Session 4D

Weed Control in Arable and Horticultural Crops

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Papers	4D-1 to 4D-7

POSSIBILITIES FOR LOW DOSE HERBICIDE MIXTURES FOR WEED CONTROL IN SUGAR BEET

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ABSTRACT

Ten experiments were carried out on loamy sand, peaty loam or sandy loam sites in Norfolk or Cambridgeshire to compare low dose multiple herbicide mixtures with typical current conventional applications. Four or five way herbicide mixes containing 114 g AI/ha phenmedipham plus other broad-leaved weed herbicides gave good weed control but reduced crop vigour. Three way mixtures of 86 g AI phenmedipham, 100 g AI ethofumesate and 350 g AI metamitron, 200 g AI lenacil or 325 g AI/ha chloridazon plus a litre of mineral oil gave good weed control and crop safety.

INTRODUCTION

Low volume, low dose applications (Smith, 1983) are almost universally used for weed control in UK sugar beet (Anon, 1992a). However, Richard-Molard & Muchembled (1988) suggested that four way mixes of lower doses of herbicides may reduce costs while maintaining reliable weed control. Subsequently even more complicated mixtures were tested in France in the late 1980s. In Belgium and The Netherlands three way mixes (often referred to as the FAR [phenmedipham, activator, residual] technique) have been adopted by growers (Hermann *et al*, 1992). The experiments reported here seek to examine the possibilities for using such lower dose mixtures in the UK.

METHOD

Multiple low dose mixtures of three to five herbicides were tested and compared with current practices. Experiments were carried out between 1989 and 1993 inclusive on up to three soil types, at Morley, Norfolk (sandy loam [SL]), Colney and Attlebridge (1993 only), Norfolk (loamy sand [LS]) and Mepal, Cambridgeshire (peaty loam [PL], 15-37% o.m.). A randomised block design with four replicates (three on peaty loam site in 1991) was used for all trials. Plot sizes ranged from 2 to 3 m wide and from 12 to 24 m long. Treatments were applied by gas pressurised knapsack sprayers in 80 l/ha water using fine quality sprays through 01 size flat fan 80° or 110° nozzles at 2 bar pressure.

No pre-emergence herbicides were used but the peaty loam sites were treated overall with diquat plus paraquat before the sugar beet emerged. Whilst handweeded controls were used on some PL sites, untreated controls were not. The first treatments were applied to cotyledon weeds, as far as conditions allowed, on the dates given in Table 1. Subsequent treatments were applied as fresh flushes of weeds reached the cotyledon stage. Some treatments (denoted by [f] in the following tables) were applied at more frequent intervals than others.

The experiments were drilled between 19 March (PL 1993) and 4 April (PL 1992). The main weeds at the SL sites were *Polygonum aviculare*, *Fallopia convolvulus* and *Chenopodium album*, with these three plus *Viola arvensis* at the LS site. The main weeds on the PL site were *P. aviculare*, *F. convolvulus*, *P. lapathifolium*, *P. persicaria*, *Aethusa cynapium* and *C. album*. Assessments were by counts or scores (0 to 10 linear scale at the LS and SL sites where 0 = dead and a 0 to 9 scale at the PL site [Anon, 1992b]).

TABLE 1. Dates of application of treatments

Year	Site and dates			
1989	LS	25/4 & 16/5	SL	31/3, 4/5 & 18/5
1990	LS	24/4, 4/5 & 18/5	SL	1/5 & 17/5
1991	LS	29/4, 21/5 & 11/6	LS[f]	29/4, 8/5, 13/5, 21/5 & 28/5
	PL	23/4, 9/5, 18/5 & 31/5		
	SL	10/5	SL[f]	10/5, 17/5 & 24/5
1992	LS	23/4 & 10/5	LS[f]	23/4, 3/5, 10/5 & 15/5
	PL	19/4, 3/5, 15/5 & 2/6	PL[f]	19/4, 28/4, 3/5 & 31/5
	SL	10/5 & 22/5	SL[f]	10/5 & 18/5
1993	LS	1/5	LS[f]	1/5 & 10/5
	PL	22/4, 30/4, 19/5 & 2/6	PL[f]	22/4, 30/4, 6/5, 18/5 & 1/6
	SL	29/4 & 22/5	SL[f]	29/4, 6/5 & 22/5

RESULTS

In the tables of results the following abbreviations are used to identify each treatment: P = phenmedipham (EC), M = metamitron (WG), E = ethofumesate (EC), C = chloridazon (SG), L = lenacil (WP) and O = mineral oil (97% - doses in tables are litres of product). Treatments bracketed together with '()' or '[]' are sequences. The following symbols are also used, [a] denotes that second and subsequent sprays are at double dose (except mineral oil which remained constant), # denotes that variable doses between 1 and 1.5 times that stated were used and [b] is used where the last spray was not applied.

In 1990 the higher doses of the multiple mixes, whilst giving acceptable weed control, tended to damage the crop (Table 2) and such doses were not tested in following years. At the LS site this damage was evident before the last spray was applied. The lower dose mixtures performed better used with, rather than without mineral oil. *Matricaria matricarioides* was not effectively controlled by the low dose mixtures.

The good weed control given by mixtures applied with mineral oil was noted in subsequent years. In 1991 at the LS site the use of ethofumesate appeared essential for good weed control, whereas lenacil had a relatively small effect and excluding metamitron similarly reduced weed control at the SL site. At the PL site, all low dose mixtures gave good initial weed control, but later in the season reductions in weed vigour were less than those achieved by conventional treatments. However, low dose mixtures of four AIs applied with mineral oil gave commercially acceptable levels of crop damage at the SL site.

In 1992 the mixtures of five AIs at the LS and SL sites resulted in severe crop vigour reductions, although these were outgrown by the middle of July. These treatments gave poorer control of *M. matricarioides* and poorer crop safety than low dose mixtures of three AIs. At the PL site, mixtures of four AIs gave better weed control than those of three AIs, except where the latter were applied at higher doses. In 1993 at all three sites, the use of the three way mix with oil gave as good weed control and crop safety as the conventional treatments.

TABLE 2. Results of 1989 and 1990 experiments

Dose (g AI/ha)						Total weeds/m²				Beet vigour	
						1989		1990		1990	
P	M	E	C	L	O	SL 17/6	LS 22/6	SL 20/6	LS 14/6	SL 28/5	LS 18/5
-	-	-	-	-	-	34.3	47.1	38.9	63.1	9.3	9.8
29	175	50	163	100	-	12.6	30.4	-	-	-	-
29	175	50	163	100	1000	7.5	22.5	-	-	-	-
29	175	50	163	200	-	-	-	17.3	67.0	7.5	8.0
29	175	50	163	200	-	-	-	17.9^{a}	58.9^{a}	7.0^{a}	7.0^{a}
29	175	50	163	200	1000	-	-	10.6	50.5	7.5	7.8
29	175	50	163	200	1000	-	-	9.3^{a}	38.4^{ab}	6.3^{a}	5.8^{ab}
57	350	100	-	400	-	12.3	21.5	-	-	-	-
57	350	100	350	400	-	-	-	8.8	59.4^{b}	7.0	6.5^{b}
57	350	100	350	400	-	-	-	8.6^{a}	42.3^{ab}	7.0^{a}	4.8^{ab}
57	350	100	350	400	1000	-	-	7.6^{b}	36.9^{b}	4.0^{b}	5.5^{b}
57	350	100	350	400	1000	-	-	-	13.3^{ab}	-	2.5^{ab}
57	350	100	650	-	-	13.1	25.7	-	-	-	-
57	350	200	-	200	-	12.0	21.2	-	-	-	-
57	350	200	325	-	-	10.8	25.0	-	-	-	-
57	700	100	-	200	-	10.8	22.8	-	-	-	-
57	700	100	325	-	-	9.6	25.0	-	-	-	-
114	175	50	163	100	-	12.6	26.0	-	-	-	-
114	700	200	-	400	-	10.0	22.2	-	-	-	-
114	700	200	650	-	-	8.4	19.5	-	-	-	-
114	700	200	650	800	-	-	-	3.4^{b}	33.8^{b}	4.3^{b}	4.5^{b}
114	700	200	650	800	1000	-	-	2.7^{b}	13.4^{b}	2.8^{b}	2.0^{b}
(-	1190	-	-	-	1700)						
(194	875	-	-	-	1000)						
(399	-	-	-	-	-)*	-	-	8.1^{b}	27.7	8.8^{b}	7.5
[-	1190	-	-	-	1700]						
[399	-	-	-	-	-]	9.7	25.2	-	-	-	-
SED (36 d.f. 1989; 30 d.f. 1990)						0.72	3.64	2.93	6.43	0.33	0.79

* tank mixed with 600 g AI tri-allate (EC)

TABLE 3. Results of 1991 experiments

Dose (g AI/ha)						Total weeds/m²		Vigour	
								beet	weeds
P	M	E	C	L	O	SL 3/7	LS 1/7	SL 4/7	PL 4/7
-	-	-	-	-	-	23.2	52.8	10.0	-
-	175	50	-	100	1000	-	-	-	4.3
29	-	50	-	100	1000	-	-	-	4.2
29	-	50	163	200	1000	12.8	18.4	10.0	-
29	175	-	-	100	1000	-	-	-	5.0
29	175	-	163	200	1000	13.8	26.5	9.0	-
29	175	50	-	-	1000	-	-	-	4.2
29	175	50	-	100	-	-	-	-	5.2
29	175	50	-	100	1000	-	-	-	3.5
29	175	50	-	200	1000	11.3	16.3	9.8	-
29	175	50	163	-	1000	10.9	16.4	9.5	-
29	175	50	163	200	-	15.0	25.1	9.8	-
29	175	50	163	200	1000	10.8	13.9	9.3	-
86	-	100	325	-	-	13.6	19.7	9.5	-
86	175	100	-	-	-	15.8[a]	15.1[a]	9.8[a]	-
86#	350#	100#	-	-	-	-	-	-	3.2
194	875	-	-	-	1000	-	-	-	1.7
285	-	-	-	-	-[f]	7.0	12.0	8.3	-
-	1050	-	-	-	1500[f]	3.0	6.8	9.5	-
(-	1190	-	-	-	1700)				
(160	700	200	-	-	-)				
(194	875	-	-	-	1000)				
(240	-	300	-	-	-)	-	-	-	1.3
[-	1190	-	-	-	1700]				
[285	-	-	-	200	-]	13.3[b]	17.6	9.8[b]	-
SED (33 d.f. SL & LS; 34 d.f. PL site)						1.79	4.74	0.42	0.65

In all the experiments the low dose mixtures (up to 86 g AI/ha phenmedipham combinations) gave equivalent beet populations and sugar yield to the conventional treatments and generally acceptable weed control.

DISCUSSION AND CONCLUSIONS

The need for addition of mineral oil to the low dose mixtures is probably due to the low amount of surfactants present in the resultant mixtures. The mixtures of five AIs were intended to provide control of a broad spectrum of weeds thus reducing management decisions regarding herbicide selection. In general they achieved this, although control of *M. matricarioides* by the low dose mixtures of five AIs was poor. This might be overcome by the addition of clopyralid. In some situations a single component could be left out without adversely affecting weed control. However, this requires a management decision, as would the inclusion of clopyralid, which is contrary to the original concept of multiple low dose mixtures which were intended to provide a simple blueprint for beet weed control.

The three way (FAR) mixes do require a management decision when selecting appropriate AIs. However, when used with mineral oil, they appear to be more promising than the conventional treatment regimes used in these experiments. Until 1993 the use of 285 g AI/ha phenmedipham applied alone at frequent intervals gave as a good weed control as most other treatments, but the 1993 results suggest that there will be occasions when the three way (FAR) mixes will give greater latitude in spray timing.

TABLE 4. Results of 1992 experiments

Dose (g AI/ha)						Total weeds/m²			Beet vigour
P	M	E	C	L	O	SL 30/6	LS 17/6	PL 10/6	PL 18/5
-	-	-	-	-	-	19.0	14.1	-	8.6
29	175	50	-	100	1000[f]	-	-	20.3	6.8
29	175	50	163	200	1000[f]	5.0	3.6[b]	-	-
29	175	50	163	200	1000	3.9	10.5[b]	-	-
34	210	60	-	-	1000	-	-	42.0	8.0
34	210	60	-	120	1000	-	-	29.5	8.0
40	245	70	-	-	1000	-	-	38.5	8.1
46	280	80	-	-	1000	-	-	23.7	8.1
86	-	100	325	-	-	7.5	13.0	-	-
86	-	100	325	-	- [f]	9.2	7.9[b]	-	-
86	350	100	-	-		8.3	11.5	35.3	8.3
(As above but variable rate#)						-	-	16.7	8.1
86	350	100	-	-	[f]	9.6	4.2[b]	-	-
194	875	-	-	-	1000	-	-	11.3	7.4
285	-	-	-	-	- [f]	9.4	5.4	28.7	7.8
(-	1050	-	-	-	1500)				
(285	-	-	-	-	-)[f]	5.2	3.5	-	-
[-	1190	-	-	-	1700]				
[160	700	200	-	-	-]	-	12.1	-	-
(-	1190	-	-	-	1700)				
(399	-	-	-	-	-)	5.8	-	-	-
[160	-	200	-	-	-]				
[160	-	200	-	-	-]				
[194	875	-	-	-	1000]	-	-	10.0	8.0
SED (27 d.f. SL & LS; 30 d.f. PL site)						1.60	2.29	8.68	0.23

The low dose mixes (especially those of the FAR type) may prove useful to UK sugar beet growers, but these trials suggest that they may require shorter time intervals between sprays and at least one extra application compared to current conventional treatments. For this reason they are unlikely to be cost effective in situations where two sprays or less provide acceptable weed control. Where weed emergence is protracted and several applications are necessary, such as on peaty soils, such mixes could offer substantial cost savings. However, because these treatments use a diverse range of herbicides they are unlikely to receive liability backing from herbicide manufacturers.

TABLE 5. Results (total weeds/m²) of 1993 experiments

Dose (g AI/ha)								
P	M	E	C	L	O	SL 8/6	LS 25/5	PL 21/6
-	-	-	-	-	-	33.1	14.9	-
29	175	50	-	100	1000[f]	-	-	45.0
29	175	50	163	200	1000[f]	7.6	22.4	-
29	175	50	163	200	1000	16.6	15.3	-
34	210	60	-	120	1000	-	-	61.7
34	210	60	-	200	1000	-	-	58.7
46	280	80	-	160	1000	-	-	59.7
86	350	100	-	-	- [f]	10.1	14.5	-
86	350	100	-	-	-	23.1	15.3	-
86	-	100	-	200	1000	-	-	56.3
86	350	100	-	-	1000[f]	1.8	11.8	-
86	350	100	-	-	1000	18.0	14.3	93.0
86#	350#	100#	-	-	1000	-	-	81.3
285	-	-	-	-	- [f]	17.5	17.4	96.7
(-	840	-	-	-	1200)			
(285	-	-	-	-	-)[f]	7.7	19.2	80.0
[-	1190	-	-	-	1700]		11.8	
[194	875	-	-	-	-]			
[262	-	170	275	-	-]	11.8		-
(160	-	200	-	-	-)			
(240	-	300	-	-	-)			
(194	875	-	-	-	1000)	-	-	57.7
SED (27 d.f. SL & LS; 20 d.f. PL)						4.12	5.74	18.48

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ALTERNATIVES TO CHLORBUFAM PLUS CHLORIDAZON FOR EARLY WEED CONTROL IN DRILLED LEEKS

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ABSTRACT

A range of herbicide treatments was evaluated for early post-emergence weed control in drilled leeks in a glasshouse screen and in the field. Pendimethalin alone and in a mixture with chloridazon were the most effective treatments.

INTRODUCTION

Early weed control is essential in slow growing, uncompetitive crops like leeks but pre-emergence herbicides often fail to kill all of the weeds or may lack sufficient activity where soil organic matter content is high. Therefore, a post-emergence herbicide that can be applied at an early crop stage is a vital part of any weed control programme. Chloridazon plus chlorbufam has been used for early weed control in leeks since 1967 but, as from January 1994, the formulated mixture 'Alicep' will no longer be marketed for this purpose. If consistent supplies of high quality leeks are to be maintained it is imperative to find a safe and effective alternative. The experiments described here were made to test a range of treatments in a glasshouse screen, and evaluate the most promising in field trials with drilled leeks grown in a sandy loam soil and a silt soil. The treatments examined are not necessarily approved for use on leeks.

METHODS AND MATERIALS

The herbicides used were commercial formulations of bentazone (Basagran; 480 g/l SL; BASF plc), chlorbufam + chloridazon (Alicep; 20:25% w/w WP; BASF plc), chloridazon (Pyramin DF; 65% w/w SG; BASF plc), chloridazon + propachlor (Ashlade CP; 86:400 g/l SC; Ashlade Formulations Ltd), chlorpropham (Triherbide CIPC; 400 g/l EC; Bos Chemicals Ltd), ethofumesate (Nortron; 200 g/l EC; Schering Agriculture), fluazifop-P-butyl (Fusilade 5; 125 g/l EC; ICI Agrochemicals), cyanazine (Fortrol; 500 g/l SC; Shell Chemicals UK Ltd), ioxynil (Totril; 225 g/l EC; Rhone Poulenc Agriculture), linuron (Liquid Linuron; 133 g/l EC; Pan Britannica Industries Ltd), metazachlor (Butisan S; 500 g/l SC; BASF plc), methabenzthiazuron (Tribunil; 70% w/w WP; Bayer plc), pendimethalin (Sovereign 330EC; 330 g/l EC; Ciba Agriculture), prometryn (Gesagard 50 WP; 50% w/w WP; Ciba Agriculture), propachlor (Portman Propachlor 50 FL; 500 g/l LI; Portman Agrochemicals Ltd) and propyzamide (Kerb 50W; 50% w/w WP; Pan Britannica Industries Ltd).

Glasshouse screen

Leek cv Verina was sown on 7 and 21 October 1991 into '308 Hassy' trays filled with a sterilised silt soil and kept in a Venlo glasshouse under frost protection. The treatments were applied to the earlier sown leeks on 31 October when the seedlings were at the post-crook stage. The later sown leeks were sprayed at the loop stage on 7 November. The sprays were applied at a volume equivalent to 200 l/ha, using a "Mistral" ultrasonic mist applicator. Two trays of seedlings were sprayed with each herbicide treatment on each occasion. Plant fresh weight was recorded on 2 January 1992 when three samples of 50 plants were taken longitudinally across the trays of each treatment.

Field trials

Sandy loam soil

The soil was a sandy loam with 2% organic matter and a pH of 6.8. Leek cv Verina was drilled on 2 April 1992 at 25 seeds per metre of row and with three rows 61 cm apart on a 1.83 m bed. A pre-emergence spray of propachlor + chlorthal-dimethyl (4.5 + 4.5 kg AI/ha) was applied to all plots immediately after drilling. Plots, 6 m long and 1.83 m wide, were marked out in a randomised block design with three replicates of each spray treatment. There were two untreated plots per block. The herbicides were applied in 250 l/ha water using an AZO compressed air sprayer with Teejet 8002 nozzles at 2.5 bar pressure. The first sprays were applied on 1 May when the crop was at the loop stage and most weeds were at the cotyledon to 2-leaf stage. The second sprays were applied on 8 May when the leeks were at the post-crook stage and most weeds had 3 to 6 leaves. Weed numbers were recorded and percent crop injury assessed on 18 June. The plots were hand-weeded and weed fresh weight was recorded on 10 July. The leeks were then top dressed (80 kg/ha N) to stimulate crop growth. At harvest, on 5 October, the centre row only of each plot was lifted and the leeks counted, trimmed and weighed.

Silt soil

Leek cv Verina was precision drilled into a coarse alluvial silt soil of pH 7.3; 2% o.m., on 13 April. The sowing rate was 23 seeds per metre of row and there were three rows at 55cm spacings on a 1.83 m bed. A pre-emergence spray of propachlor + pendimethalin (4.5 + 0.33 kg AI/ha) was applied to all plots on 21 April. Plots, 6 m long and 1.83 m wide, were laid out in a randomised block design with three replicates of each treatment. The treatments were applied in 400 l/ha water using an OPS sprayer with Lurmark 02-F80 nozzles at 3 bar pressure. The first sprays were applied at the late-loop crop stage, on 13 May, when most weeds had 1 to 4 leaves. The later sprays were applied at the post-crook stage, on 20 May, when weeds had 4 to 6 leaves. Weed numbers per plot, percent weed cover, and the weight of 15 leek plants per plot were recorded on 17 June. All plots were hand-weeded on 19 June to reduce weed competition. The leeks were lifted, trimmed and graded on 14 October.

RESULTS

Glasshouse screen

TABLE 1. Leek fresh weight at sampling on 2 January 1991 following application of herbicide treatments at the loop or post-crook crop stage in a glasshouse screen.

Treatment (g AI/ha)	Fresh weight 50 leek plants (g)	
	Loop stage	Post-crook stage
1. Water (control)	0.85	2.59
2. Ioxynil 22.5	0.45	2.00
3. Ioxynil 33.8	0.51	2.85
4. Pendimethalin 990 + ioxynil 22.5	0.30	2.00
5. Pendimethalin 990 + ioxynil 33.8	0.40	1.42
6. Chloridazon 910 + ioxynil 22.5	0.24	1.05
7. Chloridazon 910 + ioxynil 33.8	0.23	0.70
8. Ioxynil 22.5 + cyanazine 50	0.13	0.71
9. Ioxynil 33.8 + cyanazine 75	0.09	0.29
10. Pendimethalin 990	0.68	-
11. Pendimethalin 1980	0.57	-
12. Prometryn 143.5	-	0.34
13. Prometryn 287.5	-	0.11
14. Propachlor 2250	0.52	2.50
15. Propachlor 4500	1.00	2.21
16. Propachlor 4500 + bentazone 120	0.33	0.29
17. Propachlor 4500 + bentazone 240	0.20	0.08
18. Ethofumesate 400 + propachlor 2250	0.64	1.41
19. Ethofumesate 700 + propachlor 4500	0.37	1.55
20. Propachlor 2250 + pendimethalin 660	0.58	2.64
21. Propachlor 4500 + pendimethalin 1320	0.68	1.50
22. Chloridazon 400 + propachlor 2000	0.55	2.41
23. Chloridazon 800 + propachlor 4000	0.44	1.51
24. Propyzamide 312.5	0.67	2.09
25. Propyzamide 625	0.79	2.09
26. Chlorbufam 400 + chloridazon 500	0.64	2.66
27. Fluazifop-P-butyl 31.3	0.93	2.80
28. Fluazifop-P-butyl 62.5	0.76	2.38
29. Linuron 66.5	0.10	0.09
30. Linuron 133	0.10	0.02
31. Metazachlor 750	0.20	-
LSD (5%)	0.135	0.371

The treatments are listed in Table 1. Linuron and the tank mixtures of propachlor with bentazone, and chloridazon or cyanazine with ioxynil reduced leek fresh weight when applied at the loop or post-crook crop stage. Prometryn, applied post-crook, and metazachlor, applied at the loop stage, also reduced leek fresh weight. The safest treatments at the loop stage appeared to be pendimethalin, propyzamide, propachlor, chlorbufam plus chloridazon, and propachlor plus ethofumesate, pendimethalin or chloridazon. The safest treatments at the post-crook stage were propyzamide, ioxynil, propachlor, chlorbufam plus chloridazon, propachlor plus pendimethalin or chloridazon, and pendimethalin plus ioxynil. The graminicide, fluazifop-P-butyl, had no effect on plant fresh weight when applied at either crop stage.

Field trials

Sandy loam soil

The treatments and results are given in Table 2. The pre-emergence herbicides controlled most weeds but the spatial distribution of those that remained was uneven. The main survivors were field pansy (*Viola arvensis*), common fumitory (*Fumaria officinalis*), scentless mayweed (*Tripleurospermum inodorum*) and knotgrass (*Polygonum aviculare*). The best post-emergence weed control was achieved with chloridazon + pendimethalin, pendimethalin alone, and propyzamide + propachlor. Weed control with chlorpropham, and with chlorbufam + chloridazon was also acceptable. The other treatments did not significantly reduce weed numbers compared with the pre-emergence alone. Weed fresh weight was least on plots treated with pendimethalin. There was little crop injury from any of the treatments. Angular transformation of the percent injury data was performed before analysis and the means of the transformed data are presented. At harvest on 5 October no treatment caused a significant reduction in crop yield. Leek stand at harvest was reduced by chloridazon + pendimethalin, propyzamide + propachlor, and methabenzthiazuron.

Silt soil

The treatments and results are given in Table 3. Weed numbers were low following the overall pre-emergence herbicide treatment. The most frequent survivors were common fumitory, annual nettle (*Urtica urens*), shepherds purse (*Capsella bursa-pastoris*) and common speedwell (*Veronica persica*). Methabenzthiazuron gave the best post-emergence weed control but caused crop damage and reduced leek stand and yield. Pendimethalin alone also gave good weed control but did not depress yield. The tank mix of chloridazon with pendimethalin gave the best all round results.

DISCUSSION

The safest and most effective treatment on the sandy loam soil was pendimethalin applied when the leeks were at the loop stage and the weeds were at the cotyledon stage. Propyzamide + propachlor, and mixtures of pendimethalin with chloridazon were also effective but caused some reduction in plant stand. The other treatments gave poorer weed control but with a different weed flora they might prove equal to or better than the treatments that worked well in this experiment. On the silt soil, pendimethalin + chloridazon was the best treatment.

ACKNOWLEDGMENTS

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TABLE 2. Results of crop and weed assessments made following application of post-emergence herbicides to drilled leeks on a sandy loam soil.

Treatments (g AI/ha) and crop stage	Weed number /m^2	Weed fresh wt g/m^2	% crop injury *	Leek number /m row	Leek yield t/ha
Chlorbufam 200 + chloridazon 250 loop and post-crook	1.4	389	12.92	9.1	45.9
Chloridazon 910 + pendimethalin 660 loop	0.4	154	23.74	8.1	41.3
Chloridazon 910 + pendimethalin 1320 loop	0.7	148	14.76	10.0	52.7
Propyzamide 625 loop	3.0	937	14.76	9.2	41.9
Chloridazon 430 + propachlor 2000 loop	3.2	805	4.31	9.5	48.8
Propyzamide 625 + propachlor 2250 loop	0.9	437	21.14	8.4	44.9
Fluazifop-P-butyl 62.5 loop	2.9	796	15.00	9.4	42.1
Chloridazon 910 loop	4.0	1074	0	8.9	42.4
Methabenzthiazuron 1400 post-crook	2.2	1310	18.67	7.5	40.9
Pendimethalin 1320 loop	0.5	150	4.31	10.9	52.1
Chlorpropham 400 loop	1.5	746	10.45	9.6	44.5
Chlorbufam 600 + chloridazon 750 post-crook	1.4	530	20.45	9.1	41.1
Untreated	4.6	1011	2.15	10.3	44.7
LSD (5%) for comparison with untreated	2.57	669	11.87	1.37	8.20
LSD (5%) for comparison with other means	2.96	765	13.71	1.58	9.43

*means of data transformed to angles for analysis

TABLE 3. Results of crop and weed assessments made following application of post-emergence herbicides to drilled leeks on a silt soil.

Treatments (g AI/ha) and crop stage	Weed Number /plot	Weed % cover	Leek 15 plant wt (g)	Leek number /m^2	Leek yield t/ha
Chlorbufam 200 + chloridazon 250 loop and post-crook	17.3	5.3	20.9	21.1	36.7
Chloridazon 910 + pendimethalin 660 loop	14.0	1.7	17.8	19.7	40.4
Chloridazon 910 + pendimethalin 1320 loop	6.7	0.7	27.4	22.2	40.6
Propyzamide 625 loop	13.0	4.3	20.4	20.7	38.0
Chloridazon 430 + propachlor 2000 loop	36.7	6.0	23.8	20.8	44.4
Propyzamide 625 + propachlor 2250 loop	16.3	3.3	21.5	23.0	39.8
Fluazifop-P-butyl 62.5 loop	41.7	11.7	21.9	20.3	39.9
Chloridazon 910 loop	26.3	7.7	23.8	20.4	40.7
Methabenzthiazuron 1400 post-crook	0.7	0.3	10.5	15.7	32.5
Pendimethalin 1320 loop	17.0	2.0	23.3	20.2	35.7
Chlorpropham 400 loop	23.7	8.0	24.1	20.3	37.7
Untreated	-	13.3	30.3	24.3	43.2
LSD (5%)	13.80	6.93	10.21	6.03	8.96

ALTERNATIVES TO CHLORBUFAM PLUS CHLORIDAZON MIXTURES FOR EARLY POST EMERGENCE CONTROL OF WEEDS IN DRILLED ONIONS

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ABSTRACT

A range of herbicide treatments was evaluated at two sites over two years to find a replacement for chlorbufam + chloridazon for early post-emergence weed control in drilled bulb onions. A pendimethalin + chloridazon mix was one of the most promising, but ioxynil and pendimethalin also seemed safe and effective. Methabenzthiazuron proved safe and effective on silt soils, but gave reduction in vigour (not yield) on peat soil. Several treatments gave better yields on silt soil in 1992 than chlorbufam + chloridazon.

INTRODUCTION

Bulb onions are grown on 7,000 ha in the UK and are worth around £30 million. A high proportion of these are direct drilled. The crop is not competitive and has a long germination period during which weed control can be difficult, particularly on peat soils. Poor weed control can result in severe yield reduction and cause difficulties with harvesting and drying.

In the 1970s researchers and growers developed a strategy of applying residual herbicides immediately prior to emergence of crop and weeds. This could give weed control until the first leaf stage of onion growth when several contact herbicides could be used. Due to the limited spraying opportunities and the large area that an individual grower must spray, it became common practice to apply residuals immediately post drilling leaving a gap when residual activity had ceased before first leaf stage. This gap was filled by using a mixture of chlorbufam plus chloridazon ('Alicep') applied when the cotyledon leaf of the onions was either at the 'loop' or post crook stage of development. In 1991, it was announced that the manufacture of chlorbufam would cease. An alternative control strategy was urgently needed and this paper presents the results of field trials carried out in 1991 and 1992.

MATERIALS AND METHODS

The herbicides used were bentazone (Basagran, 480 g/l SL; BASF plc), chlorbufam + chloridazon (Alicep, 20:25% w/w WP as control; BASF plc), chloridazon (Pyramin DF, 65% w/w WP; BASF plc), chloridazon + ethofumesate (Magnum, 275:170 g/l SC; BASF plc), chloridazon + propachlor (Ashlade CP, 86:400 g/l SC; Ashlade Formulations Ltd), chlorpropham (Campbells CIPC 40%, 400 g/l EC; J D Campbell & Sons), cyanazine (Fortrol, 500 g/l SC; Shell Chemicals UK Ltd), ethofumesate

(Nortron, 200 g/l EC; Schering Agriculture) fluazifop-p-butyl (Fusilade 5, 125 g/l EC; Zeneca Crop Protection), ioxynil (Totril, 225 g/l EC; Rhône-Poulenc Agriculture), linuron (Liquid Linuron, 133 g/l EC; Pan Britannica Industries Ltd), metazachlor (Butisan S, 500 g/l SC; BASF plc), methabenzthiazuron (Tribunil, 70% w/w WP; Bayer plc), pendimethalin (Stomp 330 (1991); Cyanamid of GB Ltd, Sovereign 330 (1992); Ciba Agriculture, both 330 g/l EC), prometryn (Gesagard 50, 50% w/w WP; Ciba Agriculture), propachlor (Portman Propachlor 50 FL, 500 g/l LI; Portman Agrochemicals Ltd), propyzamide (Kerb 50 W, 50% w/w WP; Pan Britannica Industries Ltd).

Trials on two sites were designed as randomised blocks with three replicates. Crops were grown to commercial standards.

Silt soil

Onions were precision drilled on 4 April 1991 (cv. Hyton) and on 18 March 1992 (cv. Caribo) into a coarse alluvial silt of pH 7.3 (2% o.m). A 1.83 m bed system with 5 rows per bed was used. Each plot was one bed wide and 6 m long. Pre-emergence herbicides were applied on 8 April 1991 and 25 March 1992 using propachlor at 4500 g/ha AI and pendimethalin at 330 g/ha AI. In 1991, treatments were applied at loop or post crook stages on 7 May and 24 May respectively in 200 l/ha water using an Oxford precision sprayer (OPS) and Lurmark 02-F80 nozzles (F80/0.80/3) at 200 kPa pressure (Table 1). In 1992, the dilution was 400 l/ha using a low drift version of the same nozzle and in 1992 all sprays were applied late in the loop stage on 28 April except for methabenzthiazuron and the second chlorbufam + chloridazon which were applied at post crook on 13 May (Table 2). The percentage of ground covered and number of weed species were recorded on 3 June in 1991 and on 27 May and 16 June in 1992. In 1992 crop vigour assessments were made, firstly by taking a 25 plant random sample per plot for fresh weight on 27 May and secondly by measuring the height of 10 plants on 16 June. Onions were lifted, dried and graded using near commercial techniques.

Peaty loam soil

Onions cv. Hysam were precision drilled in 1.68 m beds with 4 rows per bed on 20 February 1992 in to a peat loam soil with 23% o.m. content. Each plot was one bed wide and 6 m long. Pre-emergence herbicides of propachlor at 4500 g AI/ha + chlorpropham at 2240 g AI/ha were applied on 16 March. Treatment chemicals were applied in 250 l/ha water using crops with Teejet 8002 (F80/0.79/3) nozzles at 200 kPa pressure. All treatments were applied on 9 April and repeated at the post crook to true leaf stage on 13 May except for methabenzthiazuron which was applied on 13 May only (Table 3). The percentage of ground covered by weeds was recorded on 6 May and 9 June and vigour scores (where 0 = dead and 10 = vigorous) made on 19 May and 9 June.

RESULTS

Silt soil

In 1991, at the first true leaf stage, weed cover in all treatments was 5% or less (Table 1). It was observed that all treatments were as effective as the standard chlorbufam + chloridazon. Only the repeated applications of methabenzthiazuron caused any visual damage to the onions (data not presented). There were no differences in marketable yields between treatments (Table 1). There were no differences in final plant population with a mean of 70 plants/m².

In 1992, there were few weeds present and these lacked vigour at the time of the first treatment application due to dry conditions. The main weeds surviving pre-emergence sprays were fumitory (*Fumaria officinalis*), mayweed (*Tripleurospermum inodorum*) shepherds purse (*Capsella bursa-pastoris*), groundsel (*Senecio vulgaris*), speedwell (*Veronica persica*), redshank (*Polygonum persicaria*), chickweed (*Stellaria media*), knotgrass (*Polygonum aviculare*), annual nettle (*Urtica urens*), couchgrass (*Elymus repens*). Fumitory was the dominant weed.

At the first leaf stage, on 27 May, chloridazon + pendimethalin (1320 g AI/ha) ioxynil + pendimethalin, methabenzthiazuron and pendimethalin (1320 g AI/ha) (Table 2) gave the cleanest plots. Thereafter, weed control was poorer with up to 61.7% weed cover in some treatments by 16 June. Weights of onion plants taken on 27 May showed some checking from chloridazon, chloridazon + pendimethalin at 1320 g AI/ha, propyzamide, and methabenzthiazuron but later height measurements showed smaller differences. There were no differences in plant populations at harvest with a mean of 58 plants/m². The use of chloridazon alone gave a poorer ($P<0.05$) yield than chlorbufam + chloridazon. Several treatments gave higher marketable yields than the chlorbufam + chloridazon standard (Table 2).

Peaty loam soil 1992

There were no significant differences in vigour score between the treatments until 9 June when methabenzthiazuron was lower ($P<0.05$) than chloridazon + chlorbufam (Table 3). All treatments controlled weeds well in early May. On 9 June, weed control was similarly effective for all treatments except chlorpropham (at 400g AI/ha). Chloridazon alone gave a lower ($P<0.05$) marketable yield than chlorbufam + chloridazon (Table 3). Treatments of propyzamide with either ethofumesate or propachlor gave higher ($P<0.05$) yields than chlorbufam + chloridazon.

DISCUSSION

From the first year's work all materials performed reasonably well and it was not possible to select any outstanding treatments for silt soils but in 1992 several treatments gave better yields and weed control than the standard chlorbufam + chloridazon. These included chloridazon + pendimethalin, ioxynil + pendimethalin, methabenzthiazuron and pendimethalin. On peaty soils, only chlorpropham (400 g AI/ha) gave poorer weed control than chlorbufam + chloridazon. No treatment gave better weed control but several gave similarly effective control of weeds during the early growth stages. Chloridazon alone gave poorer yields, and propyzamide with either ethofumesate or propachlor gave better yields than chlorbufam + chloridazon. The best overall mixtures were chloridazon + pendimethalin and ioxynil + pendimethalin tank mixes. Methabenzthiazuron was also good but gave a temporary reduction in crop vigour which could cause problems in some seasons.

Although pendimethalin performed well it is not currently approved for use post-emergence in onions.

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TABLE 1. The effects of herbicide treatments applied from 'loop' stage of onions grown on a silt soil in 1991

Treatment (g AI/ha)	Timing	Percentage weed cover at 1 leaf	Marketable yield (>40mm) t/ha
chlorbufam (200) + chloridazon (250)	L + PC	5	37.7
chloridazon (550) + ethofumesate (340)	L	5	38.5
chloridazon (910) + pendimethalin (800)	L	<1	39.6
chloridazon (910) + pendimethalin (800)	PC	<1	42.8
chloridazon (910) + pendimethalin (1600)	L	<1	41.7
chloridazon (910) + pendimethalin (1600)	PC	2	42.0
ethofumesate (400)	L + PC	2	41.0
ethofumesate (700)	L	4	38.8
ethofumesate (700)	PC	2	38.3
methabenzthiazuron (1400)	PC	3	41.4
methabenzthiazuron (700)	L + PC	<1	36.6
pendimethalin (1200)	L	5	41.5
pendimethalin (1200)	L + PC	2	40.5
pendimethalin (800) + ioxynil (33.8)	L	5	37.5
pendimethalin (800) + ioxynil (33.8)	PC	2	40.6
LSD (5%)			5.13

L = application at onion 'loop' stage

PC = application at onion 'post crook' stage

TABLE 2. The effects of herbicide treatments applied from 'loop' stage of onions grown on a silt soil in 1992

Treatment (g AI/ha)	Percentage weed cover		Weight of 25 plants (g)	Height (mm)	Marketable yield (>40 mm)
	27 May	16 June	27 May	16 June	tonnes/ha
chlorbufam (200) + chloridazon (250)	2.3	12.6	24.5	40	50.9
chloridazon (900)	5.7	61.7	18.8	40	42.3
chloridazon (550) + ethofumesate (340)	1.5	33.3	26.0	39	60.1
chloridazon (910) + pendimethalin (660)	0.7	15.0	25.6	38	61.5
chloridazon (910) + pendimethalin (1320)	0.4	1.3	15.3	36	60.0
chloridazon (430) + propachlor (2000)	2.7	21.7	24.4	39	54.3
chlorpropham (400)	1.3	16.7	27.5	40	63.4
ioxynil (22.5) + pendimethalin (1320)	0.4	2.7	26.2	40	62.9
methabenzthiazuron (1400)	0.5	2.0	17.4	38	61.6
pendimethalin (1320)	0.4	4.3	26.3	42	64.1
propyzamide (625)	2.7	20.0	18.5	41	57.2
propyzamide (625) + propachlor (1800)	2.3	16.7	21.1	37	52.4
propyzamide (625) + ethofumesate (595)	0.8	9.7	21.2	40	59.5
LSD (5%) comparisons without chlorbufam + chloridazon	1.90	10.85	3.65	2.1	6.36
LSD (5%) comparisons with chlorbufam + chloridazon	1.65	9.40	3.16	1.8	5.51

All treatments applied at loop stage except chlorbufam + chloridazon repeated at post crook and methabenzthiazuron applied only at post crook.

TABLE 3. The effects of herbicide treatments applied from loop stage of onions grown on a peaty loam soil in 1992

Treatment (g AI/ha)	Timing	Percentage weed cover		Vigour score		Marketable yield (>40 mm)
		6 May	9 June	19 May	9 June	
chlorbufam (450) + chloridazon (562.5)	L+PC	2.7	2.0	6.0	8.3	34.4
chloridazon (910)	L+PC	3.3	4.0	5.3	7.7	29.3
chloridazon (550) + ethofumesate (340)	L+PC	4.3	4.0	6.0	8.3	35.5
chloridazon (910) + pendimethalin (660)	L+PC	1.3	0.7	5.7	8.0	33.0
chloridazon (910) + pendimethalin (1320)	L+PC	2.0	1.0	6.3	8.3	36.9
chloridazon (430) + propachlor (2000)	L+PC	2.7	6.0	6.0	8.3	33.5
chlorpropham (400)	L+PC	3.7	19.3	6.3	8.0	34.3
chlorpropham (1600)	L+PC	2.7	3.7	6.3	7.7	36.8
ioxynil (22.5) + pendimethalin (1320)	L+PC	1.7	0.7	5.7	8.0	35.9
methabenzthiazuron (1400)	PC	1.0	2.7	5.3	7.3	32.9
pendimethalin (1320)	L+PC	1.7	8.7	6.0	8.7	33.7
propyzamide (625)	L+PC	2.7	9.7	6.0	8.7	33.7
propyzamide (625 + ethofumesate (595)	L+PC	1.3	4.7	5.7	9.0	43.0
propyzamide (625) + propachlor (1800)	L+PC	2.3	7.0	5.3	8.7	40.2
LSD (5%)		4.10	10.64	0.81	0.92	4.90

A COMPARISON OF CULTURAL AND CHEMICAL METHODS OF WEED CONTROL IN POTATOES

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ABSTRACT

Cultural and chemical methods of weed control were compared in potatoes on organic and mineral soils. Cultivation stimulated emergence of large numbers of *Stellaria media* seedlings at the mineral soil site but weed biomass data confirmed that competition from weeds at all sites was similar for each method of weed control. Total yield of potatoes was also similar for each method.

INTRODUCTION

Competition from weeds can reduce the yield of potatoes and hinder harvesting (van Heemst, 1985; Nelson & Thoreson, 1981). Until the early 1960s, weed control was achieved solely by post-planting cultivations. Crop yields following post-planting cultivations were generally 95%, or more, of the yield from hand-weeded treatments (Pereira, 1941; Beveridge, *et al.,* 1964; Holmes, 1966). Where cultivations were responsible for yield reduction, they were observed to be of insufficient or excessive intensity.

New herbicides were compared, in trials, with an untreated control and the host farm's normal cultivation programme which often comprised up to 10 cultivation events. In a number of trials a less intensive cultural control was also examined and in many cases produced the highest yield observed (Pfeiffer & Phillips, 1964; Joice & Norris, 1964; North & Proctor, 1966). Yields from the best herbicides were comparable but not significantly better than those from cultivation treatments (Eddowes, 1964; North & Proctor, 1966).

The opportunities offered by herbicides to reduce labour requirements did not appear to be entirely perceived by growers. Neild (1971) observed that following an initially rapid increase in the use of herbicides, the area treated had stabilised at 50-60% and that they were generally an adjunct to, rather than a replacement of cultivations.

Of the herbicides tested in the 1960s, linuron and monolinuron gave the best combination of weed control, persistence and crop safety. Metribuzin became commercially available in the UK in 1974. As a contact and residual material with post-crop emergence applications, it demonstrated a step forward in the development of potato herbicides (Mannal *et al.*, 1972). The availability of more effective herbicides and a shrinking labour force led to fewer growers relying solely on cultivations for weed control.

In recent years concern about the environmental effects of pesticides has heightened. The objective of this work was to identify alternative methods of crop management which could provide opportunities to reduce herbicide usage on potatoes.

MATERIALS AND METHODS

Potatoes were machine planted at two light-textured sites, ADAS Arthur Rickwood (AR) (cv. Maris Piper, 1991; Estima, 1992) and ADAS High Mowthorpe (HM) (cv. Romano, 1992), with natural weed populations of contrasting species and densities.

In 1991 at Arthur Rickwood (peaty loam, 25-30% organic matter, high potential weed population), metribuzin was compared with weed control by cultivations alone, either with ridges reinstated or flattened between cultivation events. Metribuzin ('Sencorex WG' 70% W/WWG; Bayer UK) was applied at 1.05 kg AI/ha by a tractor-mounted Hardi sprayer operating at 160 kPa using F4110-20 hydraulic flat-fan nozzles to apply 200 l/ha spray volume and incorporated into pre-planting ridges (Treatment 1; Table 1).

Ridges of both post-planting cultivation treatments were knocked down by zig-zag harrows and trailing bar three weeks post-planting on 8 May, at the first flush of weed emergence. Thereafter, cultivation treatments were imposed; the frequency of cultivations was determined by the incidence of weed emergence and ceased when the crop growth was estimated to be sufficient to reduce competition from further weed growth.

The 'conventional ridge' treatment was ridged-up on 13 May, at crop emergence, by a Cousins vertical tined inter-row cultivator fitted with ridging bodies. At the next emergence of weeds, 24 May, the ridging bodies were replaced by Reekie finger weeders. Immediately following this pass, the ridging bodies were re-fitted and the ridges were reinstated. The fourth and final cultivation was made on 11 June as a single pass by the Cousins + ridging bodies (Treatment 2; Table 1).

The 'flat ridge' treatment was made by a Lilliston helical coil inter-row cultivator and immediately followed by the Cousins cultivator fitted with the Reekie weeders on 16 May. This operation was repeated at the third weed flush on 23 May. The final ridging was done using the same equipment and at the same time as the other cultivation treatment on 11 June (Treatment 3; Table 1).

A more comprehensive set of treatments was examined at two sites in 1992 (Table 1). At Arthur Rickwood the flat ridge technique was compared at two varying frequencies (Treatments 3 & 4) with metribuzin at 0.7 kg AI/ha incorporated pre-planting followed by bentazone ('Basagran' 480 g/l SC; BASF plc) at 0.72 kg AI/ha + 1.5 l/ha 97% mineral oil ('Actipron' Bayer UK) post emergence (Treatment 2), a combination of two cultivations followed by bentazone + oil (Treatment 5; Table 1) and an untreated control. Application details for metribuzin were as per 1991; bentazone was applied in 300 l/ha at 350 kPa.

In 1992 at High Mowthorpe (silty clay loam with flints over chalk, low weed population) a similar set of treatments was compared with an untreated control (Table 1): metribuzin, 0.7 kg AI/ha pre-emergence followed by 0.35 kg AI/ha metribuzin post-emergence (Treatment 2); a single pass by Hack disc cultivator at the first weed flush with (Treatment 6) or without (Treatment 3) 0.35 kg AI/ha metribuzin post-emergence; Hack disc followed immediately by a Harrow Comb multi-tine cultivator (Treatment 4); Hack disc + Harrow Comb followed by Harrow Comb at second weed flush (Treatment 5). Herbicides were applied at High Mowthorpe by a Hardi tractor-mounted sprayer operating at 200 kPa using F4110-24 hydraulic flat-fan nozzles to apply 200 l/ha spray volume.

Plots were six rows by 10-25 m of which the two centre rows were hand-lifted to determine yield. Trial design was of fully randomised blocks of eight (1991) or four replicates (1992).Weeds were assessed, in total and by species, by counting the number of plants /m^2 shortly before canopy closure. In 1992 weed above ground biomass was recorded shortly before haulm desiccation. All data were subjected to analysis of variance (GENSTAT 5) (Table 2).

TABLE 1. Herbicide dose and cultivation timing.

Site	Treatment	Herbicide	Cultivation 1	2	3	4
1991 AR	1	metribuzin[a]	-	-	-	-
	2 (ridge)	-	8 May	13 May	24 May	11 June
	3 (flat ridge)	-	8 May	16 May	23 May	11 June
1992 AR	1 Untreated	-	-	-	-	-
	2	metribuzin[b] + bentazone[c]	-	-	-	-
	3	-	6 May	22 May	-	-
	4	-	6 May	22 May	8 June	-
	5	bentazone[c]	6 May	22 May	-	-
1992 HM	1 Untreated	-	-	-	-	-
	2	metribuzin[d]	-	-	-	-
	3	-	1 June	-	-	-
	4	-	1 June	-	-	-
	5	-	1 June	26 June	-	-
	6	metribuzin[e]	1 June	-	-	-

a. metribuzin 1.05 kg AI/ha pre-planting incorporation.
b. metribuzin 0.7 kg AI/ha pre-planting incorporation.
c. bentazone 0.72 kg AI/ha + 1.5 l/ha 97% mineral oil post-em crop 15 cm.
d. metribuzin 0.7 kg AI/ha pre-em.
e. metribuzin 0.35 kg AI/ha post-em crop 12 cm.

RESULTS

1991 ADAS Arthur Rickwood

Weed control was very effective in all three treatments. Although not competitive in herbicide-treated plots, control of *Fallopia convolvulus* was better ($P<0.05$) in cultivated plots (Table 3). Yields were similar for each treatment and reflected the uniformity of weed control (Table 2). The flat ridge technique was selected for the 1992

TABLE 2. Weed number, weed biomass and total yield.

Treatment		Weed number ($/m^2$)	Weed biomass (t/ha d.m.)	Total yield (t/ha)
1991 AR	1	15.0	-	48.3
	2	15.6	-	47.4
	3	7.6	-	48.8
SED (14 df)		3.37	-	1.42
1992 AR	1	155.5	6.00	48.9
	2	68.0	0.10	56.1
	3	27.5	0.80	57.0
	4	10.5	1.81	55.0
	5	11.5	1.16	56.1
SED (16 df)		30.84	0.950	4.59
1992 HM	1	90.8	0.41	25.5
	2	0.0	0.00	35.7
	3	50.1	0.25	32.1
	4	159.0	0.08	35.9
	5	287.4	0.06	34.0
	6	0.0	0.02	33.7
SED (15 df)		86.10	0.034	2.28

experiment at Arthur Rickwood because, of the two methods examined, it appeared to perform the more effective weeding operation. The repeated ridge rebuilding also appeared to have a number of potential pitfalls. An excessive volume of soil was moved on each occasion which could increase the risk of root pruning. It could also increase clod formation in wet soil or increase soil moisture loss in dry conditions.

1992 ADAS Arthur Rickwood

A moderately high number ($155/m^2$) of particularly aggressive weeds, most notably *Chenopodium album*, constrained the yield of untreated plots (Table 2). All other treatments had lower weed populations than the untreated ($P<0.05$) and exhibited commercially acceptable levels of weed control. There were no significant differences between methods of weed control but the three cultivation treatments tended to have lowest weed populations.

Weed biomass provided a different and arguably clearer perspective of weed growth. All treatments had lower weed biomass than the untreated (6.0 t/ha) ($P<0.05$). Although there were no significant differences between treatments, cultivations tended to have higher values, due to a small number of large *C. album*. On metribuzin treated plots, there were higher numbers of *C. album*, but there was sufficient residual activity to restrict growth.

TABLE 3. Weed number /m^2 by species.

Site	Treatment 1	2	3	4	5	6	S.E.D.
1991 AR							
Galium aparine	0.5	0.2	0.2	-	-	-	0.17
Chenopodium album	1.2	1.1	0.6	-	-	-	0.66
Polygonum lapathifolium	1.2	1.6	0.6	-	-	-	0.34
Fallopia convolvulus	1.3	0.2	0.1	-	-	-	0.33
Viola arvensis	2.4	2.9	0.5	-	-	-	1.56
1992 AR							
Chenopodium album	44.0	23.0	7.5	3.5	4.0	-	10.27
Stellaria media	19.0	7.0	7.5	4.0	4.0	-	5.45
Urtica urens	30.0	6.0	7.0	1.5	1.0	-	6.77
Poa annua	23.5	24.0	3.5	0.5	0.5	-	11.75
1992 HM							
Senecio vulgaris	5.6	0.0	9.9	11.4	8.5	0.0	4.91
Sonchus asper	27.5	0.0	12.8	15.6	13.3	0.0	4.01
Stellaria media	36.8	0.0	15.5	123.9	256.3	0.0	86.10
Matricaria recutita	10.8	0.0	5.1	2.4	1.4	0.0	2.30
Papaver rhoeas	5.1	0.0	1.5	0.8	2.5	0.0	1.15
Lamium amplexicaule	3.0	0.0	2.7	1.3	0.8	0.0	1.18

There were only two weed emergence events and, therefore, increasing the number of cultivation passes did not improve weed control. There were no differences in yield, which was high, between the cultural and chemical treatments.

1992 ADAS High Mowthorpe

Weed populations in untreated plots were unusually high (91/m^2) for this site (Table 2). *Sonchus asper* was the most competitive species (Table 3). Both herbicide treatments provided long-season control of weed growth from both pre- and post-emergence applications of metribuzin.

Cultivations gave good control of most weeds but large numbers of *Stellaria media* were stimulated to emerge, especially where the Harrow Comb was used. The weed biomass data (Table 2) indicate that the relatively high numbers of *S. media* (up to 256/m^2) were not competitive with the potato crop. All treatments out-yielded ($P<0.05$) the untreated control by 6.6-10.4 t/ha but there were no differences in yield between the other treatments.

DISCUSSION

These results demonstrate that, on the light soil types tested, cultural weed control methods are capable of competing with the best herbicides currently available. Comparisons between fixed and variable costs are not straightforward but the cost of four cultivation events would equate to a herbicide programme comprising a residual and a contact material. This study has shown that as few as one or two cultivations can be appropriate but programmes will vary in an unpredictable manner from year to year. Extended periods of wet weather could, for example, compromise the efficacy of a cultivation programme. Cultural weed control may affect weed populations in subsequent crops, possibly leading to increased hebicide usage. Current work is therefore examining weed populations in two following crops.

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COMPARISON OF A PRE-EMERGENCE RESIDUAL HERBICIDE AND POST-EMERGENCE CULTIVATIONS FOR WEED CONTROL IN SPRING BEANS

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ABSTRACT

Four shallow cultivations using harrows early, late or at both timings or a mechanical weeder were evaluated as alternatives to a residual pre-emergence herbicide on crops of spring beans at two sites in 1992 and 1993. The effects on bean and weed populations and crop yield were investigated. Initial results suggest that well-timed cultivations can provide an alternative to residual herbicides for the control of many broad-leaved weed species and that generally there is no detrimental effect on plant population or yield.

INTRODUCTION

Weed control in field beans (*Vicia faba*) is usually achieved by applying a pre-emergence residual herbicide. In 1990, 87 000 ha of beans in England and Wales, 63% of the area grown, were treated with simazine alone (equivalent to 88 t AI) (Davis *et al.*, 1991). However, some soil applied herbicides used in beans, notably simazine, are now being detected in ground water prompting the need for alternatives to chemical weed control.

Recent research has shown that herbicides in winter and spring field beans rarely give any yield benefit (Cook *et al.*, 1991; Heath *et al.*, 1991). Despite this, herbicides are regularly applied, partly as an insurance and partly to avoid the need to desiccate weeds to aid harvesting. Alternative methods would not therefore necessarily need to give as good weed control as herbicides in order to be acceptable. Mechanical weed control has been tested in cereals (Rasmussen, 1991) with encouraging results. This paper investigates different timings of mechanical weeding in spring beans at two sites in 1992 and 1993 in comparison with standard herbicide treatments.

MATERIALS AND METHODS

The two sites were at ADAS Boxworth in Cambridgeshire and ADAS Drayton in Warwickshire, both on clay soils. Trials were established in commercial crops of spring beans, which received agrochemical inputs (except herbicides) according to normal farm practice. At Boxworth the varieties were Caspar, drilled on 25 February and harvested on 28 August 1992, and Victor drilled on 24 February 1993. At Drayton the variety was Troy in both years, drilled on 27 February and harvested on 5 September 1992 and ploughed-in on 18 February 1993. The treatments evaluated and target timings were :

HE. Harrow cultivation when weed size = cotyledon - 1 true leaf
HL. Harrow cultivation 2-3 weeks after first cultivation

HB. Harrow cultivation at both timings
PH. Pre-emergence herbicide as appropriate (see Table 1)
U. Untreated
W. Commercial weeder (at early timing in 1992; at both timings in 1993)(Boxworth only)

The harrows used were a 6.4m wide Parmiter zig-zag harrow with 20cm vertical tines (22 tines m^{-2}) at Boxworth and a 5m wide Parmiter flexible harrow with 6cm vertical tines (32 tines m^{-2}) at Drayton. The commercial weeder used at Boxworth was a 12m Einböck finger weeder with 38cm backward-sloping tines with vertical tips (42 tines m^{-2}). This treatment was not done at Drayton. Experimental design was a randomised complete block with four replicates and plots of 24m x 24m. Details of treatment timings are given in Table 1.

Weed and bean populations were counted 3 days before and 2 weeks after all mechanical control treatments using 12 x 0.25m^2 quadrats per plot. At the end of flowering the height of 10 plants per plot was recorded. Yields were assessed by taking 2 x 24 m cuts per plot with a plot combine harvester. Grain samples were taken and assessed for moisture content, and yields corrected to 85% d.m.. All data were subjected to analysis of variance using GENSTAT 5. Weed data were square-root transformed.

RESULTS

During cultivations with the harrows bean plants were pushed over and partially covered in soil. Many leaves were stripped from the beans and 1or 2 m^{-2} were pulled up or broken off. Large weeds (>10cm) tended to be pushed over but not uprooted. Small weeds (<10cm) were either uprooted or covered with soil. Size of weeds and beans at cultivation are detailed in Table 1. The Einböck weeder was less damaging to the crop on the settings adopted; the longer tines tended to move around the beans. No beans were pulled up or broken off and only weeds of less than 5cm were pulled up. Bean population was not significantly reduced by any treatment.

Weed control

Fool's Parsley (*Aethusa cynapium)* was present at Boxworth in 1993 and Drayton in 1992 (Figure 1a and b). Pre-emergence herbicides did not reduce populations compared to untreated when assessed pre-cultivation. Post-cultivation populations were only significantly different at Boxworth ($P<0.05$), where early harrowing was better than late harrowing, and harrowing twice was better still. Two passes with the commercial weeder was less effective than two passes with the harrow.

Orache (*Atriplex patula)* was present at Boxworth in 1993, and a combination of orache and fat hen (*Chenopodium album)* at Drayton in 1993 (Figure 1c and d). Species were not split at Drayton as the weeds were difficult to separate at the cotyledon stage. Control with the pre-emergence herbicides was good (Boxworth- $P<0.001$; Drayton- $P<0.05$). Post-cultivation populations were also significantly different (Boxworth- $P<0.001$; Drayton- $P<0.05$). Control by cultivations was better at Boxworth, where the early cultivation was better than the late, but the weeder was again less effective than the harrow treatments (Figure 1c). At Drayton two passes of the harrow were more effective than one.

Chickweed *(Stellaria media*) was present at Boxworth in 1992. Both pre- and post-cultivation populations were signficantly different between treatments ($P<0.001$) (Figure 1e). The herbicide gave better control than cultivation. Similar control was achieved from a single harrow treatment at either timing and the effect of two passes was additive. The weeder gave some control but low populations in this treatment make data interpretation difficult.

TABLE 1 Details of cultivation and herbicide treatments. (- = not recorded).

Cultivations

Treatment	Date	Approx. depth of cultivation (cm)	Surface soil conditions	Growth stage of crop (number of nodes)	Weed size	Date	Approx. depth of cultivation (cm)	Surface soil conditions	Growth stage of crop (number of nodes)	Weed size
	1992					*1993*				
Boxworth										
Harrow early	23 April	5.0	dry	3	cotyledon-4 leaves	6 May	2.5-5.0	dry	4-5	cotyledon-4 leaves
Harrow late	13 May	5.0	dry	7-8	10-20cm	20 May	2.5-5.0	dry	10	3 leaves to 20 cm
Weeder	10 April	2.5	dry	2	cotyledon-1 leaf	6 May	2.5-3.0	dry	4-5	cotyledon-4 leaves
Drayton										
Harrow early	30 April	2.5	moist	3	cotyledon-2 leaves	4 May	2.5	dry	-	cotyledon - 2 leaves
Harrow late	15 May	2.5	dry	-	cotyledon - several leaves	24 May	2.5	dry	-	1 - 6 leaves

Herbicides (appled using conventional 12m or 24m sprayers fitted with 02F110 nozzles at 2.5 bar pressure in 200-400 l water ha^{-1})

	Active ingredient and rate g AI/ha	Product used	Date applied	Surface soil conditions	Active ingredient and rate g AI/ha	Product used	Date of application	Surface soil conditions
	1992				*1993*			
Boxworth	simazine / trietazine (172.5g / 1207.5g)	Aventox SC; Dow Elanco	18 March	moist	terbutryn / trietazine (1000g / 1000g)	Senate; Schering Agriculture	19 March	dry
Drayton	simazine / trietazine (172.5g / 1207.5g)	Remtal SC; Schering Agriculture	20 March	dry	simazine / trietazine (172.5g / 1207.5g)	Remtal SC; Schering Agriculture	19 March	dry

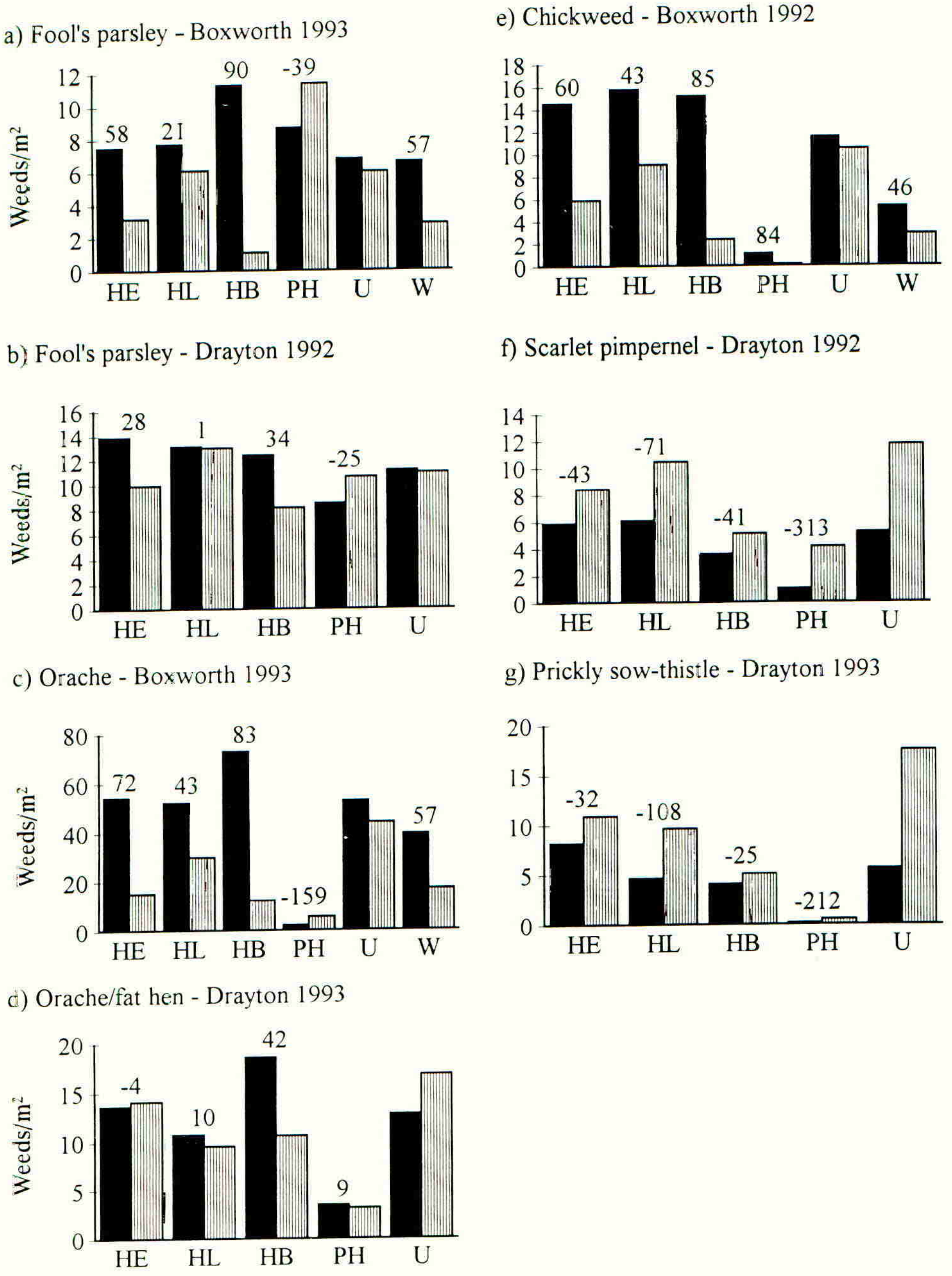

FIGURE 1. Effect of cultivation and herbicide treatments on weed populations. ■ = pre-cultivation, ▥ = post-cultivation. (Back-transformed data). Numbers above bars refer to percent 'control' achieved by cultivations, i.e. percent change between the two counts. Letters on x axis refer to treatments.

Post-cultivation populations of scarlet pimpernel *(Anagallis arvensis)* were significantly different between treatments (P<0.05) at Drayton in 1992. The herbicide treatment gave no control and populations increased between counts, due to continuing germination. All harrowing treatments helped to reduce this population increase (Figure 1f).

Prickly sow-thistle (*Sonchus asper*) occurred at Drayton in 1993. The herbicide gave a high level of control with significantly lower populations recorded pre-cultivation (P<0.001). Post-cultivation populations were significantly affected by treatment (P<0.001). Early harrowing helped to prevent some of the large increase in population seen in untreated plots and two passes gave the best control. The later cultivation had very little effect (Figure 1g).

Crop height

Crop height was decreased by harrowing twice at Boxworth in 1993 (P<0.001) and by all harrow cultivations at Drayton in 1992 (P<0.001). A single pass of the harrow reduced height by approximately 8cm, and two passes by approximately 13cm (Table 2).

TABLE 2. Effect of cultivation and herbicide treatments on crop height (cm).

	Treatment						SED
	HE	HL	HB	PH	U	W	
Boxworth							
1992	83.6	81.9	82.4	83.2	84.9	83.5	1.61
1993	121.9	122.2	114.2	129.0	130.8	127.8	2.98
Drayton							
1992	104.3	100.4	97.4	110.7	113.0	-	2.85
1993	62.4	57.1	54.1	69.1	67.8	-	5.19

Yield

Yield of seed was significantly (P<0.05) decreased at Drayton in 1992 in treatments with late harrowing (Table 3), but there was no effect at Boxworth.

TABLE 3. Effect of cultivations and herbicide treatments on yield of seed (t/ha at 85% d.m.) in 1992.

	Treatment						SED
	HE	HL	HB	PH	U	W	
Boxworth	4.21	4.02	4.20	4.51	4.12	4.08	0.198
Drayton	4.64	4.25	4.13	4.95	4.73	-	0.191

DISCUSSION

The absence of treatment effects on plant populations was similar to that found where cultivations for weed control have been used in winter beans (Cook, unpublished data).

The level of weed control given by cultivations will depend on a combination of weed growth stage, growth form, root type, weather and soil conditions. Early cultivations were generally more effective than later ones, and were also less likely to cause reductions in yield. A follow up cultivation usually improved the level of control achieved. The weeder was less effective than the harrows probably due its setting for this trial which resulted in a more gentle action and shallower working depth.

Orache and fool's parsley have their peak of germination in April/May and both weeds have tap roots. Control was poor at Drayton in 1992 probably due to the heavy soil type and was even worse in 1993 when the surface soil was moist at the early cultivation timing. Terpestra & Kounwenhaven (1981) reported that 12% less weeds were killed where the soil was wetted after cultivation. At the first cultivation timing with the harrows the fool's parsley was at cotyledon to 4 leaves stage and control was better than at the second pass (6 leaves-10cm). Control with two passes was additive; it is possible that the first pass weakens the weed and the second pass exploits this weakness. Plants left undisturbed until they are at 6 leaves-10cm high have a stronger root system. Similar results were found for chickweed, this again having a peak of germination in the spring. Control by the late harrowing was greater than that achieved for fools parsley, probably due to the weed being fibrous rooted and prostrate in habit and therefore easier to remove or cover with soil. Soil cover of 1.5-2.0cm has been found to give good control of weeds (Terpestra & Kounwenhaven, 1981). Scarlet pimpernel and prickly sow-thistle are spring germinating weeds with peaks of emergence in April/May and May/June respectively. These weeds continued to emerge after cultivation but populations were lower where cultivations had been made. As these weeds would be small or germinating around the time of cultivation, they would be very susceptible to soil movement and/or coverage with soil.

The results in this paper have demonstrated that cultivations can give satisfactory control of some weed species in spring beans and help reduce reliance on herbicides. However, weed control with cultivations does not leave the field completely clear of weeds which may add to the weed seed burden returned to the soil. This may have repercussions in following crops, although the species of weeds encountered in this series of experiments are easily controlled by herbicides in cereals. The next step in research may be the integration of low doses of herbicides and cultivations, which is being successfully tested in cereals (Blair *et al.*, 1993).

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PRELIMINARY RESULTS OF AN EVALUATION OF ALTERNATIVES TO THE USE OF HERBICIDES IN ORCHARDS

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ABSTRACT

An experiment comparing various mulches, an orchard floor vegetative cover and cultivation was started in a young, established apple orchard. In the first two years of the experiment, establishment of a low maintenance grass sward in the tree row strip severely reduced crop yield and soil and crop nitrogen concentrations. All the mulches provided good control of weeds. In the second year the organic mulches reduced soil mineral nitrogen concentrations but did not have any consistent effect upon crop nitrogen status. The black polypropylene mulch increased yield in the second year. Regular cultivation of the tree row strip achieved partial weed control, the yield was lower and soil mineral nitrogen concentration was reduced in the second year of the experiment.

INTRODUCTION

Over the past 30 years research on orchard soil management systems has established the very considerable benefits of herbicide management for controlling grass and weed competition. Herbicide management improves early growth and establishment, tree vigour and crop yield. Most benefit is reported from band application of herbicide along the tree row with the alleyway remaining in grass (Atkinson & Lipecki, 1980). Further increases in cropping have been obtained by complete elimination of vegetation from the orchard floor (Johnson *et al.*, 1983). However, concern about the effects of overall herbicide management upon soil structure and erosion risk have persuaded most growers to retain the grass alleyway (Atkinson & White, 1977).

Current practice is based upon the routine use of broad spectrum residual and contact acting herbicides. The annual use of such herbicides on apples and pears in the UK exceeds 155 tonnes of active ingredient per annum on a total national area of 33,000 ha (Davis et al., 1991) This heavy reliance upon herbicides is not consistent with the general principles and standards for Integrated Production (IP) of pome fruits in Europe (Dickler & Schaefermeyer, 1991) which aim to reduce agrochemical use in orchards by giving priority to non-chemical methods. One of the principal objections to certain herbicides is that they are known to contaminate drinking water at levels in excess of the Maximum Admissible Concentrations (Anon 1990). In the European Guidelines for IP, residual herbicides are generally in the 'not permitted' category whilst less hazardous foliage acting herbicides are in the 'permitted with restrictions' category.

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With the move towards IP and the increasing public concern about routine use of pesticides it is important to investigate possible alternatives to the use of herbicides for weed control in orchards. The three major alternative orchard floor management systems are cultivations, mulches and permanent orchard floor vegetation. Prior to the availability of suitable herbicides and the development of gang mowers suitable for cutting grass in orchards cultivation was the traditional method of controlling weed competition in orchards. A major disadvantage with cultivation was the decline in soil organic matter, the deterioration in soil structure, (Greenham, 1953) and the disturbance to the tree root system. Modern equipment allows cultivations to be shallower and to be restricted to the tree row area. These improvements may help to minimise the adverse effects of regular cultivation upon soil and roots. Research on mulches has been mainly targeted upon their value in herbicide management systems for improving moisture conservation and reducing the risk of soil erosion (Hipps *et al.*, 1990). The experiment reported in this paper examines the potential of mulches to suppress weed competition as a replacement for herbicide management. Grass swards are well known for their restrictive effect upon growth and cropping especially with trees grown on dwarfing rootstocks. A low maintenance amenity grass mix was chosen as a potentially less competitive grass sward. This paper reports preliminary results of the first two years.

MATERIALS AND METHODS

The experiment was started in spring 1991 in a three year old apple (cv Cox's Orange Pippin on M9 rootstock) orchard on a deep brickearth soil (Hamble series) in Kent. The trees were spaced 1.7 m in the row and 3.6 m between rows with 50% of the area in herbicide strip and 50% grass alleyway. The experimental treatments were applied to 50% of the orchard area centred on the tree row with the grass alleyway common to all the plots. Treatments were: 1. Herbicide management based upon residual herbicides; 2. Herbicide management based upon foliage acting herbicides permitted within IP; 3. Straw mulch (15 cm deep); 4. Bark mulch (7.5 cm deep); 5. Treatment 2 plus grass mowings returned to tree row strip; 6. Black polypropylene woven mulch (Mypex); 7. Cultivation; 8. Low maintenance amenity grass mix.

Herbicides were applied using a Cooper Pegler CP3 knapsack sprayer with a green polyjet anvil nozzle in a 50 cm shield. The pressure was 2 bar and the spray volume was 980 l/ha. The residual herbicide treatment was based upon spring (mid March) application of simazine plus amitrole (1991) or simazine and oxydiazon (1992); followed by summer application (mid June) of glufonsinate-ammonium and autumn (mid October) application of amitrole, 2,4-D, dichlorprop, MCPA and mecoprop. The IP herbicide treatments (2 and 5) were based upon spring application of amitrole plus mecoprop, summer application of glufonsinate-ammonium and autumn application of amitrole plus mecoprop. Details of products used and dose rates were:-

Amitrole (Weedazol-TL, 200g/l, A H Marks & Co. Ltd) at 800 g AI/ha.
Simazine (Simazine WP, 50% w/w, Murphy Chemicals Ltd) at 1100 g AI/ha.
Oxydiazon (Ronstar Liquid, 250 g/l, Embetec Crop Protection) at 2000 g AI/ha.
Glufonsinate-ammonium (Challenge, 150 g/l, Hoechst UK Ltd.) at 750 g AI/ha.
Mecoprop (Campbell's CMPP, 570 g/l, MTM Agrochemicals Ltd) at 2394 g AI/ha.
2,4-D, dichlorprop, MCPA and mecoprop (Campbell's New Campex, 34, 133, 53, 164 g/l, MTM Agrochemicals Ltd) at 187, 732, 292, 902 g AI/ha.

The straw and bark mulches were applied in May. The cultivation was done at approximately monthly intervals between April and October with a Heinz-Muller tractor mounted cultivator. This cultivated the soil to about 7.5 cm depth. The low maintenance grass mix was sown at 250 kg/ha in late April and consisted of 60% Lorinna perennial ryegrass, 35% Logro creeping red fescue and 5% Highland brown bent. It was mown at approximately six week intervals between April and October.

Weed populations were measured by counting and identifying weeds within five 0.5m² quadrats for each plot. Soil mineral nitrogen (SMN) measurements were made to a depth of 90 cm, taking six full depth cores on each plot. The soil samples were frozen prior to determining nitrate and ammonium concentrations. SMN concentrations were converted to quantities (kg/ha N) for the soil profile assuming a soil bulk density of 1.33 g/ml. Plots of treatment 6 were not sampled for SMN determination to avoid damage to the polypropylene mulch. Leaf samples for analysis were taken in mid-August from the mid-third of the current year's extension growth.

A randomised block design with four replicates was used. Each plot consisted of at least five trees with records being taken from the middle three trees. All data were subjected to analysis of variance and where appropriate treatment means were separated using Duncan's Multiple Range Test.

RESULTS

Weed control

Except for a build-up of groundsel (*Senecio vulgaris*) in autumn 1991 the residual herbicide treatment maintained a very high standard of weed control (Table 1). More weeds, mainly groundsel and plantain (*Plantago major*), were present on the IP herbicide plots although an acceptable commercial standard of weed control was achieved. The mulch

TABLE 1. Mean weed populations

Treatment	Number of weeds per m²			
	June 1991	October 1991	June 1992	October 1992
Residual herbicides	4	22	0	4
Contact herbicides	19	36	23	11
Straw mulch	0	1	4	3
Bark mulch	0	5	9	7
Trt. 2 plus mowings	7	31	46	12
'Mypex' mulch	0	0	1	0
Cultivation	55	45	33	45
Grass	28	10	15	5
SED	8.1	8.0	9.1	4.2

treatments controlled weed numbers effectively although there was evidence of a slight increase in weed numbers on the straw and bark treatments in year two. The highest weed populations were present in the cultivation treatment which also showed a temporary build-up of weed numbers between cultivations.

Crop Yield

In 1991 crop yields were low and very variable (Table 2) with no significant (P = 0.05) treatment effects. In 1992 the yield of the grass treatment was severely reduced (P<0.01) compared to all other treatments except cultivation. The yield on the 'Mypex' mulch treatment was higher (P<0.05) than yields on the straw mulch, cultivation and grass treatments.

TABLE 2 Marketable yield (tonne/ha)

Treatment	1991	1992†		Total (1991 + 1992)
Residual herbicide	4.3	9.9	bcd	14.2
Contact herbicide	6.1	10.9	bcd	17.0
Straw mulch	7.1	7.6	abc	14.7
Bark mulch	3.7	11.6	cd	15.3
Trt. 2 plus mowings	5.3	10.1	bcd	15.4
'Mypex' mulch	7.6	13.4	d	21.0
Cultivation	5.1	7.4	ab	12.1
Grass	7.5	5.1	a	12.6
SED	1.57	1.72		2.71

† values within the column followed by the same letter are not significantly different at P = 0.05

Nitrogen

The grass treatment consistently reduced SMN concentrations to approximately 50% of the values for the herbicide managed treatments (Table 3). The leaf nitrogen (Table 3) and fruit nitrogen (data not presented) concentrations were also reduced. The autumn 1991 SMN data does not indicate any other treatment effects but the 1991 leaf nitrogen and spring 1992 SMN concentrations were reduced by the bark mulch. By autumn 1992 the SMN concentration has been reduced by the straw and bark mulches and by cultivations to a similar level to that obtained on the grass treatment. These differences are not wholly reflected by the 1992 leaf nitrogen concentrations where only the grass treatment shows a reduction compared to the residual herbicide treatment.

TABLE 3 Soil mineral nitrogen (SMN) and leaf nitrogen concentrations

Treatment	Soil mineral nitrogen (kg/ha)† Autumn 1991		Spring 1992		Autumn 1992		Leaf nitrogen (%)† 1991		1992
Residual herbicide	128	a	112	c	103	bc	2.74	a	2.15
Contact herbicide	90	ab	94	bc	81	b	2.66	a	1.93
Straw mulch	123	a	92	bc	46	a	2.44	abc	2.01
Bark mulch	99	a	77	ab	44	a	2.31	bc	2.22
Trt. 2 plus mowings	112	a	116	c	111	c	2.56	ab	1.99
'Mypex' mulch	n.d.		n.d.		n.d.		2.57	ab	2.13
Cultivation	100	a	83	abc	55	a	2.57	ab	1.96
Grass	48	b	50	b	44	a	2.24	c	1.75
SED	20.1		15.0		12.0		0.133		0.159

† values within each column followed by the same letter are not significantly different at P = 0.05.

n.d. not determined.

DISCUSSION

The results described here clearly show that the establishment of a low maintenance grass sward within the tree row restricted growth and severely reduced marketable crop yield. These effects were associated with a sharp reduction in soil mineral nitrogen concentration and nitrogen uptake by the tree. It is likely that competition for moisture was another significant factor although this was not measured in this experiment. Clearly, the development of a satisfactory vegetative cover for orchards requires identification of plant species which are even less competitive that the low maintenance sward established in this experiment.

The use of foliage acting herbicides permitted within IP guidelines was less successful for controlling weeds than residual herbicides although a commercially acceptable standard of control was obtained. The growth, cropping, SMN and leaf nitrogen data showed no difference between the two herbicide treatments.

The mulch treatments effectively controlled weeds and had no adverse effects upon growth. However, there was some evidence of reduced yield from the straw mulch in 1992. The reduction in SMN concentrations under both organic mulch treatments in the second year of the experiment is presumably associated with the decomposition of mulching materials with a wide C/N ratio. The depletion of SMN was not consistently reflected in crop nitrogen status. The enhancement of crop yield in the second year of the experiment by the black polypropylene mulch does not appear to be associated with any change in crop nitrogen status. As the mulch is a porous thin layer, an improvement in moisture conservation seems unlikely. Mulches are known to influence soil temperatures, with reductions associated with straw mulches (Weller, 1969) and increases associated with black plastic mulches (Nielsen *et al.*, 1986). Measurement of soil temperatures on the experiment commenced in 1993 and initial results confirm this pattern (data not presented).

The cultivation treatment was only partially successful in controlling weeds. There was an indication of a reduced yield in the second year of the experiment together with a reduction in SMN concentrations. The depletion in SMN is unexpected as regular soil cultivation has previously increased mineralisation of soil nitrogen in orchards (Greenham, 1965). The depletion may be explained by the partial weed control and uptake of nitrogen by surviving weeds during the growing season.

ACKNOWLEDGEMENTS

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THE USE OF BLACK POLYETHYLENE AS A PRE-PLANTING MULCH IN VEGETABLES: ITS EFFECT ON WEEDS, CROP AND SOIL.

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ABSTRACT

There is interest in alternative methods of weed control as the availability of herbicides for vegetable crops declines and there is increased demand for information on reduced pesticide input systems. A series of trials on organic farms is described in which polyethylene was tried as a pre-planting mulch to increase weed emergence and improve the stale seedbed approach to weed control. The use of black polyethylene, laid for 2-8 weeks and lifted prior to planting, prevented weed establishment, and greatly reduced weed growth in the following planted vegetable crop. In comparison weed growth was vigorous in the following crop after use of a stale seedbed and clear polyethylene mulches laid for 2-8 weeks before to planting, with weed removal prior to planting. Crop yield was also improved by the use of the pre-planting black polyethylene mulch. There is evidence that moisture may be less limiting where the black mulch had been used, and nitrate leaching and depletion by weed growth was reduced. However, there is no clear explanation for the reduction in weed growth following use of the black mulch. The technique described could be of interest to small-scale and specialist growers, but the cost requires repeated use of materials, which will require further machinery and materials development for large-scale use.

INTRODUCTION

As the costs of developing novel herbicide products increase, or re-registration is not sought for older products, it is probable that the range of herbicides available to the vegetable grower will diminish. There is also some interest in the development of reduced pesticide input systems of production which use little or no herbicide in response to consumer demand.

This paper describes a series of trials carried out in 1990-93 on land already converted to organic standards, as part of a research programme on the use of mulches in reduced input systems for vegetables. The trial series investigated whether the traditional stale seed-bed approach to weed control could be improved by encouraging early weed growth with the use of clear polyethylene ground cover, so depleting the seedbank, or masking early weed growth with black polyethylene mulch. The polyethylene was then removed prior to crop planting following removal of any weeds present, to look at the effect on consequent weed and crop growth. Soil conditions under the black polyethylene covers were measured in one of the trials.

METHODS AND MATERIALS

The experiments in 1990 and 1991 were undertaken at the Edinburgh School of Agriculture Organic Farming Centre field site at Jamesfield Farm, Fife in a silty sandy loam over clay loam. The 1993 experiments were at the SAC/Edinburgh University Sustainable Farming Systems field site at Woodside Farm, Morayshire, on a light sandy loam. Both farms are arable with a long history of vegetable crop production.

Trial A

Calabrese (cv. Corvet) was planted on 28 June 1990 at 20 cm spacing in 60 cm rows following treatments: (i) Standard stale seedbed managed over 8 wk; (ii) Clear polyethylene (150µm) laid for 2, 4 or 8 wk onto the seedbed prior to lifting and then crop planting after any weeds present had been removed; (iii) Black polyethylene (50 µm) laid for 2, 4 or 8 wk onto the seedbed prior to lifting and then crop planting. Plots were 1.8 m beds x 3 m long, with treatments randomised in four replicate blocks.

Trials B and C

Treatments, bed size and plot size as for Trial A, excluding the clear polyethylene, with calabrese (cv. Shogun) planted on 18 June 1991, and carrot (cv. Nairobi F1) sown on 9 June 1993 at 60 plants/m of row, at 20cm spacing, otherwise on the same plot size.

Trials D and E

Treatments, bed size and plot size as in Trials B/C, plus a stale seedbed approach with extra hand-weeding in the crop. The crops were (D) calabrese (cv. Shogun) and (E) lettuce (cv. Saladin) planted on 2 June 1993.

Trial F

Treatments, bed size and plot size as in Trial C, with carrots (cv. Nandor) sown at 60 plants/m at 20cm spacing on 3 July 1991. This trial was established to monitor soil conditions underneath the black polyethylene. The soil was sampled after seedbed preparation to determine moisture content and soil mineral nitrogen on 22 April 1991. Thereafter soil samples were taken weekly for the first 2 wk then fortnightly until the mulch was removed. Samples were divided for soil moisture determination (drying at 105°C for 24 h) and extraction with 1M KCl to determine nitrate and ammonium concentration by continuous flow analysis (Best, 1976; Crooke and Simpson, 1971). Soil temperature probes (Grant Instruments) were inserted to 100 mm in all plots.

RESULTS

There were few live weeds present in the plots which had been covered by black polyethylene for 2, 4 or 8 wk, except for *Elymus repens* shoots in Trials A and B. In comparison, covering the ground with clear polyethylene in Trial A allowed considerable weed growth with close to complete ground cover after 8 weeks polyethylene cover, as was the case with the uncovered stale seedbed (Table 1). The remaining weeds in the stale seedbed and clear polyethylene plots were then removed prior to planting the crop. Weed re-growth was much greater following the use of clear polyethylene or stale seedbed methods than if black polyethylene had been used (Table 1).

TABLE 1. Effect of pre-planting treatment on weed ground cover (%) at planting (P), and 7-8 wk (7-8 w) after planting, calabrese (c), lettuce (l) and carrots (r)

Pre-planting treatment	Trial A(c) P	A(c) 7-8w	B(c) P	B(c) 7-8w	C(r) P	C(r) 7-8w	D(c) P	D(c) 7-8w	E(l) P	E(l) 7-8w
Stale s.-b.	100	42	100	75	38	48	28	79	30	91
Stale s.-b.(hw)	-	-	-	-	38	14	28	6	31	11
Black poly. 2wk	3	38	T	21	T	5	1	7	1	9
Black poly. 4wk	0	25	T	23	0	6	0	6	1	9
Black poly. 8wk	T	28	T	23	0	6	0	8	0	7
Clear poly. 2wk	47	85	-	-	-	-	-	-	-	-
Clear poly. 4wk	60	63	-	-	-	-	-	-	-	-
Clear poly. 8wk	96	60	-	-	-	-	-	-	-	-
	21 d.f.		12 d.f.		12 d.f.		21 d.f.		21 d.f.	
SED±	5.5	15.3	-	5.8	0.9	3.7	3.1	2.9	2.0	2.3

s-b. = seedbed; (hw) = plus hand-weeding; poly. = polyethylene; T = trace

TABLE 2. Effect of pre-planting treatment on marketable yield (fresh weight kg/plot) of calabrese (c) and lettuce (l)

Pre-planting treatment	Trial A(c)	B (c)	D (c)	E (l)
Stale s.-b.	0.27	0.24	1.00	7.91
Stale s.-b.(hw)	-	-	1.94	6.92
Black poly. 2wk	0.69	1.14	2.32	9.76
Black poly. 4wk	1.07	1.49	2.35	11.52
Black poly. 8wk	1.25	1.04	2.42	9.12
Clear poly. 2wk	0.10	-	-	-
Clear poly. 4wk	0.13	-	-	-
Clear poly. 8wk	0.87	-	-	-
	21 d.f.	12 d.f.	21 d.f.	21 d.f.
SED±	0.430	0.301	0.288	1.517

s.-b. = seedbed; (hw) = plus hand-weeding; poly. = polyethylene

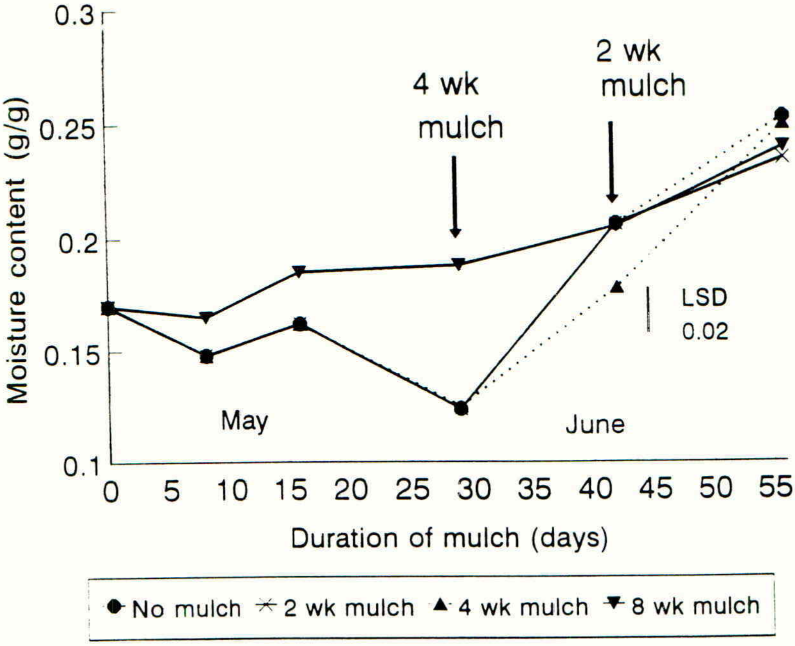

Figure 1. Changes in the gravimetric moisture content of the top 20cm of soil either uncovered or covered by black polyethylene mulch for different periods before planting.

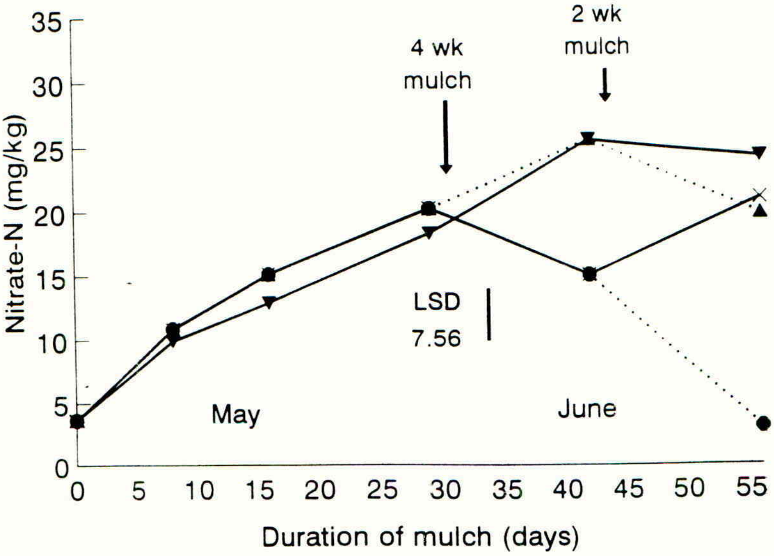

Figure 2. Changes in the nitrate-N concentration of the top 20cm of soil either uncovered or covered by black polyethylene mulch for different periods before planting. Legend as for Figure 1.

The use of the black polyethylene mulch before planting also significantly improved calabrese crop yield over the other techniques; particularly where the polyethylene had remained in place for 4-8 wk in Trial A (Table 2). The difference in yield over the stale seedbed approach, particularly from 4 wk of cover, was also noted in Trial B. In trial D, there was a similar notable improved yield in calabrese from all periods of cover over the stale seed-bed alone, even with extra hand-weeding. The lettuce crop (Trial E) showed a large yield response; particularly following 4 wk of ground cover.

The soil moisture status generally fell throughout the first 4 wk in Trial E, as potential evaporation increased (Figure 1). Thereafter, this trend was reversed as rainfall increased. The plots covered with black polyethylene at the beginning of the trial (8 wks cover) showed very significantly higher ($P<0.01$) moisture content than the uncovered plots for the first 4 wk. A steady rise in moisture content under the polyethylene was noted throughout the whole period of the cover. The plots covered for 4 or 2 wk showed a rapid rise in moisture content after covering.

There was a rapid rise in soil nitrate concentration during the first 4 wk in the uncovered plots, but then levels fell rapidly to that seen at the start of the trial (Figure 2). The plots covered for 2, 4 and 8 wk also showed an initial rise in nitrate, and these continued to rise. All the covered plots had, thereafter, higher levels of nitrate than the uncovered plots. There was no difference in ammonium levels between treatments. Temperature monitoring indicated that temperatures under plastic were higher from the middle of the day than in uncovered plots, but there was little difference in the morning.

DISCUSSION

The consistency of the effect noted in five trials on two differing soil types and sites would indicate that the phenomenon of reduced weed growth following ground cover to prevent light penetration requires further analysis. Of equal interest is the marked increase in crop yield following the use of this technique. In this series, land registered for organic farming was used, where there would normally be limits to available nitrogen and other resources not limiting in conventional farming. Other authors have indicated that the temperature of the ground under black mulches does not consistently increase (Wolfe *et al.* 1992). However, where the soil surface is covered, water loss by evaporation is reduced (Robbins *et al.* 1952). This will lead to conservation of moisture in the surface horizons of the soil compared to uncovered plots when a dry spell precedes planting. The rapid fall in the nitrate concentration of the uncovered plots after 4 wk coincided with an increase in rainfall and probably resulted from the leaching of nitrate down the soil profile. This was prevented in covered plots and nitrate will therefore be less limiting in once covered plots than where left uncovered and a wet spell preceded planting. Rapid re-emergence of weeds in stale seedbed plots would probably also have reduced available nitrate.

However, it is less clear how conditions may have reduced weed emergence and growth in the crops following the use of black polyethylene mulches. There was little evidence of high weed germination and death under the polyethylene. Factors associated with weed dormancy, but possibly also soil changes such as slight surface compaction from the presence of the mulch may be implicated, but this requires further research.

The practicalities of laying, lifting and re-laying polyethylene mulch limits the usefulness of the technique, except to the small or specialist and amenity grower, until appropriate techniques and machinery have been developed. It is only with such equipment that the economics of use become practical. However, machinery is available for lifting and re-laying specially prepared reinforced plastics which may allow the technique to be used more widely. As the availability of herbicides and the requisites of customers change, the use of mulches may become of greater interest to the vegetable grower, and the approach described in this paper may have uses for both weed control and improved crop growth.

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Evening Discussion Session 1

The Effect of Pending Legislation and other External Pressures on the Future of Pesticides Packaging

Chairman Mr R F NORMAN

Session Organiser Mr T H ROBINSON

Paper EDS-1

THE EFFECT OF PENDING LEGISLATION AND OTHER EXTERNAL PRESSURES ON THE FUTURE OF PESTICIDES PACKAGING

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ABSTRACT

Resulting from the increased environmental concern apparent over the last decade, waste has been targeted as a prime area for action. Within the waste stream, Governments and environmental groups have highlighted used packaging as a key element justifying particular control. As a consequence, legislation and regulation have developed rapidly over the last few years and will have major impact in future years. In the past, they have been influenced more by political motives or emotional factors rather than realism. This paper attempts to review broadly the main factors and trends relating to used packaging in general, and, where appropriate, to the specific pesticide industry. A number of key issues for the industry are proposed for further discussions.

INTRODUCTION

To reduce the complexities of packaging waste management to a manageable and useful presentation, three topics have been selected which I hope will provide a basic comprehension of the subject and its implications. These topics are Definitions commonly used and accepted in the industry, Legislation and Regulation with specific reference to European and German developments, and finally the Pressures and Issues relating to the pesticide industry.

WASTE MANAGEMENT DEFINITIONS

Before moving to legal aspects, it would be useful to cover some specific definitions which will assist in a better understanding of the waste management issues

Material recycling refers to mechanical recycling (either as mono-product or as mixed product) AND feedstock recycling (applicable only to plastics)

Energy Recovery refers to incineration, with recovery of heat or power, from Municipal Solid Waste, co-combustion or mono-combustion of plastics, and RDF (Refuse Derived Fuel)

Recovery is the broad definition covering Material Recycling and Energy Recovery

Options relate to the choices available for packaging waste management, regardless of material

- Waste Avoidance - reduction/reuse
- Material Recycling - mechanical/feedstock
- Energy Recovery
- Incineration
- Landfill

Although this is a common vocabulary, interpretation varies according to standpoint. While there is general acceptance that the key objective should be to conserve resources by minimising landfill, legislators tend to prioritise this list into a hierarchy, whereas industry believes that all options should have equal validity, promoting a flexible and integrated approach to waste management. In addition, of course, not all options are relevant to all materials. Operators should be free to select appropriate options on environmental, practical and economic grounds. With regulatory bodies and environmental groups focussing strongly on mechanical recycling as **the** solution to packaging waste issues, it must be remembered that it is not environmentally beneficial to recycle if the process uses more resources and energy than are gained. In the case of hazardous material packaging, material recycling is often neither an environmental nor a practical alternative. Flexibility of approach is imperative.

LEGISLATION /REGULATION

Let me state at the outset that there is little specific legislation relating to the used packaging of hazardous materials, but by implication or broad definition, they are included within some of the existing or proposed regulations.

Most current packaging legislation has been designed to control the domestic waste stream through various restrictions and targets relating to Municipal Solid Waste, but it is well worthwhile examining these proposals to detect underlying trends in official and political thinking, which will ultimately impact on the industrial packaging and hazardous material packaging markets. In the limited time available, I intend to consider two specific topics - the proposed European Directive on Packaging and Packaging Waste, and the German Packaging Ordinance of 1991.

Europe

The scope of this Directive is all-embracing. It "covers all packaging placed on the market in the Community, and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service or household level".

The major elements of the Directive concern

- ° National Targets of 90% packaging recovery (60% minimum recycling for each material and up to 30% energy recovery permitted), 10 years after entry into force of the Directive. These targets can be modified "if scientific research, or any other evaluation technique, such as eco-balances, prove that other recovery processes show greater environmental advantages".
- ° National return and management systems set up within 5 years
- ° Establishment of programmes for consumer information
- ° National implementation of designated marking systems

At the time of writing, there can be no definite projection of the final format of this Directive as it wends its way laden with many proposed amendments through the various Euro Committees, Councils and Parliament. The Commission will issue a new proposed Directive in September, taking into account the amendments from the Parliament it is prepared to accept. National Governments, via their Permanent Representations in Brussels, will continue to work towards consensus on the proposal in order for the Council of Ministers to reach a "common position", possibly in December. This position will then be considered by the Parliament in a "second reading" before submission for final adoption to the Council of Ministers. However, the general principles have been established although detail may still be influenced by the many interested parties. In particular, the plastics industry through APME/PWMI, continues to lobby for lower and more realistic recycling targets, coupled with an increased energy recovery allowance. In the interim it should be remembered that in the absence of EC rules, member states remain free to develop their own programmes, provided such programmes do not infringe EC law, particularly free trade rules.

The question now arises as to whether hazardous material packaging - and in particular pesticide packaging - will fall within the remit of the Packaging and Packaging Waste Directive. Article 1 states that "packaging waste to be considered as hazardous waste, besides having to conform with this Directive, shall be subject to specific management schemes (return, collection, treatment) if appropriate and necessary in conformity with the Council Directive 91/689 EEC on hazardous waste". This raises two further points

- domestic waste is excluded from the Hazardous Waste Directive, and therefore the packaging of garden pesticides (and other hazardous materials) would fall within the Packaging and Packaging Waste Directive.

- no current definition exists for "packaging to be considered as hazardous" in the sense that it is contaminated with hazardous material from its contents. At this time, relevant industrial packaging could fall within either Directive. Until the position is clarified, decisions are likely to be made on a national basis, leading to further confused waste management systems in Europe.

This unacceptable situation has been examined by the CEFIC Industrial Packaging Group, who in the context of the European Waste Catalogue, have submitted to EC DGXI proposed definitions for packaging that has <u>not</u> to be considered as contaminated, and for the term "empty". The proposals are as follows:

a) A contaminated packaging is defined as a packaging having one or more of the hazardous properties listed in Annex III of the Council Directive of 12 December 1991 on hazardous waste (91/689/EEC).

b) A used packaging shall <u>not</u> be considered as contaminated provided it has been:
   - <u>emptied</u> in accordance with the definition hereunder if its contents had one or more of the hazardous properties referred to in above-mentioned Annex III; H1 to H5, and if it has been closed and consigned, with its original labels still in place, to an economic operator for recovery
   OR
   -<u>cleaned</u> if its contents had one or more of the hazardous properties referred to in above-mentioned Annex III: H6 to H14
   OR
   -<u>emptied and cleaned</u> by removal of an inner liner which did not leak its contents into the packaging.

c) A packaging, or an inner liner removed from a packaging, is empty if all residues have been removed that can be removed using the practices commonly employed to remove materials from that type of packaging e.g. removing of an inner liner or pouring, pumping, aspirating, shaking, scraping, chipping, etc. or if necessary a combination of these.

Comment on these proposals is still awaited. It is important to clarify definitions, and through them the appropriate Directive under which to operate, to ensure the development of proper collection, recovery and/or disposal systems.

<u>Germany</u>

I would like to turn to German legislation, and in particular, to that known as the Töpfer Ordinance 1991 or more colloquially as the DSD or green point system. It is not directly applicable to your used packaging as it specifically excludes "packaging with residual substances or preparations, or soiled or contaminated by substances or preparations that constitute a health or environmental risk", with specific reference to plant protection agents and pesticides. Again we return to the problems of definition (soiled, contaminated), but as it is more specific than the European Directive proposals, it is probable that your packaging will fall under a new Ordinance on Packaging for Dangerous Substances, which is expected to be published in Q3 1993.

However, it is worthwhile to consider briefly the 1991 Ordinance to see what lessons can be learned. While it led the way in Europe on packaging waste regulation, it has also demonstrated that failure to consult, failure to understand basic principles, and concession to green pressures in place of realistic development, has produced disastrous results with serious implications not only for Germany, but for other European countries. In the short term, collection targets have been exceeded, resulting in a huge imbalance between collected volumes and the downstream capacity to handle it, particularly as energy recovery is currently only accepted on a very limited basis in Germany - although this may change in the future . Mountains of waste packaging are building up to be stored at high cost, finances are out of control, many packagers are rumoured to be using but not paying for the green spot, and in surrounding countries, German waste packaging - offered at negative prices -is seriously affecting local national recycling initiatives. The lesson to be learned is that legislation and regulation must be based on realism, a mutual understanding between governments and industry, and the capability of industry to absorb material collected (by all options) on an environmentally and economically sound basis, rather than be based on political expediency.

Time does not permit a review of all European countries but it is certain that through an understanding of discussion surrounding the proposed European plans, and practical experience of German developments, a more pragmatic approach to packaging waste is evolving. For example, in France, through consultation with involved parties, sensible plans are now being set on the basis of legislation for recovery of both domestic and industrial packaging waste (including that for hazardous materials). The key factor is "what can be recovered", rather than "what can be collected".

Nothing is less certain than the future of packaging legislation and regulation, but it is probably safe to predict the following "trends":

- reduction of packaging waste
  1. reuse
  2. higher contents/packaging ratio
- landfill minimisation (higher landfill costs)
- increasing legislation/regulation
  A. in short/medium term national rather than European based.
  B. manufacturers/distributors responsibility (practical and financial) for environmentally acceptable recovery or disposal
  C. more flexibility in recovery options
  D. more realistic <u>collection for recycling</u> targets
- increasing attention to industrial and hazardous material packaging (forced return systems?)

Provided these trends are followed, and assuming a non-discriminatory approach to packaging materials, plastics have nothing to fear in comparison with other materials. In fact, in addition to its well-known strengths for all forms of packaging, it is also the only material capable of being recovered by all the recognised options.

PRESSURES AND ISSUES

Moving from the general to the specific, what now are the pressures and issues facing the packaging of pesticides? They relate to two major aspects.

Firstly the packaging itself - in this case plastics - and secondly the effect on the packaging of the nature of its contents. It should be remembered that packaging in general, and plastics packaging in particular, is non-hazardous, but that status will be affected by the degree and type of contamination by the contents.

The fact that tonight we are discussing the packaging of pesticides allows us to be specific in considering the future related to packagings which have been in contact with, and almost certainly will contain residues of, hazardous materials. Although the main pressure will result from current and pending legislation, there are other factors to be taken into consideration, for example:

- Duty of Care (which has a legal basis in some countries and is implicit in others)
- public image / reactions
- pressure group attitudes

I do not intend to discuss them now in any detail as they are well-understood by most of you, but this topic can be expanded during the discussion period. These factors, of course, inter-relate, and in combination force us to consider the key issues which must be addressed to ensure a lawful and ethical basis, and a future, for our businesses. I use the word "us" deliberately because no one part of the chain stands alone on waste management issues - acceptable solutions will only be found through cooperation between government (national and local), material producers, packaging manufacturers, fillers and users, in your case, the farming community. Additionally it should not be forgotten that even among the fillers, the agrochemical industry is not unique, and many other industries (e.g. oil, fertilisers, pharmaceuticals) have similar issues to consider , and opportunities for cooperation must be sought. Your industry produces only a very small proportion of the total packaging waste. Much strength in practical terms, together with the important benefit of shared costs and resources, will be gained from working with others.

For the final part of this presentation, I would like to identify the key issues relating to the future of pesticides packaging, those which I believe to be the most important to progress. It is vital that action starts today, whether or not legislation or regulation exists, to demonstrate both proactivity and more fundamentally, a <u>real</u> knowledge of the operational processes. This will enable discussion and lobbying based on experience rather than on ignorance. Most of this sector will be in listing form with a few brief comments of explanation, and I hope it will serve to generate ideas and opinions for development in the open forum which follows.

Despite the fact that there is not yet a clear definition of either "hazardous packaging" or "non-hazardous packaging" (which as previously mentioned is being handled by CEFIC), I believe all the ensuing items require urgent attention in whichever category the packaging falls. It should also be noted that RECOVERY is not included, as I believe it is not one of the most important issues facing <u>your</u> industry - others, of course, are dedicating substantial resources to recovery systems.

A <u>Collection</u>
- industry responsibility
- bring system or regular pick-up
- synergy with - agricultural film
  - oil packaging
- cooperation with local authorities

B <u>Potential for Reuse</u>
- larger containers
- closed loop basis
- specification limitations (eg UN)
- can they be changed safely
- liner systems

C <u>Design Factors</u>
- for reuse (standardisation?)
- for recycling
- for ease of emptying
- use of recycled material in packaging
- identification/marking

D <u>Communications</u>
- users
- media, public
- within industry / across borders

E <u>Funding</u>
- industry responsibility
- to cover collection, (sorting), recovery
- which part of chain to take funding
- how much and how allocated
- control systems

F <u>Lobbying</u>
- with like-minded groups
- solutions must be realistic, environmentally and economically acceptable
- consistent legislation across Europe
- all recovery options must be available
- position on economic instruments / deposits

None of these is the sole responsibility of the agrochemical industry - as stated previously there is a chain responsibility, within which there are already a number of initiatives in progress, not all specific to agrochemicals, but from which lessons may be learned and ideas developed. Examples of current activities which would warrant examination include

ECOFUT (France)
RIGK (Germany)
VCI Project (Germany)
Second Life Plastics (UK)
TNO Study (NL)
Agricultural Pilot Programme (Germany)

In conclusion, I hope that this short presentation has provided you with an insight into the complexities and uncertainties of packaging waste management, an indication of possible trends in legislation, and direction to the issues and resulting action points which will undoubtedly confront the Crop Protection Industry over the next few years.

REFERENCES

EC - Proposed Council Directive on Packaging and Packaging Waste - COM(92) 278 final SYN 436 15th July 1992
EC - Council Directive on Hazardous Waste (91/689/EEC) 12th December 1991
Germany - Ordinance on the Avoidance of Packaging Waste (Töpfer) - Verpackungsverordnung 12th June 1991
CEFIC - European Chemical Industry Council, avenue Van Nieuwenhuyse 4, box 1, B-1160 Brussels, Belgium
ECOFUT - 5 rue de Chazelles, 75017 Paris, France
RIGK - Hessenring 121, D- 6380 Bad Homburg, Germany
Second Life Plastics - Lundholm Road, Ardeer, Stevenston KA20 3NQ, Scotland (British Polythene Industries Group)
TNO - Schoemakerstraat 97, P.O. Box 6034, 2600 JA Delft, Netherlands
VCI - Verband der Chemischen Industrie e.V., Karlstrasse 21, 6000 Frankfurt I, Germany

Evening Discussion Session 2
Weed Seed Ecology

Chairman and Session Organiser	Dr R E L NAYLOR
Paper	EDS-2

WEED SEED ECOLOGY: CURRENT DIFFICULTIES AND FUTURE DIRECTIONS.

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ABSTRACT

This paper presents an assessment of the current knowledge of weed seed ecology. This information is appraised in terms of its contribution to understanding of how weed populations arise and perpetuate. Integration of current information is needed. The needs for future research are suggested for discussion.

INTRODUCTION

Charles Darwin (1859) reported that when he collected just under 200 g (dry weight) of mud from beneath the water at the edge of a small pond, 537 seedlings emerged over the next six months . This emphasises not only the magnitude of the seed population in soil but also reminds us that not all seeds germinate at the same time. The study of weed seed ecology is important because it is from seeds that many fresh infestations originate, and it is the dynamics of the seed bank which determines whether weed populations decline or increase and at what rate. Weed seed ecology has been studied at the autecological level with many studies focussed on specific weeds of particular economic importance. There have also been synecological studies of populations, usually determining the change in numbers and species mix over time, perhaps in response to different crop management options and as a putative determinant of succession. Both types of study are important and both have been represented in the session on biology and ecology of weed seeds. The common aim is to discover what features of the species, of the environment and of the crop management system determine the successful establishment of weed populations in order to specify modifications which will ameliorate or eliminate the problems caused by weeds.

In this paper I attempt to evaluate current information, to identify the limits of our knowledge and thereby establish what future research is required to achieve our aims. Inevitably this is a personal view and is offered in the hope it will stimulate discussion.

CURRENT KNOWLEDGE

Seed production by weeds has been studied widely. Dispersal studies are also relatively common although useful quantitative information is often lacking: statements of maximum dispersal distance are of interest but of less use than information on the distribution of seeds after shedding. Incorporation of seeds into the soil seed bank is affected not only by morphological features of the seed, but by environmental and management factors. Seed size and the dormancy state of the seed at shedding can be affected by the position on and the nutrition of the parent plant. There may also be after-ripening requirements. Seed longevity in the soil has been studied in the classic experiments of Beal (Darlington & Steinbauer, 1961) and Duvel (Toole & Brown, 1946). We are now seeing advances in understanding because of quantitative studies on the persistence of seed populations and the estimation of half-lives for seed longevity.

The majority of experiments on weed seed germination tell us little about how seeds respond in the field because they have been based on simplistic ideas of what influences the transition from a dormant (in the broadest sense) seed to a germinating seed and progress to established seedling. The germination requirements have been quantified in detail for very few species but unless we know what makes a seed germinate we cannot progress to designing treatments to minimise this except by empirical investigations.

There are many examples of empirical studies aimed at identifying treatments which reduce the establishment of weed populations. Those that have advanced our understanding have made detailed assessments of the weed seed bank before, during and after an extended period during which the treatment has been constant. The investigations of Harold Roberts and various co-workers started to further our understanding of how weed seed populations could be manipulated (e.g. Roberts & Feast, 1973).

The practical application of research in weed seed ecology demands the integration of all of these factors for which a prerequisite is knowledge of the interactions. Often this knowledge is lacking. Building a computer model is an attractive research activity and many models of weed populations incorporate some treatment of the seed bank. The more useful models have specified levels of weed control that need to be achieved to prevent population increase.

INFORMATION REQUIRED FOR PROGRESS

We need to ensure that the research we do on weed seeds, whether relating to their production, dispersal, incorporation into seed banks, dormancy/germination/longevity, is relevant and will advance our understanding. The methods used for laboratory studies would benefit from standardisation and reference to the range of standard procedures for crop plants embodied in the International Rules for Seed Testing (International Seed Testing Association, 1993) is suggested. Nevertheless, laboratory studies should be designed to explain field behaviour. The interaction of the seed with its environment is little understood because we cannot predict weed infestations, sometimes not even in the broadest quantitative terms.

Empirical field studies on weed management techniques (chemical and non-chemical) will continue to be valuable in identifying useful options. However, the value of such trials can be greatly increased by gathering quantitative information on the size and composition of the weed population, its seed production, and of the seed bank before and after treatment. This would then provide valuable data for the testing of current models and the derivation of better estimates of model parameters.

Measurements of seed rain have exploited various techniques to capture seeds but their comparative efficiency needs to be determined for different species and in different habitats. In field investigations two main methods have been used to determine the population of seeds in the soil: complete extraction and counting of seeds or enumeration of emerging seedlings. The former usually makes assumptions about what is a germinable seed, is labour intensive but can give an early result. In contrast, emergence tests need to be continued for 18-24 months until further seedling emergence ceases. There is little information on the degree of correlation between results obtained using these two methods. The predictive value of information on the weed seed bank is dependent on the field sampling procedure: sampling depth should be limited to that from which most seedlings emerge which is probably the top 5 cm. Deeper sampling would increase the inaccuracy of predictions. Up-to-date information on weed seed contamination of seed stocks is needed.

Models should always be tested by comparison with actual field data which is independent of that used to derive the model. Also, and importantly, models should be delivered in an understandable way so that they illuminate rather than obscure the science. This validation process is of use in identifying areas where we have little quantitative information.

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