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EXPERIMENTS WITH A MIXTURE OF CYANAZINE AND ATRAZINE IN AMENITY PLANTINGS IN NORTHERN BRITAIN

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Summary A mixture of 25% a.i. cyanazine and 25% a.i. atrazine (Holtox) was evaluated at a number of sites in 1975 and 1976 on a range of tree and shrub species. Comparison was made with cyanazine s.c., atrazine w.p., simazine w.p. and chlorthiamid granules and applications were made both by conventional precision sprayer and with Micron ultra low volume rotary atomisers. Assessments of both weed control and crop effect were made. Cyanazine/atrazine at 5.04 kg a.i./ha gave acceptable weed control when applied to bare ground, 6.72 kg a.i./ha being necessary in situations where established weeds, in particular grasses, were present at application. The ULV rotary atomisers (also known as controlled droplet applicators or CDA.) proved to be an effective method of application. Cyanazine/atrazine was selective to most of the coniferous and deciduous tree species treated and its selectivity to a range of shrubs has been tabulated. Increase growth was recorded in coniferous species compared with both untreated controls and chlorthiamid treated plots following applications of cyanazine/atrazine.

INTRODUCTION

Amenity planting covers a wide range of situations from a forest planting on the one extreme to beds of ornamental shrubs and herbaceous plants on the other. In the forestry situation coniferous and/or deciduous trees may be planted, often in rough, poorly maintained areas, and once established be allowed to develop to form a balanced ecosystem, albeit with some assistance from man in weeding out undesirable species. In the case of beds of ornamentals grown for their aesthetic beauty continual weeding is often necessary since they do not grow large; either because of pruning or their small natural size, although weeding can be reduced by forming a good ground cover.

Over the whole range of amenity planting good weed control is necessary in the first few years to ensure low mortality and rapid establishment - the amount of weeding after the establishment period depending on the individual situation.

Handweeding has been the accepted norm but with increasing labour costs herbicide use becomes continually more attractive. Herbicides have other advantages over handweeding e.g. no root damage by cultivations leading to slower establishment, and the speed at which a weeding programme can be carried out. There are a number of problems attached to the use of herbicides in amenity situations.

1. It is a small market and does not warrant extensive research and development.

2. The wide range of species makes herbicide screening difficult and there may be variable reactions from genera within a species. Also large areas of a single species are seldom planted.

3. As in commercial forestry rough terrain, banks and close spacings often preclude the use of wheeled vehicles and make herbicide application both difficult and inaccurate.

4. Timing of application can be difficult since in a mixed planting not all species will be at the same stage of development.

5. The degree of weed control required must be known, in shrub beds in public areas 100% control may be necessary whilst in a forestry situation 60-70% control may be adequate.

Cyanazine/atrazine mixtures for weed control in forestry were introduced in 1974 by Allen (1974) and a commercial s.c. formulation containing 25% a.i. cyanazine and 25% a.i. atrazine (trade name Holtox) is presently available. This product was evaluated for use as a herbicide in amenity situations in 1975 and 1976. In the earlier forestry trials cyanazine/atrazine was applied medium volume but due to the inconvenience of water borne applications in forestry situations increasing emphasis was placed on ULV applications using CDA rotary atomisers i.e. the Micron Hulva and Herbi, with the flowable S.C. formulation. (Bals, 1975)

METHOD AND MATERIALS

In 1975 cyanazine/atrazine was evaluated in 10 replicated trials on a range of coniferous and hardwood tree species. In addition the tolerance of a range of ornamental species was evaluated at a further two sites. The species selectivity work was continued in 1976 and in both years results from applications by Oxford precision sprayer were compared with those from CDA applications.

Treatments used in the 1975 replicated trials were as follows:-

Chlorthiamid	@	4.2	kg a.i./ha
Atrazine	@	4.48	" " "
Cyanazine/atrazine	@	5.04, 6.72 and 10.08	" " "
Cyanazine	@	7.02	" " "
Untreated control			

Chlorthiamid was applied as a continuous 1m band over the trees by a Horstine Farmery airflow granular applicator, whilst the other formulations were applied by Oxford precision sprayer at 620 1/ha, again as a 1m band. There were four replicates at each site, the plots being 9.1m long and each contained a single row of trees.

Site details - 1975 replicated trials

Site	Location	Species	Planted	Treated
1	Banff	Picea sitchensis	1973	13.3.75
2	Northumberland	" "	1973	17.3.75
3	Perth	" "	1974	19.3.75
4	Angus	" "	1973	16.4.75
5	Northumberland	Larix eurolepis Pseudot suga taxifolia Picea sitchensis	1972	3.4.75

Site	Location	Species	Planted	Treated
6	Dumbarton	Alnus glutinosa	1973	7.4.75
		Acer pseudoplatanus		
		Fagus sylvatica		
7	Angus	Pinus sylvestris	1973	22.4.75
8	Perth	Picea sitchensis	1974	6.5.75
9	Fife	Betula pendula	1974	18.4.75
		Pinus sylvestris		
		Sorbus aucuparia		
10	Fife	Alnus glutinosa	1974	21.4.75
		Betula pendula		
		Fagus sylvatica		
		Fraxinus excelsior		
		Sorbus aria		
		Ulex spp.		

At sites 1 - 8 the herbicides were applied to established vegetation, the main weed species being Agropyron repens, Agrostis gigantea, Chamaenerion augustifolium, Anthoxanthum odoratum, Cirsium arvense, Dactylus glomerata, Deschampsia caespitosa, Festuca ovina, Holcus lanatus, Poa pratensis, Pteridium aquilinum and Ranunculus repens. At sites 9 and 10 application was made to weed free soil, the principle weeds which emerged being Agropyron repens, Chamaenerion augustifolium, Cirsium arvense, Matricaria spp. Myosotis arvensis, Papaver dubium, Polygonum persicaria, Stellaria media and Urtica urens.

At two further sites, one in Fife and one in Banff cyanazine/atrazine at 5.04 kg a.i./ha was applied by precision sprayer at 630 1/ha to the range of species shown in table 4 during April 1975, the plants being established in nursery beds. The treated plants were assessed for phytotoxicity in May and August and classified as tolerant, susceptible or of intermediate susceptibility.

In 1976 cyanazine/atrazine at 5.04, 6.72 and 8.40 kg a.i./ha was applied to the species in table 5 using the Micron Herbi to give a CDA application, the 50% a.i.product being used undiluted. Simazine at 2.24 and cyanazine/atrazine at 6.72 kg a.i./ha were also applied at 620 1/ha using a precision sprayer and chlorthiamid at 3.36 kg a.i./ha was applied using the Horstine Farmery granule applicator. Treatment was undertaken in May, plot size being 2m x 10m. While the precision sprayer treatments were made overhead, i.e. over the shrubs, the Herbi applications were made at a low level so that most of the foliage was not treated.

Each of the treatments was repeated 13 times, each repeat containing a different species or group of species.

RESULTS

Weed control was assessed at each site as % ground cover during or at the end of the growing season. Both at application and at the end of the season the health of the crop species was assessed, enabling an assessment to be made of the tolerance of the various species to cyanazine/atrazine.

Table 1

1975 replicated trials - % weed cover remaining

Treatments	(kg a.i./ha)	Site number 1	2	3	4	5	6	7	8	9	10	Mean
Cyanazine/	5.04	54	50	12	27	24	30	35	12	2	1	25
Atrazine	6.72	51	30	11	13	16	28	25	17	2	1	19
	10.08	20	22	7	7	9	29	14	10	1	0	12
Cyanazine	7.02	50	44	14	96	26	33	36	16	5	1	32
Atrazine	4.48	64	42	12	20	19	46	31	18	1	1	25
Chlorthiamid	4.20	25	16	20	44	15	49	48		59	7	31
Control		83	71	45	99	66	88	86	19	60	45	66
L.S.D.		23	23	12	24	14	24	20	10	-	-	

The level of control varied between sites, a reflection of the differing weed spectra present. However cyanazine/atrazine at the middle and high rates gave more consistent results than cyanazine, atrazine or chlorthiamid, the 6.72 kg a.i./ha rate giving a mean control for all sites of 71%. In this series of trials no treatment produced any adverse crop effects. At seven of the sites where coniferous species (*Picea sitchensis*, *Pinus sylvestris* and *Larix spp.*) were present the annual increment of the trees for the 1975 season were measured and the mean results are summarised in table 2.

Table 2

Mean annual increment in cm - 1975

Cyanazine/atrazine	at 5.04 kg a.i./ha	18
Chlorthiamid	at 4.20 kg a.i./ha	12.5
Untreated Control		11

In addition sites which were treated in 1973 and 1974 respectively and reported by Allen (1974) were also measured and the mean annual increments for 1975 and 1976 are presented in table 3.

Table 3

Mean annual increment in cm.

	Treated 1973 1975 INC.	Treated 1975 INC.	1974 1976 INC.
Cyanazine/atrazine at 5.38 kg a.i./ha	25	23	34
" " " 11.20 " "	27	-	-
Chlorthiamid " 4.20 " "	24	19	32
Untreated control	18	18	31

Cyanazine/atrazine has given improved tree growth over both untreated and chlorthiamid treated trees and has continued to do so in the second and third year after application.

Results of the species selectivity trials in 1975 are summarised in table 4. The cyanazine/atrazine was applied after bud burst of the deciduous species. Plants classified as susceptible were killed or severely damaged while those of intermediate susceptibility exhibited leaf scorch or some defoliation, but recovered later.

Table 4

THE SUSCEPTIBILITY OF NURSERY STOCK TO CYANAZINE/ATRAZINE AT 5.04 Kg a.i./ha

T = Tolerant I = Intermediate S = Susceptible

Chamaecyparis Lawsoniana 'Fletcheri'	T
Chamaecyparis Pisifera Plumosa	T
Chamaecyparis Pisifera Squarrosa	T
Chamaecyparis Pisifera Plumosa Aurea	T
Chamaecyparis Lawsoniana 'Stewartii'	T
Chamaecyparis Ellwoodii	T
Cupressus Leylandii	T
Juniperus Tamariscifolia	T
Juniperus X Blaauw	T
Juniperus Media Pfitzeriana Aurea	T
Thujopsis Dolobrata	T
Thuja Occidentalis Ericoides	T
Azalea spps	T
Berberis Dhrwinii	T
Berberis Stenophylla	I
Berberis Thuabergii	I
Berberis Gagnepainii	T
Betula Pendula	T
Buddleia Davidii	I
Buddleia Alba	T
Calluna Vulgaris (Mixed)	T
Corylus Contorta	T
Cornus Alba	I
Cornus Stolonifera Flaverima	I
Cornus Alba Siberica	I
Cornus Sanguinea	I
Cotoneaster Simonsii	T
Cotoneaster Franchettii	T
Cotoneaster Horizontalis	T
Cytissus Praecox	T
Deutzia X Hybrida	S
Erica Carnea (Mixed)	T
Escallonia 'Apple Blossom'	I
Fagus Sylvatica	T
Forsythia Intermedia	T
Forsythia Spectabilis	T
Fuchsia Riocartonii	I
Helianthemum Nummularium 'Pink'	S
Helianthemum Nummularium 'Yellow'	S
Hydrangea Hortensis	T
Hypericum Patulum	T
Ilex Aquifolium	T
Laburnum Anagyroides	T
Lavendula Spica	T
Leycesteria Formosa	I
Ligustrum Ovalifolium	T
Lonicera Pileata	S
Lonicera Nitida	I
Mahonia Aquifolium	T
Olearia Haastii	I
Olearia Macrodonta	I
Pachysandra Terminalis	T
Philadelphus Lemoinii	I
Philadelphus Virginal	I
Populus	T
Potentilla Fruticosa	I
Prunus Cistena	I
Rhododendron Ponticum	T
Ribes Sanguineum	T
Rose Floribunda	T
Rosmarinus Officinales	T
Rubus Tridel	T
Sambucus Nigra Aurea	S
Salix Alba	T
Salix Vitellina Britzensis	T
Santolina Chamaecyparissus	I
Sarcococca SP	T
Senecio Laxifolius	I
Spiraea X Bumalda	S
Spiraea Menziesii	S
Stephanandra Inoisa	I
Syringa Vulgaris	T
Tilia Sp	T
Ulmus Sp	T
Vaccineum Vitis Idaea	T
Veronica (SP unknown)	S
Veronica Traversii	S
Veronica Pinquefolia	S
Veronica Paggii	S
Viburnum Fragrans	I
Viburnum Opulus	I
Vinca Minor	T
Weigela Rosea	S

Young, recently planted plants proved to be less tolerant than those which had been established for six months or more. Acceptable, long lasting weed control resulted at both sites.

Concurrently with the trials reported methods of application of cyanazine/atrazine were examined, conventional application with a precision sprayer being compared with application of the s.c. formulation using CDA equipment. Applications were made at 7 sites to the following species:- Abies grandis, Acer campestre, Acer pseudoplatarus Alnus glutinosa, Betula pendula, Crataegus monogyna, Fagus sylvatica, Fraxinus excelsior, Larix eurolepis, Picea abies, Picea sitchensis, Pinus contorta, Pseudotsuga sitchensis, Rosa regosa, Rubus spps, Salix spps, Sorbus aria, Thelycrania sanguinea, and Ulex europa. Applications were made during March and April at 6.72 kg a.i./ha, the formulation being applied concentrated or diluted 1:1 or $1:1\frac{1}{2}$ with water. The treatments were not replicated and plot size varied. Results are presented in table 5.

Table 5

% Weed control -Cyanazine/atrazine applied by CDA

	Site Number						
	1	2	3	4	5	6	7
Cyanazine/atrazine 6.72 kg.a.i./ha							
Conc.	84	95	82	88	95	90	81
Dilute. 1:1	76	97	80	92		75	71
Dilute. $1:1\frac{1}{2}$	83	98	74			74	63

Acceptable weed control resulted from treatment and dilution of the product was not necessary for adequate weed control. The use of the concentrated formulation offered obvious advantages in case of handling. The only species to exhibit phytotoxicity was Larix eurolepis which showed transient needle scorch when application was made after flushing, earlier applications had no adverse effect.

The 1976 trials were designed to expand the previous year's work, paying particular attention to method of application. The high damage scores in some controls reflect difficult soil conditions at planting. Results are presented in table 6. Application was made to weed free soil in May, the ground having either been cultivated or treated with paraquat. The shrubs had been planted the previous winter. The main weeds proved to be annual and some perennial grasses and annual broadleaved weeds of which Polygonum aviculare, Polygonum persicaria and Galeopsis tetrahit were the most prevalent.

All cyanazine/atrazine treatments gave acceptable weed control, the lowest rate, i.e. 5.04 kg a.i./ha, giving superior control to either simazine at 2.24 or chlorthiamid at 3.36 kg a.i./ha. Cyanazine/atrazine at 6.72 kg a.i./ha applied with the Micron Herbi gave control almost equal to that achieved with the precision sprayer. However, while method of application had little effect on weed control, it did have a marked effect on crop phytotoxicity. The species Crataegus monogyna, Cornus alba, Thelycrania sanguinea and Viburnum opulus exhibited severe leaf scorch and defoliation when cyanazine/atrazine was applied overhead using the precision sprayer but only Viburnum opulus was affected by applications using the Herbi. During application the CDA atomiser had been some 20-25 cm above the ground and hence the majority of the foliage had not been treated. Owing to the tangential trajectory of the herbicide droplets from the CDA disc there were very few 'shadows' i.e. untreated areas, caused by obstruction from the shrubs. This proved to be more of a problem with the O.P.S. sprayer.

Table 6

1976 trials - Crop damage on the E.W.R.C. scale 1 - 9*

			CDA			Sprayer app.			
			Cyanazine/atrazine				Simazine.	Chlorthiamid.	
Rep.	Species	Control	5.04	6.72	8.40	6.72	2.24	3.36	kg a.i./ha
1	Viburnum opulus	2	4	4	1	7	2	-	
2	Cornus alba	2	2	1	1	4	1	-	
3	Crataegus monogyna	1	2	1	1	5	2	-	
4	Rubus cockburnianus	3	3	2	3	3	6	-	
5	Rosa carolina	3	3	2	3	3	1	-	
6	Berberis thuabergii	4	5	4	6	5	7	-	
7	Cotoneaster skogholm	2	1	7	2	3	3	-	
8	Cornus alba Crataegus monogyna	1	1	2	4	3	-	1	
9	Thelycrania sanguinea Crataegus monogyna	1	4	4	4	5	-	2	
10	Mixed Forestry Species	3	2	1	6	6	2	-	
11	" " "	3	2	1	3	1	3	-	
12	" " "	3	1	2	1	4	3	-	
13	" " "	3	4	2	3	1	3	-	
	% Weed cover	73.3	4.6	4.3	3.2	2.1	17.0	17.5	

* 1 = healthy 9 = dead (5 and above = unacceptable)

Mixed forestry species = Alnus glutinosa, Fagus sylvatica, Fraxinus excelsior, Pinus sylvestris, Salix alba, Sorbus aucuparia, Rosa canina.

DISCUSSION

Cyanazine/atrazine has shown itself to be a useful herbicide for use in forestry/amenity plantings. It was selective to the coniferous and deciduous tree species evaluated and to a range of shrub species when applied in the winter and spring. The tolerance of most species was increased by application prior to bud burst. Cyanazine/atrazine should not be applied to the following species:- Cornus, Deutzia, Helianthemum Lonicera, Spirea, Veronica, Viburnum and Weigela.

Selectivity can depend on the method of application, being improved by the use of CDA rotary atomisers whereby the product could be directed away from the foliage although this was not possible when shrubs were planted very close together or had a prostrate growth habit or where there was a tall well established weed flora. This technique could be useful in mixed plantations where a proportion of the species might be susceptible or untested and has the additional advantage of being a very simple method of application. No water is required, except for washing out the applicator, and the machine itself is very light and easy to handle.

Application rate of cyanazine/atrazine would depend on the species present, the weed spectrum and the degree of control required; better control would obviously be needed in amenity shrub beds than in a forestry situation. The product gave good control of germinating annual weeds and for shrubs planted in bare ground 5.04 kg a.i./ha gave adequate control for the season. However where conifers were growing in established grass and broadleaved weeds 6.72 kg a.i./ha was required. This gave control of 'fine' and 'medium' grasses but some of the 'coarse' grasses were moderately susceptible. These included Agropyron repens, Agrostis spps, Dactylis glomerata, Deschampsia caespitosa and Poa trivialis. Holcus mollis recolonised treated areas during the season in some cases. Of the perennial broadleaved weeds Urtica dioica was severely checked whilst Chamaenerion augustifolium and Cirsium arvense were slightly checked. Pteridium aquilinum and Juncus spps were not controlled.

Cyanazine/atrazine has been shown to have a beneficial effect on tree growth by reducing weed competition in trials on coniferous species, both in the year of application and in succeeding years. Whilst treated deciduous species often show a visual improvement over unweeded trees this has proved to be very difficult to quantify.

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THE EFFECT OF DALAPON AND GLYPHOSATE ON GLYCERIA MAXIMA

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Summary Dalapon was sprayed onto Glyceria maxima at doses of 10, 20 and 30 kg a.i./ha in October, 1974. In the following year shoot growth was delayed in the spring and in June the shoots were smaller than those in the untreated control plots. However, the number of shoots was not significantly reduced.

Glyphosate applied at 2 and 4 kg a.i./ha in June, August and October gave almost total control. There were no differences in the degree of control between the treatments or the time of application. Two years after treatment there was some regrowth round the edges of the treated plots but the centres were still clear of G. maxima.

INTRODUCTION

Glyceria maxima (Hartm) Holmberg is an emergent aquatic plant which frequently invades ditches, rivers and lakes causing problems with flow and access. Earlier studies on the control of G. maxima with dalapon (Barrett and Robson, 1971) showed that the plant was more susceptible to dalapon in August than in July or May. When dalapon at 22.4 kg a.i./ha was sprayed onto the leaves in August the plant was not killed but its regrowth was delayed in the following year, while treatments applied earlier in the season did not have this effect. As G. maxima is apparently more susceptible to dalapon later in the season it was decided to test the effects of a treatment applied in October to see if dalapon would kill the rhizomes when applied at this stage. The doses chosen for this treatment were approximately the same as those previously used (10 and 20 kg a.i./ha) and a higher dose of 30 kg a.i./ha was also included.

The herbicide glyphosate is also effective against many of the graminaceous weed species (MAFF, 1976). It was decided, therefore, to test the effect of this herbicide on G. maxima. Doses of 2 and 4 kg a.i./ha were chosen and it was decided to apply these treatments at various stages during the growing season to see if there was any change in susceptibility as the season progressed.

METHODS AND MATERIALS

Both experiments were done in a low-lying water meadow beside the River Wylye in Wiltshire. As far as possible uniform stands of G. maxima were selected but there were a number of broad-leaved weed species growing amongst the G. maxima. These weeds, particularly Cirsium arvense (L.) Scop., Urtica dioica L. and Galium aparine L. were controlled by spraying the whole area of the experiments with mecoprop at 3 kg a.i./ha before the experiments were set up.

The two experiments were designed as randomised blocks of 5 x 2 m plots with a path 1 m wide between them. Assessments on the regrowth were made in the following season in an area of 2 x 0.5 m in the centre of each plot.

The treatments in the dalapon experiment (experiment I) were applied on 17th October 1974 using an aqueous solution of the sodium salt. The doses of dalapon at 10, 20 and 30 kg a.i./ha were applied using a boom with four fan nozzles spraying vertically down onto the foliage. The Oxford Precision Sprayer used was calibrated to discharge 500 l/ha of spray solution and the plots were sprayed in a single swath moving from one end to the other. No surfactants or other additives were used.

The glyphosate (experiment II) was applied in the same way using doses of 2 and 4 kg a.i./ha in 500 l/ha water. Application dates were on 11th June, 20th August and 17th October 1974. These were chosen to cover the periods when the plants were actively producing vegetative growth (June), flowering (August) and before senescence (October) when there may be active translocation of photosynthates into the rhizome system (Crafts and Foy, 1959).

In the following winter the dead plant material in all the plots was cut and removed to facilitate the assessment of regrowth.

The effects of the treatments in both experiments were assessed by counting the numbers of shoots and, in experiment I, by measuring the dry weight of the shoots in the season after treatment. The first assessment on both experiments was carried out on 17th April 1975 when the young shoots in the untreated plots were approximately 10 to 20 cm in length. A second assessment was made on 17th June, 1975 when the shoots were again counted and those in experiment I were cut. The cut shoots were oven dried at 10.5°C for 24 h and then weighed.

RESULTS

Experiment I

In this experiment all thres doses of dalapon caused a significant reduction in the number of shoots that had regrown by April six months after treatment. There was no significant difference between the three treatments. However, when the second assessment was made in June, two months later, the numbers of shoots in the three treatments had increased and there was no longer a significant reduction in shoot numbers compared with the control.

Table 1

The effect of dalapon on the mean number of shoots/m^2 of Glyceria maxima in the season after treatment

Treatment	Dosage a.i.	Shoots/m^2 17th April 1975	17th June 1975
Dalapon	10 kg/ha	35.0	342
"	20 kg/ha	16.5	344
"	30 kg/ha	18.5	328
Control		377.5	540
Standard error		± 17.7	± 81.3

Despite a reduction of 40% in the numbers of shoots in the treated plots in June compared with the control there was no significant difference because of the high standard error.

The results in Table 2 show the mean dry weight per shoot, obtained from the total dry weight divided by the number of shoots.

Table 2

The effect of dalapon on the mean shoot dry weight of Glyceria maxima

(sampled in the season after treatment)

Treatment	Dosage a.i.	Shoot dry weight (g)
Dalapon	10 kg/ha	0.434
"	20 kg/ha	0.347
"	30 kg/ha	0.397
Control		0.950
Standard error		± 0.126

There was no significant difference between the three treatments but the shoots in the treated plots were all less than half the weight of the shoots in the control plots.

Because of the destructive sampling carried out on 17th June 1975 it was not possible to repeat a quantitative sampling assessment later in the season. Visual observation on the plots during the remainder of 1975 and 1976 showed that the difference in size between shoots in treated and control plots had disappeared by the end of August 1975 and did not reappear in 1976.

Experiment II

The initial assessment of the experiment was made on 17th April 1975. All the treatments gave complete control except the early treatment of glyphosate at 2 kg a.i./ha in which about 4% of the shoots survived. Because of the high degree of control obtained in this experiment the results were not analysed statistically.

Table 3

The effect of glyphosate on the mean number of shoots/m^2 of Glyceria maxima on 17th April 1975

Date of treatment	Glyphosate 2 kg a.i./ha	Glyphosate 4 kg a.i./ha	Control
11th June 1974	10.3	0	
20th August 1974	0	0	266.0
17th October 1974	0	0.3	

Repeated observations of this experiment during the remainder of 1975 showed no further regrowth and in 1976, despite some reinvasion round the sides of the plots, the centres remained clear of G. maxima.

In experiment II it was noted that there was gradual reinvasion of the plots in 1975 by Galium aparine and Cirsium arvense. On 21st May 1975 a visual estimate of the percentage of bare ground remaining in each plot was made. This showed that plots treated in June 1974 had only 10-20% of their area uncovered by weed. Those sprayed in August had 70-80% bare ground while the plots treated in October were 80-90% clear of weed. The control plots were not assessed because the dense stand of G. maxima prevented the percentage cover of the ground by G. aparine and C. arvense from being measured.

DISCUSSION

In experiment I dalapon significantly suppressed the regrowth of G. maxima up to April 1975 but the assessment made in June, two months later, showed that this suppression was only temporary. The reduced size of the shoots in June may have been caused by their delayed growth rather than a direct effect of the herbicide. The three doses of dalapon produced very similar results despite the wide range of dose.

These results tend to confirm those obtained in the previous experiment in which regrowth was delayed but not prevented by applications of dalapon in the latter half of the growing season.

The results of experiment II show that G. maxima is susceptible to glyphosate at doses of 2 kg a.i./ha and above. There was a 4% survival rate of plants treated in June at 2 kg a.i./ha but there was no indication of any significant change in the susceptibility of this plant to glyphosate between June and October. Natural die-back due to frost may sometimes reduce the effectiveness of treatments as late as mid-October and earlier application may be preferable.

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AMMONIUM ETHYL CARBAMOYLPHOSPHONATE - A REVIEW OF PROGRESS WITH TRIALS IN FORESTRY AND NON-CROPLAND AREAS

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Summary A review is made of trials from Germany and other countries with ammonium ethyl carbamoylphosphonate applied for the control of competitive deciduous tree and shrub vegetation in forestry and for brush control in non-cropland areas. Timing is critical for selective use in conifer species but adequate crop safety is demonstrated when application is made after the terminal bud has formed. A wide range of brush and tree species is controlled at 5-10 l./ha. The favourable environmental and toxicological aspects of the chemical are discussed.

INTRODUCTION

Ammonium ethyl carbamoylphosphonate was first reported at the Brighton Weed Control Conference (Niehuss and Roediger, 1974) under the code number DPX 1108. No common name has yet been assigned to it but the trademark is KRENITE. Trials were initiated in Europe during 1972 and consequently many tests have been carried out in several countries. Limited scale marketing has taken place in Germany in 1975 and is being extended to other countries in the autumn of 1976.

There has been much interest by research establishments and authorities in the chemical due to its very favourable toxicological properties, broad spectrum of action and long term effect. In addition labour shortages are serious in most countries due to physical or budgetary reasons. To forestry, local authorities and public utility employers vegetation management requires increasing attention to chemical and mechanical control and less to direct labour inputs. A chemical that provides effective control of a wide range of woody vegetation without hazard to operators, wildlife or passers by would be of real value.

Ammonium ethyl carbamoylphosphonate was shown in the papers by Niehuss and Roediger (1974), Delabraze (1975) and Dodel (1975) to have a broad spectrum of action. Further trials have helped to provide the basis for a susceptibility table given later in this paper.

Toxicology has been fully covered in the papers mentioned but soil, water and wildlife studies have been conducted and will be discussed further. The extremely safe nature of the chemical provides applicators with confidence that usage will not result in either toxic or long terms hazards to the environment.

This paper will endeavour to review on a broad level current knowledge of the activity of the compound based on experience in Europe since 1972.

METHODS AND MATERIALS

All work has been carried out using the standard liquid formulation containing 480 g a.i./l. The liquid is not volatile nor flammable but is slightly corrosive to copper and aluminium spray parts. However, in practice no problems have arisen when equipment was washed in the normal manner.

Applications have been made through a wide range of equipment varying from helicopters at 50 l./ha to hand lances applying over 1000 l./ha at high pressure. Water volumes between 200-500 l./ha have been most common.

For most non-cropland applications a non-ionic wetting agent was added at the maximum recommended rate. Early experience indicated that selectivity could be reduced when surfactant was used in conifers.

Plot size was variable since brush species were not always evenly distributed. The degree of replication has also been largely dictated by individual site requirements.

An important aspect of development has been the testing of application systems that would be commercially available. Coverage and penetration have been shown to be critical so the method of application has been an important factor.

Applications were made after terminal growth of the target brush species had been completed and before leaf senescence.

RESULTS

Trials were carried out by independent research stations, forestry authorities, our distributors and our own development staff.

Tabulation of the results from such a multitude of heterogeneous trials would be impracticable. This section will attempt to summarise the results obtained under four headings :

Toxicology and Environmental Studies. Toxicological studies have been largely conducted at the Du Pont Haskell Laboratory for Toxicology and Industrial Medicine. The acute oral LD50 rats for the commercial product is 24,000 mg/kg and the dermal LD50 for rabbits 4000 mg/kg. In feeding studies no effect could be noted from administering a level of 1000 ppm in the diet for 3 months.

Environmental studies showed that while ammonium ethyl carbamoylphosphonate is soluble in water it is readily absorbed by soil colloids. It is decomposed quickly by soil micro-organisms and therefore is not likely to run off into surface waters or leach into subterranean aquafers. Half-life for the intact chemical is 1-2 weeks. The Freundlich K equilibrium constant on a keyport silt loam soil has been found to be greater than 20, showing high adsorption to the soil.

In soil micro-organism studies, application of the chemical did not affect the populations of soil fungi and bacteria nor was there any interference with the soil nitrification process.

Ruminant feeding studies in Germany proved that ammonium ethyl carbamoylphosphonate did not affect body weight or reflexes. TL50 figures for three fish species varied from 670 to more than 1000 ppm indicating relative safety to fish. Mallard duck and bobwhite quail both had an LD50 more than 10,000 mg/kg so bird species are unlikely to be harmed by contacting the chemical.

Selective use in conifer forests. Trials in Germany, Austria, Scandinavian countries, Belgium, U.K., Czechoslovakia, Yugoslavia, France and Luxembourg have established that *Picea abies* tolerates 10 l. product/ha. *Pseudotsuga taxifolia* and *Abies spp*. have been shown to have an equivalent or even higher tolerance in Central Europe but slightly lower tolerance from preliminary trials in Scandinavia.

Pinus sylvestris and other *Pinus spp*. appear slightly less resistant than *Picea spp*. In Norway 6 l./ha is well tolerated and Yugoslavian trials point to safety at 10 l./ha. Some damage was reported to *Pinus spp*. from the U.K., Austria and Germany at 10 l./ha but this was related to the timing of application. Trials in Germany clearly established that treatment during active shoot growth and before the terminal buds had formed could result in severe damage. Provided application is made at this resistant stage *Pinus spp*. have been shown to tolerate the current maximum recommended rate of 5 l./ha.

Larix spp. have shown sensitivity in all countries to rates as low as 3 l./ha so this genus should not be treated.

Results of work in Germany with lower than standard rates have demonstrated that 3.0-5.0 l./ha may reduce the growth of competitive species by 50-100% depending on the susceptibility of the species concerned. This reduction of competition enables the conifers to grow more strongly.

Addition of surfactant particularly at higher concentrations has reduced selectivity (Delabraze, 1975). Experience with additives has been mixed and trials in Scandinavia with surfactants (Surfactant WK, Triton X100 and Triton CS7) show promising results on spruce without providing damage up to 12 l./ha of ammonium ethyl carbamoyl-phosphonate.

Non-cropland. More complete brush control is needed in most non-cropland situations where larger trees and shrubs are frequently found. Consequently higher rates have been applied. Results under powerlines, along railtracks and roads show that 6-10 l./ha will give good control of a wide range of brush and tree species.

Surfactants increased leaf wetting and coverage and improved results.

The application of ammonium ethyl carbamoylphosphonate does not usually result in any significant leaf discolouration during the weeks after treatment and before normal leaf fall. This was found valuable in situations such as roadsides, railways, forest paths etc. where members of the public usually pass. Scorched foliage often prompts adverse comments from our increasingly environment-conscious population.

Susceptibility of tree, shrub and grass species. Results have been fairly consistent in most Central European countries. Applications made before leaf senescence have provided good control of a wide range of species. Table I endeavours to categorise susceptibility of different brush species. Coverage and concentration have been found to be critical. Thorough and complete coverage of the leaves, buds and stems were found necessary for optimum control. Ammonium ethyl carbamoylphosphonate is neither volatile nor systemic in woody tissue so that control is only achieved of those plant parts covered by the spray. Variable control was usually the result of poor application, marginal rate and climatic conditions.

Compared to the standard phenoxy compounds ammonium ethyl carbamoylphosphonate provided a longer range effect on scrub growth. In addition fewer suckers were noted coming from the base and roots of plants in the year after treatment.

The spray concentration of the product should not be allowed to fall below 1% as many trials have shown less satisfactory results with lower concentrations.

Trials have been carried out on the evergreen vegetation prevalent in the Mediterranean countries. Apart from some Cistus spp. control (Dodel, 1975) results with up to 15 l./ha have not been encouraging. Trials have so far failed to indicate a time of year when satisfactory activity can be demonstrated but the effect of adding surfactants and additives is still being evaluated.

Results have also been more variable in northern areas such as Norway and N. Sweden particularly where Populus tremula and Betula spp. predominate. Control of aspen is more difficult but Betula spp. are normally well controlled when applications have been carefully made. In Norway bark injection and stump treatment (2, 4 and 8% concentrations) have indicated promise for further development.

Grass and other herbage species have been rarely affected. Consequently development of the chemical in alpine pastures in Switzerland, Austria and Germany is now being undertaken. Experience in Scandinavia indicates that damage to grasses can occur over 8 l./ha.

Preliminary trials are showing that some perennial weeds such as Convolvulus arvensis, Pteridium aquilinum, Equisetum spp. and Cirsium arvense may be controlled.

DISCUSSION

The constant search for safer, less hazardous and less persistent chemicals has resulted in the isolation and development of ammonium ethyl carbamoylphosphonate. Operators in local authorities, public utilities and even forestry may not always be adequately trained in the use of chemicals. This chemical can be applied without extra protective clothing, fear of volatile drift to nearby crops or fear of adversely affecting the environment in the short or long term. In the U.S.A. the chemical is recommended for use near domestic water supply reservoirs, streams, lakes and ponds.

Trial and commercial scale applications have demonstrated the value of the chemical in forestry and non-cropland situations but certain factors affecting performance have emerged from experience to date in West and East European countries.

Forestry. Timing is critical to ensure safety to conifer plantations particularly Pinus spp. However, provided growth has stopped and the terminal buds formed, adequate safety margins exist at the recommended rate of 5 l./ha. While Picea, Abies and Pseudotsuga spp. appear reasonably resistant, Pinus spp. are rather less so and require especial care over timing. Experience has indicated that treatment over late-season shoots must be avoided in all genera. Coniferous trees under stress are obviously not growing satisfactorily and may be susceptible to normal rates of the product. Experience proves that ammonium ethyl carbamoylphosphonate should not be applied in these cases.

Complete brush control in forestry plantations may not always be necessary. Some shading and wind protection effects from the brush species may be desirable. Lower rates of the chemical (down to 3 l./ha) have been shown to reduce growth, to hold it back, thereby allowing the conifer to grow without major competition and yet still be lightly protected. Foresters will have to experiment with rates until they find the dose most suited to the brush species involved and the degree of inhibition and length of control required.

The requirements for a non-cropland chemical must include efficacy on as wide a range of species as possible, safety to operators and the environment and still be within reasonable economic limits. Control of such problems species as Robinia pseudoacacia, Quercus spp., Fraxinus excelsior, Crataegus, Fagus and Corylus spp. is now possible. The normal senescence of treated foliage, under most circumstances, precludes adverse comment from an increasingly environment-conscious population.

Two clear factors have arisen from the development work:

Importance of coverage and the length of time taken to achieve full control. The lack of systemic action in woody tissue of established trees and shrubs and absence of volatility results in the need for careful attention to application methods. Some downward movement may be occurring in young shoots and in such perennials as Convolvulus arvensis and Pteridium aquilinum since control can be so complete.

Our experience has indicated that provided the method used gives good penetration and coverage, aerial treatment, mist blowers and hydraulic sprayers may all be used successfully if brush is treated carefully and individually. Scandinavian experience has shown that mist blowers using 2-300 l./ha will give satisfactory results. Fixed mounted mist blowers must be used carefully to provide the complete cover necessary. Spray operators need to be well trained to achieve the best results.

Size and density of brush species has been found to influence performance, Knapsack sprayers have not been satisfactory for brush over chest height. Similarly poor penetration of dense brush will only provide control of the outside plants. Helicopter applications have been largely successful, probably due to the downward and penetrating nature of the spray pattern. Normal spray application to mechanically cleared or hand cut shrub should be made when the suckers have grown up, normally a season after cutting.

Chemical trimming is feasible since only the treated parts of the tree or shrub will be affected. Such a technique is considered of interest for roadsides, near power or telegraph lines, railway tracks and public rights-of-way.

Finally it is essential that complete coverage be matched by a spray concentration that is active. The concentration of the product in the spray solution should not be less than 1%. It may be that concentration is an easier and more satisfactory method of recommending the chemical than a rate per hectare. This aspect is being investigated.

Time taken to achieve maximum control. During the season after treatment spring bud development is suppressed in susceptible species. Less susceptible species develop small miniature shoots with rather pale leaves. More resistant species may develop normal leaves but not produce any extension growth. In the second year after treatment no growth or bud development will take place in the susceptible species. Growth may still be suppressed in more resistant species. The stems of many woods plants may remain alive for two to three years. It is imperative that evaluations be carried out for at least two years following application to assess the full benefits of treatment. Experience has shown that ammonium ethyl carbamoylphosphonate may rovide longer range control than the phenoxy acids. In addition less hoots from the roots and stems have been noted compared to phenoxy ompounds.

Studies have been initiated to evaluate the importance of umidity and temperature during and after application. Experience uggests optimum uptake under high temperature and high humidity onditions and much reduced activity when the reverse is true. However, in France, Germany, Switzerland, N. Italy, Denmark, Yugoslavia nd Czechoslovakia conditions during the critical application months f August/September/October seem to allow consistently satisfactory esults in terms of brush control.

The precise role, optimum rate and method of application of any rowth regulator takes several seasons to evaluate fully. Ammonium thyl carbamoylphosphonate has already been shown to control a wide ange of woody vegetation in non-cropland and in selective treatments n forestry. Tailoring the rate to the precise local needs offers oresters and others tremendous opportunities for all types of egetation management and silviculture techniques. Continuing development and long term follow-up is needed for such versatile, sophisticated and potentially useful chemical tools as ammonium ethyl arbamoylphosphonate.

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Table I

Susceptibility of tree and shrub species to ammonium ethyl carbamoylphosphonate

l. product/ha				
10	Good control			Intermediate control
5	good control		moderate control but sufficient for silviculture	Intermediate control
3	good control	moderate control but sufficient for silviculture	Intermediate control	Practically no control
species:	*Betula verrucosa* *Alnus glutinosa* *Ligustrum vulgare* *Fagus silvatica*, seed *Quercus robur*, seed *Rubus fruticosus*, when young *Rhamnus frangula*, when young *Cornus sanguinea*, when young	*Fraxinus excelsior* *Sambuccus nigra* *Corylus avellana* *Carpinus betulus* *Rubus fruticosus* *Cornus sanguinea* *Robinia pseudoacacia* *Rhamnus frangula*	*Populus tremula*, when young *Rubus idaeus*, regrowth from new seed possible *Rubus spinosa* *Crataegus oxyacantha* *Sambuccus racemosa* *Prunus padus* *Sorbus aucuparia* *Viburnum spp*. Suckers from: *Quercus spp*. *Fagus spp*. *Tilia spp*. and *Carpinus betulus*	*Populus tremula* *Salix spp*. *Acer spp*.

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THE ECONOMIC AND TECHNICAL BENEFIT OF LONG DURATION RESIDUAL WEED CONTROL

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Summary The technical and economic benefits of mixtures of residual and contact herbicides, compared with those of residual herbicides used alone, are discussed. The efficiency of long term weed control is assessed from trials with simazine, thiazafluron and bromacil. Effects of high rates of simazine persisted into the following season, thiazafluron had more extended effect and the persistence of both was dose-related. An increase in bromacil dosage rate did not increase duration of effect. Conclusions are drawn on the opportunities presented for delaying follow-up treatments.

INTRODUCTION

Weed control on non crop land poses two problems :

1. to destroy existing vegetation

2. to prevent regrowth

From a chemical point of view it is important to make this distinction, because no herbicide is entirely able to solve both problems at the same time. To destroy vegetation knock-down herbicides are required, to prevent regrowth residual herbicides are necessary.

An all-round industrial herbicide will usually consist of two or more chemicals combined, and such combinations have been used for several years and include aminotriazole and triazines. They have two disadvantages when used year after year :

1. Weeds must be present to take full advantage of the knock-down component. The time of treatment is imposed by the additive herbicide, and the time bracket available for application is very narrow. Entire areas have to be treated at once.

2. The residual component in the mixture is reduced at the expense of the knock-down component and is often too low to achieve acceptable weed control from one treatment to the next or to prevent invasion of perennial weeds.

3. The knock-down partner for the residual herbicide has to be chosen according to the weed flora. A complete inventory of the flora has to be made well in advance and a series of products has to be carried in order to compensate for gaps in weed spectrum of each contact herbicide.

The main reason in the past for the use of such combinations was economy : inexpensive "contact" herbicides could be used instead of more costly residual herbicides. This price relationship has now almost been inversed, and for equal cost, dosage rates of residuals can be increased at the expense of most of the supplemental contact herbicides. Such an increase in dosage rates is even more practicable when in non-crop situations selectivity problems are negligible.

Increased dosage rates of residual herbicides result in improved duration effect, which in turn leads to several advantages :

1. Carry over of residual weed control to the next season

2. Widening of the time bracket for subsequent spraying. Earlier spraying becomes possible and the carry-over allows for a certain delay after vegetation flush has started.

3. An equal work load can be handled with less equipment.

4. Fewer chemicals are to be used.

5. The dead or dying weeds do not lie littered about the treated sites.

METHOD AND MATERIALS

About 20 comparative trials have been laid out across Eastern Canada : Ontario, Quebec and the Atlantic provinces in three different years.

Among the compounds compared were simazine, GS 29696 or thiazafluron (proposed) and bromacil. Simazine was used at 5,6, 11,2 and 22,4 kg a.i./ha, bromacil and GS 29696 were used at 2,8, 5,6 and 11,2 kg a.i./ha.

The applications were made in May or June 1971, 1972 or 1973.

A first evaluation according to EWRC proposed rating was made after an average of 2,7 months (minimum 2, maximum 3,5 months).

A second evaluation was made after an average of 14,7 months (minimum 13, maximum 17 months).

RESULTS

The median average of the first ratings was compared with the median average of the second ratings. (table 1).

table 1

Median averages of weed control ratings 1-9, (where 1 = complete control) from various locations (number in brackets) in Eastern Canada, at 2,7 months and at 14,3 months after application.

Treatment	Dosage kg a.i./ha	Number of months elapsed after treatment		Number of trials
		2,7 months	14,3 months	
Simazin	5,6	5,4	7,6	(5)
	11,2	4,5	6,8	(14)
	22,4	3,5	5	(11)
Thiazafluron	2,8	3,3	5,9	(4)
	5,6	2	5,3	(11)
	11,2	1,8	2	(8)
Bromacil	2,8	3,2	5,5	(5)
	5,6	2,5	6,6	(11)
	11,2	1,8	6,2	(9)

The observation was continued into the third season in a reduced number of plots (table 2).

Table 2

Median averages of weed control ratings 1-9, (where 1 = complete control) from various locations in Eastern Canada at 27 months (3rd season) after application.

Treatment	Dosage kg a.i./ha	Weed Control rating after 27 months
Simazine	5,6	8,8
	11,2	8,3
	22,4	6,8
Thiazafluron	2,8	8
	5,6	6,8
	11,2	2,6
Bromacil	2,8	8,5
	5,6	8
	11,2	7,3

DISCUSSION

With high dosage rates of simazine it is possible to achieve some degree of weed control well into the second season after application. This presents the prospect of delaying the subsequent maintenance treatment even until the growth season is advanced, without fear of any major reinfestation. With thiazafluron the opportunity is presented of making a follow-up application any time during the second season and under favourable circumstances reduce the third year treatment.

An increase in dosage rate does not produce an increase in duration effect with bromacil.

Acknowledgements

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SOME ASPECTS OF THE ECONOMICS OF USING HERBICIDES IN THE INDUSTRIAL SITUATION

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Summary In the past Local Authorities have invested a great deal of time and money in establishing the sort of environment that people enjoy. Well kept amenity areas, tidy housing estates, colourful parks, and weed free town centres. The costs of maintaining the standards set are increasing, but the availability of money and the purchasing power of that money is decreasing in the light of present economic difficulties.

Traditional methods of hand weeding are time consuming and expensive, and less effective than chemical weeding. This paper, besides looking at the safety of chemical control, compares the costs of using chemicals in shrubbery weed control, highway weed control and amenity grass management with traditional methods, using the comparative costs of three Local Authorities as an example of the difference between hand weeding and chemical weed control methods.

INTRODUCTION

"Money answereth all things"
Book of Ecclesiastes

This biblical quotation is still an eternal truth, but in these days of inflation and economic difficulty, the availability of money becomes less and less. There is pressure from all quarters to reduce spending, and nowhere is this pressure greater than in the public sector.

It is sometimes forgotten that our urban environment is not a natural one but man made and derived from the maintenance and management regimes that have been used. The establishment and management of these regimes has been as a result of high initial levels of investmant in time, labour, trees, plants and grass. These forms of management affect the competitive ability of species in plant communities, and the maintenance of desirable communities including the removal of the undesirables (weeds) is a continuing expense.

Parks are synonymous with recreation and for many people living in towns or in flats in rural surroundings, local public parks and gardens and places of outdoor recreation, may be the only areas where leisure can be enjoyed. It is vital therefore, that the continuing investment in maintaining this man made environment is maintained, despite reducing availability of the cash with which to do it.

Many local authorities have recognised that the levels of initial investment in establishing the sort of environment their citizens enjoy justifies expenditure on chemical weed control for which inexpensive hand labour is no longer available. However, for one reason and another the move to complete chemical control as a method of coping with the inescapable problem of weeds has not been as rapid as the economics would suggest.

Before we can move to greater use of herbicides we have to answer some of the questions which worry those who use herbicides and who have to justify their use to the public.

Safety

In this context the first point that we would make is that safety is as important as efficacy to the manufacturer of herbicides. That is, safe to the environment and wild life, and safe to the consumer, be he the man who applies it, a member of the general public, or his pet. Unfortunately, in the Local Authority field there is a lack of knowledge about the Pesticides Safety Precaution Scheme (P.S.P.S.) and the Agricultural Chemicals Approval Organisation (A.C.A.O.). The former organisation a committee of independent chemists and responsible to the Ministry of Agriculture, require that Manufacturers carry out exhaustive toxological and residue studies, and that in the committee's opinion they are satisfied on the safety of the products. The Approvals Organisation satisfy themselves that the product normally fulfills the claim made on the label, granting it the 'A' mark. Each product's label text is kept under constant review. Not all herbicides used in the industrial and local authority situation are listed in the Approvals book as they are primarily concerned with agricultural and horticultural pesticides. However, EEC legislation suggests that all products should be 'approved', and in time this will occur. Until this becomes the rule we would suggest that Local Authority users of chemical should, as far as possible, only use those products which carry the 'A' mark, as a large number of products used in Agriculture and Horticulture have an industrial weed control recommendation.

The second point we would draw your attention to is the use of pesticides and the public. In the Local Authority situation, pesticides are often applied in the presence of the man in the street, who, for lack of knowledge of pesticides, becomes alarmed for himself or herself, family and pets. Much more, we believe, could be done in the area of P.R. by the Authority to keep their citizens informed, who after all are paying for the service through their rates, on what is happening as well as putting their minds at ease so that when they see an application team with knapsacks on their back spraying the streets or the estate, they are not alarmed. The public will, by and large, accept the explanation, although, as in other areas of pesticide use, there will be an anti-pesticide lobby.

The last point we would make in this context is operator training. The safe use and application of pesticides by unskilled, untrained and uninformed operators, can be an environmental hazard as well as an extra expense. The expense of putting to right accidental damage by mis-application, the cost of repairing damage through drift, and the expense of extra chemical usage, because someone had not read the label to find out the correct dosage.

Economics

In these inflationary times, it is surely the cost saving aspects of chemical herbicides that will carry most weight today. Recently we carried out a mini-survey among a number of councils to compare costs of chemical with hand weeding and other forms of weed and grass control. For the purpose of this paper we have taken the figures quoted by one of the London Boroughs, one from the home counties and one other in order to be as representative as possible. Naturally, there will be variances, depending on size of authority, the labour force, and the areas of land to be maintained, and the amount of maintenance that individuals carry out.

In each of the comparisons, we have not taken into account any costs of overheads, the cost of purchasing or hiring equipment such as knapsack or power sprayers, or other specialised application equipment. Our assumption is they have this equipment and as overhead costs vary enormously, it would not be meaningful to include these.

Shrubbery Weed Control The first area of weed control that we looked at was weed control in shrubberies, including rose beds, borders and traffic roundabouts planted as shrubberies.

1. Hand Weeding

		Operator time per 100 m^2	+ Margin =	Standard Time	Average hourly wage	Cost per 100 m^2
		mins	mins	mins		
Council A	Dutch Hoe	140	25.2	165.2	£1.50	£4.13
Council B	Dutch Hoe	144	28.8	172.8	£1.73	£4.98
	Swan Neck Hoe	224.6	44.9	269.5	£1.73	£7.77
Council C	Dutch Hoe	132	23.8	155.8	£2.02	£5.25
Average	Dutch Hoe	138.6	25.9	164.6	£1.75	£4.81

Hoeing frequency is 3 to 5 times per annum depending on weed growth and season.

Therefore total average cost of dutch hoeing per annum is £14.43 to £24.05 per 100 m^2.

2. Chemical Weed Control

Granular weedkillers. 2% a.i. simazine (Weedex S2G) at recommended user price £8.25/25 kg including V.A.T.

COUNCIL	Operator time for applica- tion per 100 m^2 +	Margin =	Standard Time	Average hourly wage	Cost of labour	Rate of applica- tion 100 m^2	Cost of weedkiller + V.A.T. 100 m^2	Total cost labour & chem per 100 m^2 incl. V.A.T.
	mins							
A	23.6	4.3	27.9	£1.50	£0.70	1 kg	£0.39	£1.09
B	30.0	6.0	36.0	£1.73	£1.04	1 kg	£0.39	£1.43
	Average 26.8	5.15	31.95	£1.615	£0.86	1 kg	£0.39	£1.25

3. Wet spraying using Knapsack and 50% a.i. simazine w.p. (Weedex S50WP) at a recommended user price of £2.48 per 1 kg.

Council C did not use granular weed killers and Council A did not use wet sprays.

COUNCIL	Operator time for application per 100 m^2	Margin +	Standard =time	Average hourly wage	Cost of labour	Rate of application 100 m^2	Cost of weedkiller + V.A.T. 100 m^2	Total cost labour & chem per 100 m^2 + V.A.T.
	mins							
B	41.7	8.3	50	£1.73	£1.442	52 g	£0.129	£1.57
C	43.6	7.8	51.4	£2.02	£1.731	52 g	£0.129	£1.86
	Average 42.65	8.05	50.7	£1.875	£1.584	52 g	£0.129	£1.61

As simazine has poor contact action the ground must first be made clear of weeds by hand hoeing, therefore annual cost of treatment is the sum of 1 & 2 or 1 & 3 above:-

Granular cost for the year's treatment - £6.06 average per 100 m^2.

Using Wettable powder for the year's treatment - £6.42 average per 100 m^2.

Comparing the costs of hand weeding and chemical control, it can be seen that chemicals work out between 58-73% cheaper than hand labour. Not only is the cost of treatment less, but chemicals are more effective, they kill existing weed growth and prevent regeneration. Hoeing on the other hand only removes existing growth leaving seeds and vegetable fragments to regenerate. In addition there are the safety aspects. It has been proved that chemical treatment used correctly does not damage the desirable species, hoeing even by skilled operators can damage plants and root systems. Therefore chemicals have three major benefits, effectiveness, safety and considerable cost saving.

4. Contractors' charges for contract weed control in shrubbery situations are in the region of £2-£15 to £2-£40 per 100 m^2 including V.A.T. These charges include the chemical, the labour costs, plus some overhead charges for men and machines.

Comparing the three methods - hand weeding, chemical weeding using your own labour, chemical weeding by contractor, - chemical weeding is always the cheapest and most effective, with self application having the edge over contractor applied. Self application, besides cost saving, also utilises labour that is difficult to redeploy, and application and maintenance programmes can be planned to suit your convenience.

A logical extension of the use of safe chemicals has been the tolerance of nursery stock to these chemicals and the use of varieties tolerant to specific herbicides (in particular simazine) in the planning of shrubberies. In other words it can pay handsomely in the long term to use only chemical resistant shrubs from the outset - with weed control in mind.

Highway weed control. Weed control can realise cost savings in other directions. It is well known that weeds growing around fence posts and fencing retain moisture which rapidly causes rusting and rotting. Weed growth camouflages signs of illegal entry and is a protection for vermin. In other locations it is virtually impossible to carry out mechanical and manual weeding, and weed control is necessary for safety reasons. Such situations, for example, are motorway central reservations, around motorway furniture and crash barriers.

The practice of chemical weed control is again less expensive than either mechanical control or hand labour. Council B previously noted, practiced weed control around fence lines and the labour cost was £0.388 plus chemical cost using 4% a.i. atrazine granules (Weedex A4) at a rate of 487g per 100 meters linear of £0.185 a total of £0.473 including V.A.T. for light vegetation, and £0.80 for dense vegetation.

In the Highway situation, there is little alternative to chemical treatments for kerb, channel and pavement. A number of Local Authorities still expect their road sweepers to remove weeds manually over their section of road, but this is poorly carried out, if at all. Contractors play an important part in Highway weed control, as they have the specialised equipment for doing this work. Other authorities hire the equipment and purchase the chemical for application by their own labour.

Contractor charges for pavement spraying averages about £10.00 per pavement mile excluding V.A.T., with the chemical cost being about one third of this figure, say about £3.50, the remainder being labour charges, overheads and profit.

With reasonable training of operators marginal savings can be made by authorities doing this work themselves, especially those flagged areas around residential tower blocks.

Amenity grass management. One of the largest areas of expenditure is in the area of grass mowing. During the 32 weeks that mowing usually takes place, Local Authorities mow the same area of grass about 12-15 times, though many of them aim for less than that, and in the areas of the South West mowing can be up to 20 cycles per annum. Grass maintenance requires a high initial investment in tractors, gang mowers, motor mowers etc. In addition there is the annual recurring costs of service fuel and labour charges, and the charges for collection and removal.

The answer to the frequency of mowing problem is the use of grass growth retarders (in the main maleic hydrazide), but unfortunately the performance of inhibitors appears doubtful in many people's minds. Patchy performance, problems with application timing, weather at time of treatment and for a period after application, effect on certain grasses, and high cost of material, makes it a doubtful cost saving method of grass maintenance in the amenity areas at this moment in time. However, we would suggest that in certain difficult areas for mowing, cemeteries in particular, there could be a case for using grass growth retarders.

Costs for hand mowing of easy sites is in the region of £20-£30 per acre, with the labour content being about half of the total (£10-£15). Difficult sites could be up to double this cost, although we have not been able to get any definitive costings. The frequency of mowing these sites, because of their difficulties are reduced to about 7 times per season, depending on the year. In addition to the mowing costs there is a cost for the collection and disposal of the mowings to be added.

Estimates are that total cost of such sites are in the region of £50-£75 per acre by 7 times a season, £350-£525 per annum.

The use of grass growth retarders costs £14-£18 per acre applied per treatment. The usual practice is two applications plus the addition of a selective weedkiller. The total cost of 2 treatments with selective being about £32 per acre, and reducing mowing from 7 per season to about 3. Cost for the year being £150-£225 for mowing, plus retarder application cost of £32, a total of £180-£260, a saving of about 50% in cost.

CONCLUSIONS

We have looked at a number of areas where chemical weed control can be safely and effectively used and in every instance there is evidence of considerable cost saving.

In these times of economic stress, it is surely the cost saving aspect of chemical herbicides that must carry great weight with Local Authorities. The trend towards chemicals can only intensify, in our opinion, particularly as the availability of safe products provide a complete answer to those who may harbour doubts about the efficacy and safety about chemical weed control. So marked are the advantages that in addition to the Local Authority, industry generally could benefit from wider use of herbicides in maintaining and protecting their investments and the man made urban environment.

HERBICIDES AND HERBICIDE MIXTURES FOR THE CONTROL OF AVENA FATUA, A. LUDOVICIANA AND ALOPECURUS MYOSUROIDES IN WINTER CEREALS

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Summary Four herbicides, 2-[4-(2',4'-dichlorophenoxy)-phenoxy]-methyl-propionate (Hoe 23408), 2-[4-(4'-chlorophenoxy)-phenoxy]-isobutyl propionate (Hoe 22870), difenzoquat, and isoproturon were tested alone or as simple mixtures for their effectiveness in controlling mixed populations of *Alopecurus myosuroides* and either *Avena fatua* or *A. ludoviciana* in three experiments on winter wheat or barley. The effectiveness of the treatments on the mixed populations varied, and some of the herbicides were antagonistic to one another in mixture. The most consistent mixture tested was 2.0 kg/ha isoproturon with 0.5 kg/ha difenzoquat which when applied in the autumn controlled all three grass weeds.

INTRODUCTION

Several herbicides such as chlortoluron and isoproturon are very effective in controlling *Alopecurus myosuroides* in winter wheat and barley. They are also active on *Avena fatua* and *A. ludoviciana* but the level of this activity is unpredictable and the degree of control is often inadequate. The unpredictability may be related to weather, soil or plant factors, and one possible method of increasing reliability is to use a mixture of herbicide with differing properties.

Information from the manufacturers, subsequently published by Schumacher and Schwerdtle (1975) and Schwerdtle and Schumacher (1975) had indicated the potential activity of 2-[4-(2',4'-dichlorophenoxy)-phenoxy]-methylpropionate (Hoe 23408) against *Avena* spp, and 2-[4-(4'-chlorophenoxy)-phenoxy]-isobutyl propionate (Hoe 22870) against *A. myosuroides*. The effectiveness of difenzoquat on *Avena* spp is well known, being first reported by Shafer (1974) and subsequently by many other workers, and similarly that of isoproturon on *Avena* spp and *A. myosuroides*, first reported by Rognon *et al* (1972), Guillemenet (1973) and Proctor and Armsby (1974).

Therefore during the seasons 1974-5 and 1975-6, simple mixtures of these compounds were tested in three experiments on winter wheat and winter barley containing *A. myosuroides* and *A. fatua* or *A. ludoviciana*.

METHOD AND MATERIALS

The herbicides used in these experiments, their formulation, route of entry into the plant, and the weeds they control are given in Table 1.

Table 1

Compound	Formulation	Route of entry	Susceptible grass weeds
Hoe 22870	36% w/v e c.	foliage and soil	A.myosuroides
Hoe 23408	36% w/v e.c.	foliage and soil	Avena spp and (A.myosuroides)
difenzoquat	65% w/w W.S.P.	foliage	Avena spp
isoproturon	75% w/w W.P.	foliage and soil	A.myosuroides & (Avena spp)

The physical compatibility of the formulated compounds as mixtures was tested in the laboratory using CIPAC standard tests. All the doses of herbicides in this paper are in terms of active ingredient (a.i.)

Two of the experiments were in winter wheat and one in winter barley. All three experiments were in commercially grown crops where natural infestations of A.fatua or A.ludoviciana and A.myosuroides were expected.

Details of the sites, dates of treatment, soil conditions and stage of growth of both crop and weeds are given in Table 2

In the preliminary experiment at Lewknor in 1974-5 a Fison's Mini-Logarithmic Sprayer was used to apply the herbicide treatments at a volume rate of 250 l/ha and a pressure of 2.1 bars, through a matched pair of 8002 Teejets. Plots were 20 x 1 m and the half dose distance 5 m. Thus on plots treated with a single herbicide the final dose at the end of the run was 1/16th of the starting dose. Where mixtures of herbicides were used the dose of one was left constant while that of the other was reduced logarithmically This was achieved by placing the fixed concentration in the diluent container and, mixed with the varying constituent, in the concentrate container.

In the 1975-6 experiments finite doses of the herbicides or herbicide mixtures were applied through an Oxford Precision Sprayer pressurised by propane. The nozzles, volume rate, and pressure were the same as those used in the logarithmic sprayer in 1974-5 but the sprayer boom was fitted with four nozzles and treated a swathe of 2m. Plot length was 6 m. The experiments were of a randomised block design but the 1974-5 experiment had two blocks whereas those in 1975-6 had three. There were no discards between the plots of 2m width but an untreated area of 1 m was left between the narrower 'log' plots.

At Barnard Gate a considerable number of dicotyledonous weeds, particularly Gallium aparine, emerged on the site before the experiment was begun, and these were controlled with a normal treatment of a commercial mixture of ioxynil and mecoprop (Actril C), applied on 23rd October 1975. At Chicheley an overall treatment of paraquat was used before the crop emerged to control plants of A.fatua and A. myosuroides which had not been killed by the cultivations prior to drilling. Relatively few dicotyledonous weeds were present at this site.

At Lewknor G.aparine and Veronica spp were controlled with an overall treatment of mecoprop in early January.

Fertiliser usage at all sites was normal, additional nitrogen being applied in the spring.

A.myosuroides was assessed when all the heads had fully emerged, by scoring for vigour and density every 2.5 m down each plot treated with a 'log' dose, and by counting the heads in 20 quadrats of $(25\ cm)^2$ on each of the plots in the experiments treated with finite doses.

A.fatua and A.ludoviciana were assessed similarly just prior to harvest and numbers of panicles were counted in 3 quadrats of $(1\ m)^2$ on each plot. In addition panicles were graded for size and the number of spikelets estimated from this data (Holroyd, 1972). Effects on crops were also noted.

RESULTS

The scores from the 1974-5 experiment at Lewknor, where the doses were reduced logarithmically are illustrated in the figure. The results from the 1975-6 experiments are given in Table 3; for statistical reasons the data were subjected to a log 10 + 1 transformation but the detransformed data, as a percentage of the control, are also given.

In the 1974-5 experiment the crop grew vigorously and was always competitive with the A. ludoviciana and A. myosuroides.

Hoe 22870 gave excellent control of A. myosuroides at doses of 0.25 kg/ha and above when applied in the autumn or the spring and had no effect on the crop or A. ludoviciana. Hoe 23408 was effective on A. ludoviciana at doses above 1.0 kg/ha but was slightly less effective on A. myosuroides. There was also an indication of crop damage at 2.5 kg/ha and above.

Difenzoquat was ineffective on A. myosuroides and only the spring treatment at a dose above 1.25 kg/ha gave good control of A. ludoviciana. There were signs of crop damage above 2.5 kg/ha.

The recommended dose of isoproturon (2 kg/ha) controlled the A. myosuroides when used either in the autumn or the spring but a minimum of 4 kg/ha was required to control A. ludoviciana.

Putting the two Hoe compounds together produced a very effective combination. When the dose of Hoe 23408 was a constant 0.63 kg/ha as little as 0.13 kg/ha of Hoe 22870 was required to give almost complete control of A. myosuroides. This combination also gave good control of A. ludoviciana when applied in the autumn, but in the spring when the plants were larger a dose of 0.75 kg/ha Hoe23408 was necessary.

The mixtures of difenzoquat and Hoe 22870 were not very effective. The constant dose of 0.5 kg/ha of difenzoquat poorly controlled A. ludoviciana in this experiment, although it did not reduce the effectiveness of the Hoe 22870. However at higher doses, above 1.0 kg/ha of difenzoquat there were indications that the effectiveness of the spring application of Hoe 22870 on A. myosuroides was reduced.

Hoe 23408 and isoproturon were a useful combination in the autumn when a mixture of 0.63 kg/ha of Hoe 23408 and 1 kg/ha of isoproturon effectively controlled both weeds. The spring treatment, however, was not so effective on the A. ludoviciana although 1 kg/ha isoproturon with 1.25 kg/ha Hoe 23408 gave moderate control. The mixtures of difenzoquat and isoproturon were generally uneven in their effectiveness although autumn treatments with 1.0 kg/ha isoproturon plus 1.0 kg/ha difenzoquat or 2.0 kg/ha isoproturon plus 0.5 kg/ha difenzoquat gave good control of both grass weeds. Spring treatments were less effective although the addition of 1.0 kg/ha isoproturon increased the effectiveness of difenzoquat at 0.5 - 1.0 kg/ha.

In the 1975-6 experiments the treatments applied at Barnard Gate were very much more effective than those applied at Chicheley. Even the lowest dose of Hoe 23408 (0.25 kg/ha) in the autumn gave better than 90% control of A. ludoviciana and at a dose of 1.0 kg/ha the control of A. myosuroides was also excellent. However in the spring 2.0 kg/ha was required for adequate control, and both doses damaged the winter barley. At Chicheley the autumn treatments with Hoe 23408 were relatively ineffective on both A. fatua and A. myosuroides. In the spring excellent control of A. fatua was achieved with 1.0 kg/ha but control of A. myosuroides was poor even at 2.0 kg/ha.

Similarly 2.0 kg/ha of isoproturon in the autumn gave 95% control of both grass species at Barnard Gate and less than 70% control in the other experiment. The mixtures of 0.25 and 0.50 kg/ha isoproturon with 0.25 and 0.5 kg/ha Hoe 23408 were less effective on A. ludoviciana than 0.25 and 0.5 kg/ha of Hoe 23408 alone. At Chicheley the Hoe compound was relatively ineffective on A. fatua and A. myosuroides, with or without the addition of isoproturon, except for the spring treatment of 0.5 kg/ha Hoe 23408 plus 1.0 kg/ha isoproturon which was surprisingly more effective than the same dose of Hoe plus 2 kg/ha of isoproturon on A. fatua.

Difenzoquat which was applied only in the autumn gave 99% control of A. ludoviciana at Barnard Gate with 1.0 kg/ha but almost none with 0.5 kg/ha. The addition of 0.25 kg/ha of Hoe 23408 however increased the effectiveness of the 0.5 kg/ha dose to 100%. In contrast at Chicheley, 0.5 and 1.0 kg/ha of difenzoquat alone gave 84% and 82% control of A. fatua and effectiveness was reduced by the addition of Hoe 23408.

The addition of 1.0 and 2.0 kg/ha of isoproturon increased the effectiveness of 0.5 kg/ha of difenzoquat at Barnard Gate but reduced its effectiveness at Chicheley. Difenzoquat alone has little effect on A. myosuroides but the addition of 1.0 kg/ha increased the effectiveness of 0.5 kg/ha of Hoe 23408 at Barnard Gate although not at Chicheley. At Chicheley however difenzoquat increased the effectiveness of 2.0 kg/ha of isoproturon.

DISCUSSION

It is difficult to identify a common theme from these experiments except that the effectiveness of the individual herbicides varied considerably. No treatment with a single herbicide satisfactorily controlled both Avena spp and A. myosuroides at all three sites. Mixing the herbicides reduced the variability slightly but not always in a logical manner. One or two factors can however be identified as being relatively important. At Barnard Gate the soil was somewhat lighter, the crop was winter barley and competitive, and a high proportion of the A. ludoviciana had already emerged by the time the autumn treatments were applied. At Chicheley, in contrast the soil was heavier, the winter wheat thin and the A. fatua seedlings emerged in both the autumn and the spring. Thus at Barnard Gate all the autumn treatments with both soil and foliar acting compounds were relatively effective, whereas at Chicheley the soil acting compounds were relatively ineffective and the foliar acting herbicides applied in the autumn had no effect on the spring germinating plants.

Antagonism between compounds was variable and less logical. At Lewknor (see figure) mixtures of Hoe 23408 and isoproturon in the autumn of 1974 gave encouraging control of both grass species with little indication of antagonism, but in the autumn of 1975 at Barnard Gate isoproturon markedly reduced the effectiveness of Hoe 23408 on A. ludoviciana. On A. myosuroides the effects were more or less additive. Difenzoquat was similarly variable when it was mixed with Hoe 23408. However the addition of 0.5 kg/ha difenzoquat to 2.0 kg/ha isoproturon gave a mixture which although somewhat variable was the most consistently effective on the grass weeds in these experiments.

Finally, one of the objectives of the three experiments was to span as wide a range of the conditions experienced in winter cereals as possible, and many factors relating to the soil, crop, weed and weather varied very considerably. It is not surprising therefore that individual compounds were variable in activity, but it is disappointing that mixing the compounds did relatively little to reduce this variability.

Acknowledgements

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Table 2

Details of sites and stages of growth of crops and weeds when treated

Site, crop and soil type	Date of treatment	Stage of growth/no. of leaves on main stem and whether tillering (t)			State of	
		Crop	*Avena*	*Alopecurus*	Soil surface	Foliage
Lewknor, Oxon						
Winter wheat			*ludoviciana*	*myosuroides*		
cv Huntsman	6.12.74	2-2.5	1(0-3)	1.5(0-2)	moist	dry
sown 14.10.74						
clay loam	26.02.75	5-6(t)	5-5.5(0-6.25)(t)	4-5(3-6)(t)	moist	dry
with flints						
Barnard Gate, Oxon						
Winter barley			*ludoviciana*			
cv Maris Otter	4.11.75	4-4.25(t)	2.25-3(0-4.5)(t)	2.5-3(0-4)(t)	wet	wet
sown 22.9.75						
sandy, clay loam	27.02.76	5.75-6.5(t)	5.5-6.0(2-6.5)(t)	4.5-5.5(4-6)(t)	damp	dry
Chicheley, Bucks						
Winter wheat			*fatua*			
cv Maris Widgeon	10.12.75	2.5-3	1-2(0-2.5)	1.75-2.5(0-3)	moist	damp
sown 13.10.75						
clay loam	1.04.76	6-6.5(t)	4.5-5(1-6.5)(t)	2-3(2-7)(t)	v. dry	dry
with flints						

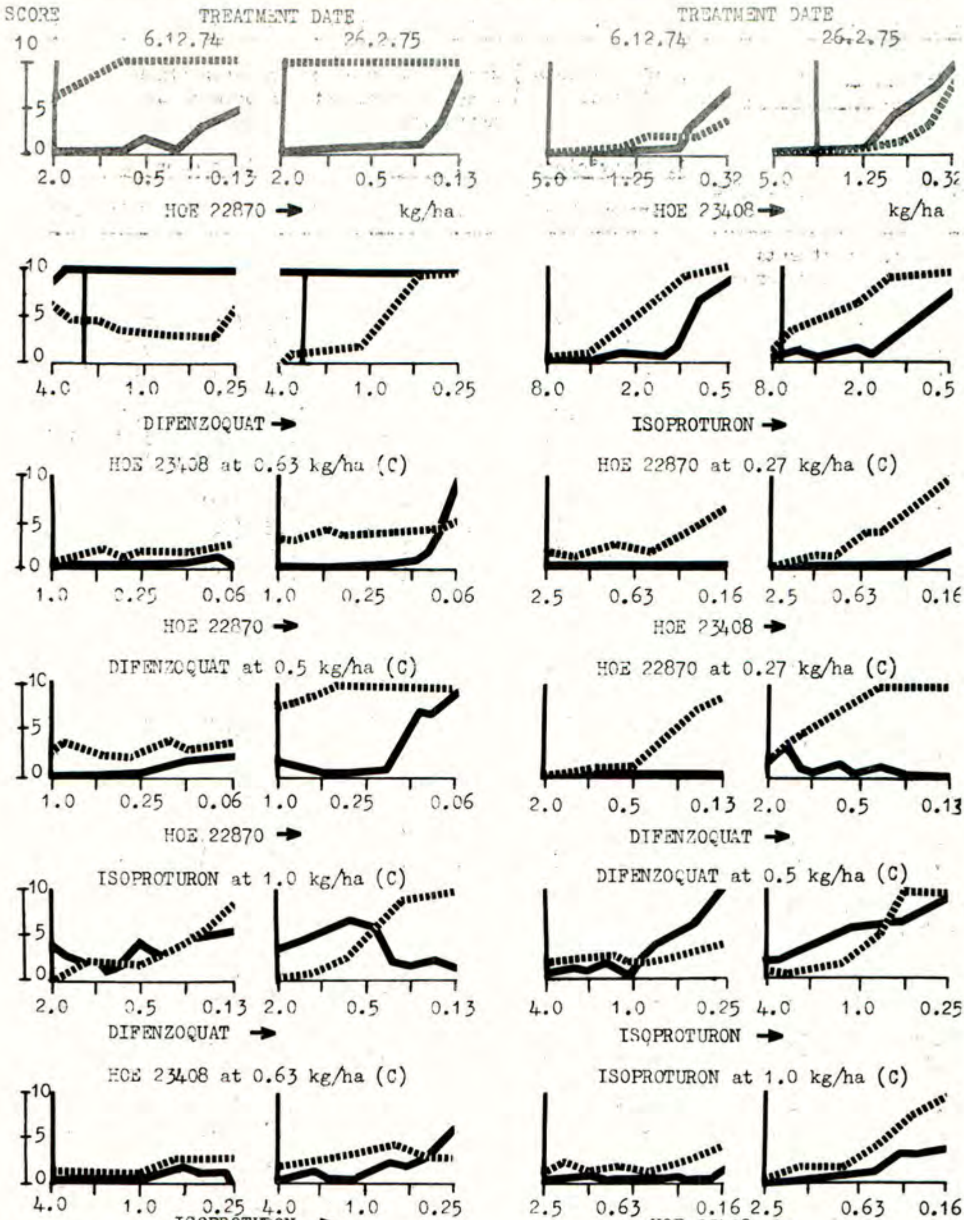
Table 3

Herbicide effects on mixtures of Avena spp & A. myosuroides in winter wheat & barley

Data:- Avena spp - no. of spikelets) subjected to a log transformation
A. myosuroides - no. of heads) detransformed data in parentheses as % of untreated

Herbicides in kg a.i./ha	A. ludoviciana Barnard Gate	A. fatua Chicheley	A. myosuroides Barnard Gate	A. myosuroides Chicheley
Autumn treatments				
Hoe 23408 + isoproturon				
0.25 + 0.00	3.80 (7)	4.27 (44)	3.76 (71)	3.89 (89)
0.50 + 0.00	2.71 (1)	4.35 (53)	3.28 (23)	3.78 (69)
1.00 + 0.00	2.54 (0)	4.38 (57)	2.46 (4)	3.28 (22)
0.25 + 0.25	4.40 (28)	4.24 (41)	3.36 (28)	3.76 (66)
0.25 + 0.50	4.30 (22)	4.37 (56)	3.31 (25)	3.81 (74)
0.50 + 0.50	4.03 (12)	4.46 (68)	3.00 (12)	3.71 (59)
0.00 + 0.25	5.03 (116)	4.34 (52)	3.80 (77)	3.97 (107)
0.00 + 0.50	4.99 (107)	4.65 (107)	3.78 (74)	3.85 (81)
0.00 + 1.00	4.71 (56)	4.06 (25)	3.65 (55)	3.10 (14)
0.00 + 2.00	3.66 (5)	4.46 (69)	2.63 (5)	3.46 (33)
difenzoquat				
0.00 + 0.50	4.89 (84)	3.83 (16)	3.88 (93)	4.01 (117)
0.00 + 1.00	2.68 (1)	3.88 (18)	3.81 (80)	3.96 (105)
0.25 + 0.50	2.41 (0)	4.23 (40)	3.54 (42)	3.89 (89)
0.50 + 1.00	2.91 (1)	4.35 (54)	2.71 (6)	3.72 (60)
isoproturon				
1.00 + 0.50	3.25 (2)	4.18 (36)	3.68 (59)	3.61 (47)
2.00 + 0.50	3.36 (3)	4.05 (27)	2.58 (5)	2.87 (8)
Spring treatments				
Hoe 23408 + isoproturon				
1.00 + 0.00	4.41 (28)	2.93 (2)	3.45 (35)	3.84 (79)
2.00 + 0.00	3.74 (6)	2.80 (1)	2.48 (4)	3.62 (48)
0.50 + 1.00	4.83 (75)	3.51 (8)	2.98 (12)	3.81 (74)
0.50 + 2.00	4.69 (54)	4.01 (24)	1.97 (1)	3.47 (34)
0.00 + 1.00	5.06 (127)	4.69 (116)	3.07 (14)	3.84 (79)
0.00 + 2.00	4.74 (61)	4.44 (65)	1.77 (1)	3.54 (40)
Untreated	4.96 (100) 3320/m²	4.62 (100) 1536/m²	3.91 (100) 668/m²	3.94 (100) 724/m²
LSD trt./trt.	0.536	0.285	0.449	0.199
trt./untrt.	0.409	0.218	0.343	0.152

Control of A. ludoviciana and A. myosuroides in W. Wheat with herbicide mixtures



▪▪▪▪▪▪▪ = A. LUDOVICIANA

——— = A. MYOSUROIDES

| = DOSE AT WHICH CROP NORMAL

(C) = CONSTANT DOSE) IN KG/HA
➔ = LOGGED DOSE)

BROAD-SPECTRUM WEED CONTROL IN WINTER AND SPRING CEREALS WITH ISOPROTURON/HYDROXYBENZONITRILE MIXTURES

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Summary Trials carried out in the UK during 1974-76 have shown isoproturon/hydroxybenzonitrile mixtures to be effective post-emergence herbicides for winter and spring cereal use.

The addition of 300g a.i./ha hydroxybenzonitriles to 1.75kg a.i./ha isoproturon maintained control of isoproturon-susceptible species which include *Alopecurus myosuroides*, *Matricaria* spp and *Stellaria media* whilst adding to the weed range hydroxybenzonitrile-susceptible weeds such as *Polygonum* spp., *Raphanus raphanistrum* and *Veronica* spp.

The mixture at weed control dose rates was safe in a wide range of winter and spring cereal varieties. Occasional early phytotoxicity (slight scorching) did not result in yield loss.

Résumé Les essais réalisés au Royaume-Uni, durant 1974-76, ont demontré l'efficacité des associations isoproturon/hydroxybenzonitriles, utilisés en pré et post-levée sur céréales d'hiver et de printemps.

L'addition de 0.3 kg m.a./ha d'hydroxybenzonitriles à 1.75 kg m.a./ha d'isoproturon a ete efficace contre les adventices sensibles à l'isoproturon comme *Alopecurus myosuroides*, *Matricaria* spp et *Stellaria media*, et en même temps a permis de maituser des adventices sensibles aux hydroxybenzonitriles, comme *Polygonum* spp., *Raphanus raphanistrum* et *Veronica* spp.

Le mélange, aux doses d'emploi, qui maituse les adventices, est selectif sur de nombreuses variétés de céréales d'hiver et de printemps.

La phytotoxicité, précoce, et occosionnelle (brûlure légere) ne diminue pas le rendement.

INTRODUCTION

Work carried out in France in 1972-73 (Rognon *et al*, 1972, Cochet *et al*, 1973) and in the UK in 1974 (Hewson, 1974) showed isoproturon to be well tolerated by winter cereals at dose rates giving excellent control of *Alopecurus myosuroides* and a range of annual broad-leaved weeds including *Matricaria* spp and *Stellaria media* with suppression of *Avena* spp. Isoproturon, as 'Tolkan' is at present marketed in the UK by May & Baker Ltd for pre- and post-emergence use in winter cereals but there are weaknesses in the weed control spectrum, notably the poor control of *Galium aparine*, *Polygonum* spp, *Raphanus raphanistrum* and *Veronica* spp.

The weed control spectra of isoproturon and the hydroxybenzonitriles are complementary. In early work in cereals a mixture of ioxynil and bromoxynil proved more effective than equivalent dose rates of ioxynil or bromoxynil alone (Wilson et al, 1968). Work with isoproturon/hydroxybenzonitrile mixtures commenced in the late spring of 1974 and initially hydroxybenzonitrile salts and esters with isoproturon were compared. These mixtures showed similar weed control activity but the isoproturon/hydroxybenzonitrile salt mixtures were safer in spring cereals and work with hydroxybenzonitrile esters was discontinued and does not feature in this report.

The majority of the work was carried out in S.E.England on a range of soil types.

METHOD AND MATERIALS

Materials and Formulations

Common name	Formulation
isoproturon	50% w/w w.p.
ioxynil Na salt	5% w/v a.c.
bromoxynil K salt	5% w/v a.c.
isoproturon + ioxynil Na salt + bromoxynil K salt 12:1:1	35% w/v suspension concentrate (ARD 12/61)
chlortoluron	80% w/w w.p.
barban + iso-octyl esters of MCPB mecoprop and dichlorprop	details not available

Isoproturon/hydroxybenzonitriles tank mix was used in 1974, the formulation (ARD 12/61) was used in 1975-76.

Spraying and assessments

Weed Control Experiments

	No. of sites		
	W.cereals	S.cereals	
1974	5	5	Small plot (2.5 x 10m) 3 replicates per treatment
1975	24	-	Small plot (2.5 x 10m) 3 replicates per treatment
1976	-	14	Small plot (2.5 x 10m) 4 replicates per treatment
1976	9	-	Farmer sprayed, non-replicated trials

At all sites weed counts were made in three 0.5m^2 quadrats in each plot.

Both plant numbers and height were recorded.

Cereal tolerance (yield) experiments

	No. of sites		
	W.cereals	S.cereals	
1974	4 wheat	4 barley	Small plot (2.5 x 15m) 3 replicates per treatment
1975	6 wheat 3 barley	-	Small plot (2.5 x 15m) 3 replicates per treatment
1976	3 wheat 2 barley	5 wheat 3 barley	Small plot (2.5 x 15m) 4 replicates per treatment

Yields were obtained with a 1.83m cut self-propelled combine, and corrected to 85% d.m.

In addition, an experiment was carried out in each of the three years to establish the tolerance of a wide range of winter and spring wheat and barley varieties. Individual variety plots were 2.5 x 3.7m with three replicates per treatment. All varieties sprayed early post-emergence (i.e. 2 leaves - early tillering). These experiments were examined at 1 and 2 weeks post spraying and thereafter at 1 month intervals for leaf damage and at a later stage for effect on crop height and ear malformation. A variety was considered tolerant to isoproturon/hydroxybenzonitriles when an E.W.R.C. crop safety score of three was not exceeded during the growing period and when no crop height reduction or ear malformation occurred.

All weed control and tolerance sites were sprayed at 250 l/ha and 1.38 bars with a small plot precision sprayer.

RESULTS

The often slow activity of isoproturon on weeds (dependent on weather conditions) is accelerated by hydroxybenzonitrile addition. This applies to both grasses and broad-leaved weeds. The visible effects of the isoproturon-hydroxybenzonitrile mixture on weeds consists initially of a growth check followed by progressive necrosis.

When crop damage occurred this consisted of slight scorch (small necrotic lesions) on older leaves.

DISCUSSION

Winter cereal weed control

The addition of hydroxybenzonitrile to isoproturon did not affect the degree of *Alopecurus myosuroides* control normally obtained with isoproturon alone, 1.5 + 0.25 kg a.i./ha giving good control (Table 1). Hydroxybenzonitrile addition to isoproturon improved *Avena fatua* suppression by a further 10% but this still fell short of commercially acceptable control. The apparent poor control of *Poa annua* by all treatments in 1974 was due to other weeds reducing the unsprayed control *Poa* population.

The excellent isoproturon control of *Chrysanthemum segetum*, *Stellaria media* and *Tripleurospermum maritimum* spp *inodorum* was maintained with hydroxybenzonitrile addition and the good control of *Papaver rhoeas* and *Sinapis arvensis* normally achieved with isoproturon was improved. Hydroxybenzonitrile addition gave control of the moderately isoproturon-resistant *Polygonum* spp and *Veronica* spp when these weeds were fully germinated, and also achieved some suppression of *Galium aparine*.

Winter cereal crop tolerance

All varieties tested at a wide range of growth stages tolerated isoproturon/hydroxybenzonitrile at dose rates in excess of those necessary for weed control (Tables 3 and 4). High yield increases obtained in our trials are indicative of excellent control of competitive weeds, in particular *A.myosuroides*.

Spring cereal weed control

Avena fatua was suppressed if sprayed before tillering (Table 2).

The control of isoproturon-susceptible species was again maintained with hydroxybenzonitrile addition and control of *Fumaria officinalis*, *Polygonum* spp, *Raphanus raphanistrum* and *Veronica* spp achieved.

RESULTS

Table 1

Mean % control of weed numbers, Winter cereals, 1974-76

Species	Year	Weed growth stage and number of sites		Isoproturon + HBN salts 1.5+0.25	Isoproturon + HBN salts 1.75+0.30	Isoproturon 1.5	Isoproturon 2.0	Chlortoluron 2.7
				Compound and dose rate (kg a.i./ha)				
Alopecurus myosuroides	1974	2-26 tillers	1	79	-	71	76	75
	1975	0-8 tillers	15	83	86	83	91	87
	1976	4-10 tillers	5	85	85	-	95	-
Avena fatua	1974	0-6 tillers	2	38	-	29	49	31
	1975	0-3 tillers	12	59	53	47	61	57
	1976	0-3 tillers	4	65	75	-	-	-
Poa spp	1974	7cm	1	38	-	54	0	53
	1975	0-5 tillers	5	85	89	93	89	91
	1976	3cm	1	70	93	-	93	-
Chrysanthemum segetum	1975	2-7 leaves	2	99	99	100	100	86
Galium aparine	1974	8-18cm	1	68	-	26	9	43
	1975	1-10cm	8	45	49	15	9	58
	1976	up to 20cm	2	33	65	-	-	-
Papaver rhoeas	1974	1-5cm	1	99	-	70	82	74
	1975	Pre-em-8cm	3	99	99	93	99	89
	1976	4-12cm	2	98	98	-	-	-
Polygonum aviculare	1975	pre-em-Cot.	4	22	33	16	28	97
	1975	1-5 leaves	2	81	92	60	70	94
Polygonum convolvulus	1975	pre-em-Cot.	7	19	7	21	10	47
	1975	2-4 leaves	1	100	100	93	71	100
	1976	2-3 leaves	1	98	98	-	-	-
Polygonum persicaria	1975	pre-em-Cot.	2	0	5	0	0	58
	1975	2-3 leaves	1	100	100	85	96	100
	1976	2-3 leaves	1	98	98	-	-	-
Sinapis arvensis	1975	Cot.-flower	5	97	95	75	90	83
Stellaria media	1974	2-13cm	4	98	-	98	99	99
	1975	1-15cm	9	97	98	98	99	99
Tripleurospermum maritmum ssp inodorum	1974	5-15cm	2	99	-	96	99	89
	1975	1-8cm	9	100	100	99	99	98
	1976	5-15cm	2	98	98	-	-	-
Veronica spp	1975	pre-em-3 lvs	1	53	32	38	60	54
	1975	5-14cm	3	96	96	66	47	94
	1976	4 lvs-10cm	6	94	92	-	-	-

In the following table (Table 2) weed control in spring cereals is presented. In 1976 Anagallis arvensis, Aphanes arvensis, Atriplex patula, Chenopodium polyspermum, Polygonum hydropiper and P. lapathifolium (one occurrence each) were very susceptible to the rates of isoproturon/hydroxybenzonitriles quoted in the table. The lower mean % control of P.convolvulus and P.persica was due to prolonged germination in dry conditions on organic soils which necessitated repeat sprayings of cereals by many farmers.

Table 2

Mean % control of weed numbers, Spring cereals, 1974-76

Species	Year	Weed growth stage and number of sites		Isoproturon + HBN salts 1.5+0.25	Isoproturon + HBN salts 1.75+0.30	Isoproturon 1.5	Isoproturon 2.0	Bromoxynil + Ioxynil + 2,4-DP esters 0.77
				Compound and dose rate (kg a.i./ha)				
Avena fatua	1974	1-9 tillers	1	17	-	8	36	-
	1976	0-4 tillers	5	45	50	-	-	22
Poa annua	1976	1-4 leaves	1	55	61	-	-	0
Capsella bursa-pastoris	1976	3-6 leaves	1	100	100	-	-	100
Chenopodium album	1974	4 lvs-11cm	2	100	-	94	99	-
	1976	Cot.-6 lvs	7	99	99	-	-	99
Chrysanthemum segetum	1974	9 cm	1	81	-	94	100	-
	1976	Cot.-7 lvs	3	98	98	-	-	64
Fumaria officinalis	1974	up to 11cm	1	100	-	76	42	-
Galeopsis spp	1976	Cot.-6 lvs	3	83	87	-	-	52
Galium aparine	1974	up to 13cm	1	75	-	31	16	-
	1976	Cot.-7cm	3	49	77	-	-	79
Matricaria recutita	1974	9cm	1	100	-	100	100	-
	1976	Cot.-12 lvs	7	100	100	-	-	91
Myosotis arvensis	1976	2-5 lvs	1	58	92	-	-	86
Papaver rhoeas	1976	2-13 lvs	2	100	100	-	-	97
Polygonum aviculare	1974	up to 9cm	1	81	-	47	69	-
	1976	Cot.-5 lvs	8	87	94	-	-	74
Polygonum convolvulus	1974	up to 13cm	2	99	-	45	64	-
	1976	Cot.-3 lvs	8	89	92	-	-	94
Polygonum persicaria	1974	up to 8cm	1	99	-	91	100	-
	1976	Cot.-3 lvs	4	70	73	-	-	65
Raphanus raphanistrum	1974	up to 8cm	1	94	-	57	39	-
	1976	2-many lvs	2	83	88	-	-	83
Sinapis arvensis	1976	Cot.-4 lvs	1	99	100	-	-	99
Spergula arvensis	1976	4-10 lvs	1	100	100	-	-	72
Stellaria media	1974	up to 20cm	4	99	-	98	99	-
	1976	Cot.-8cm	5	99	99	-	-	77
Urtica urens	1976	Cot.-4 lvs	2	94	92	-	-	83
Veronica persica	1974	4-13cm	1	58	-	0	86	-
	1976	Cot.-6cm	4	93	93	-	-	94
Viola arvensis	1974	Cot.-2 lvs	1	100	-	59	100	-
	1976	Cot.-4 lvs	5	49	66	-	-	90

Spring cereal crop tolerance

The isoproturon/hydroxybenzonitriles mixture was well tolerated by all spring cereal varieties tested (Table 4) with the possible exception of Sappo spring wheat. This variety tolerated the mixture in three of the four sites sprayed but gave noticeable early damage on one site which did not however result in yield loss (Table 3, 1st Sappo site).

Table 3

Effect on yields of cereals of isoproturon/hydroxybenzonitrile mixtures
(Treatment yield expressed as percentage of unsprayed control yield)

Crop and year of work		Variety	Crop Growth stage	weeds/m^2 on control	Isoproturon + HBN salts 1.5+ 0.25	Isoproturon + HBN salts 1.75+ 0.30	Iso-proturon 2.0	Standard	Unsprayed Control Yield dt/ha
W.wheat	1974	Capelle	1-5 tillers	105	120*	-	114	106	35.1
		Champlein	1-4 tillers	112	106	-	104	98	56.4
		Flinor	1-3 tillers	284	187	-	208	150	19.3
		Flinor	1-3 tillers	87	103	-	104	113	66.5
	1975	Champlein	1 leaf	57	104	104	97	106	53.9
		Champlein	3-5 tillers	75	110	119	131	127	47.4
		Champlein	4-6 tillers	91	111	109	103	89	43.7
		Flinor	Pre-em	42	104	111	104	111	50.3
		Flinor	2-4 lvs	245	124	135	139	120	37.2
		Flinor	4-5 tillers	41	126	125	130	119	38.6
	1976	Bouquet	2-3 tillers	86	104*	105*	104*	102	42.2
		M.Fundin	2-3 tillers	6	98	99	98	92	37.3
		M.Huntsman	5-6 tillers	42					
W.barley	1975	M.Otter	2 lvs	7	97	112	110	109	51.9
		M.Otter	2-3 lvs	185	99	108	116	129	23.6
		M.Otter	3-4 tillers	205	104	120	88	92	25.1
	1976	M.Otter	3-4 tillers	9	98	99	93	94	51.5
		M.Otter	1-5 tillers	8	105	106	104	100	50.3
S.wheat	1976	Sappo	3 lvs - 2 tillers	66	103	103	-	-	38.7
		Sappo	2-3 tillers	75	104	98	-	-	55.6
		Sappo	2-3 tillers	96	100	96	-	-	46.4
S.barley	1974	Julia	1-4 tillers	340	91	-	85	107	36.2
		M.Mink	2-5 tillers	342	97	-	95	98	45.9
		Vada	1-3 lvs	225	111	-	118	111	23.0
	1976	M.Mink	3-5 tillers	39	100	100	-	-	44.0
		M.Mink	2-4 tillers	413	109	104	-	107	26.3
		Sultan	3-5 tillers	280	94	92	-	94	41.3
		Sultan	2-4 tillers	56	113	114	-	117	23.5
		Tern	3-5 tillers	115	99	92	-	90	15.4

* Significantly different from control at the 5% level.

Standard - Winter cereals - Chlortoluron 2.7 kg a.i./ha
Spring cereals - Barban 0.3 kg a.i./ha + iso-octyl esters of mecoprop, MCPB and dichlorprop.

Table 4

Summary of cereal variety tolerance trials 1974-76

Varieties tolerating Isoproturon+hydroxybenzonitrile 2.0 + 0.33 kg a.i./ha

Winter Wheat	Bouquet Cappelle-Desprez Champlein Flinor	Maris Hobbit Maris Huntsman Maris Nimrod Maris Ranger	Maris Widgeon West Desprez
Winter Barley	Astrix	Maris Otter	Mirra
Spring Wheat	Kleiber Sirius	Maris Butler Maris Dove	
Spring Barley	Abacus Aramir Armelle Berac Hassan	Imber Julia Lofa-Abed Maris Mink Mazurka	Proctor Sultan Wing Vada Zephyr

Weed control conclusions

Weed control is expressed in Tables 1 & 2 as percentage control of plant numbers, which does not take account of the reduction in the bulk of surviving weeds given by isoproturon/hydroxybenzonitriles. This can be generally demonstrated by the following figures, in which numbers vs bulk control are compared over all 1976 spring cereal trials (isoproturon/hydroxybenzonitriles 1.5 + 0.25 kg a.i./ha, 14 sites, 25 annual grass and broad-leaved weeds).

Percentage control of numbers - 80%

Percentage control of bulk - 96%

This is further taken into consideration in Table 5.

Table 5

Susceptibility of main weed species - 1974-76

Species	Compound and dose rates (kg a.i./ha)					
	Winter cereals			Spring cereals		
	Isoproturon + HBN salts		Isoproturon	Isoproturon + HBN salts		Isoproturon
	1.5+ 0.25	1.75+ 0.30	1.75	1.5+ 0.25	1.75+ 0.30	1.75
Alopecurus myosuroides	S	S	S	-	-	-
Avena fatua	MR	MR	MR	R	MR	MR
Poa annua	MS	S	S	-	-	-
Chenopodium album	-	-	-	S	S	S
Chrysanthemum segetum	S	S	S	S	S	S
Fumaria officinalis	-	-	-	S	-	-
Galeopsis spp	-	-	-	S	S	-
Galium aparine	MR	MR	R	MR	MS	MR
Matricaria recutita	-	-	-	S	S	S
Papaver rhoeas	S	S	S	S	S	S
Polygonum aviculare	S	S	MR	S	S	MR
P. convolvulus	S	S	MS	S	S	MS
P. persicaria	S	S	MS	S	S	MS
Raphanus raphanistrum	-	-	-	S	S	R
Sinapis arvensis	S	S	MS	S	S	S
Stellaria media	S	S	S	S	S	S
Tripleurispermum maritimum ssp inodorum	S	S	S	-	-	-
Urtica urens	-	-	-	S	S	-
Veronica spp	S	S	MR	S	S	MR

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CONTROL OF PROBLEM WEEDS IN CEREALS WITH 3,6-DICHLOROPICOLINIC ACID AND MIXTURES WITH PHENOXY HERBICIDES

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Summary 3,6-dichloropicolinic acid is a new post-emergence growth regulator herbicide with selectivity to cereals, maize, sorghum, flax, grasses and brassica crops. Combined with phenoxy herbicides at dose rates from 0.05 - 0.1 Kg/ha it controlled resistant Compositae weeds in cereal crops and improved the control of *Polygonum* species. Application to cereals at growth stages from one leaf to second node formation did not result in crop phytotoxicity. Dissipation of soil residues were considerably more rapid than for the structurally related product picloram and showed an average half life of 73 days in laboratory soil studies.

Résumé L'acide 3,6-dichloropicolinique est un nouvel herbicide de post levée avant les propriétés d'un regulateur de croissance. Il s'est montré sélectif des cultures de céréales, maïs, sorgho, lin, graminées et crucifères. Associé aux phénoxy-herbicides à des doses allant de 50 a 100 g/ha, il assure la destruction des composées résistantes dans les cultures céréalières et améliore l'efficacité à l'égard des polygonacées. Sa sélectivité s'avère aussi remarquable sur les céréales traitées depuis le stade une feuille jusqu'à la formation du deuxième noeud. La dégradation des résidus de cet herbicide dans le sol est considérablement plus rapide que pour celle du piclorame auquel sa structure s'apparente. Les études réalisées au laboratoire ont montré que sa demi-vie était en moyenne de 73 jours.

INTRODUCTION

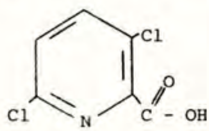
Major use of phenoxy herbicides in cereal crops during the last thirty years has created resistant broad-leaf weed populations generally controlled by herbicide mixture products. These products often fail to adequately control composite species and may be phytotoxic resulting in lowered grain yield. A new growth regulator material 3,6-dichloropicolinic acid is described which in mixture with phenoxy herbicides effectively controls most Compositae whilst also having a wide safety margin to cereal crops.

3,6-dichloropicolinic acid induces auxin type responses in growing plants, severe epinasty and fasciation of the crowns and leaf petioles of *Matricaria spp*. are particularly characteristic. It is absorbed by roots and foliage and is readily translocated throughout the plant. Maximum herbicidal response to foliage applications have been obtained in actively growing plants. The chemical is not metabolised within green plants and application under adverse growing conditions has often led to satisfactory weed control once active growth recommenced. Post-emergence application at growth stages between 1 leaf and second node formation to a large number of wheat, barley and oat varieties has not given rise to phytotoxicity or ear malformation. In use, application timing is dependent upon normal recommendations for the other phenoxy mixture components and also on the stage of weed growth. 3,6-dichloropicolinic acid in common with most herbicides has the greatest effect on weeds up to the small-plant stage.

3,6-dichloropicolinic acid under the code number DOWCO* 290 is under development in many European countries for control of resistant weeds in a number of crops. It was introduced into the U.K. cereal market in 1976 in combination with mecoprop and also in oil seed rape in combination with benazolin. The product alone has also been commercialised in Sweden for control of Matricaria spp. in oil seed rape. This paper briefly describes some of the properties of 3,6-dichloropicolinic acid, specific market developments are described by Haagsma (1975), Engstrom (1976), Gummesson (1976), Naish (1975), Gilchrist and Page (1976) and Mayes et al (1976).

METHOD AND MATERIALS

3,6-dichloropicolinic acid has the following structure and properties:-



Molecular weight	:	192.
Physical state	:	White, odourless, crystalline solid.
Melting point	:	151 - 152°C.
Vapour pressure	:	1.2 X 10^{-5}_{mm} Hg at 25°C.
Solubility at 25°C	:	Approximately 1000 ppm in water, greater than 25% W/W in methanol, acetone and xylene.

Toxicology

In toxicity tests 3,6-dichloropicolinic acid administered as the technical material showed the following:-

Acute toxicity

Acute oral LD50 male rat	> 5000 mg/kg
female rat	4300 mg/kg
Acute dermal LD50 rabbit	> 2000 mg/kg
Skin irritancy rabbit	slight
Eye irritancy rabbit	The technical material is a severe eye irritant if not washed promptly from the eye.

Toxicity to birds

8 day dietary LC50 values

Mallard duck	> 4640 ppmw
Bobwhite quail	> 4640 ppmw

* Trademark of The Dow Chemical Company.

Toxicity to fish

LC50 values at 96 hours

Rainbow trout	103.5 mg/litre of water
Bluegill	125.4 mg/litre of water

In glasshouse and field experiments 3,6-dichloropicolinic acid was used as a 300 g/l.a.e. monoethanolamine salt formulation; mecoprop, dichlorprop and picloram as commercially available potassium salt formulations. For glasshouse evaluations plants were grown in soil-less compost and treatments applied by standard moving nozzle or moving belt sprayers. Design of field experiments occasionally varied between locations, but most utilised $25m^2$ plots in a randomised block design with 3 - 5 replicates. Treatments were applied by knapsack sprayer with spray pressure of 2.76 bar and application volume 337 l/ha. Weed counts were made by random placement of 25 X 25cm quadrants.

Soil residues were determined using two bioassay techniques. One method followed that of Allot and O'Neill (1970) where lettuce were transplanted at their third true leaf stage into soil to be bioassayed and the plants allowed to grow until the eighth true leaf stage when assessment by visual and fresh weight determination was made. The second technique was employed for soil cores, where each core was split lengthwise and seeded with lettuce.

In laboratory leaching studies soil cores, hand packed according to the method of Weber (1971), were treated with herbicide applied in aqueous solution to their upper surfaces. Leaching was promoted by application of a precise daily aliquot of water to the upper surface of each soil core. Leaching of herbicide was measured by bioassay as described.

In field studies leaching depth was measured on soil cores taken from each plot by means of a metal tube with removable inner 7cm. diameter plastic liner which was driven into the soil to the required depth.

Composition of the soils used in field leaching studies were as follows: sandy loam 2.4% O.M., 17.0% clay + silt, 80.6% sand; clay 2.3% O.M., 39.2% clay + silt, 53.5% sand.

RESULTS

Biological Performance

Initial post-emergence greenhouse evaluation of 3,6-dichloropicolinic acid on a range of weeds (Table 1) showed promising activity on Compositae and moderate activity on Polygonaceae; Solanaceae and Chenopodiaceae were moderately resistant. Little to no efficacy was demonstrated against Papaveraceae and Caryophyllaceae, whilst Cruciferae, Rubiaceae and Gramineae appeared to be tolerant.

Table 1

Summary of Post-emergence glasshouse evaluations of 3,6-dichloropicolinic acid

Assessment 17 - 21 days   4 = death 1 = no effect

Weed Species	Stage of growth (No of leaves)	3,6-dichloropicolinic acid (g/ha)			
		25	50	100	250
Matricaria chamomilla	4	-	3	3	3
Tripleurospermum maritimum ssp inodorum	6 - 8	2	3	3	3
Senecio vulgaris	1 - 2	2	3	3	3
Galinsoga parviflora	1	3	4	4	4
Rumex acetosella	1 - 2	2	2	3	-
Polygonum aviculare	4	1	1	2	2
P. lapathifolium	4	1	3	3	3
P. convolvulus	2 - 3	2	3	3	3
Amaranthus retroflexus	Cotyledon	1	1	1	1
Solanum nigrum	1 - 3	1	2	2	3
Stellaria media	2 - 4	1	1	1	1
Cerastium holosteoides	2 - 4	1	1	1	-
Galium aparine	2 - 3	1	1	1	2
Urtica urens	2 - 4	1	1	2	-
U. dioica	1	-	1	1	1
Papaver rhoeas	5 - 7	1	1	1	-
Anchusa arvensis	2 - 4	1	1	1	-
Capsella bursa-pastoris	4 - 6	1	1	1	-
Sinapis arvensis	2	1	1	1	-
S. alba	Cotyledon	-	1	1	1
Avena fatua	1	-	1	1	1
Alopecurus myosuroides	1	-	1	1	1
Panicum miliaceum	1 - 2	-	1	1	1

Results from more than 50 research trials in a number of countries during 1973-74 confirmed the greenhouse conclusions and showed the following weed species to be susceptible to 3,6-dichloropicolinic acid at rates of use from 50 - 100 g/ha:-

Anthemis cotula
Bifora radians
Centaurea cyanus
Chrysanthemum segetum
Cirsium arvense
Matricaria matricarioides
Polygonum persicaria
P. lapathifolium
P. convolvulus
Senecio vulgaris
Sonchus oleraceus
Trifolium pratense
T. repens
Tripleurospermum maritimum ssp inodorum
Tussilago farfara
Vicia sativa

Continuing field development has demonstrated that all Compositae and legume species encountered were highly susceptible; of the common Polygonum species P. aviculare was the most resistant, whilst P. convolvulus the most susceptible species.

An unexpected finding during the development of phenoxy-propionic mixture combinations for use in cereals was the considerable enhancement of herbicidal activity shown particularly against Compositae. The degree of enhancement illustrated in Table 2 enabled a reduction in use rate of the mixture components to a level below that which would provide commercial weed control with the individual component alone. Similar synergistic responses have also been noted in mixture with a range of other herbicides.

Table 2

Percentage reduction of Mayweeds in winter barley var Maris Otter

Mecoprop/3,6-dichloropicolinic acid tank mix

Mecoprop g/ha a.e.	3,6-dichloropicolinic acid (g/ha) 0	30	50	70	90
0	0	2	39	66	78
560	24	37	68	91	100
1120	35	70	96	100	100
2240	43	96	100	100	100
2800	51	82	100	100	100

Dichlorprop/3,6-dichloropicolinic acid tank mix

Dichlorprop g/ha a.e.	3,6-dichloropicolinic acid (g/ha) 0	30	50	70	90
0	0	8	63	76	86
560	17	59	80	96	100
1120	16	70	80	99	99
2240	58	87	97	100	100
2800	40	97	100	100	100

* Initial population 700 - 800 plants/m^2 predominantly Tripleuropsermum maritimum ssp inodorum but Anthemis cotula and Matricaria matricarioides also present. Stage of weed growth 6 - 12 leaves, crop fully tillered.

Soil behaviour and persistence

In soils, 3,6-dichloropicolinic acid exists primarily as a salt because of its low equilibrium constant (pka 2.33) and is therefore subject to leaching. Laboratory tests using soil columns have indicated a decreasing rate of leaching as follows:- Loamy course sand = sandy loam > peat > silty loam.

In a field experiment carried out under conditions of low rainfall 3,6-dichloropicolinic acid applied to a clay soil leached less than the related product picloram as measured by a lettuce bioassay method (Table 3). In a separate experiment soil residues from application of 3,6-dichloropicolinic acid at 100, 200 and 400 g/ha to a sandy loam soil were detected at 22 days to a depth of 15cm, whilst a trace residue (< 0.01 ppmw) was found at 30cm, 150 days after application of the 400 g/ha rate.

Table 3

Depth of leaching of 3,6-dichloropicolinic acid in clay soil 29 days after application

Treatment	Dose (g/ha)	Depth of leaching (cm)
3,6-dichloropicolinic acid	100	2.2
	200	3.3
	400	6.5
picloram	25	6.3

Soil studies have shown that 3,6-dichloropicolinic acid is biodegraded. In sterile soil no degradation occurred; whilst half life of C^{14} labelled material varied from 317 days in air dried soil to 37 days at a moisture content 30% of field capacity. Under controlled temperature and moisture conditions soil degradation proceeded at constant rate such that half life of 0.25 and 1.0 ppm was 35 and 118 days respectively. From laboratory studies an average half life of 73 days was postulated. This work continues under field conditions and to date it has been shown that carry over of soil residues to crops following cereals is unlikely to occur.

DISCUSSION

In common with other growth regulator materials the speed of action of 3,6-dichloropicolinic acid was found to be directly related to prevailing growth conditions. However, the rapid translocation within green plants and their inability to metabolise the compound suggest that final weed control may be independent of adverse weather conditions following application.

3,6-dichloropicolinic acid showed excellent activity on the Compositae and this was enhanced by admixture with phenoxy herbicides such that most species had similar sensitivity to the product at 50 - 100 g/ha a.e. Susceptibility of some Compositae weeds decreased with increasing age thus Senecio vulgaris was only moderately susceptible beyond the four leaf stage of growth, mayweeds appeared susceptible at most growth stages as was Cirsium arvense (root kill has also been reported for this weed). Of the Polygonum species encountered P. convolvulus was the most susceptible, control of P. lapathifolium and P. persicaria was variable and appeared related to plant growth stage. Control of P. aviculare was related to leaf characteristics such that only broad leaf sub-species were susceptible and then at the two - four leaf stage only.

3,6-dichloropicolinic acid has shown outstanding selectivity to cereal crops when applied over a wide range of growth stages and should form a useful mixture component particularly for control of Compositae weeds.

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DEVELOPMENT OF 3,6-DICHLOROPICOLINIC ACID + MECOPROP MIXTURES FOR SELECTIVE BROAD-LEAF WEED CONTROL IN CEREALS IN THE U.K.

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Summary 3,6-dichloropicolinic acid is a new herbicide selective in graminaceous crops with potent activity against Compositae weeds and useful activity against other weed families such as the Polygonaceae. Because of its limited spectrum of weed control, formulated mixtures with phenoxy herbicides have been developed for wide spectrum broad-leaf weed control in cereals.

One such mixture of 3,6-dichloropicolinic acid + mecoprop which was introduced commercially in 1976 has given excellent control of most of the major weeds of winter cereals in the U.K., with a tendency to out-yield standard winter cereal herbicides. This mixture has shown particularly selective crop safety characteristics at double dose rates in relatively weed free crops.

Two formulated mixtures coded EF 268 (3,6-dichloropicolinic acid + mecoprop + 2,4-D) and EF 269 (3,6-dichloropicolinic acid + mecoprop + MCPA) were developed for use in spring cereals. Both have given effective wide spectrum broad-leaf weed control, comparable to commercial standards.

Résumé L'acide 3,6-dichloropicolinique nouvel herbicide selectif des cultures de graminées a une éfficacité remarquable sur les Composées mais également bonne sur d'autres familles de mauvaises herbes telles que les Polygonacées. En raison de son spectre herbicide limité ce sont des formulations où il est en mélange avec des herbicides phenoxy qui ont été développées afin d'obtenir un large spectre d' éfficacité sur les mauvaises herbes dicotyledones dans les céréales.

Une telle formulation introduit commercielement en 1976 contenant acide 3,6-dichloropicolinique et mécoprop a eu une excellente éfficacité sur la plupart des principales mauvaises herbes des céréales d'hiver en Grande Bretagne. Sa sélectivité a l'égard de la culture s'est montrée particulièrement bonne et les rendements ont été fréquemment meilleurs que ceux obtenus avec les références du commerce.

Deux formulations - EF 268 (acide 3,6-dichloropicolinique et mécoprop plus 2,4-D) et EF 269 (acide 3,6-dichloropicolinique et mécoprop plus MCPA) sont développées sur céréales de printemps. Toutes deux ont eu une bonne éfficacité sur un large spectre de mauvaises herbes dicotyledones comparable à celle des références.

INTRODUCTION

The chemical structure, physical and toxicological properties of 3,6-dichloropic-olinic acid and its development as a selective broad-leaf herbicide in cereals under the code number DOWCO* 290 has been described by Brown and Uprichard (1976). This work demonstrated excellent control of annual and perennial weeds of the Compositae family at relatively low dose rates with useful activity mainly against the Umbelliferae, Papilionaceae and Polygonaceae families. In order to achieve wide spectrum broad-leaf weed control in cereals in the U.K. mixture formulations were indicated.

3,6-dichloropicolinic acid + mecoprop mixtures were evaluated from 1974 - 1976 in winter sown cereals, while three component mixtures of 3,6-dichloropicolinic acid + mecoprop + MCPA or 2,4-D were evaluated in 1975 - 1976 in spring cereals. This paper reports the results of these field trial programmes leading to the commercial introduction of a 3,6-dichloropicolinic acid + mecoprop formulation, 'Seloxone'.

METHOD AND MATERIALS

A range of tank mixes and formulations based on DOWCO 290 were evaluated during 1975 and 1976 on winter and spring cereals as shown below:-

Winter cereals 1975 - "Seloxone" formulated product containing 12.5g 3,6-dichloropicolinic acid + 560g mecoprop a.e./l. applied at 4 or 5 l/ha in efficacy trials and up to 10 l/ha in tolerance trials.

Spring cereals 1975 - 3 component tank mixtures based on 3,6-dichloropicolinic acid + mecoprop + MCPA or 2,4-D, rates as shown in tables of results.

Spring cereals 1976 - EF268 and EF269 formulations containing 18g 3,6-dichloropicolinic acid + 350g mecoprop + 100g 2,4-D a.e./l. and 18g 3,6-dichloropicolinic acid + 350g mecoprop + 210g MCPA a.e./l.

Commercial standards used in all trials as appropriate, i.e. winter cereals - TBA/dicamba/mecoprop/MCPA ('Cambilene') and mecoprop/2,4-D ('Methoxone 4X'). Spring cereals - dicamba/mecoprop/MCPA ('Banlene Plus') and bromoxynil/ioxynil/MCPA/2,4-DP ('Tetroxone') and 2,4-DP/MCPA ('New Hemoxone'), all applied at recommended dose rate.

Altogether thirty-two replicated efficacy trials were carried out using 4-8m x 30m plots with four replicates. Applications were made by 'PP' CO_2 sprayer or Land Rover sprayer fitted with rear mounted boom and p.t.o. driven Allman roller vane pump. Water volume was 200-300 l/ha at approximately 2 bar. Four crop tolerance trials were carried out in relatively weed free winter cereal crops. Each trial employed six replicates and 2.7m x 40m plots with application by Lenton Small Plot Sprayer. A total of eighty-eight grower trials were applied to 0.5 - 1 ha. unreplicated plots by Land Rover or tractor mounted sprayer. Both replicated and grower trials were distributed throughout the U.K.

Application to winter cereal efficacy trials and 1975 spring cereal trials was made from the 5-leaf stage of the crop while application to three crop tolerance trials was made at jointing as a stringent test of crop safety. In the 1976 spring cereal trials applications were made at both the 3- and 5-leaf stages.

Assessments of all broad-leaf weed species were made by 5 x 1m quadrat counts per plot both before and approximately 8 weeks after spraying. Crop scorch was assessed after 12-17 days on a 0-10 scale where 10 = complete crop dessication.

* Trade Mark of The Dow Chemical Company.

Table 1

Mean percentage weed control in replicated and grower trials in winter cereals 1975

Weed Species	Replicated trials: DOWCO 290+ CMPP 4 l/ha	Replicated trials: CMPP/2,4-D	Replicated trials: TBA + dicamba + CMPP + MCPA		Grower trials: DOWCO 290 + CMPP 4 l/ha		Grower trials: DOWCO 290 + CMPP 5 l/ha	
Matricaria spp.	96.2	71.8	90.4	(5)	92.5	(10)	98.8	(5)
Chrysanthemum segetum	87.0	51.0	50.0	(1)	80.0	(2)	NR	
Stellaria media	98.2	96.8	98.7	(9)	98.3	(9)	99.0	(10)
Galium aparine	81.5	76.5	93.5	(2)	94.2	(6)	99.8	(5)
Papaver rhoeas	86.5	89.8	89.2	(6)	60.0	(6)	65.0	(2)
Fumaria officinalis	100.0	100.0	100.0	(3)	100.0	(1)	100.0	(1)
Polygonum aviculare	86.2	88.7	95.0	(4)	89.5	(4)	95.0	(3)
Polygonum convolvulus	98.3	91.0	75.7	(3)	100.0	(2)	100.0	(2)
Polygonum persicaria	97.5	97.0	99.0	(2)	100.0	(1)	100.0	(1)
Veronica spp.	70.0	72.5	54.6	(5)	79.4	(8)	81.2	(8)
Aphanes arvensis	52.3	NR	NR	(3)	94.0	(3)	87.5	(4)
Myosotis arvensis	26.7	NR	NR	(3)	50.0	(3)	83.3	(6)
Chenopodium album	100.0	100.0	100.0	(1)	100.0	(1)	NR	
Ranunculus arvensis	100.0	100.0	100.0	(1)	NR		NR	
Urtica urens	NR	NR	NR	(-)	NR		100.0	(1)
Aethusa cynapium	78.0	NR	78.0	(1)	NR		NR	
Viola arvensis	75.0	NR	NR	(3)	46.7	(3)	67.5	(2)
Galeopsis tetrahit	NR	NR	NR	(-)	67.5	(4)	60.0	(2)
Sonchus oleraceus	95.0	NR	NR	(2)	NR		NR	
Sinapis arvensis	100.0	100.0	100.0	(4)	100.0	(6)	100.0	(6)
Spergula arvensis	50.0	50.0	50.0	(2)	NR		NR	
Cirsium arvense	NR	NR	NR	(-)	83.3	(3)	NR	

Number of sites reported shown alongside in brackets

NR = not recorded

Table 2

Mean crop scorch and yield in winter cereal replicated trials 1975

Treatment	1 Astrix	2 MHM	3 MHM	4 Atou	5 Atou	6 MHM	7 Mega	8 Atou	9 MHM	Overall Mean
	Site number and cultivar≠									
	Mean crop scorch on 0 - 10 scale									
DOWCO290+CMPP. 4 l/ha	-	0	-	1.25	1.25	0.75	0	0	0	0.5
CMPP+2,4-D	-	1.0	-	2.25	2.0	1.75	0	0	0	1.0
TBA+dicamba+CMPP+MCPA	-	0.5		1.25	1.75	2.0	0	0	0	0.8
Control	-	0	-	0.25	0.25	0.25	0	0	0	0.1
	Mean yield (t/ha)									
DOWCO290+CMPP. 4 l/ha	3.43	5.76	4.05	5.25	-	4.71	6.38	5.69	5.67	5.12
CMPP+2,4-D	3.26	5.61	3.72	5.07	-	4.40	6.38	5.89	5.83	5.02
TBA+dicamba+CMPP+MCPA	3.35	4.71	3.48	5.07	-	4.41	6.47	5.93	5.71	4.89
Control	3.04	5.63	3.53	4.85	-	4.84	4.22	5.88	6.34	4.79
Standard error %	2.7	4.5	4.3	2.8		5.1	2.9	3.9	5.2	
Coefficient of variation	8.5	8.5	11.8	5.7		11.1	4.8	6.6	9.1	
degree of significance	***	**	NS	NS		NS	***	NS	NS	
LSD 5%	0.39	0.66	-	-		-	0.43	-	-	
1%	0.53	0.9	-	-		-	0.58	-	-	

≠ All sites winter wheat except Site 1 = winter barley

MHM = Maris Huntsman

Trials were harvested by combine harvester and plot yields corrected to 15% moisture content.

RESULTS

Percent weed control by species derived from quadrat counts are summarised in Table 1 (Winter cereals) and Table 4 (Spring cereals). Yields at harvest are shown in Tables 2 & 3 (Winter cereals) and Table 5 (Spring cereals). 3,6-dichloropicolinic acid is presented as DOWCO 290 and mecoprop as CMPP for the sake of brevity.

Table 3

Mean yield in winter cereal crop tolerance replicated trials 1975

(expressed as percentage of untreated)

Treatment			Winter wheat Bouquet	Winter wheat Huntsman	Winter wheat Ranger	Winter barley Astrix
DOWCO 290 + CMPP	5	l/ha	105.5	102.0	97.8	95.6
	7.5	l/ha	105.5	104.0	100.8	102.6
	10	l/ha	100.5	105.0	99.0	99.0
Growth stage at application			jointing	tillered	jointing	jointing
Standard error %			2.7	2.3	1.6	2.2
Degree of significance at 5% level			NS	NS	4.5	NS
Untreated yield (t/ha)			6.4	6.9	6.1	6.7

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DISCUSSION

Winter cereals - The replicated trials (Table 1) show that 3,6-dichloropicolinic acid + mecoprop gave a commercially acceptable level of control of most of the major weed species commonly occurring in U.K. winter cereals. This is confirmed by the grower trial results.

Crop scorch assessments (Table 2) show that 3,6-dichloropicolinic acid + mecoprop tended to cause less scorch than commercial standards; this mainly took the form of tip scorch. Some crop prostration was also noted following the use of other commercial standards, but not following application of 3,6-dichloropicolinic acid + mecoprop.

Yield results showed that 3,6-dichloropicolinic acid + mecoprop gave a mean yield increase for all replicated trials of 6.9% over untreated controls, greater than that given by other commercial standards. Application of up to double rates at jointing resulted in no yield loss, demonstrating the crop safety of this mixture.

Spring cereals - Replicated trial results from twenty-three sites in 1975 and 1976 are shown in summarised form (Table 4). Both tank mix treatments containing 3,6-dichloropicolinic acid gave comparable weed control to the commercial standards used when applied at the 5-leaf stage of the crop. Similarly EF268 and EF269 gave comparable results from 5-leaf stage application, while EF269 applied at the 3-leaf stage gave superior weed control to 5-leaf stage application on all species encountered except *Chrysanthemum segetum* and *Aphanes arvensis*.

Table 4

Mean percentage weed control in spring cereal replicated trials 1975/76

(dose rates as shown at foot of Table 5)

	ENGLAND 1975						SCOTLAND 1975				ENGLAND 1976						
	DOWCO290+CMPP+MCPA	DOWCO290+CMPP+2,4-D	DOWCO290+CMPP. 4 1/ha	dicamba+CMPP+MCPA	ioxynil+bromoxynil+ 2,4-DP + MCPA	Number of sites	DOWCO290+CMPP+MCPA	DOWCO290+CMPP+2,4-D	2,4-DP+MCPA	Number of sites	EF 269. 3-leaf	EF 269. 5-leaf	EF 268. 5-leaf	DOWCO290+CMPP. 4 1/ha. 3-leaf	dicamba+CMPP+MCPA 5-leaf	ioxynil+bromoxynil+ 2,4-DP+MCPA.3-leaf	Number of sites
T. inodorum	99	98	98	94	95	2	100	100	83	1	85	75	78	92	63	72	4
C. segetum	-	-	-	-	-	-	-	-	-	-	74	89	87	82	31	47	2
Fumaria officinalis	77	91	91	79	49	1	94	92	100	1	100	100	97	100	99	95	1
P. convolvulus	84	92	77	78	96	3	90	98	98	1	97	78	76	91	91	97	4
P. aviculare	49	48	40	57	23	3	56	45	52	3	80	64	52	60	85	77	8
P. persicaria	80	79	68	92	92	3	-	-	-	-	97	-	-	-	100	99	1
Stellaria media	82	100	100	95	87	1	91	96	100	2	96	85	83	100	95	81	5
Spergula arvensis	-	-	-	-	-	-	95	100	99	1	97	66	37	89	97	90	2
Veronica spp.	64	78	53	94	90	1	42	39	73	2	27	0	0	0	23	46	6
Galium aparine	36	65	80	78	97	1	-	-	-	-	66	44	0	47	47	77	2
Galeopsis tetrahit	21	14	9	66	32	1	-	-	-	-	-	-	-	-	-	-	-
Papaver rhoeas	96	93	92	91	69	1	85	92	100	1	-	-	-	-	-	-	-
Sinapis arvensis	100	100	100	100	100	1	-	-	-	-	100	86	100	100	100	100	2
Raphanus raphanistrum	-	-	-	-	-	-	-	-	-	-	100	94	97	100	98	100	1
Myosotis arvensis	-	-	-	-	-	-	40	18	31	1	100	84	79	84	100	5	2
Aphanes arvensis	-	-	-	-	-	-	-	-	-	-	72	88	66	43	37	59	1
Viola spp.	85	91	49	85	62	1	-	-	-	-	80	51	52	75	92	88	2
Daucus carota	97	97	94	91	90	1	-	-	-	-	100	85	83	99	99	98	2
Atriplex patula	94	90	68	81	70	1	-	-	-	-	92	83	85	78	84	96	1
Chenopodium album	-	-	-	-	-	-	-	-	-	-	98	-	-	-	100	97	3
Lapsana communis	78	86	93	0	34	1	-	-	-	-	-	-	-	-	-	-	-
Sonchus oleraceus	34	79	73	78	58	1	-	-	-	-	68	-	-	-	60	0	1
Linaria vulgaris	63	46	29	19	16	1	-	-	-	-	-	-	-	-	-	-	-

Table 5

Mean yields in spring cereal replicated trials 1975/6 (t/ha)

		Site number and cultivar ≠											
Treatment		1	2	3	4	5	6	7	8	9	10	11	12
DOWCO290+CMPP+ MCPA	3-leaf	-	-	-	1.75	2.10	3.10	3.91	3.38	3.58	3.53	4.17	1.68
	5-leaf	2.94	3.17	5.26	1.66	2.14	2.96	3.78	3.46	3.46	4.03	4.84	1.94
DOWCO290+CMPP+ 2,4-D	5-leaf	3.05	2.89	5.27	1.84	2.05	3.01	3.41	3.50	3.41	4.44	4.56	1.68
DOWCO290+CMPP 4 l/ha	3-leaf	-	-	-	1.75	1.97	3.05	3.72	3.57	3.34	3.41	4.07	1.61
	5-leaf	3.05	3.14	5.63	-	-	-	-	-	-	-	-	-
dicamba+CMPP+ MCPA	5-leaf	3.03	3.03	5.28	1.68	2.00	3.02	3.82	-	3.39	-	-	1.80
ioxynil+2,4-DP+ bromoxynil+MCPA	3-leaf	-	-	-	1.73	2.10	3.12	3.83	3.44	3.53	3.84	4.25	1.76
	5-leaf	2.90	3.37	5.30	-	-	-	-	3.64	-	4.66	4.59	-
Control		2.93	2.71	5.34	1.84	2.19	3.05	3.58	3.33	3.41	3.88	-	1.70
Standard error		3.8	2.2	2.8									
Coefficient of variation		12.4	7.3	5.3									
Degree of significance		NS	***	NS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LSD 5%		-	0.27	-									
LSD 1%		-	0.37	-									

Dose rate of DOWCO 290+CMPP+MCPA applied: Sites 1-3 (1975) 50+1550+600g a.e./ha - tank mix (Scotland 72g DOWCO290)
Sites 4-12(1976) 72+1400+840g a.e./ha - EF 269

Dose rate of DOWCO290+CMPP+2,4-D applied: Sites 1-3 (1975) 50+1550+420g a.e./ha - tank mix
Sites 4-12(1976) 72+1400+400g a.e./ha - EF 269

≠ Varieties: Sites 6,7 & 8 = Maris Mink. 3,4 & 12 = Julia. 1 = Proctor. 2 = Hassan.
5 = Golden Promise. 10 = Armelle (all spring barley).
9 = Maris Dove. 11 = Sicco (spring wheats).

The superior control of corn marigold by 5-leaf application was due to its prolonged period of germination. Application when the crop had 5 leaves also gave useful suppression of perennial weed species such as Field bindweed (Convolvulus arvensis) at site 11 with consequent yield increase. EF269 tended to give higher overall mean yields than EF268 at most sites harvested in 1975/76 and compared favourably with commercial standards used.

In conclusion, 3,6-dichloropicolinic acid represents a novel addition to the range of broad-leaf cereal herbicides. Its two distinctive attributes are its potency against weeds of the Compositae family such as Tripleurospermum maritimum spp. inodorum and Chrysanthemum segetum; and its wide margin of selectivity in cereals. These factors enable formulated mixtures containing 3,6-dichloropicolinic acid to offer enhanced activity against phenoxy resistant weeds coupled with a tendency to greater crop safety and increased yields.

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SELECTIVE BROAD-LEAF WEED CONTROL IN CEREALS WITH A PRODUCT BASED ON 3,6-DICHLOROPICOLINIC ACID, DICHLORPROP AND MCPA

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Summary Mixtures of 3,6-dichloropicolinic acid with dichlorprop and MCPA possess a high level of activity against weeds of the Compositae in addition to those controlled by the two latter constituents. They are particularly effective against Matricaria recutita, Anthemis arvensis, Anthemis cotula, Tripleurospermum maritimum ssp inodorum, Chrysanthemum segetum, Galium aparine, Stellaria media, Polygonum persicaria and Polygonum convolvulus. A combined formulation has been field tested in over a hundred trials during two seasons at a range of rates of use, in g a.e./ha, 3,6-dichloropicolinic acid 50-75, dichlorprop 2300-2800, and MCPA 700. Higher rates have been included to test crop safety and this has been of a high order.

Resumé Des mélanges de 3,6 acide dichloropicolinique avec du dichlorprop et MCPA possèdent un niveau d'activité élevé contre les mauvaises herbes des composés, outre celles détruites par les deux derniers constituents. Ils se révèlent particulièrement efficaces contre ce qui suit: Matricaria recutita, Anthemis arvensis, Anthemis cotula, Tripleurospermum maritimum ssp inodorum, Chrysanthemum segetum, Galium aparine, Stellaria media, Polygonum persicaria et Polygonum convolvulus. Une formulation combinée a fait l'objet d'essai sur le terrain au cours de plus d'une centaine d'essais pendant deux saisons selon une gamme de taux d'utilisation en g a.e./ha, 3,6 acide dichloropicolinique 50-75, dichlorprop 2300-2800 et MCPA 700. Des taux plus élevés ont été employés dans des essais de protection de céréales et la protection de ces dernières s'est avérée élevée.

INTRODUCTION

In the late spring of 1974, 3,6-dichloropicolinic acid was made available by the Dow Chemical Company to the Boots Company for field testing. The compound was of particular interest because of its high level of activity against members of the Compositae, (Brown and Uprichard 1976). This presented a fresh approach to the problem of controlling important weeds such as Maticaria recutita, Tripleurospermum maritimum ssp inodorum, Anthemis cotula, Anthemis arvensis and Chrysanthemum segetum. These weeds are particularly competitive in cereal crops and their presence adds to the problems of harvesting. It was therefore decided to evaluate this compound in formulation with dichlorprop and MCPA to produce a broad spectrum product for use in cereals. The addition of MCPA was considered desirable to enhance control of Papaver rhoeas and Galeopsis tetrahit.

METHOD AND MATERIALS

In 1974 three exploratory replicated logarithmic dosage trials were carried out to establish the optimum range of rates of each constituent for further testing. For this purpose 3,6-dichloropicolinic acid, dichlorprop and MCPA were tank mixed.

This stimulated a large programme of replicated and user trials in 1975 and 1976 to test several formulations in winter and spring wheat, barley and oats. A series of thirty-nine widespread replicated trials was laid down in weed infested fields. A proportion of these were sited where crops were thin and uncompetitive or weed growth hard. In such unsatisfactory conditions for treatment, differences of response between formulations could more readily be established. A further thirteen replicated trials were sited in relatively weed free fields for yield determination. There were three and six replicates respectively in the weed infestation and the yield trials. Formulations were applied at normal, one and a half and double rates. Untreated controls were included in all trials as were standards where appropriate. Plot size was from 30-120m^2 according to circumstances. Applications were made in 225 l/ha of water at 2 bar using the Lenton Small Plot Sprayer or a modification of this machine calibrated for use on a tractor. As a stringent test of crop safety six yield sites were treated after the cereal was jointed. All other sites were treated prior to this stage, winter cereals when fully tillered and spring cereals at five leaves.

In 1976, sixty unreplicated user trials were carried out at normal rates with three of the most promising formulations. Using his own tractor and sprayer, calibration and application were undertaken by the farmer under supervision. Plot size was 0.8 ha with an untreated strip between each treatment, appropriate standards being applied to the rest of the field.

Weed and crop assessments were made visually on an arithmetic scale. Yields were determined by harvesting with a Claas 'Comet' combine adapted for small plot work.

For the 1975 and 1976 seasons potassium salt formulations were prepared in which the constituents were present in different ratios, the chosen rate of use for each constituent falling within the following limits.

Component	detailed trials 1975 g a.e./ha	yield trials 1975 and all 1976 trials g a.e./ha
3,6-dichloropicolinic acid	50-100	50-75
dichlorprop	2000-3000	2300-2800
MCPA	700	700

Products based on the following mixtures were applied as standards where appropriate:

benazolin + dicamba + dichlorprop

dicamba + 2,3,6-TBA + mecoprop + MCPA

dicamba + mecoprop + MCPA

RESULTS

Preliminary trials in 1974 showed applications of 3,6-dichloropicolinic acid at rates between 50-100g a.e./ha in mixture with dichlorprop and MCPA, to be very active against Matricaria and Tripleurospermum ssp. The presence of dichlorprop at 2000-3000g a.e./ha and MCPA at 500-1000g a.e./ha was shown to be necessary to broaden the spectrum.

In 1975 and 1976 weeds were found to be well controlled within a narrower range of rates than in 1974 (Tables 1-3). Results with Polygonum aviculare where this weed occurred in conjunction with Compositae are given in Table 4.

Table 1

Replicated and user trials 1975 and 1976 weed control scores (0-10) with 3,6-dichloropicolinic acid + dichlorprop + MCPA

Weeds	rate of 3,6-dichloropicolinic acid + dichlorprop (g a.e./ha) 50 + 2300	50 + 2800	60 + 2800	75 + 2300	62.5 + 2500
	(a common rate of MCPA, i.e. 700g a.e./ha was employed)				
Matricaria, Anthemis and Tripleurospermum ssp	7.6(3)	7.9(46)	7.4(40)	8.7(16)	9.0(4)
Chrysanthemum segetum	7.3(3)	7.9(18)	8.4(15)	-	-
Galium aparine	-	8.7(14)	8.9(15)	8.0(5)	-
Stellaria media	7.0(5)	8.7(54)	9.1(48)	8.1(21)	8.1(6)
Polygonum convolvulus	7.6(3)	8.7(21)	8.9(18)	8.6(5)	8.7(3)
Polygonum persicaria	-	9.0(11)	9.1(11)	9.7(4)	9.8(2)
Polygonum aviculare	7.3(3)	7.9(25)	8.4(22)	5.2(11)	6.2(6)
Papaver rhoeas	8.0(2)	8.0(22)	8.5(20)	-	-

Weed control scores: 7-10 - satisfactory to good

<7 - commercially unacceptable

0 - no effect

Figures in brackets indicate number of occurrences.

Table 2

Replicated trials 1975 and 1976 weed control scores (0-10) with

3,6-dichloropicolinic acid 50-75g + dichlorprop 2300-2800g + MCPA 700g a.e./ha

Weed	satisfactory conditions for growth and spraying number of results scoring		unsatisfactory conditions for growth and spraying ≠ number of results scoring	
	7-10	< 7	7-10	< 7
Matricaria recutita	6	0	3	3*
Anthemis ssp	1	0	0	0
Tripleurospermum maritimum ssp inodorum	8	0	3	2*
Galium aparine	5	0	4	0
Stellaria media	12	1	12	7
Polygonum convolvulus	6	0	0	2
Polygonum persicaria	5	0	0	0
Polygonum aviculare	6	4	1	4
Papaver rhoeas	2	0	1	1
Galeopsis tetrahit	1	1	0	0

≠ The large number of trials in this category was planned to ensure rigorous testing.

Weed control scores 7-10 - satisfactory to good

< 7 - commercially unacceptable

0 - no effect

* The response of commercial standards was similar in these circumstances.

Table 3

User trials 1976 weed control scores (0-10) with

3,6-dichloropicolinic acid 50-75g + dichlorprop 2300-2800g + MCPA 700g a.e./ha

Weed	satisfactory conditions for growth and spraying		unsatisfactory conditons for growth and spraying	
	number of results scoring		number of results scoring	
	7-10	<7	7-10	<7
Anthemis, Matricaria and/or Tripleurospermum ssp	26	0	2	4*
Chrysanthemum segetum	12	0	0	1
Galium aparine	14	0	1	0
Stellaria media	42	0	1	1
Polygonum convolvulus	15	0	2	1
Polygonum persicaria	7	0	1	0
Polygonum aviculare	24	0	1	0
Papaver rhoeas	15	0	6	1
Galeopsis tetrahit	3	4	1	1
Lapsana communis	0	0	1	0
Fumaria officinalis	1	0	1	0
Echium vulgare	0	1	0	0
Senecio vulgaris	2	0	0	0
Spergula arvensis	1	0	0	0

Weed control scores: 7-10 - satisfactory to good

<7 - commercially unacceptable

0 - no effect

* The response of commercial standards was similar in these circumstances.

Table 4

Control of Polygonum aviculare with

3,6-dichloropicolinic acid 50-75g + dichlorprop 2300-2800g + MCPA 700g a.e./ha

Predominant Weeds	Number of sites at which control of Polygonum aviculare was: acceptable	not acceptable
Compositae	15	1
Polygonum aviculare	14	6

There was no loss of yield in either season at normal rates of application (Table 5) despite the late spraying in six out of thirteen trials. Yield reductions at the higher rates were generally associated with this late spraying. The one exception to this occurred in trial 12 in 1976, a season in which crops were often under severe moisture stress.

DISCUSSION

The outstanding feature of this trial series has been the excellent control of composite weeds within the range of rates 3,6-dichloropicolinic acid 50-75g, dichlorprop 2300-2800g and MCPA 700g a.e./ha. Particularly of note, the control of Matricaria recutita, Anthemis cotula and Anthemis arvensis has been as effective as that of Tripleurospermum maritimum ssp inodorum. It is of importance that other members of the compositae, Chrysanthemum segetum, Lapsana communis and Senecio vulgaris have also proved susceptible to the mixture.

The breadth of spectrum of this formulation is very satisfactory, and amongst other major weeds of cereals in the U.K., Galium aparine, Stellaria media, Polygonum convolvulus, Polygonum persicaria, Spergula arvensis and Fumaria officinalis have been well controlled (Table 1). The occasional poorer results has always been associated with unsatisfactory conditions at the time of treatment when standards have behaved similarly (Tables 2 and 3). There has been a useful suppression of Polygonum aviculare where it occurred in conjunction with compositae (Table 4).

The inclusion of MCPA ensured good control of Papaver rhoeas. Galeopsis tetrahit was controlled at the seedling stage, but in common with all other hormone type herbicides resistance to the mixture increased rapidly with age. Other common weeds susceptible to MCPA were well controlled.

Thus these mixtures have been shown to be herbicidally very effective with a satisfactory margin of crop safety (Table 5) providing normal recommendations regarding stage, growth and climatic conditions for application of hormone type herbicides are followed.

Table 5

Yields with 3,6-dichloropicolinic acid + dichlorprop + MCPA
(expressed as percentage of untreated)

Trial	Crop	Stage	application rate ≠ rate≠ X1	rate X1½	rate X2	% SE	Sig dif 1%**	5%*	untreated yield t/ha
1	wb Astrix	j	96.4	102.0	98.0	2.2	NS	NS	6.7
2	ww Bouquet	j	96.6	100.0	100.5	2.7	NS	NS	6.4
3	ww Huntsman	ft	102.0	100.0	105.0	2.3	NS	NS	6.9
4	sb Mink	5-61	99.7	98.5	93.3	3.1	NS	NS	5.5
5	sw Dove	j	100.4	101.0	105.6	3.1	NS	NS	3.5
6	ww Ranger	j	98.2	100.3	94.5*	1.6	NS	NS	6.1
7	sb Gerkra	j	98.1	92.4**	92.4**	2.1	5.6	4.2	4.0
8	wb Otter	ft	100.0	100.0	95.7	3.7	NS	NS	4.6
9	ww Freeman	ft	96.3	92.6	96.3	3.7	NS	NS	4.2
10	ww Huntsman	ft	100.0	93.5	95.4	4.1	NS	NS	4.7
11	wo Quest	j	96.0	97.7	94.6*	2.5	NS	5.0	4.7
12	ww Bouquet	ft	99.6	96.4	94.8**	1.8	4.9	3.7	5.0
13	sb Hassan	5-61	98.7	100.0	101.0	3.6	NS	NS	4.2

≠ X1: rate of 3,6-dichloropicolinic acid and dichlorprop in trials 1-6 75 + 2300 g a.e./ha trials 7-13 60 + 2800 g a.e./ha a common rate of MCPA, i.e. 700 g a.e./ha was employed.

Key: ww = winter wheat
sw = spring wheat
wb = winter barley
sb = spring barley
wo = winter oats

j = jointing
ft = fully tillered
5-61 = 5-6 leaf

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Proceedings 1976 British Crop Protection Conference - Weeds

EFFECTS OF A DICAMBA/MCPA/MECOPROP MIXTURE ON EIGHT SPRING BARLEY CULTIVARS

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Summary Because of dicamba injuries to spring barley in the hot summer of 1972 in Finland (60-65 ^{0}N) a field experiment was laid down at Tikkurila in each of three years 1973-1975. The tolerance of eight commonly grown cultivars to dicamba was tested by applying 120 g/ha a.e. dicamba mixed with phenoxyherbicides. The first spraying was made at the 1-node stage, and the second as late as at the last leaf stage of barley.

Dicamba shortened the straw, decreased lodging and bending of the ear in the ripe crop. The bending was found to run parallel to the yield decrease.

The second treatment significantly lowered the average yields. Cultivars Otra, Etu, and Pomo were susceptible. More tolerant were Pirkka, Paavo, Birgitta, Ingrid and Karri.

The yields in the hot summers 1973 and 1975 differed significantly from those of the cool summer 1974 when the first treatment did not affect the yield of any cultivar.

A genetic aspect can be seen in the most susceptible cultivars Etu and Pomo which have Bonus as a parent in common.

The approved dose of dicamba, 75-90 g/ha a.e., and application at the beginning of tillering, and latest at the end of tillering, seem to be safe for barley cultivars grown in Finland.

Résume En raison des dommages dicamba enregistré sur órge de printemps durant l'été chaud de 1972 en Finlande (60-65 ^{0}N) une expérimentation en plein champs a été effectuée à Tikkurila en 1973-1975. La tolérance au dicamba de huit variétés généralement cultivées a été essayée en appliquant 120 g/ha m.a. de dicamba en association avec des phénoxy-herbicides. La première pulvérisation a eu lieu au stade d'un noeud et la deuxième à la phase de la dernière feuille de l'orge.

Le dicamba a raccourci le brin et réduit la verse et le ployage de l'épi de l'orge mûre. Il a été constaté que le ployage était sensiblement parallèle à la diminution des rendements.

Le second traitement a abaissé les rendements en moyenne dans une mesure significative.

Les variétés Otra, Etu et Pomo étaient sensibles. Pirkka, Paavo, Birgitta, Ingrid et Karri se sont avérés les plus résistants. Les rendements des étés chauds 1973 et 1975 différaient significativement des rendements de l'été frais 1974 où le premier traitement n'avait

abaissé le rendement d'aucune variété.

L'influence de la génétique ressort du fait que les variétés les plus sensibles Etu et Pomo ont le Bonus comme parent commun.

La dose de dicamba approuvée, 75-90 g/ha m.a., et le traitement au début du tallage ou au plus tard à sa fin semblent être sûr pour les variétés d'orge cultivées en Finlande.

INTRODUCTION

Dicamba has been used since 1966 in Finland for weed control in spring cereals in mixtures with phenoxy herbicides. It is effective against the Polygonum species and has proved economical. It had not caused any problems until the hot, and after the spraying time, dry summer of 1972 when it unexpectedly caused severe yield reduction, specially at late applications and particularly in a new cultivar Pomo. Most of the field experiments for official approval had been made on cultivar Pirkka with no adverse effects.

Friesen et al (1964) have reported on the tolerance of wheat and barley to dicamba both in greenhouse and field experiments. Sprayings made at the "boot" and "headed" stages coincided with the initiation of the floral parts and caused very drastic reductions in the numbers of normally fertilized florets and fully developed kernels. They also found that the much greater activity of dicamba in the greenhouse compared to the field trials at comparable rates suggests increased phytotoxicity under conditions conducive to rapid and lush growth.

Zick et al (1963) and Allen (1966) have shown that in barley the varietal response was more pronounced than in the other cereals, and that the susceptible cultivars suffered especially from the late treatments, although the damaged barley showed an ability to recover and often yielded normally.

Many farmers in Finland tend to spray late in order to obtain a good control of Cirsium arvense and Sonchus arvensis, or to mix herbicides with liquid fertilizers and chlormequat.

To obtain some information on the possible varietal responses to dicamba field experiments were laid down at Tikkurila in 1973, 1974, and 1975 with some new barley cultivars grown in Finland.

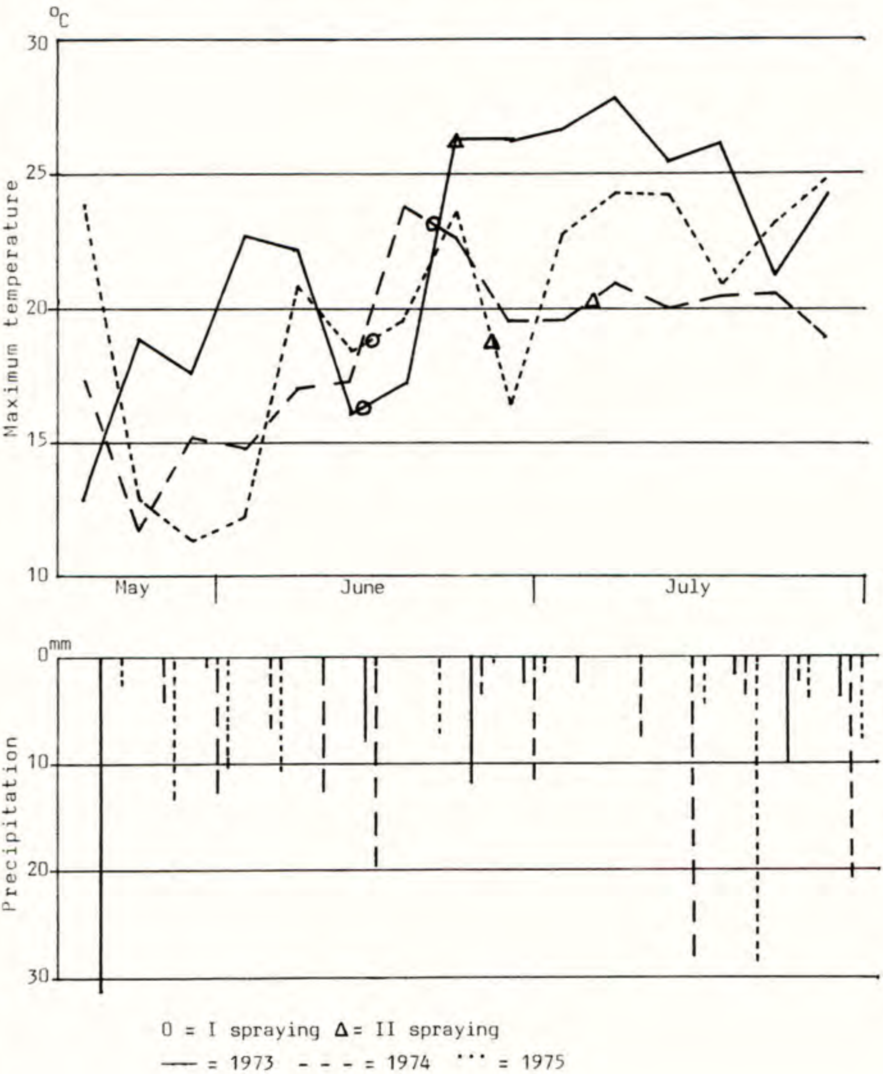
METHODS AND MATERIALS

A split-plot design with four replications was used. The plot size was 12 m^2. Five-hundred germinating seeds per m^2 of the following cultivars were sown:

six-row:	Otra (Tammi x Edda)	growing time	86 days
	Pirkka (Ta 04369 x Ta 05864)	"	87 "
	Etu (Bonus x Varde)	"	89 "
	Paavo (Tammi x (Kulta x OAC 21)	"	91 "
	Pomo (Voitto x Vega) x Bonus)	"	92 "
two-row:	Birgitta (Vega x Opal) x Maja)	"	95 "
	Ingrid (Balder x (Binder x Opal)	"	94 "
	Karri (Carlsberg x Rigel)	"	95 "

A mixture of MCPA, mecoprop, and dicamba 1044, 724, and 120 g/ha a.e. respectively, was sprayed with an Azo field plot sprayer at a pressure of 3 bars in 200 l/ha of water. The first sprayings marked with a "0" in Fig. 1 were made in 1973 and 1974 when the crop was at "1st node detectable" (growth stage 31, Zadoks et al 1974) and in 1975 at the begnning of stem elongation (30). The crop was then 20-27 cm high, depending on the cultivar. The second spraying time (marked with a triangle in Fig. 1) was when flag leaf was just visible (37), in a crop 25-60 cm high, except in 1975, when boots were already swollen (45) in Otra, Pirkka, and Etu. The interval between the first and second treatment was in 1973 only 9 days, in 1974 15 days, and in 1975

Fig. 1.
Maximum temperatures and precipitation over 5-day periods



11 days. Maximum temperatures and precipitation over 5-day periods (WMO pentads) are also shown in Figure 1.

Straw length was measured, lodging and bending of the ear were assessed visually before harvest. Straw length is expressed as % of untreated cultivars, lodging and bending as percent figures.

All the cultivars were harvested with a Hege 125 plot combine, in 1973 on the 2nd of August, in 1974 on the 2nd of September, and in 1975 on the 8th of August.

Statistical treatment is made conventionally as an Analysis of Variance and as a Tuckey-Hartley test (Snedecor and Cochran 1971). Significant differences are expressed in Figure 3 by *, and **, at the 5 % and 1 % levels respectively.

RESULTS

No visual symptoms were observed other than a shortening of the straw, and a reduction in the normal bending of the ear compared with untreated cultivars. Lodging likewise decreased as a result of the treatments. Obvious differences in these respects were found between the cultivars, as is seen in Figure 2.

Figure 3 shows the relative yields of different cultivars compared with the untreated. The yield decrease is clearly seen in the sensitive cultivars Otra, Etu, and Pomo, while Pirkka, Paavo, Birgitta, Ingrid, and Karri were more tolerant to dicamba.

On the average, there was a statistically significant difference (at the 5 % level) between the untreated cultivars and the later treatment, as well as between the first and the second sprayings. The effect of the treatments between the years 1973 and 1974, and also 1974 and 1975 differed statistically (at the 1 % level). The untreated cultivars yielded, on average, 3600 kg/ha in 1973, 5010 kg/ha in 1974, and 3910 kg/ha in 1975.

The 1000 kernel weight was affected only in Otra where the treatments significantly increased it (at the 5 % level).

The hectolitre weight was significantly(at the 1 % level)decreased only in Pirkka and only by the later treatment.

At the ripening time dead lesions were seen in the axis of the ears of severely injured plants. The damaged kernels contained a not identified sugar liquid instead of starch. No external defect was seen even in the empty grains, before they were ripe.

DISCUSSION

Yield decreases caused by the dicamba/MCPA/mecoprop-mixture were dependent on the cultivars. The losses seem due to dicamba, as shown by Allen (1966). On the other hand, e.g. Fiddian (1962), observed that MCPA and mecoprop did not result in varietal differences in barley.

Fig. 2.
Straw length of the barley cultivars as % of untreated cultivars, lodging and bending of the ear in %

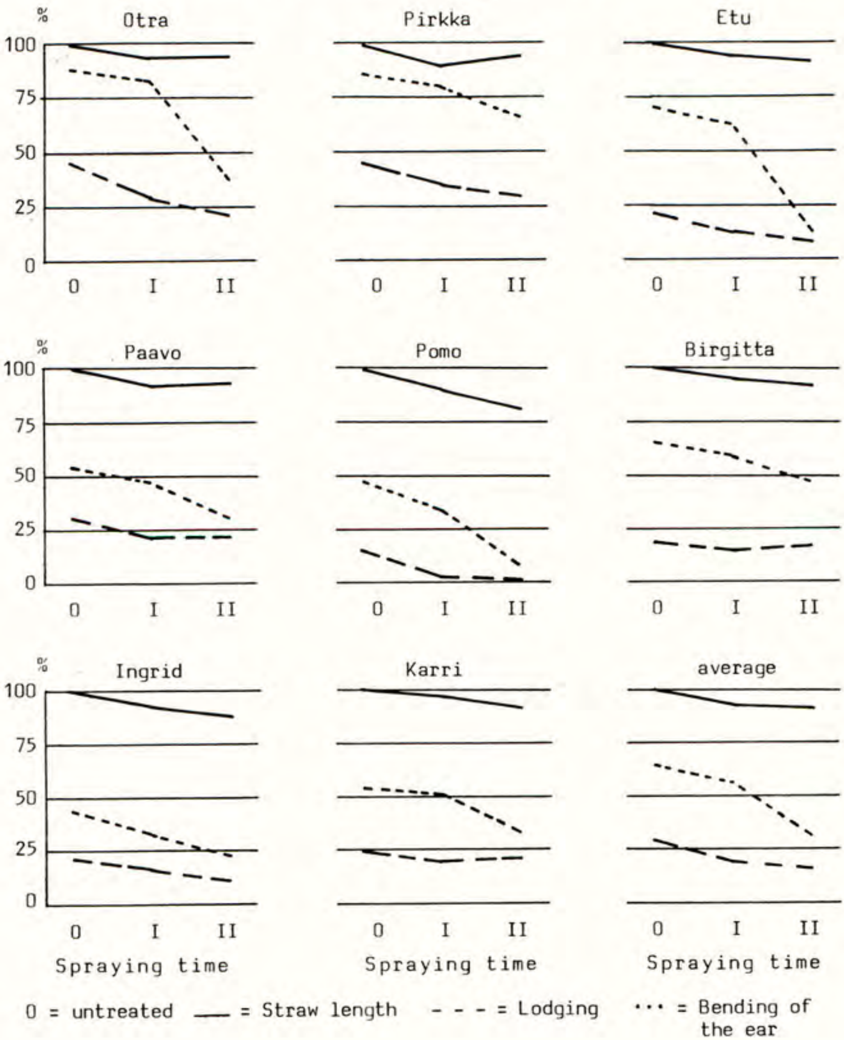
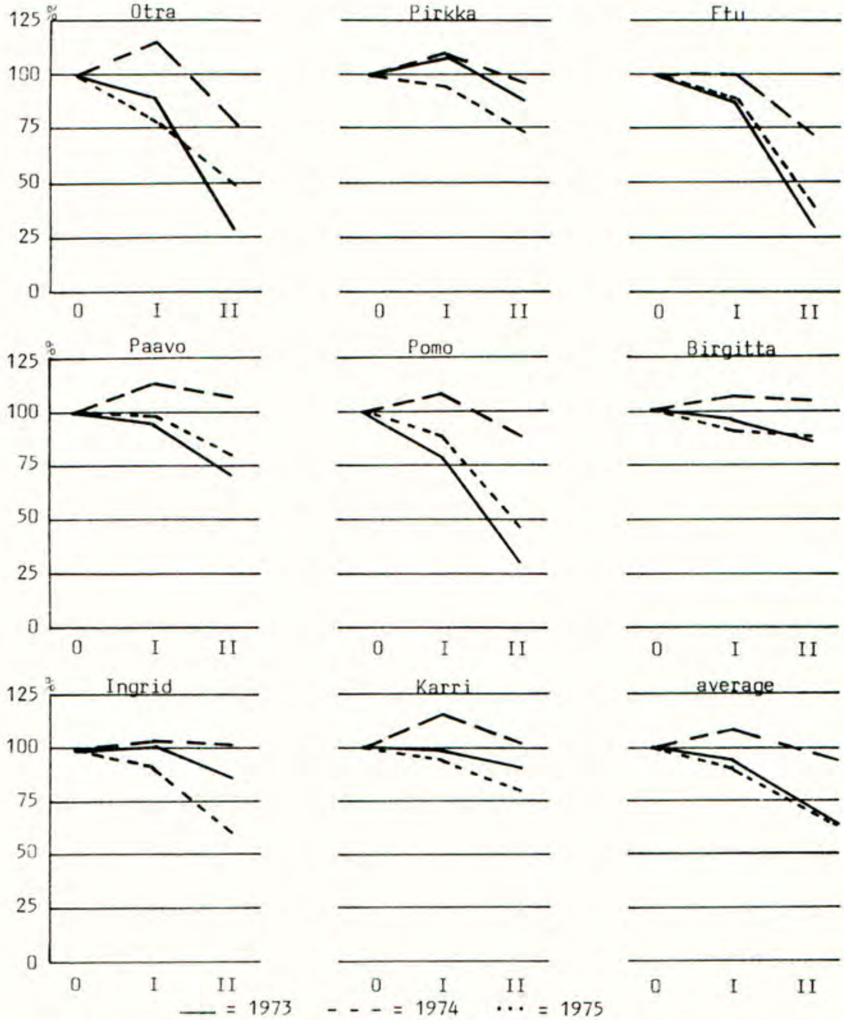


Fig. 3.
Relative yields of the barley cultivars



Statistically significant differences in the yields (Tuckey-Hartley test)

	Otra			Pirkka			Etu			Paavo		
	0-I	0-II	I-II	0-I	0-II	I-II	0-I	0-II	I-II	0-I	0-II	I-II
1973	x	xx	xx	xx	x	-	x	xx	xx	-	x	x
1974	-	x	xx	-	-	-	-	xx	xx	-	-	-
1975	x	xx	xx	-	xx	xx	-	xx	xx	-	xx	xx

	Pomo			Birgitta			Ingrid			Karri		
	0-I	0-II	I-II	0-I	0-II	I-II	0-I	0-II	I-II	0-I	0-II	I-II
1973	xx	xx	xx	-	xx	x	-	x	x	-	xx	xx
1974	-	x	xx	-	-	-	-	-	-	xx	-	xx
1975	xx	xx	xx	-	-	-	xx	xx	xx	-	xx	xx

In his experiments Allen (1966) applied a MCPA and dicamba-mixture 0.84 and 0.14 kg/ha a.e. at fully tillered and jointing to early boot stages of several barley cultivars. His conclusion, the same as was found in this report, was that some cultivars showed marginal sensitivity. Reduced yields were especially apparent at high-dose and late-stage applications. The varietal differences in the tolerance to dicamba were emphasized in these circumstances, in which an over-dose and an overdue application time were used. The approved dose of dicamba in Finland is 75-90 g/ha a.e. mixed with phenoxyherbicides (Anon. 1972). The latest permitted spraying time is the end of tillering (20-22). With correct doses serious yield losses are not likely to occur, as was also observed by Allen (1966) and Friesen et al (1968).

A hot weather period following the treatments in 1973 and 1975 resulted in a lush growth and caused severe damage especially after the late treatment, which is also pointed out by Friesen et al (1964). After a cool summer, as in 1974, the first spraying had no harmful effects on the yield of the eight cultivars. The second application resulted only in minor yield reductions.

In warm conditions it is often difficult for a farmer to spray at the right time owing to the rapid growth of the crop in the Finnish conditions (60-65 $^{\circ}$N).

The first symptom of a dicamba injury was the shortening of the straw, shown also by Friesen et.al. (1964) in wheat. Varietal differences were small. Lodging decreased in relation to straw length, but to a certain degree this was due to emptiness of the ears. Kernels did not develop normally in the injured ears, a fact reported also by Holroyd (1962), although they seemed healthy until the crop ripened.

Undeveloped ears did not bend in a ripe crop when fully grown. The bending was quite parallel to the yield decreases. Only in a few cases did the injuries extend to the 1000 kernel weight and the hl-weight.

Growing time of the cultivars varies, and their growth rhythm is different. At the time of spraying all the cultivars were not exactly at the same growth stage, especially at the second treatment. This may have a consequense to their dicamba tolerance. The late cultivars were, on the average, more tolerant than the early ones. On the other hand, the second earliest cultivar, Pirkka, was not susceptible. The growth habit of a cultivar may as well be of some importance. A cultivar with horizontal leaves compared to those with more vertical leaf position may get more spray. However, Pirkka with quite a horizontal leaf position responded less than one could expect.

A genetic susceptibility to dicamba can perhaps be seen in the most sensitive cultivars Etu and Pomo with one parent, Bonus, in common. Carlsberg was shown to be tolerant by Allen (1966) and in fact Carlsberg is a parent also in cv. Karri, which proved to be tolerant.

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