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THE USE OF BENTAZONE AND PYRIDYL HERBICIDES ALONE AND IN MIXTURES FOR THE CONTROL OF CREEPING THISTLE (CIRSIUM ARVENSE L.) IN GRASSLAND

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NOTE

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THE USE OF BENTAZONE AND PYRIDYL HERBICIDES ALONE AND IN MIXTURE FOR THE CONTROL OF CREEPING THISTLE (CIRSIUM ARVENSE L.) IN GRASSLAND

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SUMMARY

In two outdoor pot experiments on well established creeping thistle (C. arvense), bentazone and two pyridyl acid herbicides, triclopyr and clopyralid were tested, alone and in mixture, for efficacy of control. None of the herbicides used singly killed the plants, these eventually recovering, even though considerable reduction of root systems occurred. Binary tank mixtures were more effective, a bentazone/clopyralid mixture eradicating the weed in both experiments. Mixtures of triclopyr with bentazone or clopyralid also reacted synergistically, the triclopyr/bentazone mixture giving eradication in one experiment as did a mixture of all three herbicides. In a field experiment with thistles growing in permanent pasture, mixtures of triclopyr with bentazone or clopyralid gave better control than bentazone alone or other standard treatments. Most treatments checked grass growth initially but recovery was rapid, such that dry matter yield was in excess of untreated control plots.

INTRODUCTION

Creeping thistle (Cirsium arvense L.) is the most common weed of established pastures of beef- and sheep-producing farms in the U.K., especially on older pastures and there is evidence that this and other Cirsium species can reduce animal output (Roberts, 1982; Peel and Hopkins, 1980). Cutting the flowering stems prevents seed production but even with regular and frequent topping it can take two years to eradicate the weed. However, it can persist and spread because it is perennial with a deep extensive root system. In favourable conditions the roots, whether whole or fragmented by cultivation, can quickly produce new shoots or can remain dormant in the soil for long periods (Anon. MAFF, 1977). Cultivation and chemical methods of control have not always been successful. Phenoxyalkanoic herbicides (2,4-D, MCPA, 2,4-DB, MCPB, dichlorprop, mecoprop) and dicamba, alone or in mixtures can kill the shoots but there is regrowth the following year. Bentazone has proved potentially useful (Penner, 1972) but depends on favourable environmental conditions with many species (Adamczewski, 1977; Dannigkeit, 1977; Nalewaja, Pudelko, Adamczewski, 1975). More recently, clopyralid has been approved for control of young creeping thistle in strawberry and beet crops. These and several other herbicides have been studied routinely at LARS Weed Research Division on well-established plants grown outdoors in large pots and tested further in small-scale field trials. Although none have given a consistently high level of control when applied alone, certain mixtures of these and other herbicides have. Two of these pot experiments, together with one field experiment are described in this report.

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* Herbicide Group ** Grass and Fodder Crops Group

MATERIALS AND METHODS

Pot Experiments

Plant raising: In the early autumn, single root fragments 4 to 5 cm long were sown 1.2 cm deep in 9 cm diameter pots containing a sterilized soil, peat, sand mixture (4:1:1 by volume). These were kept in a glasshouse at 15 ± 5°C until reaching the 3-5 leaf stage in mid October when they were moved to a cold frame to overwinter. In April or May, plants were potted on into 23 cm diameter pots containing the same growing medium, but fortified with John Innes base fertilizer at 6g/kg of soil, these pots being kept in the open on a paved area. In addition to normal rainfall, each pot was connected to a drip feed through which the plants were irrigated or fed with liquid fertilizer (0.5% v/v Vitafeed) during the course of the experiment.

Treatment: Plants were up to 30 cm high and about two weeks from flowering when sprayed. There were 4 to 10 shoots per pot, with 15 to 20 leaves per shoot and well developed roots up to 40 cm long. Plants were brought into a covered area the day before spraying and kept there for 24 hours afterwards. Treatment was on 1 June 1977 (experiment 1) and 12 June 1979 (experiment 2) using a laboratory sprayer with a Spraying Systems 'Teejet' 8001 nozzle operating at 210 kPa pressure and delivering a volume of 195 l/ha. Controlled droplet applications (CDA) of triclopyr were carried out by means of a spinning disc operating above the pots which moved on a conveyer belt. Volume rate was 20 l/ha. There were three replicates for each treatment, including untreated controls.

Commercial formulations of herbicides were used as supplied by the manufacturer; bentazone as a 48% w/v a.i. aqueous concentrate, clopyralid as a 10% w/v a.i. aqueous concentrate (monoethanolamine salt) and triclopyr either as the ethylene glycol butylether ester (48% w/v a.e. emulsifiable concentrate) or the triethylamine salt (36% a.e. w/v aqueous concentrate). Surfactant (0.5% v/v Agral 90) was added to all spray solutions. Plants were watered from overhead 24 h after spraying, with a rose attached to a water line, to simulate heavy rainfall. After this pots were repositioned on the paved area in three randomized blocks and the drip feed re-attached.

Assessment: Shoots were cut off to soil level and weighed, seven (experiment 1) and nine weeks (experiment 2) after spraying and their fresh weight recorded. Plants were then left to regenerate for seven and nine weeks in experiments 1 and 2 respectively, when any regrowth was harvested. Observations were then made of the root systems and with certain treatments root dry weight was measured. Results are presented in Tables 1 and 2. Tests of synergism for mixtures were applied by the method of Colby (1972) -

$$\text{where } E_1 = \frac{X_1 Y_1}{100}$$

(E_1 = the expected growth as a % of control with both herbicides and X_1 and Y_1 = growth as a % of control with each of the herbicides, respectively).

An alternative test considered synergism to have occurred only when the difference between % growth with the mixture and the most active component was greater than the least significant difference (LSD).

Field Experiment

The sward, located at Begbroke Hill, had not been ploughed nor received fertiliser for at least 40 years. It consisted of 50% *Agrostis tenuis* and *Festuca rubra* with the remainder consisting of a wide range of grass and broadleaved species. Plot size was 5 m x 2 m laid out in a randomized block design of 3 replicates.

Treatment: Bentazone at 1.5, 3.0 and 4.5 kg ha^{-1} a.i., bentazone at 2.5 kg ha^{-1} a.i. + triclopyr ester at 0.5 kg ha^{-1} a.i. and clopyralid at 0.2 kg ha^{-1} a.i. + triclopyr at 0.75 kg ha^{-1} a.i. were applied on 14 July 1978. All treatments were sprayed in 300 l/ha aqueous spray solution at 210 kPA pressure through Teejets (No. 8002) fitted to an Oxford Precision Sprayer. At spraying the temperature was 22 ^{o}C, relative humidity 76%, with no cloud cover. The density of the *C. arvense* infestation was uniform with 12 plants/sq.m although height was variable between 10 - 45 cm. The grass was 4 cm high. All foliage was dry at spraying.

Assessment: Quadrats (30 cm x 30 cm) were placed around ten *C. arvense* plants chosen at random on each plot. All *C. arvense* and grass herbage was harvested from within each quadrat on 6 October 1978 and 25 June 1979. Fresh weights were recorded and the material was then dried at 100 ^{o}C for at least 6 h before weighing again. Results are presented in Table 3.

RESULTS

Pot Experiments

In the first experiment (Table 1), all the triclopyr and clopyralid treatments caused severe epinasty within a few hours of spraying, a symptom which persisted until harvest. The stems swelled and split and later became brittle. A moderate necrosis of leaves developed within a few days of applying triclopyr. Bentazone symptoms developed several days after treatment with a general collapse and necrosis of leaf tissue with some yellowing. The yellowing was often pronounced in the newly developing leaves. All these symptoms appeared with the bentazone mixtures also. The three herbicides alone reduced shoot fresh weight by between 37 and 77% at the first harvest with bentazone marginally more active than triclopyr and clopyralid. At the regrowth assessment there was full recovery of shoots from the low rates of all the herbicides and from the high rates of triclopyr salt and ester. bentazone was again marginally more active than clopyralid. Root dry weights showed this trend also but to a greater degree and even the high rate of triclopyr salt had caused 49% reduction.

Increased activity resulted with all three binary mixtures. Eradication was achieved by both bentazone mixtures at one or more doses while clopyralid/triclopyr (0.125 + 1.0 kg/ha) gave 96 and 98% reduction of shoot fresh and root dry weight respectively.

In the second pot experiment (Table 2), there was eventual recovery from all three herbicides when applied singly even after quite severe, initial symptoms. Clopyralid was marginally more active than triclopyr and bentazone. There was no difference between the salt and ester formulations of triclopyr, neither did controlled droplet applications (CDA) change the level of activity. Increased activity was found in all of the binary mixtures, in particular clopyralid + bentazone (0.2 + 3.0 kg/ha), which reduced shoot fresh weight initially by 99%, eventually eradicating all plant systems. Increased effects resulted from the clopyralid/triclopyr mixture, especially where the ester formulation of triclopyr was used. The three-way clopyralid/triclopyr salt/bentazone mixture was very effective, with higher doses giving eradication and lower doses finally reducing shoots and roots by 98 and 99% respectively.

In the field experiment, dry weight reductions of 67 to 78% were caused by all treatments except bentazone at the two lowest doses when assessed in

October. However at final assessment, because of a high standard error, none of the treatments were significantly different from the control. Even so, considerable reduction of C. arvense plants was evident, with the mixtures containing triclopyr being the most effective; that with clopyralid resulting in a 75% dry weight reduction, while with bentazone there was a 73% reduction. Despite an initial check to the grass sward by all of the treatments, none caused any significant reduction in grass yield, even three months after spraying, while at the final assessment in the following summer, all treatments except bentazone alone at the lowest rate had dry matter yields in excess of the untreated control.

DISCUSSION

All the herbicide treatments used in the field experiment, except bentazone at 1.5 kg/ha, were successful in reducing the amount of C. arvense present. The slight, though non-significant, increase in grass yield indicates that there was no direct herbicide effect and this coupled with the slight reduction following the low dose of bentazone suggests that compensating grass growth was achieved by the effective reduction of the weed. The products approved for use in grassland usually require repeated application for eventual solution of the problem (Roberts, 1982), as shown in the field experiment where the MCPB mixture with either bentazone or MCPA was only partially effective with one application. Clear economic advantages should be possible for a herbicide treatment which does not need repeated application.

None of the herbicides used singly in these trials would appear to be adequate for this purpose. However, binary mixtures of bentazone with one or other of the pyridyl acids (clopyralid or triclopyr), of the pyridyl acids with each other, or a mixture of all three herbicides, resulted in increased control, or even eradication, thus raising the possibility of reduced dosages, which may be more acceptable, economically and environmentally. Subjecting the pot experiment data to tests of synergism or antagonism according to Colby's formula (Colby, 1967) confirmed that nearly all of the combinations were synergistic. However, only those mixtures in Tables 1 and 2 which are asterisked are considered synergistic, i.e. where the combination reduced weight by a value greater than the least significant difference when compared with the most active component applied alone. This appeared to be a more stringent test of synergism than that of Colby, 1967.

Unfortunately it was not possible to subject the field data to such tests for practical reasons. However, the effect on the C. arvense, though not as great as in the pot experiments, was substantial, indicating at least some suppression of the root system. Recently clopyralid and triclopyr and other chemically related herbicides were shown to be physically and biologically compatible with certain herbicides used for control of Avena fatua, a distinct advantage over the phenoxyalkanoic herbicides which are antagonistic (Taylor, Loader and Norris, 1983). A binary mixture of clopyralid and triclopyr has shown useful control of ragwort (Senecio jacobea) in Scotland (Richards, et al. 1983) and has been launched commercially for use in grassland (Anon, 1983). The spectra of seedling broad-leaved weed control for both herbicides has been reported previously (Richardson and Parker, 1977) and embraces a wide range of species. Results on well-established perennial broad-leaved weeds have shown promise for example on gorse, docks and other species (Richardson, W.G. unpublished data). A disadvantage of these herbicides in the context of grassland management, however, is that clover and other legumes are very sensitive and these species are usually found in the same sward situations as thistles. In conclusion the value of pot experimentation for evaluation of herbicides, alone and in mixture is emphasized, the time from treatment to final assessment being much shorter, during which effects on the vegetative root system can be estimated. Furthermore, the investigation of the ratio of herbicides in mixture is more easily undertaken, an aspect which needs more detailed work in pots and in the field with these herbicides.

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Table 1. Effect of bentazone, triclopyr salt and clopyralid, alone and in binary mixture on *Cirsium arvense* (Pot experiment 1)

	Dose kg ai/ha	1st harvest Shoot fresh wt.(g)		Regrowth Shoot fresh wt.(g)		Root dry wt. (%)
		mean	%	mean	%	
Untreated control	-	241	100	41	100	100
Bentazone	1.5	152	63	39	95	62
	3.0	55	23	15	36	15
Clopyralid	0.125	125	52	62	152	-
	0.25	114	47	26	63	44
Triclopyr salt	0.5	80	33	51	125	-
	1.0	92	38	39	95	51
Triclopyr ester	0.5	99	41	51	125	-
	1.0	75	31	43	104	-
Clopyralid/ triclopyr salt	0.125+0.5	74	31	36	88	31
	0.125+1.0	25	10*	2	4***	2
	0.25+0.5	91	38	9	22	11
	0.25+1.0	62	26	9	22	13
Clopyralid/ bentazone	0.125+1.5	86	36	27	66	35
	0.125+3.0	19	8	8	19	7
	0.25+1.5	11	4***	2	4*	1
	0.25+3.0	1	1	0	0	0
Bentazone/ triclopyr salt	1.5+0.5	95	40	28	68	37
	1.5+1.0	66	28	6	15**	9
	3.0+0.5	17	7	0	0	0
	3.0+1.0	9	4	0	0	1
	s.e.±	20	8	8	19	-

*, **, *** indicate mixture significantly different from components alone (P < 0.05, 0.01, 0.001)

Table 2. Effect of bentazone, triclopyr and clopyralid, alone and in mixture on Cirsium arvense (Pot experiment 2)

	Dose	1st harvest		Final harvest		
	kg ai/ha	Shoot fresh wt.(g)		Shoot fresh wt.(g)		Root dry wt.
		mean	%	mean	%	%
Untreated control	-	294	100	121	100	100
Bentazone	1.5	275	94	97	80	–
	3.0	229	78	94	78	49
Triclopyr salt	0.375	302	103	95	79	–
	0.75	202	69	78	64	53
" CDA	0.375	290	99	97	80	–
Triclopyr ester	0.375	262	89	104	86	–
	0.75	237	81	96	79	57
" CDA	0.375	263	89	93	77	–
Clopyralid	0.2	205	70	54	45	30
Clopyralid/ triclopyr salt	0.1+0.375	172	58	49	40	23
	0.2+0.75	95	32	29	24	14
Clopyralid/ triclopyr ester	0.1+0.375	172	58	45	37	17
	0.2+0.75	55	19**	5	4*	3
Clopyralid/ bentazone	0.1+1.5	240	82	60	49	–
	0.2+3.0	1	1***	0	0**	–
Bentazone/ triclopyr salt	1.5+0.375	255	87	69	57	–
	3.0+0.75	72	24*	32	26*	15*
Clopyralid/ triclopyr salt/bentazone	0.1+0.375+1.5	143	49	2	2	1
	0.2+0.75+3.0	18	6***	0	0**	<0.1
	S.E. ±	36	12	14	12	11

*, **, *** indicate mixture significantly different from components alone ($P < 0.05, 0.01, 0.001$)

Table 3. Effect of various herbicide treatments on dry matter yield ($g/30\ cm^2$) of Cirsium arvense in grass (field experiment)

	Rate (kg ai/ha)	1st assessment (6 Oct 1978)		Final assessment (25 June 1979)	
		C.arvense	Grass	C.arvense	Grass
Untreated control	-	11.6	14.9	5.1	24.0
Bentazone	1.5	8.9	13.6	5.2	22.7
	3.0	5.8	17.1	2.6	25.3
	4.5	3.4*	12.6	2.1	29.2
Bentazone/triclopyr	2.5+0.5	2.6*	14.9	1.9	28.6
Clopyralid/triclopyr	0.2+0.75	3.8*	14.4	1.3	29.7
+Bentazone/MCPB	1.5+1.5	3.4*	18.7	2.0	28.7
++ MCPA/MCPB	0.56+1.4	3.4*	14.0	3.7	29.7
	s.e. ±	1.12	1.35	2.28	6.12

* indicates statistically significant from control ($P < 0.05$)

\+ proprietary mixture 'Basagran MCPB'

++ MCPA as K salt, MCPB as Na salt

ABBREVIATIONS

ångström	Å
Abstract	Abs.
acid equivalent*	a.e.
acre	ac
active ingredient*	a.i.
approximately equal to*	$\simeq$
aqueous concentrate	a.c.
bibliography	bibl.
boiling point	b.p.
bushel	bu
centigrade	C
centimetre*	cm
concentrated	concd
concentration	concn
concentration x time product	ct
concentration required to kill 50% test animals	LC50
cubic centimetre*	cm^3
cubic foot*	ft^3
cubic inch*	in^3
cubic metre*	m^3
cubic yard*	yd^3
cultivar(s)	cv.
curie*	Ci
degree Celsius*	^oC
degree centigrade	^oC
degree Fahrenheit*	^oF
diameter	diam.
diameter at breast height	d.b.h.
divided by*	÷ or /
dry matter	d.m.
emulsifiable concentrate	e.c.
equal to*	=
fluid	fl.
foot	ft

freezing point	f.p.
from summary	F.s.
gallon	gal
gallons per hour	gal/h
gallons per acre	gal/ac
gas liquid chromatography	GLC
gramme	g
hectare	ha
hectokilogram	hkg
high volume	HV
horse power	hp
hour	h
hundredweight*	cwt
hydrogen ion concentration*	pH
inch	in.
infra red	i.r.
kilogramme	kg
kilo ($x10^3$)	k
less than	$<$
litre	l.
low volume	LV
maximum	max.
median lethal dose	LD50
medium volume	MV
melting point	m.p.
metre	m
micro ($x10^{-6}$)	μ
microgramme*	μg
micromicro (pico: $x10^{-12}$)*	μμ
micrometre (micron)*	μm (or μ)
micron (micrometre)*†	μm (or μ)
miles per hour*	mile/h
milli ($x10^{-3}$)	m
milliequivalent*	m.equiv.
milligramme	mg
millilitre	ml

† The name micrometre is preferred to micron and μm is preferred to μ.

millimetre*	mm
millimicro* (nano: $x10^{-9}$)	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	>
multiplied by*	x
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million	ppm
parts per million by volume	ppmv
parts per million by weight	ppmw
percent(age)	%
pico (micromicro: $x10^{-12}$)	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	±
post-emergence	post-em
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.

pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch	in^2
square metre*	m^2
square root of*	√
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables etc.

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28. The post-emergence selectivity of eight herbicides between pasture grasses: RP 17623, HOE 701, BAS 3790, metoxuron, RU 12068, cyprazine, MC 4379, metribuzin. October 1973. A M Blair. Price - £1.00

* 29. The pre-emergence selectivity between pasture grasses of twelve herbicides: haloxydine, pronamide, NC 8438, Orga 3045, chlortoluron, metoxuron, dicamba, isopropalin, carbetamide, MC 4379, MBR 8251 and EMD-IT 5914. November 1973. A M Blair. Price - £1.30

30. Herbicides for the control of the broad-leaved dock (Rumex obtusifolius L.). November 1973. A M Blair and J Holroyd. Price - £1.06

31. Factors affecting the selectivity of six soil acting herbicides against Cyperus rotundus. February 1974. M L Dean and C Parker. Price - £1.10

32. The activity and post-emergence selectivity of some recently developed herbicides: oxadiazon, U-29,722, U-27,658, metflurazone, norflurazone, AC 50-191, AC 84,777 and iprymidam. June 1974. W G Richardson and M L Dean. Price - £3.62

33. A permanent automatic weather station using digital integrators. September 1974. R C Simmons. Price £0.63.

34. The activity and pre-emergence selectivity of some recently developed herbicides: trifluralin, isopropalin, oryzalin, dinitramine, bifenox and perfluidone. November 1974. W G Richardson and M L Dean. Price - £2.50

35. A survey of aquatic weed control methods used by Internal Drainage Boards, 1973. January 1975. T O Robson. Price - £1.39

36. The activity and pre-emergence selectivity of some recently developed herbicides: Bayer 94871, tebuthiuron, AC 92553. March 1975. W G Richardson and M L Dean. Price - £1.54

37. Studies on Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L. October 1975. G W Ivens. Price - £1.75

38. The activity and pre-emergence selectivity of some recently developed herbicides: metamitron, HOE 22870, HOE 23408, RH 2915, RP 20630. March 1976. W G Richardson, M L Dean and C Parker. Price - £3.25

39. The activity and post-emergence selectivity of some recently developed herbicides: HOE 22870, HOE 23408, flamprop-methyl, metamitron and cyperquat. May 1976. W G Richardson and C Parker. Price - £3.20

40. The activity and pre-emergence selectivity of some recently developed herbicides: RP 20810, oxadiazon, chlornitrofen, nitrofen, flamprop-isopropyl. August 1976. W G Richardson, M L Dean and C Parker. Price - £2.75.

41. The activity and pre-emergence selectivity of some recently developed herbicides: K 1441, mefluidide, WL 29226, epronaz, Dowco 290 and triclopyr. November 1976. W G Richardson and C Parker. Price - £3.40.

42. The activity and post-emergence selectivity of some recently developed herbicides: KUE 2079A, HOE 29152, RH 2915, Triclopyr and Dowco 290. March 1977. W G Richardson and C Parker. Price - £3.50

43. The activity and pre-emergence selectivity of some recently developed herbicides: dimefuron, hexazinone, trifop-methyl, fluothiuron, buthidazole and butam. November 1977. W G Richardson and C Parker. Price - £3.75.

44. The activity and selectivity of the herbicides: ethofumesate, RU 12709 and isoproturon. December 1977. W G Richardson, C Parker, & M L Dean. Price - £4.00

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62. The activity and pre-emergence selectivity of some recently developed herbicides: UBI S-734, SSH-43, ARD 34/02 (= NP 55), PP 009 and DPX 4189. February 1981. W G Richardson, T M West and C Parker. Price - £3.50

63. The activity and post-emergence selectivity of some recently developed herbicides: SSH-41, MB 30755, AC 213087, AC 222293 and Dowco 433. May 1981. W G Richardson, T M West and C Parker. Price - £3.50

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