1.0 "	27.51	15.54
S.E.	2.04	1.41
CV%	25.70	23.85
Unsprayed control	27.60	7.12

Experiment 3

This experiment compared the effect on yield and weed control of pre-emergence applications of linuron on a peat soil in 1964. Linuron was applied before crop emergence at 1.0, 1.5 and 2.0 lb/ac and effected a partial weed control. Doses of 1.5 and 2.0 lb/ac were similar in effect and significantly better than 1.0 lb/ac. The results are presented in Table 3. A moderate control of Polygonum persicaria (red shank) was achieved with doses of 1.5 and 2.0 lb/ac which also gave a good control of Stellaria media (chickweed). Rumex acetosella (sheep's sorrel) and Poa annua (annual meadow grass) were not controlled.

Table 3.

Yield of carrots (var. Chantenay Red Core) and weed counts per 3 ft^2 following pre-emergence herbicide treatments on a peat soil

	Total marketable yield lbs/24 ft^2	Total weed count	Polygonum persicaria	Rumex acetosella	Stellaria media	Poa annua
Pre-emergence herbicide						
1. Linuron 1.0 lb/ac	8.83	54.40	29.21	11.90	5.12	4.13
2. Linuron 1.5 "	10.62	36.13	16.30	12.60	1.39	3.13
3. Linuron 2.0 "	10.96	34.23	12.13	16.88	1.60	2.15
S.E.	N.S.	3.73	3.74	N.S.	1.21	N.S.
Unsprayed control	10.83	89.50	49.27	12.30	7.53	3.53
CV%	35.10	22.02	47.71	47.57	109.81	99.36

Experiment 4

Table 4 shows the effect of a number of pre-emergence herbicides on weed control and carrot yield and of linuron as a post-emergence treatment in 1965. The principal weeds on this site were Chenopodium album (fat hen) Polygonum persicaria (red shank) and Agropyron repens (couch grass). Linuron at 2.0 lb/ac gave the most satisfactory overall weed control. Crop yield was unaffected by the pre-emergence herbicides.

The post-emergence application of linuron at 1.0 lb/ac gave a significantly higher yield than the unsprayed control.

Table 4.

Weed control and yield of carrot (var. Chantenay Red Core) following pre-emergence herbicide treatments combined with a post-emergence linuron application

	Weed score	Carrot yield lbs/140 ft^2
Pre-emergence herbicide		
1. Trifluralin 1.5 lb/ac	3.2	75.43
2. Linuron 1.0 "	2.3	70.50
3. Linuron 2.0 "	1.1	68.50
4. Prometryne 0.75 "	3.1	66.50
5. Linuron + chlorpropham 1.0 + 1.0 lb/ac	2.3	76.64
6. BV 201 3.0 "	2.1	75.14
7. Chloroxuron 2.5 "	4.0	68.31
S.E.	-	N.S.
Post-emergence herbicide		
1. No herbicide	3.0	69.14
2. Linuron 1.0 lb/ac	2.0	75.31
S.E.	-	0.36
CV%	-	12.75

Trifluralin and BV 201 were soil incorporated before sowing

Weed Control in Parsnips

Experiments were designed in 1964 and 1965 to examine the tolerance of parsnips to pre- and post-emergence applications of linuron and prometryne. From Table 5 it is evident that yield was unaffected by the herbicide treatments. Pre-emergence applications of linuron from 1.0 to 2.0 lb/ac gave an adequate weed control in 1965 under conditions at Loughgall as shown by the weed scores in Table 5. Post-emergence herbicide treatments tended to give a less satisfactory weed control, due primarily to the incidence of Agropyron repens (couch grass). The principle weeds in the 1965 trial were Stellaria media (chickweed), Capsella bursa-pastoris (shepherd's purse), Spergula arvensis (corn spurrey), Senecio vulgaris (groundsel) and Poa annua (annual meadow grass).

A weed count following the pre-emergence treatments is also included in Table 5 from which it can be seen that all four herbicide treatments were significantly better than the unsprayed control and that linuron at 1.0 and 2.0 lb/ac gave significantly better weed control than prometryne at 0.75 lb/ac.

Table 5.

Yield of parsnips (var. Offenham), weed counts and weed scores, following pre- and post-emergence herbicide applications

	Total yield (1964) lbs/24 ft^2	Total yield (1965) lbs/24 ft^2	Weed count/ 3 ft^2	Log 1 + x	Weed score
Pre-emergence herbicide					
1. No herbicide	-	11.88	162.83	3.17	4.2
2. Linuron 1.0 lb/ac	19.21	12.98	12.61	1.89	2.1
3. Linuron 1.5 "	18.37	-	-	-	-
4. Linuron 2.0 "	19.45	12.07	7.50	1.54	1.3
5. Prometryne 0.75 "	-	13.10	15.25	2.08	1.9
S.E.	N.S.	N.S.	-	0.14	-
Post-emergence herbicide					
1. No herbicide	19.44	-	-	-	-
2. Linuron 0.5 lb/ac	18.00	-	-	-	-
3. Linuron 1.0 "	19.61	11.28	-	-	2.5
4. Linuron 2.0 "	-	13.41	-	-	2.4
5. Linuron 3.0 "	-	12.69	-	-	1.4
6. Linuron 0.5 " + Prometryne 0.5 "	19.00	-	-	-	-
7. Prometryne 0.75 "	-	12.60	-	-	3.1
S.E.	N.S.	N.S.	-	-	-
CV%	8.1	17.47	-	16.22	-
Unsprayed control	18.2	12.34	164.50	-	-

Log 1 + x transformation used for statistical analysis of weed count

Weed Control in Parsley

None of the treatments caused visible crop damage.

Table 6 shows that linuron, prometryne, trifluralin and simazine applied as pre-emergence treatments to parsley in 1964 all gave an equivalent overall weed control up to three months after treatment. There were no significant treatment differences except with respect to the control of Lamium purpureum (red dead nettle), where prometryne and trifluralin were significantly better than the other treatments. Post-emergence applications of linuron and prometryne had a similar effect. A post-emergence application of solan also gave a similar degree of weed control but there was a suggestion that it was slightly superior to other post-emergence treatments for the control of Stellaria media (chickweed) and Lamium purpureum (red dead nettle.

Table 6

Mean weed counts per yd^2 following the application of pre- and post-emergence herbicides to parsley (var. Moss curled)

		Total weed count	Capsella bursa-pastoris	Senecio vulgaris	Stellaria media	Lamium purpureum
Pre-emergence herbicide						
1. Linuron	1.0 lb/ac	25.64	0.74	7.85	2.98	5.97
2. Prometryne	1.0 "	23.91	6.73	2.61	2.99	1.87
3. Trifluralin	3.0 "	20.91	2.24	7.47	2.61	0.74
4. Simazine	0.5 "	19.79	2.61	4.12	1.12	4.48
S.E.		N.S.	N.S.	N.S.	N.S.	1.84
Post-emergence herbicide						
1. Linuron	0.75 lb/ac	19.91	1.49	7.29	1.31	3.54
2. Prometryne	0.75 "	25.15	4.66	3.73	3.54	2.99
S.E.		N.S.	N.S.	N.S.	N.S.	N.S.
Solan	4.0 "	22.62	2.25	5.22	0.00	1.48
No herbicide		104.78	26.98	9.72	20.97	9.72

Weed Control in Celery

In this experiment herbicides were applied either before or after planting. The results in Table 7 show that CDAA and CDEC significantly reduced yield but that no other treatment had an adverse effect. The weed scores show that post-planting applications of prometryne, linuron, monolinuron and a mixture of chlorpropham + linuron gave an extremely good weed control.

Table 7.

Mean yield and weed scores following the application of either pre- or post-planting herbicides to self blanching celery (var. Lathom Blanching)

			Yield lbs/84 ft^2	Weed score
Herbicide treatment:				
1. No herbicide			173.16	3.7
2. CDAA*	3.0	lb/ac	152.81	2.7
3. CDEC*	3.0	"	154.54	4.0
4. Prometryne*	0.75	"	182.68	2.7
5. Prometryne**	0.75	"	196.96	0.0
6. Linuron*	1.0	"	185.28	2.5
7. Linuron**	1.0	"	167.96	0.0
8. Monolinuron*	2.0	"	167.09	0.7
9. Cycluron + BIPC*	1.0	"	186.58	3.2
10. Chlorpropham**	1.0	"	188.74	1.5
11. Chlorpropham**	1.0	"	190.91	0.0
+ Linuron	1.0	"		
S.E.			10.16	-

*Pre-planting treatments
**Post-planting treatments

DISCUSSION

The results of the experiments reported in this paper - which were primarily designed to examine the tolerance of carrots, parsnips, parsley and self blanching celery to various herbicides - show that these crops possess an adequate tolerance to linuron and prometryne to ensure a satisfactory weed control under Loughgall conditions on mineral soils. Yield was not adversely affected by either linuron or prometryne. It is evident that linuron can be applied to carrots and parsnips at doses up to 2.0 lb/ac as a pre-emergence treatment and up to 1.0 lb/ac as a post-emergence treatment although parsnips sprayed at the 3-4 true leaf stage were shown to tolerate 3.0 lb/ac. Combinations of pre- and post-emergence applications would appear to be desirable in these crops to ensure an adequate weed control. On the evidence in this paper such combinations are unlikely to have detrimental effects on crop yields.

Linuron and prometryne applied about a week after planting were also shown to be suitable post-planting treatments for self blanching celery on a mineral soil. Further work is required, however, with this crop to examine its degree of tolerance to different times of application on several soil types. This would be particularly relevant on peat soils where celery is frequently grown in Northern Ireland.

From Table 3 it is apparent that linuron failed to provide an adequate weed control on the peat site at doses up to 2.0 lb/ac. A higher dose might be more effective on this soil type but its efficiency would also depend on the prevalent weed species. Further work is required to determine the most satisfactory herbicide and its optimum dose on peat under Northern Ireland conditions.

On mineral soils linuron at a dose of 1.0 lb/ac will provide an adequate weed control. From Table 7, however, it is evident that the post-planting treatments of both linuron and prometryne provided a better weed control than the pre-planting applications. This was due to the presence of weed seedlings at the later time of application which were controlled by contact action. This result emphasises the importance of timing the application with respect to weed growth - when the stage of growth of the crop permits - to take full advantage of both the contact and residual effects of the herbicides.

Trifluralin at 1.5 lb/ac gave only a partial weed control following soil incorporation (Table 4) but it was more effective against some weeds at 3.0 lb/ac without soil incorporation (Table 6). This herbicide merits further investigation before final conclusions are drawn.

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WEED CONTROL TRIALS ON TRANSPLANTED AND DIRECT SOWN BRASSICA CROPS IN NORTHERN IRELAND

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Summary Experiments are described in which desmetryne, prometryne, ametryne and simazine were applied to transplanted cabbage, broccoli and Brussels sprouts. Simazine gave the most satisfactory weed control without crop damage. Desmetryne and prometryne damaged broccoli severely in 1964 but not in 1965 when slightly lower doses were applied. Trifluralin incorporated into the soil before sowing cauliflower and Brussels sprouts gave an adequate initial weed control. A post-emergence herbicide was also necessary to maintain a satisfactory control. When applied to direct sown cauliflower at the 3-4 true leaf stage desmetryne caused severe damage and reduced yield but simazine had no adverse effects. Several new triazines showed promising results in transplanted Brussels sprouts. Lenacil at 16.0 oz/ac had no adverse effects in this crop and merits further investigation.

INTRODUCTION

In 1964 (Allott 1964) trials were described in which desmetryne and prometryne were applied to transplanted and direct sown brassicae. It was shown that these herbicides could be applied to transplanted Brussels sprouts and cabbage safely but that broccoli was more susceptible. Other herbicides were, therefore, examined over the past two years to determine whether they can be applied to broccoli and cauliflower with greater safety and to compare their weed control spectra with desmetryne and prometryne. Following earlier trials in which trifluralin was applied as a pre-emergence herbicide to direct sown crops as a surface application (Allott 1964) further trials were conducted in which this herbicide was incorporated into the soil before sowing Brussels sprouts and cauliflower.

This paper summarises the results of experiments conducted during 1965 and 1966 which were designed to evaluate the most successful herbicides in both transplanted and direct sown crops under Northern Ireland conditions.

METHOD AND MATERIALS

Desmetryne, prometryne, ametryne and simazine were applied to cabbage (var. Primo) and broccoli (var. April Glory) immediately and three weeks after planting and to direct sown cauliflower (var. All the year round) and Brussels sprouts (var. Irish Elegance) at the 3-4 true leaf stage.

Trifluralin which was incorporated into the soil by tine harrowing was also applied to the direct sown crops as a pre-sowing treatment.

Nitrofen, trietazine and lenacil were applied as post-planting treatments to transplanted Brussels sprouts. Two new triazines 2-methylthio-4-ethylamino-6 tert. butylamino-s-triazine (GS 14260), and 2-methylthio-4-isopropylamino-6 (y methoxypropylamino)-s-triazine (G 36393) and a wettable powder containing 22.5% 2-methylthio-4-isopropylamino -6 (y methoxypropylamino)-s-triazine (G 36393) and 5% simazine were also applied to transplanted Brussels sprouts together with two other new herbicides 2-chloro-N-isopropylacetanilide (CP 31393) and 2-chloro-2,6-diethyl-N- (methoxy methyl) acetanilide (CP 50144). The treatments in all trials were in factorial arrangements except in experiments 1 and 4 in which a randomised block design was used. Treatments were replicated three times unless otherwise stated.

Weed density was assessed either by counts in each of three 12 in. quadrats thrown at random in each plot or by scoring on a scale from 0 - 5 in which 0 = no weeds and 5 = weeds dominant. Crops were scored for vigour or damage as necessary and the fresh weight of cabbage and number of marketable heads of broccoli and cauliflower were recorded. The direct sown Brussels sprouts were not grown to maturity but an assessment of the treatment effects was obtained from living plant counts. Statistical significance is indicated, where appropriate, by the standard error of the difference between two treatment means.

RESULTS

Experiment 1

This experiment was designed to compare the effect of desmetryne and prometryne at two doses on the yield of broccoli when the herbicides were applied two weeks after planting. From Table 1 it can be seen that the number of marketable heads was significantly reduced by all herbicides. Prometryne, however, was less severe than desmetryne. The addition of dicamba to desmetryne increased its phytotoxic effects.

Table 1.

The effect of post-planting herbicide applications on the yield of broccoli (var. April Glory)

	Size of curds as percent of total curds for each treatment				Total marketable curds/64 ft^2
	$<3\frac{1}{2}$ in.	$3\frac{1}{2}$ to 5 in.	5 to 7 in.	>7 in.	
Herbicide					
No herbicide	13.69	38.35	32.87	4.11	18.25
Desmetryne 8.0 oz/ac	42.86	28.57	26.53	4.08	12.25
Desmetryne 12.0 "	45.45	18.18	34.09	2.27	11.00
Desmetryne 8.0 " + Dicamba 1.0 "	60.00	22.50	17.50	0.00	10.00
Prometryne 8.0 "	41.66	28.33	30.00	0.00	15.00
Prometryne 12.0 "	51.78	21.43	26.78	0.00	14.00
S.E.	-	-	-	-	2.44

Experiments 2 and 3

Table 2 shows the yield of cabbage and broccoli following post-planting applications of four triazines at two times after planting. The yield of both crops was unaffected by either the time of application or by the herbicides.

All herbicides gave a measure of weed control in both crops. Simazine tended to be the most effective and to have the most prolonged effect as shown by the weed scores from the broccoli experiment.

Time of application of the herbicides with respect to the planting date did not significantly affect weed control but there is a suggestion that it was improved slightly by the later application. This effect can also be seen from Table 3 which shows the interactions between herbicide and time of application. This table shows that although differences in weed counts are not statistically significant there is a tendency for desmetryne, prometryne and ametryne to give the most satisfactory weed control when applied three weeks after planting. Simazine however gave the best results when applied immediately after planting. These trends occur in both the total weed count and in the counts of the two most common weeds Chenopodium album (fat hen) and Senecio vulgaris (groundsel).

Table 2.

Weed control and yield in cabbage (var. Primo) and broccoli (var. April Glory) following post-planting applications of four triazines (Main Effects)

Herbicides	Cabbage		Broccoli		
	Total weed count/3 ft^2	Yield lbs/plant	Weed scores 1	Weed scores 2	No. marketable heads
No herbicide	48.20	2.80	5.0	5.0	16.33
Desmetryne 4.0 oz/ac	-	-	2.0	3.7	18.50
Desmetryne 8.0 "	23.83	2.83	1.5	2.3	19.33
Desmetryne 12.0 "	18.83	2.91	-	-	-
Prometryne 4.0 "	-	-	2.5	3.2	19.00
Prometryne 8.0 "	26.83	2.83	1.9	2.7	18.66
Prometryne 12.0 "	20.83	2.70	-	-	-
Ametryne 4.0 "	-	-	2.0	3.2	18.66
Ametryne 8.0 "	21.17	2.84	1.9	3.0	18.00
Ametryne 12.0 "	16.00	3.07	-	-	-
Simazine 8.0 "	12.83	2.87	1.5	2.3	19.83
Simazine 16.0 "	14.00	2.91	1.3	1.7	17.66
S.E.	8.30	N.S.	-	-	N.S.
Time of application. Immediately after planting	25.60	2.85	2.7	3.6	18.70
Three weeks after planting	19.48	2.88	1.6	2.3	18.18
S.E.	N.S.	N.S.	-	-	N.S.

1. Yield of cabbage = mean weight per plant.
2. Weed scores for broccoli 1 = Three weeks after herbicide treatment
   2 = Seven weeks after herbicide treatment

Table 3.

Weed control in cabbage (var. Primo) following post-planting applications of four triazines (Interactions)

Time of application / Herbicides		Total weed count/3 ft^2 1	Total weed count/3 ft^2 2	Chenopodium album count/3 ft^2 1	Chenopodium album count/3 ft^2 2	Senecio vulgaris count/3 ft^2 1	Senecio vulgaris count/3 ft^2 2
No herbicide		49.33	47.00	6.66	13.33	19.33	18.33
Desmetryne	4.0 oz/ac	-	-	-	-	-	-
Desmetryne	8.0 "	36.00	11.66	4.33	0.00	9.00	0.00
Desmetryne	12.0 "	17.66	20.00	1.00	0.00	6.00	0.00
Prometryne	4.0 "	-	-	-	-	-	-
Prometryne	8.0 "	29.00	24.66	6.66	0.00	6.66	11.66
Prometryne	12.0 "	26.33	15.33	0.66	0.00	5.66	0.66
Ametryne	4.0 "	-	-	-	-	-	-
Ametryne	8.0 "	29.00	13.33	3.33	0.00	6.33	1.00
Ametryne	12.0 "	17.66	14.33	0.33	0.00	3.00	0.00
Simazine	8.0 "	8.66	17.00	0.33	1.33	0.00	4.33
Simazine	16.0 "	9.66	18.33	2.00	3.66	0.00	3.66
S.E.		N.S.		N.S.		N.S.	

Time of application 1. Immediately after planting
2. Three weeks after planting

Experiment 4

In this herbicide screening trial it is evident from Table 4 that simazine at 12.0 and 16.0 oz/ac, GS 14260, G 36393, G 36393 + simazine, desmetryne at 12.0 oz/ac and CP 31393 at 80.0 oz/ac gave an adequate weed control. Weed scores show that these herbicides all gave a good control of the principal weeds - Senecio vulgaris (groundsel) and Stellaria media (chickweed). Nitrofen at 40.0 oz/ac gave a moderate control of Senecio vulgaris (groundsel) but was less satisfactory against Stellaria media (chickweed). Prometryne at 12.0 oz/ac gave a good control of Stellaria media (chickweed) but failed to control Senecio vulgaris (groundsel). Crop vigour scores show that desmetryne and prometryne reduced slightly the growth of Brussels sprouts. No other treatment had an adverse effect.

Table 4.

Weed and crop vigour scores following the application of post-planting herbicides to Brussels sprouts (var. Irish Elegance)

Herbicides		Weed scores: Total weed	*Senecio vulgaris*	*Stellaria media*	Crop vigour
No herbicide		5.00	3.66	3.66	4.33
Simazine	12.0 oz/ac	1.00	0.00	0.00	4.00
Simazine	16.0 "	1.00	0.00	0.33	4.33
GS 14260	12.0 "	0.66	0.33	0.00	4.00
G 36393	12.0 "	1.33	0.00	0.00	4.00
G 36393 + simazine	12.0 "	1.33	0.00	0.00	4.33
CP 31393	80.0 "	1.66	1.33	0.00	4.00
Nitrofen	40.0 "	2.33	1.00	2.66	4.66
Desmetryne	12.0 "	0.66	0.00	0.33	3.00
Prometryne	12.0 "	2.66	2.33	0.66	3.00
Trietazine	12.0 "	2.33	2.66	1.33	4.00
Lenacil	16.0 "	2.00	0.33	1.00	4.00
CP 50144	16.0 "	3.66	3.33	1.00	4.66

Crop vigour scores. 0 = very poor 5 = vigorous healthy plant

Experiment 5

Table 5 shows that pre-planting applications of trifluralin and benefin in Brussels sprouts reduced the overall weed population appreciably.

Post-planting applications of simazine, desmetryne and prometryne all gave a good general weed control but simazine was most satisfactory. Desmetryne and prometryne failed to control *Poa annua* (annual meadow grass).

Crop vigour scores show that simazine slightly checked growth but no treatment seriously affected crop vigour.

Table 5.

Weed and crop vigour scores following pre- and post-planting herbicide treatments in Brussels sprouts (var. Irish Elegance)

Pre-planting herbicides		Weed scores: Total weed	*Poa annua*	*Stellaria media*	*Capsella bursa-pastoris*	Crop vigour
No herbicide		3.06	2.26	1.20	1.00	2.80
Trifluralin	32.0 oz/ac	1.60	0.60	0.93	0.86	2.73
Benefin	32.0 "	1.93	1.26	1.20	0.86	2.46
Post-planting herbicides						
No herbicide		4.22	2.22	2.88	3.33	2.77
Simazine	16.0 oz/ac	0.33	0.11	0.00	0.00	2.11
Desmetryne	12.0 "	1.88	1.77	0.00	0.00	2.77
Prometryne	12.0 "	1.77	1.77	0.00	0.00	2.33
Nitrofen	40.0 "	2.77	1.33	2.66	1.33	3.33

Crop vigour scores 0-5. 0 = very poor. 5 = vigorous healthy plant

Experiment 6

A pre-sowing application of trifluralin gave an appreciable overall weed control without crop damage to direct sown cauliflower as shown by the weed scores in Table 6 which were recorded two months after application. Simazine and ametryne at 8.0 oz/ac were the most successful post-emergence treatments with respect to weed control. Simazine was the only post-emergence herbicide to give an appreciable weed control two months after treatments as shown by the weed counts.

Trifluralin did not affect crop yield but post-emergence treatments of desmetryne at 8.0 oz/ac and ametryne at 4.0 and 8.0 oz/ac significantly reduced yield. The other post-emergence treatments had no effect on yield.

Table 6.

Effect of pre- and post-emergence herbicides in direct sown cauliflower (var. All the year round)

Pre-sowing herbicide	Weed scores	Total weed count	*Poa annua* count	*Senecio vulgaris* count	Total marketable heads
No herbicide	3.8	28.10	9.96	8.46	18.66
Trifluralin 16.0 oz/ac	1.8	26.45	7.04	11.66	16.62
S.E.	-	N.S.	0.96	1.53	N.S.
Post-emergence herbicide					
No herbicide	3.5	31.17	9.20	11.20	22.00
Desmetryne 4.0 oz/ac	3.5	25.50	8.00	6.20	21.00
Desmetryne 8.0 "	2.3	29.17	10.00	11.00	8.33
Prometryne 4.0 "	3.2	29.67	11.33	10.33	22.50
Prometryne 8.0 "	2.7	31.17	8.00	14.83	22.00
Ametryne 4.0 "	2.8	27.50	9.50	9.50	15.16
Ametryne 8.0 "	2.2	32.17	9.00	14.17	7.83
Simazine 8.0 "	2.2	11.83	3.00	3.33	22.33
S.E.	-	3.79	1.94	3.06	2.67
Unsprayed control	5.0	44.33	9.00	15.33	23.00

Experiment 7

Crop damage scores and living plant counts in Table 7 show that a pre-sowing application of trifluralin had no effect on direct sown Brussels sprouts. Post-emergence treatment with prometryne caused slight damage, ametryne caused severe damage and desmetryne was intermediate as shown by crop damage scores.

A living plant count showed that only ametryne at 12.0 oz/ac caused a severe reduction in plant numbers. Simazine did not affect the crop.

Table 7.

Crop damage scores and living plant counts following the application of pre- and post-emergence herbicides to direct sown Brussels sprouts (var. Irish Elegance)

	Crop damage scores	Living plant count
Pre-sowing herbicide		
Nil	2.1	11.33
Trifluralin 16.0 oz/ac	2.0	12.00
S.E.	-	N.S.
Post-emergence herbicide		
Desmestryne 8.0 oz/ac	2.3	12.20
Desmetryne 12.0 "	3.0	12.00
Prometryne 8.0 "	1.0	13.00
Prometryne 12.0 "	2.2	11.50
Ametryne 8.0 "	4.0	11.00
Ametryne 12.0 "	4.3	6.83
Simazine 8.0 "	0.1	13.17
Simazine 16.0 "	0.1	13.66
S.E.	-	0.69
Unsprayed control	0.0	12.66
Pre-emergence trifluralin only	0.0	12.00

Crop damage scores 0-5. 0 = No damage 5 = very severe damage

DISCUSSION

Results with respect to the time of application of desmetryne and prometryne to cabbage confirm those obtained in 1964 (Allott 1964). It is apparent that these herbicides can be applied safely to cabbage either immediately after planting when the plants are in a wilting condition or three weeks later when they have regained their full turgidity. On this evidence they can also be applied in a similar manner to broccoli at doses up to 8 oz/ac. As shown in 1964, however, broccoli is susceptible to damage by these herbicides at doses of 8 oz/ac and above and further trials with this crop are, therefore, desirable. Ametryne and simazine can also be applied without damage to these crops at the same time with respect to planting. Simazine has the advantage that it will provide a more complete and prolonged weed control than the other chemicals. Due to the residual properties of simazine, however, it is likely to have limitations with respect to its use in annual crops such as these, but it merits further investigation to verify crop tolerance both with respect to individual crops and to evaluate suitable crop rotations on different soils. This is the subject of a current investigation at Loughgall.

Desmetryne, prometryne and ametryne tended to give a slightly better weed control when they were applied three weeks after planting rather than immediately following planting. This was due to the contact action of these herbicides which enabled them to control weed seedlings which had germinated before treatment. This confirms the 1964 result with desmetryne and prometryne (Allott 1964). As expected simazine tended to give the most satisfactory weed control when applied immediately after planting.

The new triazines which were examined initially in Brussels sprouts gave promising results and merit more extensive investigation in other crops. 2-chloro-N-isopropylacetanilide (CP 31393) and lenacil also merit further investigation with particular respect to crop tolerance.

Following preliminary investigations in 1964 with direct sown crops further trials in 1965 confirmed that trifluralin can be used in direct sown Brussels sprouts and cauliflower as a pre-sowing treatment incorporated into the soil by tine harrowing. Post-emergence treatments are also necessary to maintain an adequate weed control throughout the life of the crop. Desmetryne and ametryne are liable to cause considerable crop damage in direct sown crops at doses above 4.0 oz/ac and at this level weed control is not adequate under Northern Ireland conditions. Prometryne and simazine are less likely to cause damage at doses up to 6.0 oz/ac and will be the subject of further investigation.

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EXPERIMENTS WITH HERBICIDES IN DIRECT DRILLED CABBAGE AND CAULIFLOWER

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Summary Experiments are described in which a-chloro-N-isopropylacetanilide (CP 31393) and nitrofen were the principal herbicides examined for pre and post-emergence application in direct drilled cabbage and cauliflower. CP 31393 at doses up to 5.85 lb/ac showed greater selectivity in cabbage than nitrofen 1.05 lb and 2.1 lb/ac applied at the 1 - 2 true leaf stage. Cauliflower at the 1 - 2 true leaf stage also showed good tolerance to CP 31393 4.55 lb/ac. A mixture of CP 31393 4.55 lb + chlorpropham 0.5 lb gave highly promising results as a pre-emergence treatment in cauliflower and was more selective than nitrofen 3.0 lb + chlorpropham 0.5 lb/ac. Trifluralin 1.0 and 2.0 lb/ac incorporated prior to sowing was effective under moist conditions but poor weed control resulted when the soil was dry. Results with CDEC + chlorpropham and desmetryne are also included.

INTRODUCTION

Until recently, the need for satisfactory chemical weed control in cabbage and cauliflower was not such a pressing problem. These crops were generally transplanted and cultivation usually gave adequate weed control.

In recent years a rapid change to direct drilling has taken place in Ireland. Over 50% of the cabbage and cauliflower crops grown for processing in 1966 were sown in this way. For the successful adoption of direct drilling a herbicide with high crop tolerance is needed to give control of weeds particularly in the early stages of growth when crops suffer most from weed competition. To satisfy these requirements the herbicide must be suitable for pre-emergence or early post-emergence application.

Desmetryne is the most widely used post-emergence herbicide in Brassicae but it is not recommended for use in cabbage before the 3 - 4 true leaf stage. At this stage the crop has usually suffered from weed competition and the weeds are often too far advanced in growth to be suppressed effectively. In cauliflower the use of desmetryne is not recommended because of the risk of crop injury.

METHODS AND MATERIALS

All experiments were carried out at Kinsealy on a medium loam soil containing 23.1% clay and 7.6% organic matter. A randomised block design with four replicates was used. Plot size varied from 10 - 24 yd^2. Sprays were applied at a volume of 40 gal per acre using an Oxford Precision Sprayer. All doses are given as lb/ac a.i.

In the cauliflower experiments weed density was assessed on 20% of the total plot area. When crops were thinned the weight and number of plants removed were recorded. Visual assessments of crop injury and degree of weed control were made. All experiments were sown with a hand pushed seeder. In the cabbage experiments the lowest seeding rate possible with this machine was used to simulate precision sowing but with cauliflower a higher seeding rate was used.

Experiment 1 (Cabbage)

This experiment was designed to compare the effect of pre-sowing and pre-emergence application of herbicides in direct sown cabbage. Treatments are shown in Table 1. Seed, var. Greyhound, was sown on 23 March 1966 under cold, moist soil conditions. Trifluralin treatments were applied to the soil surface and raked into the top 2 in. on the day prior to sowing. The remaining treatments were applied on 6 April, 10 days before crop emergence. All plots were handweeded 2 months after sowing when final weed and crop assessments were made. Following thinning on 15 June plots were again hoed and handweeded. Crop was harvested on 18 July.

Experiment 2 (Cabbage)

Nitrofen and a-chloro-N-isopropylacetanilide (CP 31393) at different doses applied at the 1 - 2 true leaf stage ($1\frac{1}{2}$ in. high) and 3 - 4 true leaf stage (5 in. high) were compared with desmetryne 0.375 lb applied at the latter stage. Treatments are given in Table 2. Variety, date of sowing and crop emergence was the same as Experiment 1. When treatments were applied at the 1 - 2 true leaf stage there was a weed cover of 30%; Veronica spp. were the predominant species and had 2 rough leaves at this stage. Weed growth was considerably advanced and most species had 6 - 10 rough leaves when applications were made at the 3 - 4 true leaf stage of the crop. All plots were hoed and handweeded on 3 June and again 2 weeks later. The crop was harvested on 21 July.

In both cabbage experiments the predominant weed was Veronica spp. Other species in order of prevalence were Polygonum aviculare, Stellaria media, Papaver rhoeas, Fumaria officinalis, Senecio vulgaris, and Sinapis arvensis.

Experiment 3 (Cauliflower)

This experiment was on similar lines to that carried out on cabbage in Experiment 1 except that fewer treatments were included. Because of the poor control of Polygonum aviculare and Polygonum convolvulus given by CP 31393 in the cabbage experiments a mixture of this material and chlorpropham was used. Treatments are given in Table 3. Cauliflower var. All The Year Round was sown on 7 July 1966 under dry, warm soil conditions. Trifluralin was applied and incorporated in top 2 in. immediately prior to sowing. Application of pre-emergence treatment was carried out the following day 6 days before the crop emerged. Plots were thinned on August 10, when the crop had 3 true leaves. Weed counts were recorded on August 4 and all plots were then handweeded.

Experiment 4 (Cauliflower)

Five herbicides were compared for post-emergence applications in direct drilled cauliflower. Treatments are given in Table 5. Seed var. All The Year Round was sown on 18 July 1966 in a stale seed bed prepared 12 days previously. Paraquat 1.0 lb/ac was applied to all plots 2 days before the crop emerged on July 25. When paraquat was applied there was a 40% cover of weed seedlings mainly Stellaria media. Treatments at 1 - 2 true leaf stage were applied 11 days after crop emergence. Plots were weed free at this time except for a few small seedlings of Poa annua. Later treatments at the 3 - 4 true leaf stage were applied on August 18; weed cover was then over 50% and most species had 2 - 4 rough leaves.

Thinning was not carried out until 6 Sept. by which time plants generally had 6 - 8 true leaves. Weed counts and weights were recorded 2 days later and all plots were then hoed and handweeded.

The two principal weed species occurring in both cauliflower experiments were Stellaria media and Poa annua. Among other species in order of prevalence were Polygonum aviculare, Fumaria officinalis, Senecio vulgaris, Capsella bursa-pastoris, Urtica urens and Chenopodium album.

RESULTS

Experiment 1

During the six weeks following crop emergence all treatments caused crop check in varying degrees. Most severe damage occurred in plots treated with nitrofen 4.2 lb and nitrofen 3.0 + chlorpropham 0.5 lb/ac and was least where CP 31393 3.9 lb, CDEC 1.8 lb + chlorpropham 0.25 lb and trifluralin 1.0 and 2.0 lb were used. Remaining treatments were intermediate in their effect.

CP 31393 gave good control of most species except Polygonum aviculare and Fumaria officinalis. Veronica spp. were not completely controlled at 3.9 lb. Stellaria media was resistant to nitrofen even at 4.2 lb. At this dose all other species were well controlled. Partial resistance was shown by Papaver rhoeas and Fumaria officinalis to nitrofen 2.1 and 3.0 lb, but complete control of Veronica spp. and Polygonum aviculare was obtained at these doses. The mixture of nitrofen 3.0 lb and chlorpropham 0.5 lb gave the best control of all treatments in the trial. Assessments made 7 weeks after application showed that this treatment was still highly effective. Only moderate weed control was given by CDEC 1.8 lb + chlorpropham 0.25 lb; Veronica spp. proved particularly resistant and only partial control of Sinapis arvensis, Papaver rhoeas, Senecio vulgaris and Fumaria officinalis was obtained. Both trifluralin treatments (1 and 2 lb) gave good control of most species except Senecio vulgaris and Sinapis arvensis. Fumaria officinalis and Veronica spp. were also not completely controlled. The latter species however was reduced by 80% compared with untreated control plots. The higher dose gave only slightly better control of weeds.

Experiment 2

Most severe crop check occurred with nitrofen applied at the 1 - 2 true leaf stage. Plants were approximately half the size of those in control plot when assessments were made 3 weeks after spraying in plots treated with nitrofen 1.05 lb/ac. Weight and number of thinnings in Table 2 show that reduction in plant stand and vigour occurred with nitrofen 2.1 lb/ac applied at this stage. Following thinning surviving plants made a good recovery and final yield was not reduced as compared to control plots. Good crop selectivity was shown by CP 31393 at both stages of application. Only slight temporary check was evident in plots treated with this material at 5.85 lb at the 1 - 2 true leaf stage.

Nitrofen 1.05 and 2.1 lb/ac applied at the 3 - 4 leaf stage caused scorching particularly of the younger crop leaves. This was more severe at the higher dose and the growing point of small plants showed slight damage. Severe chlorosis and slight necrosis of the older leaves followed the application of desmetryne 0.375 lb at the 3 - 4 true leaf stage but the younger central leaves were undamaged and crop injury was not as severe as with nitrofen 2.1 lb applied at the same stage. When treatments were applied at the 1 - 2 true leaf stage most weed species were at the

Table 1

Experiment 1 - Effect of pre-emergence treatments on direct drilled cabbage

Treatment	Dose lb/ac	Yield tons/ac	Total no. of plants per 24 ft row	Wt. of thinnings tons/ac	Assessments (May 13) Crop	Weeds
1. CP 31393	3.9	20.3	38	1.69	9.0	8.8
2. "	5.85	19.6	35	1.39	8.3	9.6
3. Nitrofen	2.1	16.5	30	1.22	8.0	9.4
4. "	3.0	14.6	27	0.88	7.5	9.3
5. "	4.2	16.5	25	0.64	5.0	9.4
6. Nitrofen + chlorpropham	3.0 0.5	15.0	24	0.87	3.0	10.0
7. CDEC + chlorpropham	1.8 0.25	16.1	35	1.30	9.0	8.0
8. Trifluralin	1.0	19.9	35	2.26	9.5	8.1
9. "	2.0	15.7	32	1.69	9.0	8.5
10. Control		21.4	35	1.54	10.0	3.0
F Test		NS	NS	***		
S.E. of Treatment mean		2.31	3.6	0.23		

Trifluralin treatments incorporated prior to sowing.
Remaining treatments applied pre-emergence.
Rating Scale - Weeds : 0 (dense cover of weeds) - 10 (no weeds)
Crop : 0 (complete kill) - 10 (no damage)

Table 2

Experiment 2 - Effect of post-emergence treatments on direct drilled cabbage

Treatment	Dose lb/ac	Yield tons/ac	No. of thinnings per 12 ft row	Wt. of thinnings tons/ac	Assessments (June 2) Crop	Weeds
1. CP 31393	3.9	15.4	28	3.7	9.1	5.6
2. "	5.85	16.7	24	3.0	9.5	7.3
3. Nitrofen	1.05	14.0	20	2.3	6.6	6.6
4. "	2.1	11.0	17	1.1	3.8	7.6
5. CP 31393	3.9	13.7	23	2.6	9.4	1.9
6. "	5.85	13.6	26	2.4	9.0	3.2
7. Nitrofen	1.05	16.6	26	2.8	7.4	3.9
8. "	2.1	12.1	28	2.3	6.2	5.6
9. Desmetryne	0.375	11.8	23	2.0	7.3	4.5
10. Control		10.6	26	2.1	9.0	0.6
F.Test		NS	NS	**		
S.E. of Treatment mean		2.07	3.41	0.43		

Treatments 1 - 4 applied at 1 - 2 true leaf stage.
Remaining treatments applied at 3 - 4 true leaf stage.

cotyledon - 2 rough leaf stage. CP 31393 gave good control of Stellaria media, Senecio vulgaris and partial control of Veronica spp. at this stage. However poor control of Polygonum aviculare, Fumaria officinalis and Papaver rhoeas was obtained. With the later application weed growth was considerably advanced and only Stellaria media was checked.

All species except Stellaria media and Papaver rhoeas were well controlled with nitrofen at the 1 - 2 true leaf stage. The higher dose gave only slightly better control. Good control of Veronica spp., Polygonum convolvulus and Galeopsis tetrahit was still obtained with the later application of this herbicide but Senecio vulgaris, Fumaria officinalis and Polygonum aviculare were only slightly checked. Desmetryne 0.375 lb gave good control of most species except Veronica spp., Polygonum aviculare and Poa annua.

Experiment 3

The crops showed good tolerance of all treatments except nitrofen 3.0 lb + chlorpropham 0.5 lb which caused a significant reduction in stand and vigour (Table 3). The best treatment both for weed control and absence of crop injury was CP 31393 4.55 lb + chlorpropham 0.5 lb. Only a few plants of Fumaria officinalis survived this treatment in the 6 week period following spraying. Afterwards some Stellaria media and Poa annua tended to become established. Nitrofen 3.0 lb + chlorpropham 0.5 lb also gave excellent weed control and had slightly longer residual activity than the previous treatment.

Weed control with the split application of nitrofen 1.5 lb + chlorpropham 0.5 lb pre-emergence followed by CP 31393 4.55 lb at the 2 - 3 true leaf stage was slightly less effective than the single pre-emergence application of CP 31393 + chlorpropham.

The residual activity of CDEC 1.8 lb + chlorpropham 0.25 lb was short lived. Three to four weeks after spraying many species including Stellaria media, Poa annua, Senecio vulgaris, Chenopodium album and Fumaria officinalis became established.

Poor weed control was obtained with the incorporation of trifluralin 1.0 lb prior to sowing.

Experiment 4

The crop was highly tolerant of CP 31393 4.55 lb applied at the 1 - 2 true leaf but the addition of chlorpropham 0.5 lb caused a serious check to crop vigour at both stages of application. This is indicated in Table 5 for weight of thinnings.

Desmetryne 0.25 lb at the 3 - 4 true leaf stage also caused serious reduction in vigour and severe necrosis particularly of the two older leaves, however this growth check was not as persistent as with CP 31393 + chlorpropham applied at the same stage. Nitrofen 1.05 lb at the 3 - 4 true leaf stage was highly selective.

The application of CP 31393 4.55 lb at the 1 - 2 true leaf stage gave good control particularly of Stellaria media. Poa annua and Fumaria officinalis were only partially controlled and Polygonum aviculare proved resistant to this treatment. The addition of chlorpropham did not give any improvement in weed control. Weed control was slightly less effective with the later application of all treatments. Nitrofen 1.05 lb gave poor control of Stellaria media and Poa annua. Polygonum aviculare and Fumaria officinalis were partially resistant but good control was obtained of Lamium purpureum, Chenopodium album, Senecio vulgaris and Veronica spp.

Desmetryne 0.25 lb failed to control Poa annua and Polygonum aviculare but gave good control of other species.

Table 3

Experiment 3 - Effect of pre-emergence treatments on direct drilled cauliflower.

(Mean of 4 replicates)

Treatment	Dose lb/ac	No. of thinnings per 8 yd row	Wt. of thinnings tons/ac	Assessments on crop July 28	Aug. 16	Sept. 15	Assessments on weeds July 28	Aug. 16	Sept. 15
1. CP 31393 +	4.55								
chlorpropham	0.5	57	0.44	9.5	9.6	9.3	10.0	8.8	6.9
2. Nitrofen +	3.0								
chlorpropham	0.5	32	0.20	8.0	8.5	8.6	9.5	8.4	8.1
3. CDEC +	1.8								
chlorpropham	0.25	57	0.45	9.8	9.3	8.9	8.9	3.5	4.3
4. Trifluralin	1.0	43	0.32	10.0	9.3	8.3	1.3	3.6	2.4
5.a)Nitrofen +	1.5								
chlorpropham	0.5	56	0.37	9.3	8.5	8.4	8.1	7.4	5.4
b)CP 31393	4.55								
6. Control		52	0.36	10.0	9.6	8.8	1.9	4.6	1.8
F Test		**	*						
S.E. of Treatment Mean		4.6	0.05						

Treatment 4 incorporated prior to sowing.
Treatment 5 (b) applied at 2 - 3 leaf stage.
Remaining treatments applied after sowing.

Table 4

Experiment 3 - Treatment effects on weed population (4 Aug.).

(Mean of 4 replicates)

Treatment	Dose lb/ac	Number of weeds per 6 yd^2: *Stellaria media*	*Fumaria officinalis*	*Poa annua*	*Veronica* spp.	*Capsella bursa-pastoris*	Total weight of all weeds tons/ac
1. CP 31393 +	4.55						
chlorpropham	0.5	1	16	0.5	0	0	0.03
2. Nitrofen +	3.0						
chlorpropham	0.5	4	30	0.5	0	1	0.06
3. CDEC +	1.8						
chlorpropham	0.25	39	19	24	29	8	0.16
4. Trifluralin	1.0	580	11	35	19	2	0.99
5.a)Nitrofen +	1.5						
chlorpropham	0.5	43	70	3	0	3	0.09
b)CP 31393	4.55						
6. Control		1018	26	41	8	14	1.37

Table 5

Experiment 4 - Effect of post-emergence treatments on direct drilled cauliflower and weed population

(Mean of 4 replicates)

	Dose lb/ac	No. of thinnings per 24 ft row	Wt. of thinnings tons/ac	No. of main weeds per 4.5 yd^2		Total wt of all weeds tons/ac	Assessments (Sept. 2)	
				Poa Annua	Stellaria media		Crop	Weeds
1. CP 31393 + chlorpropham	4.55 0.5	121	2.7	40	1	0.31	7.0	8.4
2. CP 31393	4.55	121	3.6	13	3	0.36	9.6	8.4
3. CP 31393 chlorpropham	4.55 0.5	112	2.6	44	1	0.22	7.6	8.1
4. Nitrofen	1.05	112	4.4	47	27	0.42	9.4	7.0
5. Desmetryne	0.25	113	1.9	67	10	0.27	5.1	8.0
6. Control		120	4.3	63	23	1.29	10.0	3.5

Treatments 1, 2 applied at 1 - 2 true leaf stage.
Treatments 3, 4, 5 applied at 3 - 4 true leaf stage.
Rating Scale - Weeds : 0 (dense cover of weeds) - 10 (no weeds)
Crop : 0 (complete kill) - 10 (no damage)

DISCUSSION

The results of these experiments suggest that CP 31393 is a promising herbicide for both pre-emergence and early post-emergence application in direct drilled cabbage and cauliflower. No significant crop injury occurred at doses up to 5.05 lb applied pre-emergence or post-emergence at the 1 - 2 true leaf stage in cabbage. In cauliflower also no crop damage was apparent with a dose of 4.55 lb applied at the 1 - 2 true leaf stage.

Many growers are now practising the stale seed bed technique using paraquat as a means of controlling weeds in the early stages of crop growth in direct drilled *Brassicae*. This method combined with an application of CP 31393 at 1 - 2 true leaf stage is suggested as a means of obtaining prolonged weed control in such crops.

Though nitrofen 1.05 lb showed greater selectivity than desmetryne 0.25 lb at the 3 - 4 leaf stage in cauliflowers, the failure of this herbicide to control *Stellaria media*, usually one of the most troublesome species in *Brassicae*, is a serious drawback. The addition of chlorpropham to this herbicide is advocated for control of *Stellaria media*; however, the results obtained in Experiment 4 where CP 31393 + chlorpropham mixture caused reduction in plant vigour indicate that chlorpropham is too dangerous for post-emergence application.

Though no crop injury was apparent where CP 31393 4.55 lb + chlorpropham 0.5 lb was applied pre-emergence in cauliflower, further trials will be necessary before recommendations can be made.

HERBICIDE TRIALS IN FRENCH BEANS

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Summary Monolinuron, monolinuron + dinoseb-acetate and a-chloro-N-isopropylacetanilide (CP 31393) were the main herbicides assessed for pre-emergence application on French beans over a wide range of soil types. Monolinuron + dinoseb-acetate showed greater crop selectivity than monolinuron alone at doses necessary for equivalent weed control and was more effective than dinoseb-amine. Crop damage and depression in plant stand occurred with dinoseb-acetate applied at the 2 simple leaf stage. Severe growth check also occurred with CP 31393. 1 - (3, 4 - dichlorobenzyl) - 3 methyl - 2 - pyrrolidinone (BV 201) showed considerable promise because of high crop tolerance and excellent weed control. At one site monolinuron 0.5 lb + paraquat 0.5 lb was very effective under stale seed bed conditions. Results with metobromuron, dinoseb-amine and 75% 3, 4 - dichlorobenzyl-N-methyl carbamate + 25% 2, 3 - dichlorobenzyl-N-methyl carbamate are also included.

INTRODUCTION

At the last British Weed Control Conference results were reported in which eight herbicides were compared as pre-emergence treatments on French beans (Cassidy & Doherty, 1964). Work continued in 1965 and 1966 on the testing of the most promising of these herbicides together with newer ones introduced since 1964. The trials described in this paper refer to results obtained in 1966. Results from 1965 trials have already been reported (Cassidy & Doherty, 1965).

In Ireland the production of French beans for processing is of recent origin and whilst moderate weed control can be obtained with the pre-emergence application of dinoseb-amine particularly where the stale seed bed technique is used, there is need for a material with sufficient residual activity to give season long weed control.

METHOD AND MATERIALS

Three types of trials were conducted:

(a) Replicated small plot trials of randomised block design in which 8 herbicides were compared on 2 soil types. (Sites A, B)

(b) Three treatments were tested under stale seed bed conditions at 4 sites. These trials were also of randomised block design with four fold replications. (Sites C-F)

(c) Five treatments were evaluated on a semi-commercial scale in large unreplicated plots (0.125 ac. per treatment) at 9 sites. (Sites G - O)

In the replicated trials herbicides were applied in water at a volume of 40 gal/ac. using an Oxford Precision Sprayer or a pressure retaining knapsack. Plot size varied from 10 - 20 yd^2. A Land Rover mounted Allman Sprayer or knapsack sprayer was

Table 1

Site Details Trials A - F

	A	B	C	D	E	F
	Kinsealy, Co. Dublin	Ballinagree, Co. Carlow	Kinsealy, Co. Dublin	Ballymacada, Co. Cork	Ballylinan, Co. Laois	Ballinagree, Co. Carlow
Soil Type	Medium loam	Gravelly fine sandy loam	Medium loam	Fine sandy loam to loam	Sandy loam to loam	Details as for Site B
Organic Matter (%)	7.6	3.9	7.6	3.8	3.8	
Clay; Silt (%)	23.1, 37.2	8.7, 29.3	23.1 37.2	15.4, 28.7	14.6, 29.4	
Number of days seed bed prepared before drilling	2	10	20	14	14	
Date of drilling; Spraying	June 8 June 15	May 20 May 25	June 23 June 28	May 21 May 28	May 18 May 26	
Rainfall (in.) during 3 weeks after spraying	1.8	3.0	1.0	Not recorded	2.7	
Prevalent weeds	Poa annua, Veronica spp., Fumaria officinalis, Stellaria media, Lamium purpureum, Capsella bursa-pastoris	Polygonum aviculare, Poa annua, Veronica spp., Viola tricolor, Polygonum convolvulus	Poa annua, Veronica spp., Lamium purpureum, Polygonum aviculare	Poa annua, Veronica spp., Anthemis cotula, Polygonum aviculare, Stellaria media	Veronica spp., Chenopodium album, Stellaria media, Euphorbia helioscopia, Anagallis arvensis	

Particle size of clay < .002 mm.
Particle size of silt < .02 mm.

used for the large single plot trials.

At least two visual assessments of treatment effect on crop and weeds were made. Small plot trials were harvested by hand once only and the large single plots by mechanical harvester. Plant counts were recorded in replicated trials. In the unreplicated plots 6 random samples of 4 row x 1 yd were taken in each plot at harvesting to assess treatment effects on plant population and yield. Detailed weed counts were taken at Kinsealy only. The variety Processor was sown in all trials. Site details (A - F) are given in Table 1.

RESULTS

Site A

High crop selectivity was shown by all pre-emergence treatments except a-chloro-N-isopropylacetanilide (CP 31393) which, particularly at 6.8 lb, caused severe reduction in crop vigour. The crop however recovered from this check and yields were not significantly reduced. Leaf scorch but no reduction in plant stand occurred in plots treated with dinoseb-acetate 2.4 lb at the late simple leaf stage. The most effective weed control was given by 1 - (3, 4 - dichlorophenyl) - 3 - methyl - 2 - pyrrolidinone (BV 201) 6 lb. In plots treated at this dose only a few stunted Fumaria officinalis and Veronica spp. survived (Table 2). Good control was also obtained with monolinuron + dinoseb-acetate, metobromuron and monolinuron but Fumaria officinalis and Veronica spp. were not completely controlled even at the higher doses of these herbicides.

CP 31393 gave good control of Veronica spp., Lamium purpureum and Poa annua but poor control of Fumaria officinalis and Polygonum aviculare. Dinoseb-acetate 2.4 lb failed to control Poa annua and Polygonum aviculare but other species were well suppressed.

Site B

When the first assessments were made 3 weeks after the application of pre-emergence treatments during which 3 in. of rain fell most treatments were showing high crop selectivity on this light soil. Most severe crop injury and plant kill occurred with dinoseb-acetate 2.4 lb applied at the early simple leaf stage. Slight chlorosis and reduction in crop vigour was apparent in plots treated with CP 31393 at 4.55 and 6.8 lb. Later assessments showed that the crop made a good recovery from this initial check but yields at the higher dose tended to be low. Severe chlorosis occurred with 75% 3, 4 - dichlorobenzyl-N-methyl carbamate + 25% 2, 3 - dichlorobenzyl-N-methyl carbamate (UC 22463) 6 lb but final yields were not reduced. Slight growth retardation was also evident in plots treated with monolinuron 1.5 lb/ac.

Excellent weed control which was maintained up to harvesting was given by BV 201 4.0 and 6.0 lb, UC 22463 4.0 and 6.0 lb, metobromuron 2.25 lb, monolinuron 1.5 lb and monolinuron 0.93 lb + dinoseb-acetate 2.8 lb. Monolinuron 0.75 lb and monolinuron 0.63 lb + dinoseb-acetate 1.88 lb did not completely suppress Veronica spp. and Polygonum aviculare. Control was better and more prolonged with these treatments than with dinoseb-amine 3.5 lb. The latter treatment gave poor control particularly of Polygonum aviculare, Poa annua and Viola tricolor. CP 31393 4.55 lb was not very effective against Polygonum aviculare, Fumaria officinalis, Viola tricolor and Polygonum convolvulus. Control was much improved at 6.8 lb but Polygonum aviculare still showed resistance. Veronica spp. were very susceptible to both doses. Some resistance was shown by these species to metobromuron 1.5 lb but complete control was obtained at 2.25 lb/ac. At this site also BV 201 was the most promising of the newer herbicides tested because of high crop selectivity and excellent weed control. On this gravelly fine sandy loam soil (clay 8.7%, organic matter 3.9%) insignificant crop injury occurred at a dose 50% above that needed to give satisfactory season long weed control. This is shown in Table 2 where BV 201 6.0 lb gave the highest yield of

Table 2

Sites A, B. Treatment effects on yield, bean and weed population

(Mean of 4 replicates)

Treatment	Dose lb/ac	Site A: Yield tons/ac	Site A: No.of bean plants per 8 yd row	Site B: Yield tons/ac	Site B: No.of bean plants per 8 yd row	Number of main weeds per 5 yd^2 (Aug.2) Site A: *Fumaria officinalis*	*Poa annua*	*Lamium purpureum*	*Veronica* spp.
1.Monolinuron + dinoseb-acetate	0.63 1.88	7.54	53	6.75	94	4	6	3	11
2.Monolinuron + dinoseb-acetate	0.93 2.88	7.86	56	7.20	97	4	4	1	14
3.Monolinuron	0.75	7.79	55	6.49	94	4	0.5	1	14
4. "	1.5	7.23	50	6.02	79	8	0	1	15
5.Metobromuron	1.5	7.64	53	6.46	84	11	2	0.25	17
6. "	2.25	7.98	66	7.04	83	3	0	2	11
7.CP 31393*	4.55	7.51	53	6.75	98	13	3	2	2
8. "	6.8	6.97	60	5.56	77	7	1	0	0.5
9.BV 201*	4.0	7.44	55	6.96	91	6	5	2	6
10. "	6.0	7.95	60	8.48	101	2	0	0	3
11.UC 22463*	4.0	n.u.	-	7.37	95	-	-	-	-
12. "	6.0	n.u.	-	7.08	92	-	-	-	-
13.Dinoseb-amine	3.5	7.59	46	6.32	83	6	44	16	13
14.Dinoseb-acetate	2.4	8.10	51	4.56	66	1	136	3	6
15.Control		7.63	57	4.76	81	2	95	8	25
16.Control		6.02	52	4.33	84	13	134	34	68
F test		x	N.S.	xxx	N.S.				
S.E. of treatment mean		0.34	4.4	0.52	7.5				

* a-chloro-N-isopropylacetanilide (CP 31393)
1 - (3, 4 - dichlorophenyl) - 3 methyl - 2 - pyrrolidinone (BV 201)
75% 3, 4 dichlorobenzyl-N-methyl carbamate +
25% 2, 3 " " " " (UC 22463)
n.u. not used

Treatment 14 Applied post emergence at late simple leaf stage Site A and early simple leaf stage at Site B. All other treatments applied pre-emergence. Control plot (Treatment 15) received 2 handweedings and Treatment 16 one handweeding after weed counts were recorded at Site A. Both control treatments were not handweeded at Site B but all plots were steerage-hoed twice.

all treatments in the trial.

Sites C - F

Good crop selectivity was shown by all treatments (Table 3). At Site C slight chlorosis of the simple leaves was apparent on the occasional plant where monolinuron 0.5 + dinoseb-acetate 1.5 lb was applied. A very slight temporary reduction in vigour also occurred with this treatment at Site E.

Very few weed seedlings had emerged at Sites E and F when treatments were applied although seed beds had been finally prepared over 2 weeks beforehand. At the other sites and particularly at C there was good weed cover when spraying was carried out.

The assessments given in Table 4 show little difference in degree of weed control between the two mixtures containing monolinuron. At Site C however where weeds were in the 2 - 4 rough leaf stage at spraying and Poa annua, Veronica spp. and Lamium purpureum were the principal species, monolinuron 0.5 lb + paraquat 0.5 lb gave excellent control and was much more effective than monolinuron 0.63 lb + dinoseb -acetate 1.88 lb. This effect can be attributed to the greater contact action of paraquat on these species.

Both monolinuron treatments gave more prolonged weed control than dinoseb-amine but none proved sufficiently long lasting to give satisfactory control up to harvesting except monolinuron + paraquat at Site C and monolinuron + dinoseb-acetate at Site D. One steerage hoeing was given in early July at Sites D and E and 2 hoeings at Site F. At Site D the low yields with dinoseb-amine cannot be attributed entirely to the relatively poor annual weed control obtained. Agropyron repens which occurred unevenly over the trial area was present in 3 of the 4 plots treated with this herbicide and caused severe competition.

At Sites D, E and F dinoseb-amine gave better control of Veronica spp. than monolinuron treatments but the latter proved more effective against Stellaria media, Chenopodium album, Polygonum persicaria and Polygonum aviculare. Anagallis arvensis and Euphorbia helioscopia which occurred in Trial E were partially resistant to all treatments.

Sites G - O

These trials were carried out on growers' crops in the Carlow and Cork areas on a range of soil types varying from gravelly coarse sandy loam to loams. Treatments are given in Table 5. Rainfall recorded at 4 Carlow sites showed that up to 3 in. fell in the 3 week period following application.

Crop response was similar to that obtained in replicated trials; CP 31393 4.55 lb/ac. caused severe crop damage in the initial stages. Although crops recovered well, growth retardation was still evident at many sites 2 months after application and yields were reduced as compared with monolinuron + dinoseb-acetate and monolinuron treatments.

Severe crop scorch occurred at all sites where dinoseb-acetate 2.4 lb/ac. was applied post emergence at the 2 simple leaf stage. Most severe injury, often resulting in death, occurred with smaller less developed plants. This was particularly apparent at the Cork sites where dinoseb-acetate was applied under dry overcast conditions following a period of heavy rain. Only slight reduction in plant stand was evident at the Carlow sites where application was made after a period of dry weather. Surviving plants made excellent recovery at all sites and though yields were generally lower than monolinuron or monolinuron + dinoseb-acetate treated plots this can be attributed mainly to poorer weed control and reduced plant stand and not to any persistant check to crop vigour.

Table 3

Sites C - F. Treatment effects on yield and bean population

(Mean of 4 replicates)

Treatment	Dose lb/ac	Site C		Site D		Site E		Site F	
		Yield tons/ac	No.of bean plants/16 yd row	Yield tons/ac	No.of bean plants/16 yd row	Yield tons/ac	No.of bean plants/16 yd row	Yield tons/ac	No.of bean plants/16 yd row
Monolinuron + paraquat	0.5 0.5	7.7	129	6.8	213	3.3	107	3.5	151
Monolinuron + dinoseb-acetate	0.63 1.88	7.4	126	7.1	216	3.5	99	3.3	159
Dinoseb-amine	3.7	7.9	128	3.5	206	3.1	102	3.8	181
F test		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E. treatment mean		0.18	5.6	1.53	7.5	0.32	11.1	0.45	10.9

Table 4

Sites C - F. Assessments on weed control

(Mean of 4 replicates)

Treatment	Dose lb/ac	Site C		Site D		Site E		Site F	
		July 7	Aug. 2	June 10	June 30	June 15	July 7	June 15	July 7
Monolinuron + paraquat	0.5 0.5	10.0	9.5	9.8	7.9	7.0	6.6	7.8	4.8
Monolinuron + dinoseb-acetate	0.63 1.88	7.6	5.3	9.4	8.0	8.1	7.1	8.5	6.9
Dinoseb-amine	3.7	8.8	5.1	9.9	4.3	5.4	4.7	8.3	5.6

Rating scale : Weeds : 0 (Dense cover of weeds) - 10(no weeds)

Table 5

Sites G - O. Assessments on weeds

Site	Soil Type	Clay % .002	Silt % .02	Organic matter %	Date of assessment	Assessments on weeds – Treatments A	B	C	D	E
G Oakpark Co. Carlow	Gravelly coarse sandy loam	9.0	11.8	5.1	June 14 Aug. 5	10.0 9.0	10.0 9.5	10.0 7.0	10.0 9.0	n.a.
H Ballylinan Co. Leix	Sandy loam to loam	14.2	29.0	3.8	June 15 July 7	5.0 2.0	8.5 7.0	8.5 6.0	9.5 8.5	8.5 8.5
I Rathstewart Co. Carlow	Loam	17.0	33.1	5.3	June 16 Aug. 30	9.0 6.0	9.5 8.0	7.0 3.0	10.0 8.0	 4.0
J Castledermot Co. Carlow	Loam	19.6	34.0	7.0	June 17 July 21	9.5 4.0	10.0 6.0	9.0 4.0	9.5 5.0	n.a.
K Ballinagree Co. Carlow	Gravelly fine sandy loam	8.7	29.3	3.9	June 17 July 21	6.0 5.0	8.5 6.0	5.0 3.0	8.5 7.0	6.0 2.0
L Ballinacurra Co. Cork	Gravelly sandy loam	11.0	26.6	5.8	July 30 Aug. 8	7.0 6.0	8.0 9.0	4.0 6.0	8.5 9.0	6.0 4.0
M Monageer Co. Cork	Fine sandy loam	14.9	32.2	5.0	June 30 Aug. 8	7.0 5.5	8.5 8.0	3.5 3.5	9.0 9.0	7.0 5.0
N Carrigshane Co. Cork	Fine sandy loam	13.7	31.9	3.2	June 29 Aug. 8	9.5 10.0	10.0 10.0	7.5 10.0	10.0 10.0	9.0 10.0
O Ballyquirke Co. Cork	Gravelly sandy loam	9.3	20.2	4.9	June 30 Aug. 8	7.0 8.0	9.5 10.0	5.0 5.0	9.0 9.5	8.0 7.0

A Monolinuron 0.5 lb + dinoseb-acetate 1.5 lb B Monolinuron 0.75 lb + dinoseb-acetate 2.25 lb C CP 31393 4.55 lb
D Monolinuron 1.0 lb E Dinoseb-acetate 2.4 lb
Rating scale : Weeds: 0 (dense cover of weeds) - 10(no weeds)

At sites K, L, N, O plots were steerage-hoed after the first assessment. At site N plots were also handweeded.

Table 6

Sites G - O. Treatment effects on yield and plant population

Site	Monolinuron 0.5 lb + dinoseb-acetate 1.5 lb			Monolinuron 0.75 lb + dinoseb-acetate 2.25 lb			CP 31393 4.55 lb			Monolinuron 1.0 lb			Dinoseb-acetate 2.4 lb		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
G	3.2	4.7	99	4.8	6.5	102	2.6	4.4	86	4.1	5.4	84	n.u.	n.u.	n.u.
H	2.5	3.6	45	2.2	4.1	55	2.1	3.3	61	2.8	4.4	60	2.5	3.2	55
I	3.4	5.3	103	3.1	4.6	101	2.0	3.1	87	2.8	4.1	108	n.h.	4.0	94
J	0.4	0.8	55	1.4	2.0	47	1.0	1.4	52	1.0	1.9	65	n.u.	n.u.	n.u.
K	3.5	4.9	80	3.7	5.2	84	2.3	5.6	90	3.3	6.3	96	3.2	6.4	84
L	6.7	6.6	77	6.9	8.1	97	5.5	6.3	87	5.6	8.6	95	2.1	3.6	69
M	n.h.	1.5	99	n.h.	2.9	102	n.h.	0.6	101	n.h.	3.9	103	n.h.	0.6	55
N	4.1	6.3	115	3.8	5.8	124	1.3	3.0	103	2.7	3.5	82	1.2	1.8	41
O	2.3	5.0	115	4.3	8.4	124	1.2	2.3	121	3.5	6.4	121	2.1	4.5	85
Mean	3.3	4.3	88	3.8	5.3	93	2.0	3.3	78	3.2	4.9	90	2.2	3.5	69

n.h. not harvested
n.u. not used

A Yield tons/ac mechanically harvested
B Yield tons/ac mean of 6 samples
C Bean population 000s/ac

The mixture of monolinuron + dinoseb-acetate showed excellent crop selectivity at all sites, except at Site N where on a light poorly textured sandy soil, slight chlorosis was apparent on the occasional plant where the higher dose was used. At this site monolinuron 1.0 lb caused more general chlorosis of the simple leaves with reduction in crop vigour and yield. Chlorosis and slight necrosis also occurred at Site M with this treatment.

Taking all sites into consideration monolinuron 0.75 lb + dinoseb-acetate 2.25 lb was more selective than monolinuron 1.0 lb and this is reflected in the average yield from both treatments (Table 6). Practically no difference in weed control was observed between these two treatments. Both gave good control of most species. However Veronica spp., Polygonum aviculare, Fumaria officinalis and Euphorbia helioscopia which occurred at many sites were partially resistant. Species well controlled included Chenopodium album, Senecio vulgaris, Stellaria media, Poa annua, Polygonum persicaria, Capsella bursa-pastoris, Papaver rhoeas, Sinapis arvensis and Sonchus oleraceus.

Monolinuron 0.5 lb + dinoseb-acetate 1.5 lb gave good control in the early stages but on the heavier soils this dose proved insufficient for satisfactory prolonged control.

Poor control of Polygonum species and Fumaria officinalis was obtained with CP 31393 but as in the other trials Veronica spp. were well controlled. Polygonum aviculare and Poa annua were the main species resistant to dinoseb-acetate.

DISCUSSION

The expansion in the acreage of French beans for processing and the rapid adoption of mechanical harvesting has highlighted the need for satisfactory chemical weed control. The recommended herbicide (dinoseb-amine) is widely used at present; but even where the stale seed bed method is adopted this herbicide has not shown sufficient residual activity under Irish conditions to maintain satisfactory long season control. This defect is particularly evident where wide row spacings are used to facilitate mechanical harvesting. Undoubtedly a herbicide providing good initial control would be satisfactory for French beans grown in narrow rows as the strong crop canopy would prevent the establishment of later germinating weeds. Following the good results obtained in 1965 with monolinuron + dinoseb-acetate much experience was gained with this mixture in this year's trials. The results suggest that this treatment offers a suitable alternative to dinoseb-amine particularly where annual weeds other than Veronica spp., Fumaria officinalis and Polygonum aviculare are predominant. As with all soil applied herbicides the correct dose of this material both for crop selectivity and effective weed control will vary with soil type. Results would suggest a dosage range of monolinuron 0.5 + dinoseb-acetate 1.5 lb for light soils to 0.9 + 2.7 lb for heavy soils. The greater safety with the mixture of monolinuron + dinoseb-acetate is probably due to several factors; firstly, for equivalent weed control a smaller amount of monolinuron is applied in the mixture than where this herbicide is used alone. In addition the risk of overdosing is less with a treatment like monolinuron + dinoseb-acetate where a relatively large amount of product is required per acre than where a much lower dose is used as with monolinuron.

Stage of application and weather conditions influenced the degree of damage which occurred with post emergence application of dinoseb-acetate. Because of the serious damage caused in these trials the use of this herbicide under Irish conditions appears hazardous.

CP 31393 seriously checked crop vigour in the early stages of growth and this material would not appear to have sufficient selectivity at doses required for adequate weed control.

Although tested for one year only BV 201 showed considerable promise in all trials.

Acknowledgements

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PROMETRYNE - A REPORT ON ITS USE IN PEAS

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Summary Results are presented of trials testing pre-emergence applications of prometryne, carried out during the period 1961-66, which suggest that the material would be suitable for use in peas on medium- and heavy-textured soils. The selectivity on light sandy soils was shown to be insufficient for it to be safely used on these free-draining soils.

Weed control and yield comparisons made with post-emergence applications of dinoseb-amine were favourable, indicating that the material could profitably replace dinoseb under certain conditions, notably for early sown crops or where weed species are present which are difficult to control with dinoseb.

INTRODUCTION

The most widely used herbicides in peas are dinoseb-amine and dinoseb-ammonium applied post-emergence. These materials can give very good results, providing all the requirements for their satisfactory application are met. Air temperatures must be relatively high during and for several hours after application and the crop must be dry and free from damage caused by hail, wind, blowing soil, harrowing or rolling. For best results, weeds should not be beyond the seedling stage. This presents problems in early drillings since weeds are often at a suitable stage for spraying before temperatures are high enough for dinoseb to be used successfully. Certain weeds are resistant to dinoseb once they are past the seedling stage and perhaps the most troublesome of these is Polygonum aviculare (knotgrass), which can seriously interfere with harvesting. An added difficulty encountered when treating vining peas is the difference between varieties in their susceptibility to scorch.

The need to replace, or supplement, the dinoseb herbicides with more efficient materials prompted the work with residual herbicides which started at the P.G.R.O. in 1958. The results from 1961 to 1962 and from 1963 to 1964 were reported at the 6th and 7th British Weed Control Conferences respectively. (King & Hancock 1962; King & Gent 1964). Throughout this work prometryne has proved to be a promising pre-emergence herbicide in peas and it is now used commercially; the results of all the work with prometryne undertaken by the P.G.R.O. are presented herein.

METHOD AND MATERIALS

Constant rate trials were carried out in 1961, 1963, 1964 and 1966 and all applications were made with an Oxford Precision Sprayer at a volume of 50 gal/ac. Plot size was .005 acre in 1961 and 1963; in 1964 and 1966 .0025 acre plots were used. Four-fold replication was employed in 1963 and 1964 with three replications in 1966 and two in the 1961 observation trials. Weed counts or assessments were made and yields were taken except in 1961. Samples of produce were canned for taint tests from trials in 1963, 1964 and 1966.

Varying dose trials were conducted from 1962 to 1964, applications being made with a van der Weij logarithmic sprayer testing a 10 to 1 dose dilution over a 65 ft plot. Volume was 50 gal/ac and two-fold replication was used. Visual assessments were made of weed control and crop damage.

In 1965 ten one acre farmer-tests were carried out in which prometryne was applied at doses of 1.25 or 1.5 lb/ac according to the soil texture. Sample weed and plant counts were made on the treated area and on the rest of the field.

A 50% wettable powder formulation of prometryne and an 18.5% wt/vol alkanolamine salt formulation of dinoseb were used in this work and doses are given in active ingredient. Pre-emergence applications were generally made seven days after sowing, radicle and plumule being present in most cases. Dinoseb was applied when the majority of the weeds were still in the seedling stage.

RESULTS

1961 Observation trials

Prometryne was tested at four sites with the following soil types:-

Site 1	Peaty clay loam,	organic matter 17.5%	clay	30%
2	Very fine sandy loam,	" " 2.4%	"	10%
3	Clay loam,	" " 2.8%	"	20%
4	Peaty loam,	" " 20.3%	"	20%

Table 1

Crop vigour and weed control assessments
(mean of two replicates)

Material	lb/ac	Site 1 crop	Site 1 weeds	Site 2 crop	Site 2 weeds	Site 3 crop	Site 3 weeds	Site 4 crop	Site 4 weeds
Prometryne	0.75	10.0	2.5	10.0	6.0	10.0	3.5	10.0	4.5
	1.50	10.0	2.0	10.0	8.5	10.0	3.5	10.0	6.0
Dinoseb-amine	2.5	10.0	8.8	10.0	7.5	9.5	8.0	10.0	9.0

Crop vigour rating 10 = no effect; 0 = complete crop kill
Weed control rating 10 = complete control; 0 = no control

Seedbed conditions at sites 1 and 3 were dry and cloddy when the pre-emergence applications were made and weed control was not satisfactory. There was no effect on the crop from either dose of prometryne at the four sites.

1962-1964 Logarithmic observation trials

Prometryne was tested on ten sites during this period as follows:-

1962	Site 1	Loamy sand,	organic matter 1.6%	clay	10%
	2	Peaty loam,	" " 24.6%	"	20%
	3	Clay loam,	" " 3.0%	"	30%
1963	4	Silty clay loam,	analysis not available.		
	5	Loamy sand,	" " 1.4%	"	4%
	6	Very fine sandy loam,	" " 2.8%	"	14%
1964	7	Loamy coarse sand,	" " 1.3%	"	4%
	8	Silty loam,	" " 10.2%	"	20%
	9	Silty clay loam,	" " 7.0%	"	30%
	10	Peaty loam,	" " 24.2%	"	-

Table 2

Assessments of weed control and crop vigour

Site	Soil type	Dose range tested lb/ac Maximum	Minimum	Minimum * effective dose	Maximum** tolerated dose	Selectivity*** factor
1	Loamy sand	10.5	1.1	1.1	2.2	2.0
2	Peaty loam	10.3	1.0	2.5	10.3	4.1
3	Clay loam	10.5	1.1	1.4	8.6	6.1
4	Silty clay loam	7.5	0.8	n.a.	7.5	-
5	Loamy sand	7.0	0.7	0.7	2.8	4.0
6	Very fine sandy loam	7.5	0.8	1.0	4.2	4.2
7	Loamy coarse sand	7.4	0.7	0.7	0.7	1.0
8	Silty loam	7.8	0.8	0.8	7.0	8.7
9	Silty clay loam	7.7	0.8	1.6	7.7	4.8
10	Peaty loam	8.5	0.9	3.1	8.5	2.7

* the minimum effective dose giving acceptable weed control.

** the maximum dose tolerated by the crop.

*** selectivity factor = $\frac{\text{the maximum dose tolerated by the crop}}{\text{the minimum effective dose for weed control}}$

n.a. not assessed as insufficient weeds present.

The material showed satisfactory selectivity on all the soils tested except two light free-draining soils. On these soils the degree of crop damage could also be linked to the level of rainfall which followed the application. Thus at site 5 on a loamy sand the crop tolerated 2.8 lb/ac when the rainfall following application was low, while at site 7 on a coarse sandy loam 0.7 lb/ac caused quite severe crop damage following heavy rain soon after application. At this site the material caused crop damage at the lowest dose tested and the maximum tolerated dose was probably lower than 0.7 lb/ac.

1963-1964 Yield trials

During 1963 and 1964 prometryne was included in replicated trials at four sites in each year. Yields of either vined or dried peas were recorded and are presented in table 3. Weed counts and assessments were made and the percentage weed control figures appear in tables 3 and 4. The results for post-emergence dinoseb-amine are included for comparison. The soil texture details for the sites are as follows:-

1963	Site 1	Very fine sandy loam,	organic matter 3.8%,	clay 13%,	silt 18%
	2	Fine sandy loam,	" " -	" 15%,	" 20%
	3	Loamy very fine sand,	" " 1.8%,	" 21%,	" 11%
	4	Clay loam,	" " 2.9%,	" 36%,	" 18%
1964	5	Loamy fine sand,	" " 2.6%,	" 14%,	" 12%
	6	Silty clay loam,	" " 2.6%,	" 15%,	" 30%
	7	Peaty loam,	" " 17.8%,	-	-
	8	Fine sandy loam,	" " 2.2%,	" 26%,	" 18%

Table 3

Weed control and yields 1963-1964

Weed control is presented as the percentage of the weed population on the untreated control.
Yields are presented as a percentage of the untreated control.

Material	lb/ac	Weed control	Yield	Weed control	Yield	Weed control	Yield	Weed control	Yield
					Site				
1963		1		2		3		4	
Prometryne	1.5	-	-	100	95	-	-	-	-
	1.9	92	106	-	-	99	99	-	-
	2.3	-	-	-	-	-	-	88	123
Dinoseb-amine	0.9	-	-	42	107	-	-	-	-
	1.9	88	107	-	-	70	95	63	104
					Site				
1964		5		6		7		8	
Prometryne	1.5	98	138	94	97	82	123*	n.a.	101
Dinoseb-amine	1.9	65	124	74	121*	85	119*	n.a.	96

* significant difference from untreated control at $P = 0.05$
n.a. not assessed as insufficient weeds present.

Table 4

The percentage control of weed species by prometryne 1963-1964

The dose at each site is the same as presented in table 3.
The mean percentage control for dinoseb-amine is taken from results at all sites except site 7.

Weed species	Site 1	3	4	5	6	7	Mean	dinoseb-amine mean
Aethusa cynapium	-	-	67	-	-	-	67	33
Capsella bursa-pastoris	-	100	-	-	100	-	100	96
Chenopodium album	-	-	-	-	92	42	67	100
Fumaria officinalis	-	100	-	-	-	-	100	91
Galium aparine	33	-	62	-	-	-	48	88
Tripleurospermum maritimum ssp *inodorum*	100	100	-	100	-	-	100	54
Poa annua	-	-	-	-	87	-	87	0
Polygonum aviculare	91	100	96	91	-	-	95	48
Polygonum convolvulus	100	100	97	-	-	87	96	98
Urtica urens	-	100	-	99	-	-	100	60
Sinapis arvensis	-	-	-	-	-	100	100	-
Stellaria media	100	100	100	-	98	96	99	89
Veronica spp.	95	96	93	90	81	50	84	93

Prometryne gave better weed control than post-emergence dinoseb-amine at six of the seven sites where weed counts were possible, and higher yields than dinoseb-amine at five of the eight sites. At site 2 (fine sandy loam) and site 6 (silty clay loam) dinoseb-amine gave a higher yield in spite of giving less satisfactory weed control. No visual effect on the crop from prometryne was recorded at either of these sites. Counts were made of the predominant weed species present at six sites and the results are presented in Table 4. Prometryne gave satisfactory control of the following ten species; Capsella bursa-pastoris (shepherd's purse), Fumaria officinalis (fumitory), Tripleurospermum maritimum ssp inodorum (scentless mayweed), Poa annua (annual meadow grass), Polygonum aviculare (knotgrass), Polygonum convolvulus (black bindweed), Urtica urens (annual nettle), Sinapis arvensis (charlock), Stellaria media (chickweed) and Veronica spp (speedwells; spp). Control of Aethusa cynapium (fool's parsley), Chenopodium album (fat hen) and Galium aparine (cleavers) was less satisfactory. Prometryne gave better control than dinoseb-amine of most of the species recorded with the exception of fat hen, cleavers and Veronica spp (speedwell species).

1965 - Farmer tests with prometryne

The texture of the soils covered by these tests ranged from a very fine sandy loam which contained 10% of clay and silt, to a clay loam which contained 37% clay and 18% silt. Seven varieties of vining and dried peas were covered by this work. At eight sites the 1.5 lb/ac dose was used, 1.25 and 1.0 lb/ac doses being used at the two other sites. The volume used varied from 20 to 60 gal/ac and the interval between drilling and application varied from 4 days to 18 days. The earliest application was made on March 29th and the latest site to be sprayed was treated on April 22nd.

At nine of the ten sites weed counts and assessments showed that prometryne had given useful control, although at three of these sites control of Sinapis arvensis (charlock) and Brassica nigra (black mustard) was not fully effected and some of these weeds grew through the crop later in the season. At the remaining site prometryne failed to give satisfactory control. No crop damage was recorded at any site. At six of the ten sites weed control was considered to be equal or superior to the standard post-emergence dinoseb-amine treatment. Farmer reaction to the material was generally favourable.

1966 - Prometryne/pre-sowing wild oat (Avena fatua) herbicide trial

This trial was designed to assess possible effects of using pre-emergence prometryne after pre-sowing wild oat herbicides. Pre-sowing applications of tri-allate, propham and TCA were made on March 22nd and immediately incorporated with spring-tine cultivators set to penetrate 3 inches. The trial was drilled with vining peas on the following day. On April 4th a pre-emergence application of prometryne was made on one of the two plots in each replication which had already received an application of tri-allate, propham or TCA. The trial was hand-weeded to avoid weed competition effects. Propham caused delayed emergence and stunting while TCA caused some loss of bloom, but by flowering neither of these effects were visible. The trial was harvested at the vining pea stage and samples from each treatment canned for taint assessment.

Table 5

Yields of vined peas

Materials				Yield interpolated to T.R.115	Yield as a % of control
Pre-sowing	lb/ac	Pre-emergence	lb/ac	cwt/ac	
Tri-allate	1.5	Nil		50.4	96
Tri-allate	1.5	+ prometryne	1.5	54.3	104
Propham	3.0	Nil		43.1	83
Propham	3.0	+ prometryne	1.5	48.0	92
TCA	7.0	Nil		51.0	98
TCA	7.0	+ prometryne	1.5	54.1	104
Nil		prometryne	1.5	53.6	103
Untreated control				52.2	100

There was no evidence from this trial that the pre-emergence use of prometryne, following pre-sowing applications of tri-allate, propham or TCA, had any unfavourable effect on crop growth or yield. In each case when prometryne followed a pre-sowing herbicide the combined treatment gave a higher yield than the pre-sowing treatment alone. The single application of prometryne also resulted in a 3% increase over the untreated control. Prometryne applications gave excellent weed control. Although hand weeding was carried out on the other treatments it could not take place until the weeds were large enough to handle and it would appear that the yield differences were due to the early weed competition prior to this hand-weeding. The delayed emergence and stunting on the propham treatments not only delayed maturity, but also reduced the yield at tenderometer reading 115 compared to the control. This damage would probably not have occurred if an interval had been left between the chemical application and the sowing of the peas as is normally done in practice.

Taint assessments

No taints were detected in samples taken from prometryne treated plots in 1963 and 1964. The results of the samples taken from the 1966 trial are not available.

DISCUSSION

The selectivity of prometryne is best illustrated from the ten logarithmic dose trials which covered a wide range of soil types. On the five heavy- and medium-textured soils the minimum effective dose was approximately 1.2 lb/ac and this with a maximum tolerated dose of approximately 7.0 lb/ac resulted in high selectivity figures. On the lighter-textured sandy soils the minimum effective dose was approximately 0.8 lb/ac and while over 2.0 lb/ac was tolerated by the crop at two sites, at a third site the maximum tolerated dose was as low as 0.7 lb/ac.

It would appear that prometryne has adequate selectivity on medium- or heavy-textured soils. Selectivity on light sandy soils is not however, high, particularly where heavy rainfall occurs. On heavy soils containing more than 20% clay fraction, the dose for satisfactory weed control in these trials was approximately 1.25 lb/ac. Prometryne gave useful control on peaty soils at doses of approximately 3.0 lb/ac, but the cost of such an application would be uneconomic in practice.

In the majority of the replicated yield trials prometryne gave better weed control and higher yields than dinoseb-amine. Weed counts showed that while prometryne did not control cleavers or fat hen as effectively as dinoseb-amine, control of the other species assessed was generally very much better. This included good control of some of the more troublesome weeds in the pea crop such as knotgrass and mayweed.

The ten one-acre commercial applications confirmed the safety of prometryne when used on medium or heavy soils and demonstrated its superiority over dinoseb-amine under certain conditions. At three sites the failure of prometryne to give complete control of charlock and black mustard, the survivors subsequently growing through the crop, indicates the advantage of the continued use of a post-emergence herbicide where large populations of these particular weeds are present. The almost complete failure of prometryne at one site could partly be explained by the use of a low dose (1.0 lb/ac), on a relatively heavy soil, applied to a dry and cloddy seedbed.

There were no discernible effects on crop growth or yields from the use of a pre-emergence prometryne application following pre-sowing tri-allate, propham or TCA applications.

The work carried out with prometryne suggests that it will prove to be a very useful material for use in peas, particularly for early sown crops where difficulties are often encountered with the application of dinoseb or where some of the more difficult weed species such as knotgrass, mayweed, Urtica urens (annual nettle) or Poa annua (annual meadow grass) are present. The selectivity on light soils was not always satisfactory and prometryne should not be used on soils low in clay and containing a high percentage of coarse sand.

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WEED CONTROL IN DWARF BEANS - A PROGRESS REPORT 1965-1966

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Summary The results are presented of two years of experiments in which one post-emergence and six pre-emergence herbicides were assessed on a range of soils. The most promising pre-emergence materials were 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone, monolinuron and a mixture of dinoseb-acetate and monolinuron. Patoran and N-isopropyl-alpha-chloroacetanilide proved less efficient in this work. The post-emergence dinoseb-acetate application did not adequately control weeds and the effect on the crop was sufficient to suggest that it would not be suitable for use in dwarf beans. The pre-emergence dinoseb in oil application, included as a standard, gave very poor weed control in five of the six experiments.

INTRODUCTION

The rapid increase in the acreage of dwarf beans for processing has meant that the crop is now grown on a far more extensive scale than previously. Mechanical harvesting has replaced hand-picking and these two factors have increased the need for efficient chemical weed control. Although the crop is still grown in wide rows, inter-row cultivations do not adequately meet the needs of the crop. Weeds left in the row, particularly those which branch profusely, interfere with mechanical harvesting; loose soil and clods pushed into the row by cultivations also reduce harvesting efficiency. Hand labour, if available, is costly and the hand pulling or hoeing of weeds in the row loosens the bean plants, which again affects harvesting. Under very weedy conditions, the cost of hand-weeding can exceed £20 per acre. The number and usefulness of materials available is limited and there is an urgent need for new residual herbicides with crop tolerance and more prolonged activity than pre-emergence dinoseb. A post-emergence herbicide would also be of considerable value. Weed control work in dwarf beans commenced at the P.G.R.O. in 1964 with three varying dose trials applied with a logarithmic sprayer, testing a number of pre- and post-emergence herbicides. The most promising materials were tested in replicated constant-rate trials in 1965 and 1966 and the results are summarised in this report.

METHOD AND MATERIALS

Randomised block design with three replicates was used in the experiments which were sited in commercial dwarf bean crops. Plot size was 18' x 6'. Applications were made with an Oxford Precision Sprayer at a volume of 50 gal/ac and all doses are given as lb a.i./ac. Weed counts in a number of random quadrats, and visual assessments of weed control and crop vigour were made on each plot. Weed control is expressed in the tables as the percentage kill of the control values. In 1965 all three trials received at least one of the routine inter-row cultivations carried out on the crop; in 1966 only site D received cultivations. These cultivations were generally carried out shortly before flowering. Yields of beans were recorded and these are presented in the tables as percentages of the untreated or hoed control values, differences from the control statistically significant at $P = 0.05$ are indicated by asterisks. Samples from treated plots were processed where necessary for taint assessments.

Three experiments were conducted each year and the site details are as follows:-

1965 Site A	Silty clay loam,	organic matter 3.1%,	silt 20%;	clay 40%
" B	Very fine sandy loam,	" " 2.5%,	" 13%;	" 15%
" C	Sandy clay loam,	" " 3.2%,	" 16%;	" 20%
1966 " D	Sandy clay loam,	" " 2.9%,	" 15%;	" 25%
" E	Loamy very fine sand,	not available,	" 10%;	" 10%
" F	Very fine sandy loam,	" " 2.4%,	" 14%;	" 6%

Pre-emergence applications were made approximately seven days after drilling, post-emergence applications in the 1965 experiments were made when the beans had two simple primary leaves and before the first trifoliate leaves were open. The weeds were mainly at the seedling to first and second true leaf stage at this time.

RESULTS

In 1965 one post-emergence and three pre-emergence materials were included, two dose rates of each being tested with the exception of dinoseb in oil where a single rate was used.

Table 1

Weed control and yields - 1965

Material	Dose lb/ac	Application	Weed kill (%)			Yield as percentage of the hoed control		
			A	B	C	A	B	C
Monolinuron	0.75	pre-emerg.	88	66	65	104	97	103
Monolinuron	1.50	" "	100	79	59	104	106	87
Patoran	0.75	" "	84	58	29	113	79	89
Patoran	1.50	" "	98	n.u	54	98	n.u	107
Dinoseb in oil	2.50	" "	86	2	17	108	62*	100
Dinoseb-acetate	1.25	post-emerg.	73	20≠	50≠	102	64*	81
Dinoseb-acetate	2.50	" "	93	50≠	53≠	101	83	91
S.E. per plot (% of mean)						4.5	9.7	9.3

n.u not used at this site.
≠ counts not recorded at these sites and figures relate to visual assessments.

There was approximately 0.5 in. of rain in the seven days before and after the pre-emergence application at each experiment and at all sites the seedbed was level with a fine tilth. Slight marginal chlorosis was recorded at site C in late July on the plots treated with monolinuron at doses of 0.75 and 1.5 lb/ac and patoran at 1.5 lb/ac. Reduced vigour was also noted on the dinoseb in oil plots. The post-emergence dinoseb-acetate applications caused leaf scorch, which was most severe at site C. Recovery was rapid and although evidence of reduced leaf area and slight scorch could be seen for approximately ten days following the application, by harvest no damage was evident. The effects recorded on the pre-emergence treated plots were quickly outgrown and were not visible later in the season.

At site A the weed population was low and the competition was insufficient to significantly affect yields. Weed populations were high and growth vigorous at site B on the very fine sandy loam soil. The dominant weed present was Chenopodium album (fat hen) and the populations of Tripleurospermum maritimum ssp inodorum (scentless mayweed), Polygonum convolvulus (black bindweed) and Stellaria media (chickweed) were also high. The only treatment to give adequate weed control under these conditions, was monolinuron at 1.5 lb/ac and this gave the only increase in yield over the hoed control recorded at this site. Monolinuron and patoran at 0.75 lb/ac and the post-emergence dinoseb-acetate application at 2.5 lb/ac were less satisfactory; these treatments would possibly have been acceptable combined with inter-row cultivations. At the third site weed populations were low and all the treatments, with the exception of dinoseb in oil, gave adequate control of the weeds present.

In 1966 three trials were carried out testing five pre-emergence materials. Three materials, 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone (BV.201), N.-isopropyl-alpha-chloroacetanilide (CP 31393) and a mixture of dinoseb-acetate plus monolinuron were tested at normal and twice normal dosage rates. These materials had shown promise in varying-dose logarithmic trials carried out in 1965. A single dose rate of monolinuron and of dinoseb in oil were included. Weed counts and yields were recorded and are summarised in table 2.

Table 2

Weed control and yields - 1966

Material	Dose lb/ac	Weed kill (%)			Yield as percentage of control		
		D	E	F	D	E	F
BV 201	4.0	53	100	98	110	126	303 *
BV 201	8.0	64	98	100	124	127	297 *
CP 31393	4.0	37	90	95	113	120	213 *
CP 31393	8.0	57	96	100	121	121	298 *
Dinoseb-acetate plus monolinuron	2.25 0.75	37	98	99	107	125	306 *
Dinoseb-acetate plus monolinuron	4.5 1.5	74	99	100	108	121	310 *
Monolinuron	1.5	76	96	99	107	132	294 *
Dinoseb in oil	2.5	0	50	62	94	119	131
S.E. per plot (% of mean)					5.0	6.2	17.4

At site D the seedbed was dry and very cloddy at the time of the applications, but rain fell shortly afterwards. The seedbed was level at sites E and F, ahd while the soil was dry at site E, light rain fell immediately before applications were made at site F. No germinated weeds were present at any site at the time of the pre-emergence applications.

The application of N-isopropyl-alpha-chloroacetanilide (CP 31393) at 8.0 lb/ac caused appreciable stunting at site E which was still evident at flowering. By harvest, however, the effects could not be detected. Less severe symptoms from this treatment were also recorded during growth at site F. Weed populations were not high at sites D and E, but at site F there was severe weed competition mainly from Tripleurospermum maritimum ssp. inodorum (scentless mayweed), Urtica urens (annual nettle) and Chenopodium album (fat hen).

Weed control was generally less satisfactory at site D than at the other two sites, probably due to the applications being made to a dry and cloddy seedbed. Dinoseb in oil failed to give any weed control at this site and it was the only treatment which gave a lower yield than the hoed control. The weed control given by this material was also poor at the two other sites and yield increases over the control were generally lower than those given by other treatments. This was particularly noticeable at site F where dinoseb in oil was the only material which did not adequately control the dense weed population. The other treatments gave very significant increases in yield over the untreated control at this site.

Taint assessments

No taints were detected in any of the samples of produce taken from the treated plots at the three sites in 1965. The results of samples taken from the 1966 trial are not available.

DISCUSSION

An application of dinoseb in oil at 2.5 lb/ac was included in these experiments as a standard treatment, on the basis of its present commercial use. The failure of this treatment to give adequate weed control at five of the six sites illustrates the weed control problems in this crop at the moment. Even combining the application with inter-row cultivations would have left too many weeds in the row for efficient harvesting. The residual activity of the material was very limited and except where a high proportion of the weed population had germinated at the time of spraying control was poor. Almost all the other treatments tested proved superior to dinoseb in oil.

In 1965 the direct comparison of the same doses of monolinuron and patoran indicated that monolinuron gave better weed control, and patoran was excluded from further experiments. In 1966 two dosage rates of a mixture containing dinoseb-acetate and monolinuron were tested. The higher rate of this mixture contained 1.5 lb/ac of monolinuron and under the conditions of these experiments the results proved almost identical to those given by a straight monolinuron application at 1.5 lb/ac. The addition of dinoseb-acetate, which is primarily a contact herbicide, would be of most benefit if germinated weeds were present at spraying, and this did not occur at any of the sites in 1966. 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone (BV 201) and N-isopropyl-alpha-chloroacetanilide (CP 31393) were tested at rates of 4.0 and 8.0 lb/ac. In each of the three experiments BV 201 gave superior weed control and higher yield increases over the control than CP 31393 at the same rate. No effect on the crop was recorded for BV 201 at either 4.0 or 8.0 lb/ac, but the higher dose of CP 31393 caused stunting at two sites. The effects had been outgrown by harvest and yield was not affected.

The post-emergence dinoseb-acetate applications tested in 1965 did not give very efficient weed control, and they caused leaf scorch. The crop recovered very rapidly from these effects, but it is felt that under less satisfactory growth conditions yields could be affected. Dinoseb-acetate applied post-emergence does not appear to possess sufficient selectivity to be used as a routine application on dwarf beans.

The most promising material tested in this series of experiments was 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone (BV 201) applied pre-emergence at a dose of 4.0 lb/ac. This treatment gave good weed control and no effect on the crop was recorded at either 4.0 or 8.0 lb/ac. The selectivity of this material has also proved very satisfactory in three years of logarithmic dose trials (not reported in this paper). Monolinuron, either as a straight application or in mixture with dinoseb-acetate, has also given encouraging results. Weed control was satisfactory in both years and yield increases over the control were good. In these experiments the material has proved safe even at relatively high doses, but the soil types covered did not include a very light free-draining soil. Results suggest that while a dose of 0.75 lb/ac is capable of adequate weed control on medium-textured soils, 1.0 to 1.5 lb/ac is required for control on soils containing a high proportion of silt and clay.

Cassidy and Doherty (1964) reported that monolinuron showed promise in trials carried out on dwarf beans in Ireland.

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RESEARCH REPORT

TRIALS ON THE USE OF CHARCOAL TO MAKE SAFE THE USE OF SOME TRIAZINE HERBICIDES ON GREEN PEPPERS

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Summary Root dusting with charcoal renders possible the successful application of some residual herbicides as a pre-planting application for green peppers. Experiments with plants in pots indicated that the charcoal treatment would make safe applications of prometryne, simazine, atrazine and propachlor and mixtures of these materials. Field trials, however, showed that atrazine damaged the crop. Monolinuron, linuron and metobromuron were toxic to green peppers, even when roots were coated with charcoal.

INTRODUCTION

The production of green peppers could be made cheaper by the use of herbicides, as the present repeated hand cultivations to control weeds account for a large part of the growing costs. The possibilities, however, are limited, since this crop is damaged by herbicides currently used in other crops. The use of charcoal as a root coating to reduce damage was, therefore, investigated.

METHOD AND MATERIALS

The trials were carried out in the Novi Sad region of Yugoslavia in 1966. Experiments 1 and 2 were carried out in pots in the greenhouse and Experiment 3 in the field on chernozem of the Bačka loess terrace, described by Nejgebauer /1951/. The nature and doses of the herbicides applied are indicated in the tables of test results. The treatment of the soil with herbicides was carried out every time one week before transplanting the green peppers. The treatment with charcoal was effected by trailing the wetted root system of the plants intended for transplanting through charcoal dust. The average consumption of charcoal in such rapid and simple treatment amounted to 350 mg per plant. At fortnightly intervals the transplanted peppers were irrigated in the field at a rate of 25 $l./m^2$. The variety used in these tests was invariably Californian Wonder.

The assessment scale for crop injuries was as follows:
1 = no injury: 2 = slight injury: 3 = moderate injury: 4 = severe injury: 5 = complete mortality.

RESULTS

Experiment 1

The test results concerning the effect of charcoal in reducing the toxicity of prometryne, monolinuron, linuron and metobromuron on transplanted green pepper are presented in Table 1.

Without a protective charcoal layer on the root, prometryne and linuron, applied at the lowest dose, caused severe injury. These materials at higher rates and monolinuron and metobromuron at all rates killed all the plants.

With application of charcoal, prometryne caused slight injury only at the rate of 2,0 kg of active material per hectare, while in the case of lower doses it had no toxic effect on transplants. In the case of the other herbicides the reduction of toxicity by application of charcoal was not sufficient to allow their use for weed control in transplanted green pepper crops.

Table 1

Effect of charcoal on the toxicity of different herbicides as applied to green peppers

Herbicides	Injury rating 1 - 5 kg a.i./ha With charcoal 1,0	1,5	2,0	Without charcoal 1,0	1,5	2,0
Prometryne	1	1	2	4	5	5
Monolinuron	4	4	5	5	5	5
Linuron	3	4	5	4	5	5
Metobromuron	4	4	5	5	5	5

Experiment 2

The test results concerning the effect of charcoal in reducing the toxicity of simazine, atrazine and a mixture containing these herbicides are presented in Table 2.

Table 2

Effect of charcoal on the toxicity of simazine, atrazine and a mixture with prometryne or propachlor to green peppers

Herbicides	Rate kg a.i./ha	Injury rating 1 - 5 With charcoal	Without charcoal
Simazine	0,125	1	2
"	0,250	1	4
"	0,375	1	5
"	0,500	3	5
Atrazine	0,125	1	3
"	0,250	1	4
"	0,375	1	5
"	0,500	3	5
Simazine + prometryne	0,375 + 2,0	1	5
Atrazine + prometryne	0,375 + 2,0	1	5
Simazine + propachlor	0,375 + 3,0	1	4
Propachlor	3,0	1	4

Where charcoal was not used, the lowest doses of simazine and atrazine only caused moderate injury, whereas in all other cases there was either severe injury or complete mortality in the transplanted green peppers. Where charcoal was applied, only the highest doses of simazine and atrazine caused moderate injury, while in the other cases there was no injury.

Experiment 3

The results obtained under field conditions concerning the effect of charcoal in reducing the toxicity of herbicides on transplanted green peppers are presented in Table 3.

Table 3

Effect of charcoal in reducing the toxicity of herbicides on transplanted green peppers

		With charcoal				Without charcoal			
			Weight of pepper plants				Weight of pepper plants		
Herbicides	Dose kg a.i./ha	No.of plants per 15 m^2	kg/15 m^2	gr/per plant	Formed fruits %	No.of plants per 15 m^2	kg/15 m^2	gr/per plant	Formed fruits %
Check	-	100	6,95	69,5	99,7	100	6,22	62,2	100
Prometryne	1,5	97,5	6,92	71,0	108,6	0	0	0	0
Prometryne+simazine	1,5+0,375	97,2	6,94	71,4	104,0	0	0	0	0
Prometryne+atrazine	1,5+0,375	90,7	5,96	65,7	88,8	0	0	0	0
Propachlor+simazine	3,0+0,375	98,5	7,31	74,2	114,7	0	0	0	0
LSD 5%		1,3	0,49		8,6				
LSD 1%		1,8	0,68		11,9				

The number of plants, which also represent the percentage of plants in relation to control, was considerably reduced after application of charcoal only in soil treated with a mixture of prometryne + atrazine. The individual weight of the remaining pepper plants was also appreciably lower in this combination of herbicides. On the other hand, the weight of pepper plants was greater in soil treated with a mixture of propachlor + simazine. The average weight per pepper plant in all cases of charcoal application was higher than when no charcoal was used. The percentage of formed fruits was considerably reduced by the use of prometryne + atrazine, while in the case of the application of the other herbicides it was increased, particularly on soil treated with a mixture of propachlor + simazine. On the whole the characteristic differences in the results obtained indicate that without the use of charcoal there was complete mortality of transplanted green pepper plants.

The results concerning the efficiency of the herbicides applied in the weed control in crops of transplanted green peppers treated and untreated with charcoal are presented in Table 4.

With all the herbicides applied the efficiency of weed control was greater in green pepper crops treated with charcoal. On soil untreated with herbicides the use of charcoal had no effect on the development of weeds.

DISCUSSION

The experiments reported in the present paper showed that transplanted green pepper is highly susceptible to triazine herbicides applied in the normal manner. It was found that the plants were most susceptible during the first two weeks after transplanting. At this period they are in a state of stagnation and possess the least general resistance.

Table 4

Influence of charcoal on the efficiency of weed control

Treatment	Dose kg a.i./ha	With charcoal: No.of weeds per sq. m.	With charcoal: %	Without charcoal: No.of weeds per sq. m	Without charcoal: %
Check	-	70,8	100,1	70,7	100,0
Prometryne	1,5	14,8	20,9	17,9	25,3
Prometryne + simazine	1,5 + 0,375	10,6	15,0	11,6	16,4
Prometryne + atrazine	1,5 + 0,375	11,3	16,0	14,0	19,8
Propachlor + simazine	3,0 + 0,375	16,2	22,9	16,5	23,3

The use of charcoal was found to render possible the application of some such herbicides to which the transplanted green pepper is otherwise susceptible. Application was made by trailing the wetted roots of the plants through charcoal dust immediately before transplanting. The average quantity of charcoal taken up was 350 mg per plant.

In pot trials charcoal treatment protected the plants in the case of prometryne at 1,5 kg a.i./ha, simazine and atrazine up to 0,375 kg, simazine or atrazine at 0.375 together with prometryne at 2,0 kg, simazine at 0,375 plus propachlor at 3,0 kg or propachlor alone at 3,0 kg. Slight damage occurred with prometryne alone at 2,0 kg in Experiment 1, but was tolerated at this rate in Experiment 2.

Simazine or atrazine caused moderate damage at 0,5 kg a.i./ha. Charcoal treatment did not provide protection against linuron, monolinuron or metobromuron even at 1,0 kg a.i./ha.

In the field trial charcoal protected the transplanted peppers against prometryne 1,5 kg or the mixtures of simazine 0,375 kg with prometryne 1,5 or propachlor 3,0 kg but in this experiment the mixture of atrazine 0,375 kg and prometryne 1,5 kg caused moderate damage despite the indication of complete safety in the pot trial. The use of charcoal had no direct influence either on the growth of the crop plants or on the efficiency of the herbicides.

The field trial indicated that whereas the normal use of the herbicides on unprotected plants caused 100% mortality of the crop, by protecting the green pepper transplants with charcoal the effect of any slight loss of plants was more than offset by the increased yield per plant. The degree of weed control obtained, from 75 - 85% can be regarded as satisfactory.

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EVALUATION OF HERBICIDES FOR WEED CONTROL IN DWARF BEANS

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Summary In 1964-66, thirty chemicals were examined in field tests with dwarf beans on a sandy loam. Most of the chemicals showed an inadequate degree of selectivity. Of the soil-acting herbicides applied before crop emergence, consistently best results were given by 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone at 4 and 6 lb/ac. Other chemicals that appeared to be promising in 1966 were 3,4-dichlorobenzyl methylcarbamate, 2-chloro-2,6-diethyl-N-(methoxymethyl) acetanilide and a mixture of dinoseb-acetate plus monolinuron. Experiments with dinoseb-acetate as a post-emergence spray suggested that this treatment might be useful as an emergency measure.

INTRODUCTION

The position regarding chemical weed control methods for dwarf French beans was stated by Cassidy & Doherty (1964) and has changed but little during the past two years. Pre-emergence applications of dinoseb, either as the amine or in oil, remain the accepted treatment but do not provide sufficiently reliable or long-lasting weed control to meet the requirements imposed by mechanical harvesting.

During 1964-66, small-scale field tests were made at Wellesbourne with thirty different herbicides, and the results obtained are summarized in this report.

METHODS AND MATERIALS

The experiments were all on a sandy loam of the Newport series which was relatively low in organic matter. In most experiments a randomized block design with two to four replicates was used, with small plots of 3 to 8 yd^2. The sprays were applied in a volume of 100 gal/ac and all doses are given as lb/ac a.i.

Weed kill was assessed either by counting survivors in a number of random quadrats on each plot or visually on a scale of 0 - 10, where 0 = no effect and 10 = complete kill. In some experiments the effect on the crop was determined in the absence of any appreciable weed competition and in all the experiments hand-weeded controls were included. Crop injury was assessed visually on a scale of 0 - 10 and comparative yield estimates obtained by recording weights of total crop or of pods and haulm at a single harvest.

RESULTS

Pre-emergence applications

In 1964, more than twenty soil-acting herbicides were examined in three field tests in which application was made shortly after sowing. In all three tests there was appreciable rainfall, but its distribution during the first few weeks varied from test to test.

Some of the herbicides showed little selectivity; bromacil and isocil caused very severe crop damage even at 0.125 lb/ac, while lenacil and norea injured the crop at 0.5 lb/ac. MCPB at 1 and 2 lb/ac gave only poor weed control and at both doses reduced crop growth. Of the substituted ureas included in the tests, buturon and trimeturon gave only moderate weed control at doses which were without effect on the crop. Better weed control was obtained with linuron, monolinuron and metobromuron, all of which gave complete kill of Chenopodium album, Polygonum aviculare and various other species at doses within the range 0.5 to 2 lb/ac. In all three tests, however, these materials at 2 lb/ac virtually eliminated the crop and at lower doses gave injury which varied widely in degree from test to test. It appeared that although there might be a possibility of using low doses of 0.5 to 0.75 lb/ac, there would be a distinct risk of crop damage on light soils. One treatment which gave good results was trifluralin, applied to the soil surface at 4 lb/ac. This gave complete weed control and even at 8 lb/ac did not affect the crop.

Some of the treatments were included in an experiment in 1965 together with other herbicides not previously examined. There was a dense weed infestation of 43 plants/ft^2, mainly Chenopodium album, Senecio vulgaris, Veronica persica, Poa annua and Capsella bursa-pastoris. The sprays were applied immediately after sowing and rainfall during the following three weeks was 0.30 and 0.63 in. None of the sprayed plots was weeded, and the results are shown in Table 1.

Table 1

Effect of pre-emergence sprays on dwarf beans var. Masterpiece

1965

Herbicide, lb/ac		Weed kill 0 - 10	Crop injury 0 - 10	Weed wt. kg/plot	Crop wt. kg/plot
Linuron	0.5	5.0	0.0	10.9	4.9
"	0.75	7.5	0.3	4.4	10.1
"	1	8.8	0.6	0.4	16.0
Monolinuron	0.5	6.5	0.3	5.8	13.1
"	0.75	6.2	0.0	5.5	8.6
"	1	8.7	0.3	2.0	15.2
Prometryne	1	6.2	0.3	10.8	6.4
"	2	9.0	2.7	4.5	13.4
GS 14260	1	3.0	0.0	11.6	4.0
"	2	8.3	3.3	5.3	10.9
CP 31393	5.75	8.2	0.0	8.2	10.2
"	7	8.8	0.0	5.5	12.5
BV 201	4	7.8	0.0	1.7	11.2
"	6	8.7	0.0	0.4	16.1
Trifluralin	4	7.5	0.0	2.2	12.7
Weeded control		-	-	-	16.3
Unweeded control		-	-	14.2	1.9

Most treatments gave moderate or good weed control and considerable depressions in weed weight at harvest as compared with unweeded plots. Crop injury in this experiment was only slight, except for the higher doses of the two triazine herbicides. Linuron and monolinuron caused injury to only a few plants even at 1 lb/ac, although damage in the previous year was severe, and this dose gave crop weights approaching that from the weeded plots. Initial weed control with a-chloro-N-isopropylacetanilide (CP 31393) was good, but some plants of <u>Chenopodium album</u> were not killed and exerted a competitive effect later in the season. Trifluralin and 1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone (BV 201) failed to control <u>Senecio vulgaris</u> completely, but otherwise gave excellent results with no adverse effect on the crop.

The same treatments were included in a second adjacent experiment, carried out at the same time but differing in that 0.8 in. irrigation was given and all plots were weeded. All treatments gave better weed control than that shown in Table 1, but there was rather greater crop injury with prometryne and 2-methylthio-4-ethylamino-6-tert. butylamino-1,3,5-triazine (GS 14260). In this experiment CP 31393 caused an initial check to crop growth, but this was not reflected in the weights of pods and haulm, which like those from all other treatments except prometryne 2 lb/ac were equal to or slightly greater than that from the control.

Table 2

<u>Effect of pre-emergence sprays on dwarf beans var. Masterpiece, 1966</u>

Herbicide, lb/ac		% weed kill		Crop injury		Crop wt. as % of weeded control	
	Experiment	1	2	1	2	1	2
CP 31393	4	87	88	0.7	1.3	80	83
"	4 + chlorpropham 0.5	90	96	1.3	3.0	91	84
BV 201	4	92	99	0.0	0.0	104	100
"	6	97	100	0.0	0.0	99	106
C 6313	1	86	97	0.0	0.7	94	97
"	2	90	99	2.3	0.7	103	104
UC 22463	4	98	100	1.3	0.0	92	106
"	6	100	100	0.3	0.0	117	99
CP 50144	0.5	87	96	0.0	0.0	101	106
"	1	91	96	0.0	0.0	94	111
"	2	94	99	0.0	0.0	107	101
Dinoseb-acetate 1.87 + monolinuron	0.63	84	95	0.3	0.0	91	107
Dinoseb-amine	4	86	84	0.0	0.0	101	102
Unweeded control		-	-	-	-	71	82

From preliminary tests with a range of crops in 1966, it appeared that N'(4-bromo-3-chlorophenyl)-N-methoxy-N-methylurea (C 6313), 3,4-dichlorobenzyl methylcarbamate (UC 22463) and 2-chloro-2,6-diethyl-N-(methoxymethyl) acetanilide (CP 50144) merited further evaluation as possible pre-emergence treatments in dwarf beans. They were included, together with CP 31393, BV 201, dinoseb-amine and a mixed formulation of dinoseb-acetate and monolinuron in two replicated experiments. One was sown in mid-May, the other in early June, and both were sprayed the day after sowing. None of the sprayed plots was weeded and the results are shown in Table 2.

The weed densities were 12 and 10 plants/ft^2 respectively, resulting in statistically significant reductions in crop weight on the unweeded plots. The main species were Poa annua, Fumaria officinalis, Stellaria media, Capsella bursa-pastoris and Trifolium repens.

CP 31393 4 lb/ac alone gave good weed control, the survivors being Fumaria officinalis together with occasional plants of Polygonum aviculare, Raphanus raphanistrum and Thlaspi arvense, and addition of 0.5 lb/ac chlorpropham gave some improvement. Both treatments, however, caused a check to the crop which remained evident throughout the growing period, and which was greater where chlorpropham had been added. The crop weights at harvest were less than those obtained with most other treatments, although the reduction was statistically significant ($P = 0.05$) in only one out of four instances. BV 201 gave an excellent result. The plots were clean at harvest except for a few small plants of Senecio vulgaris and there was no adverse effect at all on crop growth or final weight. C 6313 caused slight damage to a small proportion of the crop plants, but again had no effect on weight at harvest and there was excellent control of all species except Fumaria officinalis and Veronica persica, some of which survived. CP 50144 had no effect on the crop, although in the preliminary tests there had been slight injury at 2 lb/ac, and the weed control was good.

Almost complete weed kill was obtained with UC 22463 in both experiments. In the first experiment there was some initial chlorosis, but this was outgrown and there was no significant effect on ultimate weight. Dinoseb-acetate plus monolinuron caused slight crop injury attributable to the monolinuron in the first experiment but not in the second. Weed control was good, with Fumaria officinalis and Veronica persica the only surviving species. Dinoseb-amine, included here as a standard and applied one day after sowing, gave almost complete control of all species present except Poa annua and Trifolium repens and the crop weights were no different from those of the weeded control plots.

The mixture of dinoseb-acetate 1.87 lb plus monolinuron 0.63 lb/ac was included in a third experiment begun in mid-June 1966, and 98% kill of weeds was obtained, the only survivors being a few plants of Fumaria officinalis and Veronica persica. The only effect on the crop was slight injury attributable to monolinuron in a few of the plants, and the final crop weights equalled those from hand-weeded control plots. Also included in this experiment was BV 201 at 4 and 6 lb/ac. This herbicide again gave complete weed control in the early stages of crop growth and at harvest the plots were clean except for occasional small late-germinated Poa annua and Senecio vulgaris. There was no evidence of any adverse effect on crop growth, and the final crop weights were slightly greater than those from the hand-weeded controls.

A preliminary test was made of ester formulations of chloramben and 3-nitro-2,5-dichlorobenzoic acid, applied at 2, 4 and 6 lb/ac immediately after drilling dwarf beans. The triethylamine salt of 3-nitro-2,5-dichlorobenzoic acid was included at the same doses for comparison. All the treatments gave good weed control, ranging from 80 to 99%, with the chloramben ester slightly superior to the other two materials. Observations made 3 weeks after spraying showed that at 4 and 6 lb/ac the chloramben ester had caused quite marked stunting of the crop, but this was later outgrown and final weights were only slightly less than those from hand-weeded control plots. Both salt and ester of 3-nitro-2,5-dichloro-benzoic acid also caused stunting of the crop at 4 and 6 lb/ac. In addition, the ester resulted in symptoms of growth-regulator injury similar to that produced by 2,4-D on the trifoliate leaves. This was very marked at 6 lb/ac and all the plants on these plots were affected, but was much less obvious at 2 and 4 lb/ac. These symptoms were not observed on any of the other plots in the experiment except with the salt at 6 lb/ac where a few plants were affected. There was appreciable recovery, however, and the final crop weights were again only 10 to 20% less than those from hand-weeded control plots.

Post-emergence applications

A series of experiments was conducted with dinoseb-acetate as a post-emergence treatment on dwarf beans. In 1964 it was applied at 1.6, 2.4 and 3.2 lb/ac to dwarf beans in the full unifoliate leaf stage. One series of plots was treated during the day when the laminae were horizontal; a second series was treated at 10 p.m. when the laminae had assumed their vertical 'sleep' position. Injury was limited to patchy scorch of the unifoliate leaves and some scorch of the expanding first trifoliate leaf and was not serious. There appeared to be some check to growth with the highest dose but this was overcome, and the final crop weights from all treatments were similar to those from hand-weeded controls, with no differences either between doses or times of application. Excellent control of dicotyledonous weeds was obtained, and it appeared that it was worth investigating dinoseb-acetate further.

In 1965, dinoseb-acetate at 2.4 lb/ac was applied to dwarf beans at four growth stages in an experiment which was hand-weeded throughout, and the results are shown in Table 3.

Table 3

Effect of dinoseb-acetate 2.4 lb/ac applied to dwarf beans var. Masterpiece at four growth stages

Stage of growth	% leaf loss attributable to treatment	Wt. pods as % of control	Wt. haulm as % of control
Crook	7	100	98
Early unifoliate leaf	15	94	87
Full unifoliate leaf	31	92	93
1 - 2 trifoliate leaf	-	92	87

Three types of damage to the crop could be observed. First, there was scorching of the expanding leaf tissues, sometimes severe, and resulting in distortion of the lamina during subsequent expansion. Second, there was the appearance of patchy necrosis of the fully-expanded leaves; this appeared to be of little consequence. The third effect was that after treatment, the pulvini at the point of attachment of the laminae to the petioles in the unifoliate leaves suffered injury and became flaccid. Leaves so affected were observed to rotate in the wind, and often the laminae were torn off. Counts were made of the numbers of plants in which either one or both laminae of the unifoliate leaves were lost and adjusted for losses in the control plants (Table 3). The greatest loss of leaves occurred after application at the full unifoliate leaf stage which was followed by several days of high winds. During the summer, there was adequate soil moisture and conditions were favourable for recovery. None of the treatments had any significant effect on the weight of pods or haulm, nor was maturity affected.

The response of four varieties of beans to treatment at three growth stages was examined in a further experiment in 1965, and the results are shown in Table 4.

Table 4

Effect of dinoseb-acetate 2.4 lb/ac on four varieties of dwarf beans

Stage of growth	Processor	Harvester	Masterpiece	Tendergreen
		% leaf loss		
Full unifoliate	30	11	45	31
Early 1 trifoliate	8	10	11	12
Control	6	2	7	5
		Wt. pods as % of control		
Full unifoliate	85	91	116	91
Early 1 trifoliate	79	99	123	102
1-2 trifoliate	70	84	88	97
		Wt. haulm as % of control		
Full unifoliate	91	91	113	100
Early 1 trifoliate	80	84	128	92
1-2 trifoliate	67	84	104	93

As in the previous experiment, high winds occurred after spraying at the full unifoliate leaf stage and a proportion of the plants lost either one or both laminae of the unifoliate leaves. This loss was especially marked in Masterpiece and least in Harvester. Damage to the expanding tissues was caused, but there were no consistent varietal differences in the extent to which it occurred. All the treatments gave complete kill of the dicotyledonous weeds present, mainly Chenopodium album, Senecio vulgaris and Capsella bursa-pastoris, leaving only Poa annua. All the plots were weeded after assessments had been made. Despite the initial crop damage, there was considerable recovery, and with the exception of Processor at the 1-2 trifoliate leaf stage, the reductions in weights of pods and haulm were not statistically significant. There was, however, a tendency in three of the four varieties for the lowest yields to be obtained after the latest application. The relatively high values for weight in Masterpiece were a consequence of weed competition on one of the three replicate control plots of this variety.

In 1966, single treatments of dinoseb-acetate 2.4 lb/ac at the unifoliate leaf stage were included in the three experiments already referred to. In the first, the crop weight at harvest was 86% of that from the weeded control, a depression just statistically significant at P = 0.05. In the second, some 20% of the plants lost one or two unifoliate leaves and the weight at harvest was 79% of the weeded control, again a significant depression, and in this instance the weight was rather less than that of plots not weeded at all. In the third experiment, there was no leaf loss at all attributable to spraying and despite the presence of Poa annua and Trifolium repens, the crop weight was 98% of that from the weeded control plots.

DISCUSSION

Most of the herbicides examined have shown either inconsistent performance or lack of sufficient selectivity. Certain materials, however, have shown distinct promise as pre-emergence treatments for use on dwarf beans. Outstanding among them was BV 201, which gave no crop injury in any of the five experiments in which it was included and which at 4 and 6 lb/ac gave excellent weed control. The list of susceptible weed species reported by McRae & de Sarjas (1965) includes all the major annual weeds of vegetable crops in Britain, and the present data also suggest that this herbicide has a wide spectrum of activity. Of the species encountered, *Senecio vulgaris* was the most tolerant. A few plants of *Aethusa cynapium* were also seen in treated plots, as might be expected from the known tolerance of umbelliferous crops (McRae & de Sarjas, 1965).

Results for a single year only were obtained with UC 22463 but they confirm the promise for weed control in dwarf beans indicated by Herrett (1965). Although some initial chlorosis occurred, the growth of the crop was not affected. Most major weeds of vegetable crops are listed as susceptible (Herrett, 1965) and in the present experiments only a few plants of *Fumaria officinalis* survived 4 lb/ac.

The mixed formulation of dinoseb-acetate plus monolinuron gave good results, but the fact that some damage to a small number of plants occurred suggests that on a light soil a dose of monolinuron as little as the 0.63 lb/ac used here may involve some risk. The tests with CP 31393 confirmed the relative tolerance of beans to pre-emergence applications (Selleck et al., 1965), but in three of them there was a definite check which was not outgrown. Moreover, the spectrum of weeds controlled is not so wide as that of the two other herbicides mentioned above. CP 50144 appears to be considerably more active, and the results obtained were encouraging. Trifluralin 4 lb/ac gave good results in 1964 and 1965, but is not effective against *Senecio vulgaris*, and *Capsella bursa-pastoris* is also relatively tolerant. The ester formulation of chloramben, stated to be less readily leached than chloramben salt, (Amchem Products, Inc 1965) gave encouraging results in the preliminary test, but further work is required before any conclusion can be drawn.

It should be stressed that the experiments were carried out on a sandy loam under conditions of adequate soil moisture. Weed control might be less complete in other situations, but on the other hand, the experiments did provide a fairly rigorous test of the safety to the crop of the materials examined.

In all the experiments with post-emergence sprays of dinoseb-acetate some damage occurred, and it would be expected that the extent might vary considerably with weather conditions and the 'hardness' or otherwise of the crop. The most discouraging feature of the damage was the leaf loss when high winds followed spraying. Green (1963) has shown that dwarf beans are especially sensitive to loss of photosynthetic tissue when at the unifoliate leaf stage. Nevertheless, the results suggest that this treatment might possibly be useful in an emergency where a crop has a dense infestation of susceptible weeds which it is not feasible to remove by other means.

Acknowledgments

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EXPERIMENTS WITH ALPHA-CHLORO-N-ISOPROPYLACETANILIDE IN VEGETABLE CROPS

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Summary In field tests on a sandy loam, carrots, parsnips, parsley, lettuce and red beet were susceptible to pre-emergence applications; spinach showed greater tolerance. Drilled cabbage, radish and turnip were initially checked by 4 lb/ac but recovered. No damage was caused by overall application on transplanted cabbage, cauliflower and Brussels sprouts. Broad, runner and dwarf beans and peas were relatively tolerant but some check occurred from which recovery was not always complete. Onions and leeks were very tolerant both pre-and post-emergence. Almost complete kill of Poa annua, Senecio vulgaris, Veronica persica, Capsella bursa-pastoris and several other species was consistently obtained. Control of Chenopodium album, Fumaria officinalis, Stellaria media and Trifolium repens was more variable, while Polygonum spp. and cruciferous species other than C. bursa-pastoris were tolerant of 4 lb/ac. The possibility of extending the range of weeds controlled by addition of chlorpropham was examined.

INTRODUCTION

The properties of alpha-chloro-N-isopropylacetanilide (CP 31393) and its potential uses for selective weed control have been reviewed by Selleck et al. (1965). Several vegetables were among the crops which showed some tolerance to pre-emergence applications and these findings have been confirmed by Verlaat (1966).

Experiments to determine the possible uses of this herbicide for weed control in vegetable crops were made at Wellesbourne in 1965 and 1966, and the results are summarized in the present report.

METHODS AND MATERIALS

The experiments were all on a sandy loam of the Newport series, relatively low in organic matter. Except where stated, a randomized block design was used with two to four replicates and small plots of 3 to 8 yd^2. The sprays were applied at a volume of 100 gal/ac. A 65% wettable powder formulation was used, and all doses are given as lb/ac a.i. In some experiments additions of chlorpropham (40 emulsifiable concentrate) were made to the sprays. Weed kill was assessed by counting survivors in a number of random quadrats on each plot. In some experiments all plots were then weeded in order to assess the effect of the herbicide on the crop in the absence of any appreciable weed competition; in others, the plots were not weeded, and were compared with both unweeded and hand-weeded controls. Visual assessments of crop injury were made, together with records of crop fresh weight or marketable yield.

RESULTS

Weed control

Applications of doses of 3.5 to 7 lb/ac prior to weed emergence were made on more than thirty occasions. Control of the mixed populations of annual weeds encountered was generally good, and in 1966 in twenty applications of 4 lb/ac ranged from 57 to 98%, with a median of 74%. There were considerable variations in the relative susceptibility of different weed species. Complete or almost complete kill of Poa annua was consistently obtained, and Veronica persica, Capsella bursa-pastoris and Senecio vulgaris were also very susceptible. Limited data indicated that *Anagallis arvensis*, *Plantago major*, *Matricaria matricarioides*, *Tripleurospermum maritimum* ssp. *inodorum* and *Solanum nigrum* could also be included in this group.

Trifolium repens, *Stellaria media*, *Chenopodium album* and *Fumaria officinalis* were generally less susceptible. Partial kill was obtained, but some survivors, especially of *Chenopodium album* and *Fumaria officinalis*, were usually present, although often reduced in vigour.

Polygonum aviculare showed a greater tolerance, and control of this species was not adequate; *P. convolvulus* showed similar tolerance. Cruciferous weeds other than *Capsella bursa-pastoris* were little affected by the herbicide, although sometimes vigour was reduced at the higher doses. Species encountered and which showed tolerance were *Thlaspi arvense*, *Sinapis arvensis*, *Raphanus raphanistrum* and *Sisymbrium officinale*.

Increasing the dose from 4 to 6 or 7 lb/ac had little effect on the degree of weed control. Where chlorpropham at doses of 0.25 or 0.5 lb/ac was added, however, the overall result was improved because of the sensitivity of *Polygonum aviculare*, *Stellaria media* and to a lesser extent, *Fumaria officinalis* and *Chenopodium album* to this herbicide.

Crop tolerance

In several tests CP 31393 was applied to a range of vegetable crops drilled in the field at the normal depths. Carrot, parsley, parsnip and lettuce proved very susceptible; all were completely killed by 7 lb/ac and either killed or severely injured by 3.5 lb/ac. Red beet was somewhat less susceptible, but in all the tests was quite markedly affected by 3.5 lb/ac; spinach, however, showed only slight injury with 7 lb/ac. The large-seeded legumes, pea, dwarf French bean and broad bean, showed slight retardation of growth but stand was not reduced. Radish and cabbage were initially retarded but clearly showed appreciable tolerance and appeared to recover. Onion and leek emerged as the most tolerant of the crops examined, and even with 7 lb/ac there was only slight stunting which was later overcome. These results suggested that further experiments would be merited with the large-seeded legumes, brassica crops, onions and leeks, and some results obtained are described below.

Peas

In an unreplicated test in 1965, excellent weed control was obtained with pre-emergence applications of 3.5 and 7 lb/ac without adverse effect on the crop. Applications of 4 lb/ac shortly before crop emergence were included in two replicated experiments in 1966. In the first, only moderate weed kill was obtained (65%) because of the presence of some *Polygonum aviculare* and at harvest the crop weight was 30% less than that from the weeded control. The crop weight was also less, though not quite significantly so ($P = 0.05$), than that from control plots left unweeded. It was observed that the crop plants were checked at an early stage and recovery was not complete. In the second experiment, the weed kill was 98% and although a check was again visible a month after treatment, the crop recovered and the crop weight at harvest was no different from that on the weeded control plots.

Broad beans

Application of 4 lb/ac 2 weeks after sowing broad beans in March 1966 gave 84% weed kill, with *Polygonum aviculare* and *Chenopodium album* the main survivors. Some check to the crop was apparent about a month after emergence, and at harvest there was a significant 20% reduction in crop weight from that on weeded control plots.

Runner beans

Applications were made to runner beans one day after sowing in late May of 4 lb/ac with and without addition of 0.5 lb/ac chlorpropham. These treatments gave 80 and 70% weed kill respectively, with *Fumaria officinalis* the main survivor. There were no visible effects on the crop and the weights at harvest were 86 and 85%

of those from the weeded control plots. These values were greater than the value of 74% recorded from unweeded plots.

Drilled brassicas

In a preliminary test with cabbage in 1965, doses up to 7 lb/ac applied immediately after drilling had no effect on plant stand but there was some check to growth. This was soon outgrown at 3.5 lb/ac but with 7 lb/ac recovery took longer and fresh weights were less than those from the control until 8 weeks after emergence. In a second test later in the season there was again no effect on stand, and fresh weights taken 5 weeks after emergence were no different from those from weeded control plots.

To determine the progress of recovery from initial check an experiment was carried out in 1966 in which fresh weights were obtained at intervals after treatment. Treatment with 4 lb/ac alone was compared with this dose plus chlorpropham at 0.25 and 0.5 lb/ac, and the results are shown in Table 1.

Table 1

Effect of CP 31393 with and without chlorpropham on the growth of drilled cabbage var. Winningstadt

	% weed kill		Cabbage, fresh wt./plant as % of control					
	4 lb/ac	6 lb/ac	4 lb/ac			6 lb/ac		
			3 May	11 May	6 Jun	3 May	11 May	6 Jun
Alone	57	62	70	80	104	59	64	91
with chlorpropham 0.25	76	89	59	71	86	48	57	80
" " 0.5	90	90	46	44	57	59	45	69

The main weed species were Poa annua, Polygonum aviculare, Stellaria media and Trifolium repens. All treatments gave complete kill of Poa annua and addition of chlorpropham increased the kill of the other species. Where CP 31393 was applied alone, there was an initial check which was rather greater with 6 lb/ac than with 4 lb/ac but by 6th June, 8 weeks after emergence, the values for fresh weight approached those from the weeded control plots and no differences were apparent. Addition of chlorpropham resulted in a greater degree of check which was not outgrown during this period.

In a second experiment, the same treatments were compared on four varieties of cabbage, Winningstadt, Primo, Offenham and January King, and on savoy, turnip and radish. The results were similar to those already described; there were no reductions in stand and the check caused by CP 31393 at 4 and 6 lb/ac was overcome within 8 weeks. Addition of chlorpropham resulted in more pronounced checks to growth which were still apparent after this period.

Transplanted brassicas

An application of 7 lb/ac was made on transplanted cabbage var. Utility 2 weeks after planting, when many of the weeds were in the cotyledon stage. There was a dense stand of weeds, 40 seedlings/ft^2, but excellent control of Poa annua, Capsella bursa-pastoris and Senecio vulgaris was obtained. The overall weed kill was 67%, but the survivors were mainly Chenopodium album which remained small and stunted and would have had little competitive effect. All the plots were weeded by hand and the marketable cabbage cut when ready. There was no effect on crop maturity and the numbers and weights of marketable heads equalled those from the control plots.

Results obtained with Brussels sprouts var. Jade Cross were similar. The overall weed kill was 80%, the survivors again being small plants of Chenopodium album, and there were no adverse effects on crop growth or weight at harvest.

In 1966 applications of 4 and 6 lb/ac were made on early summer cauliflower var. 110, raised in peat pots, 11 days after transplanting when weeds were just germinating. There was good control of weeds, present in numbers of $16/ft^2$, and only some plants of Polygonum aviculare, Fumaria officinalis and Thlaspi arvense survived. No crop injury was observed, the sprayed plots were not weeded, and the marketable heads were cut when ready. The yields were almost the same as those from the weeded control plots (Table 2), and there was no effect on mean cutting date.

Table 2

Effect of CP 31393 on transplanted early summer cauliflower and summer cabbage

	% weed kill		Wt. marketable heads as % of weeded control	
	cauliflower	cabbage	cauliflower	cabbage
4 lb/ac	82	96	97	94
6 lb/ac	89	90	94	96

The same treatments were included in an experiment with cabbage var. Winningstadt, applied a week after transplanting. Weed control was excellent, with more than 90% kill of a stand of 10 $plants/ft^2$, some Fumaria officinalis and Stellaria media remaining. No injury to the crop was observed and the marketable weights (Table 2) were little different from those of the weeded control plots. The cabbage were cut on eight occasions, and in this experiment 4 lb/ac resulted in a delay of 5 days in the date on which 50% of the heads had been cut. This is unlikely to have been due to the herbicide, however, since the cutting curve for the higher dose of 6 lb/ac closely followed that for the weeded control plots, with no delay.

Excellent weed control and absence of any apparent crop injury was also obtained in an experiment with Brussels sprouts var. Avoncross treated in mid-June at the same time as the cabbage.

Onions

Three small tests in 1965 showed that at doses up to 7 lb/ac CP 31393 had little effect on onions when applied at various times prior to emergence. The greatest injury observed was a slight temporary check with the higher doses. It was also found that there was no adverse effect from treatment after the crop had emerged.

In 1966 a comparison was made of the effects of 4 lb/ac with and without 0.5 lb/ac chlorpropham when applied to drilled onions var. Rijnsburger at three pre-emergence and one post-emergence stage of growth. Counts of surviving weeds were made, and all plots were then weeded and the weight of bulbs at harvest determined. The results are shown in Table 3.

Table 3

Effect of CP 31393 with and without chlorpropham on drilled onions

Stage of growth		% weed kill		Stand as % of control		Yield as % of control	
	lb/ac	4	4 + 0.5	4	4 + 0.5	4	4 + 0.5
After drilling		60	69	90	76	103	107
15 days after drilling		74	89	86	75	104	101
Prior to emergence		73	92	97	83	107	107
Loop stage		65	81	97	66	110	96

Weed control was better 15 days after drilling than when the sprays were applied immediately afterwards, and addition of chlorpropham increased weed kill. There was little effect on onion stand from CP 31393 at any of the stages, but where chlorpropham was applied there was a consistent reduction. The onions emerged well and there were 19 plants/ft row on the control plots; even where the stand was reduced therefore, there was compensatory growth by the survivors and the yields of bulbs were not affected.

The same treatments were compared in a second experiment at three post-emergence stages of growth, and the results are given in Table 4.

Table 4

Effect of CP 31393 with and without chlorpropham on drilled onions

Stage of growth		% weed kill		Stand as % of control		Yield as % of control	
	lb/ac	4	4 + 0.5	4	4 + 0.5	4	4 + 0.5
Loop		60	66	96	99	106	115
Late crook		69	71	98	89	108	99
Late 1 true leaf		-	-	87	89	111	112

All plots in this experiment received a paraquat/diquat contact pre-emergence treatment, but by the time the onions had reached the loop stage there were appreciable numbers of seedling weeds present. Addition of chlorpropham increased the kill obtained; all the plots were weeded before application at the 1 true leaf stage. In contrast with the previous experiment, treatment at the loop stage did not reduce stand even with 0.5 lb/ac chlorpropham, and there was no marked reduction at later stages. Yields were, in general, slightly higher than those of the control plots.

Pre-emergence applications of 4 lb/ac were made in three other experiments with onions and in none of them was there any significant effect on crop stand or growth. Where 0.5 lb/ac chlorpropham was added, weed control was greatly improved but there was a variable reduction in crop stand. In an experiment drilled in mid-March, the stand reduction was 33%; in another drilled in April there was a reduction of only 13%. When applied to salad onions var. White Lisbon in August, there was a negligible reduction of 9% from the control stand.

Leeks

Several small tests on drilled leeks indicated that this crop showed the same tolerance as onions to CP 31393. Overall applications of doses up to 7 lb/ac applied at various times after transplanting also had no adverse effects on the crop.

DISCUSSION

The relative tolerance to CP 31393 recorded in the present tests agrees well with the picture presented by Verlaat (1966). Carrots, parsnips, parsley and lettuce were very susceptible. Red beet showed rather greater tolerance, but the results of several tests were consistent in showing that this crop was injured by doses sufficient for weed control. Spinach appeared to be more tolerant, as found by Verlaat (1966), and CP 31393 would appear to merit further testing on this crop, especially in relation to control of Senecio vulgaris. The drilled cruciferous crops examined, which included radish, turnip and various varieties of cabbage, all showed a high degree of tolerance but there was a consistent check to early growth. This has also been noted in the review by Selleck et al. (1965). The results (e.g., Table 1) indicate, however, that this check is outgrown within a period of 8 weeks. Overall applications on transplanted cauliflowers, cabbage and Brussels sprouts (Table 2) had no adverse effect on crop growth or yield.

The results with onions and leeks confirm the high tolerance of these crops reported by Selleck et al. (1965) and Verlaat (1966). In none of the experiments was there any significant reduction in stand, and any slight initial check that occurred was rapidly outgrown. The herbicide appeared to be equally safe when applied at any time pre-emergence and also during the early post-emergence stages (Tables 3 and 4).

Selleck et al. (1966) state that all varieties of beans are resistant to CP 31393. The results from the present tests are not entirely in accord with this conclusion. Although in runner beans no visible injury was observed, in the single experiment conducted with this crop the crop weight was less than would have been expected from the degree of weed control obtained. In broad beans, there was a definite effect on growth in the replicated experiment cited and crop weight was significantly reduced despite a high degree of weed control. In three out of four replicated experiments on dwarf beans (Roberts & Wilson, 1966), a similar check was observed although in only one did a significant yield depression occur. A check to growth was also recorded in two experiments with peas, and in one of them the crop weight was slightly less than that from unweeded control plots. It appears, therefore, that although the large-seeded legumes are undoubtedly relatively tolerant, some effects on growth can result from pre-emergence applications in the range 3.5 - 7 lb/ac, and unlike the effects on cabbage, may not always be entirely overcome.

The results confirm that a number of important weeds of vegetable crops, including Poa annua, Senecio vulgaris, Veronica persica and Capsella bursa-pastoris are susceptible to CP 31393 at 4 lb/ac, and almost complete kill of these species was consistently obtained. Chenopodium album, Fumaria officinalis and Stellaria media, however, were more variable in their response, while Polygonum aviculare, P. convolvulus, Thlaspi arvense, Sinapis arvensis and Raphanus raphanistrum could be classed as effectively resistant. Where these species are important, CP 31393 cannot be expected to give adequate overall weed control.

Selleck et al. (1966) record promising results on bulb crops with a mixture of CP 31393 and chlorpropham. The weed spectra controlled by these materials are to some extent complementary, and in the present experiments addition of 0.5 lb/ac chlorpropham consistently gave a great improvement in the control of Polygonum spp., Stellaria media, Fumaria officinalis and also of Chenopodium album and Trifolium repens. With drilled brassica crops on this light soil, however, even as little as 0.25 lb/ac chlorpropham added to 4 lb/ac CP 31393 gave more pronounced and persistent stunting than CP 31393 alone (Table 1), and under these conditions its use would not seem to be feasible.

Addition of 0.5 lb/ac chlorpropham on onions sown early in the year resulted in depressions in stand of 30% or more, but these were less marked later in the year. Chlorpropham alone at this dose is normally considered safe on the Wellesbourne soil, even with outbursts of heavy rain such as occurred in 1966, and the injury observed was greater than was expected. No direct comparison of chlorpropham alone and in combination with CP 31393 is available from the experiments, but the possibility of an interaction between them cannot be excluded.

The impression was gained that the period for which CP 31393 persisted in the soil in herbicidal concentrations was relatively short, especially in wet conditions. Several tests were made in which soil samples were removed from treated plots at weekly intervals and the amount of herbicide remaining determined by laboratory bioassay using ryegrass shoot growth. These tests, at various times between January and June 1966, showed that following application of 7 lb/ac, most of the activity had disappeared within 3 to 7 weeks. This result is in accord with the information given by Selleck et al. (1966).

The experiments as a whole, although limited to one soil type, suggest that CP 31393 shows considerable promise in several crops. The main problem would seem to be tolerant weed species such as *Polygonum aviculare* and the fact that in onions, the period for which weed control persists is not sufficiently long. Further work is required to establish how the herbicide can be used to best advantage.

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