SESSION 8B

WEED CONTROL IN TROPICAL AND SUB-TROPICAL CROPS II

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WEED CONTROL IN FLUE-CURED TOBACCO IN ZIMBABWE

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Summary. A number of herbicides were tested on three different weed spectra in flue-cured tobacco. Perfluidone (3.0 kg a.i./ha), metolachlor (2.0 and 1.75 kg a.i./ha), UBI-S734 (1.5 kg a.i./ha) and metazachlor (0.6 kg a.i./ha) applied after transplanting, controlled a weed spectrum dominated by *Cyperus esculentus*. A population of mainly *Eleusine indica* and *Cleome monophylla* was most effectively controlled by pebulate-napropamide (5.4+1.1 kg a.i./ha) incorporated deep after ridging and diphenamid (4.85 kg a.i./ha) applied after transplanting. Metazachlor (0.6 kg a.i./ha) and metolachlor (1.85 kg a.i./ha) applied after transplanting, gave the best control of weeds in late planted tobacco. Generally good weed control resulted in higher yields except where the herbicide was phytotoxic to tobacco. Combining chemical and manual weed control often improved yields, especially where the dominant weeds, *C. esculentus* and annual grasses, were more competitive. All herbicides reduced the weed populations in comparison with the untreated plots and facilitated hand cultivation.

Weed competition, herbicides, hand cultivation, *Cyperus esculentus*, *Eleusine indica*, metolachlor, metazachlor, pebulate, phytotoxicity.

INTRODUCTION

In 1981-82, 46 612 ha of flue-cured tobacco was grown in Zimbabwe. The estimated crop was 90 million kg and the value exceeded Zimbabwe $200 million (£150 million). About 95% of the crop is exported earning foreign currency vital to the economy of this newly independent country. Almost all the flue-cured tobacco is produced on large estates, the average crop size is 40 ha and sophisticated tractor-mounted equipment is available for cultivation and herbicide application.

Field trials have established the critical period for weed competition in flue-cured tobacco, from the quarter grown (about 4 weeks after transplanting) to the topping (removal of flower) stage (about 8-9 weeks). Competition affects yield more than quality of the cured tobacco (Cousins, 1979). Cousins and Lapham (1980) showed that competition from a weed spectrum consisting mainly of the annual grass *Eleusine indica* was more severe than that from a weed population of yellow nutsedge, *Cyperus esculentus*. More recent research has shown however, that the latter can cause similar reductions in tobacco yield (Cousins, 1981).

A postal survey of 651 tobacco growers in 1980-81 indicated that both these weeds were very important and certain broadleaved weeds and perennial grasses were becoming a problem. The same survey indicated that about one third of the crop is treated with herbicides and two thirds of the herbicides used were for the control of yellow nutsedge (Cousins, 1981).

The Tobacco Research Board recommends an integrated weed control programme that combines herbicides, hand and mechanical cultivation for satisfactory early season weed control, which prevents competition during the critical period of tobacco growth. Increasing costs of production, particularly hand labour and tractor fuel, have stimulated an interest in the more efficient use of current herbicides and a search for more effective ones.

METHOD AND MATERIALS

The weed control efficacy and phytotoxicity to tobacco of seven herbicides for control of yellow nutsedge were tested in Trial 1, ten herbicides for annual grass and broadleaved weed control in Trial 2 and nine in Trial 3 for annual grass control in late planted tobacco. Full details of the three trials are tabulated (Table 1). Methods of application and the abbreviations used are in Table 2. Rates of active ingredient tested are shown in the tables of results. The full chemical names of herbicides coded are as follows :-

CGA 82725	:	2-propynyl 2-[4-3(3,5-dichloro-2-pyridyloxy)-phenoxy]-propanoate
NC 20484	:	2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate
UBI-S734	:	2-[(1-(2,5-dimethylphenyl) ethyl] sulfonyl) pyridine-1-oxide
VEL. 5052	:	N-chloroacetyl-2,6-dimethyl-anilinoacetaldehydeethyleneacetal

The tobacco was grown under standard cultural practices for Zimbabwe and the natural weed spectrum in the fields was used to determine the efficacy of the herbicides. Weeds were counted and phytotoxic symptoms in the tobacco were recorded at various stages during the growth of the crop. Dry mass of weeds was measured at each cultivation and at final harvest. Yield and quality of cured tobacco was assessed.

RESULTS AND DISCUSSION

Metolachlor and pebulate, which are currently recommended by the Tobacco Research Board in Zimbabwe, satisfactorily controlled the dominant weeds, *C. esculentus*, the annual grasses *E. indica* and *Dactyloctenium aegyptium* in Trial 1 (Table 3). Metazachlor and perfluidone also significantly ($P < 0.001$) reduced early season weed populations. At final harvest all herbicides except metazachlor (g.t.s.) and NC 20484 (g.t.s.) reduced weed dry mass. Highest yields of tobacco were from plots treated with metazachlor (p.p.s. and o.t.), metolachlor (2.00 kg a.i./ha, o.t.), pebulate (g.t.d.) and UBI-S734 (g.t.d. and o.t.). Deep incorporation of of NC 20484 and metazachlor resulted in early season phytotoxic symptoms on the tobacco and also gave lowest yields. Yields of tobacco from all cultivated plots were similar to those from the untreated plots and where metolachlor (2.00 kg a.i./ha), pebulate (g.t.d.), UBI-S734 (g.t.d.) and metazachlor (p.p.s. and o.t.) were applied, cultivation produced little additional benefit.

In Trial 2 the dominant weeds were *E. indica*, *Cleome monophylla*, *Richardia scabra* and *Tagetes minuta*. Grass-weed control was satisfactory with all herbicides at 24 and 70 days after planting (Table 4). Broadleaved weeds were not controlled well except by diphenamid and the pebulate-napropamide mixture. Final weed dry mass was least in the above two treatments and in metazachlor, oryzalin and the metolachlor-metobromuron treatments. Only those herbicides that controlled the broadleaved weeds gave good yields of tobacco in this trial. Hand cultivation combined with herbicide application significantly ($P < 0.05$) improved yield except in the pebulate-napropamide, diphenamid and metolachlor (o.t.) plots.

Tobacco planted later in the season generally has more plentiful and reliable rainfall and weed growth is more of a problem. In Trial 3 the main grass weeds were *E. indica* and *Urachloa* spp., a sedge *Monandrus squarrosus* and the broadleaved weeds *Amaranthus spinosus*, *A. hybridus*, *Nicandra physalodes*, *Physalis angulata*, *Hibiscus trionum* and *H. cannabinus*. All herbicides tested reduced grass numbers but only paraquat and metazachlor significantly ($P < 0.05$) reduced the number of broadleaved weeds (Table 5). Metazachlor, metolachlor and paraquat reduced the

Table 1

Details of three field trials testing herbicides in flue-cured tobacco in Zimbabwe

	Trial 1	Trial 2	Trial 3
Location	Bromley farming area, 60 km East of Harare	Kutsaga Research Station, Harare	Centenary farming area, 160 km North of Harare
Main weed species	Yellow nutsedge and annual grasses	Annual grasses and broadleaved weeds	Annual grasses and broadleaved weeds
Soil type	Medium grained granite sand $<$ 7% clay	Medium grained granite sand $<$ 7% clay	Sandy loam 15% clay
Tobacco cultivar	Kutsaga Mammoth E	Kutsaga 51E	Kutsaga 51E
No. of treatments	14	20	18
Statistical design	4 randomized blocks of treatments, main plots treated with herbicides and split for cultivation and no cultivation		
Plot size	main plot 17.92 x 2.40 m (64 plants) sub plot 7.28 x 2.40 m (26 plants)		
Sprayer	tractor mounted boomsprayer with roller pump knapsack sprayer for directed spray		
Nozzles	8204 flat fan		
Volume rate	300-350 l/ha		
Spray pressure	200 kPa for pre-plant application 150 kPa for post-plant application		
Herbicide application	September/October	September/October	December/January
Planting date	20 October 1981	27 October 1981	22 December 1981
Cultivation dates	10/11, 8/12/81 10/3/82	24/11, 17/12/81 15/3/82	15/1, 27/1, 14/4/82
Final harvest	10 March 1982	15 March 1982	14 April 1982
Rainfall, planting to final harvest	574 mm	484 mm	616 mm

Table 2

Methods of application of herbicides tested in flue-cured tobacco in Zimbabwe

Method of application	Abbreviation
Sprayed onto soil surface and disk-harrowed to a depth of 120-150 mm before ridging up	pre-ridge incorporated (p.r.i.)
Sprayed over the ridge, before transplanting holes were made and incorporated 50-100 mm deep with rotary cultivator (gang-tiller)	gang-tilled deep (g.t.d.)
As above but only incorporated 20-40 mm deep	gang-tilled shallow (g.t.s.)
Sprayed over the ridge, before transplanting holes were made but not incorporated	pre-plant surface application (p.p.s.)
Sprayed over the tobacco transplants immediately after setting in the field	applied over transplants (o.t.)
Spray directed between rows of tobacco (after weeds have emerged) leaving an untreated strip between plants along top of ridge	directed spray (d.s.)
Sprayed over the tobacco transplants after weeds have emerged	applied over the transplants post emergent (o.t.p.e.)

numbers of sedge plants but this species did not appear to be very competitive.

Despite the growth of broadleaved weeds, yield was only slightly improved by hand cultivation, except in the untreated plots. Tobacco grew very fast and probably shaded weeds on the ridge, reducing their vigour and competitiveness. Broadleaved weed control by diphenamid was disappointing. Although paraquat was successful, some tobacco leaf damage occurred and the weeds in the untreated strip between plants could compete with the crop in some seasons. Timing of post-emergent sprays is critical and often coincides with rainy spells when conditions are unsatisfactory for application. Therefore, the practicability of post-emergent sprays is dubious under farm conditions.

In these three trials metolachlor was very satisfactory for grass and sedge control. Metazachlor (p.p.s. and o.t.) was as good and controlled a wider spectrum of broadleaved weeds. UBI-S734 (g.t.d. and o.t.) controlled yellow nutsedge but not broadleaved weeds. Pebulate gave good control of grass and yellow nutsedge and when mixed with napropamide it was effective against broadleaved weeds as well. Oryzalin, diphenamid, pendimethalin and the metolachlor-metobromuron mixture also controlled some broadleaved weeds. Trifluralin, recommended for annual grass control, was disappointing especially where it was applied before ridging.

Table 3

Effects of herbicides for control of yellow nutsedge on weed number, weed dry mass and tobacco yield (Trial 1:1981-82)

Herbicide	Rate kg a.i./ha	Application method	Weeds/m² 21 days after planting Broadleaved	Sedge	Grass	Dry mass weeds removed, g/m² Not cultivated	Total yield of cured tobacco, kg/ha Not cultivated	Cultivated
None	-	-	28.0	24.9	85.5	423	1 727	2 967
Metolachlor	1.75	o.t.	0.7	16.7	0.3	69	2 812	3 124
	2.00	o.t.	0.4	8.1	0.0	52	3 046	2 995
Pebulate	5.40	p.r.i.	3.6	1.8	4.7	116	2 562	2 861
	5.40	g.t.d.	2.8	1.6	2.8	92	3 064	2 958
UBI-S734	1.50	p.r.i.	11.5	15.7	6.7	143	2 461	2 849
	1.50	g.t.d.	7.1	1.5	7.5	136	2 920	3 058
	1.50	o.t.	4.6	11.3	0.3	73	2 891	3 009
Metazachlor	0.60	p.r.i.	4.8	8.3	6.6	218	2 221	2 733
	0.60	g.t.d.	3.8	3.8	10.1	202	2 059	2 887
	0.60	g.t.s.	4.1	5.5	7.7	350	2 356	2 931
	0.60	p.p.s.	2.1	13.0	2.5	105	3 211	2 889
	0.60	o.t.	0.2	18.8	0.1	77	2 952	2 954
NC 20484	2.00	p.r.i.	7.0	5.8	11.1	148	2 206	2 963
	2.00	g.t.d.	5.2	0.4	25.1	221	2 380	3 080
	2.00	g.t.s.	5.8	6.9	16.8	273	2 492	3 334
	2.00	p.p.s.	1.3	1.7	3.2	125	2 515	2 863
Perfluidone	2.50	p.p.s.	2.4	5.8	2.1	131	2 479	2 893
	3.00	o.t.	0.8	12.7	0.1	43	2 887	3 039
Vel. 5052	2.00	o.t.	3.3	10.2	1.9	155	2 570	3 021
Mean			5.0	8.7	9.8	158	2 591	2 970
Standard error of differences			2.1	7.9	7.0	53	245	
L.s.d. p = 0.05			4.3	15.7	14.0	107	490	
= 0.01			5.7	21.0	18.6	142	651	
= 0.001			7.4	27.3	24.2	184	848	

Table 4

Effects of herbicides for control of annual grasses and broadleaved weeds on weed number, weed dry mass and tobacco yield (Trial 2:1981-82)

Herbicides	Rate kg a.i./ha	Application method	Weeds/m^2 24 days after planting Broadleaved	Sedge	Grass	Dry mass weeds removed, g/m^2 Not cultivated	Total yield of cured tobacco, kg/ha Not cultivated	Cultivated
None	-	-	22.3	1.19	12.10	256	1 669	3 063
Trifluralin	0.50	p.r.i.	14.0	2.18	5.56	141	1 991	3 013
	0.50	g.t.d.	11.8	1.12	1.39	130	2 216	3 225
Pendimethalin	0.66	g.t.d.	9.1	1.06	1.98	184	2 117	3 156
	0.66	g.t.s.	10.4	1.46	2.18	155	2 369	3 345
	0.66	p.p.s.	9.6	0.20	4.43	194	1 995	3 196
	1.00	g.t.d.	4.3	0.40	1.65	125	2 506	3 307
	1.00	g.t.s.	12.8	1.19	3.44	205	1 702	3 338
	1.00	p.p.s.	12.2	0.13	2.58	125	2 319	3 184
Metolachlor	1.50	p.p.s.	25.7	0.40	1.85	114	2 166	2 936
	1.50	o.t.	18.5	0.60	6.48	146	2 046	3 138
Diphenamid	4.85	o.t.	3.6	0.07	2.45	51	2 791	3 251
Metazachlor	0.60	o.t.	13.2	0.53	1.19	85	2 516	3 279
Oryzalin	1.20	o.t.	14.0	0.60	2.98	78	2 574	3 405
Napropamide	1.10	o.t.	24.3	0.93	6.94	147	1 691	3 207
UBI-S734	0.50	g.t.s.	30.8	0.99	2.12	139	1 786	3 152
Metol./metobrom.°	2.0/1.0	o.t.	9.2	0.20	1.92	83	2 067	3 241
Pebulate/naprop.+	5.4/1.1	g.t.d.	1.5	0.26	0.40	47	3 014	3 238
Mean			13.7	0.75	3.42	340	2 194	3 204
Standard error of differences			9.7	0.79	2.11	39	297	
L.s.d. p = 0.05			19.5	1.59	4.24	79	596	
= 0.01			26.0	2.12	5.65	105	794	
= 0.001			34.0	2.77	7.37	136	1 035	

° metolachlor/metobromuron mixture
+ pebulate/napropamide mixture

Table 5

Effects of herbicides for annual grass control in late planted tobacco on weed number, weed dry mass and tobacco yield (Trial 3:1981-82)

Herbicides	Rate kg a.i./ha	Application method	Weeds/m^2 53 days after planting: Broadleaved	Sedge	Grass	Dry mass weeds removed, g/m^2: Not cultivated	Total yield of cured tobacco, kg/ha: Not cultivated	Cultivated
None	-	-	28.0	85.8	42.7	392	1 538	2 193
Metolachlor	1.85	o.t.	16.5	3.4	1.2	29	1 979	2 002
	2.20	o.t.	24.2	2.9	1.9	116	2 156	2 112
Trifluralin	0.50	p.r.i.	19.7	115.7	11.2	220	1 792	2 085
	0.50	g.t.d.	26.6	93.3	20.6	188	2 091	2 236
Metazachlor	0.60	o.t.	4.2	0.8	1.2	9	1 962	2 171
Fluazifop butyl	0.50	o.t.p.e.	19.6	64.8	1.6	231	1 996	2 322
CGA 82725	0.50	o.t.	41.7	77.4	5.0	135	2 113	2 110
	0.75	o.t.	24.1	53.4	1.6	107	1 915	2 072
	1.00	o.t.	32.3	120.2	4.0	206	1 696	2 156
Sethoxydim	0.50	o.t.p.e.	27.4	93.1	11.0	135	1 638	2 069
Diphenamid	7.15	o.t.	30.0	71.8	12.0	150	1 940	2 062
Pendimethalin	1.50	p.p.s.	16.5	49.3	9.9	127	2 043	2 166
Paraquat	0.80	d.s.	9.9	33.5	15.9	89	2 209	2 038
Mean			22.9	61.8	10.0	152	1 933	2 128
Standard error of differences			6.1	19.7	4.8	52	174	
L.s.d. p = 0.05			12.2	39.1	9.6	103	347	
= 0.01			16.2	51.9	12.7	137	459	
= 0.001			21.0	67.2	16.5	177	595	

Although there was little benefit from cultivation in Trials 1 and 3, the situation in Trial 2 was closer to that pertaining under farming conditions. In these circumstances it would be advantageous to cultivate resistant weeds to prevent competition.

Correct selection of herbicides and methods of application give excellent early season weed control in tobacco, which can sometimes be beneficially supplemented by cultivation, depending on climatic conditions and weed spectrum. In addition the removal of weeds is easier and quicker where a herbicide has been used.

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GREENHOUSE AND FIELD PERFORMANCE OF BUTAM AND UBI-S734 FOR WEED CONTROL IN TOBACCO

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Summary. In field studies on Oriental tobacco, control of most common grass and broadleaf weeds with preplant incorporated butam (N-benzyl-N-isopropyl-1,2-dimethylpropionamide) and UBI-S734 (2-[[1-(2,5-dimethylphenyl)ethyl] sulfonyl] pyridine 1-oxide), applied alone or in combination compared favourably with other registered herbicides on tobacco. Only UBI-S734 or the combination controlled *Cyperus* spp. In high organic matter soils, weed control on burley tobacco was not adequate. No tobacco injury or effect on *in vivo* nitrate reductase activity was measured at 30 or 60 days after herbicide application. Yield, quality, nicotine, total N, alkalinity number and smoking of herbicide-treated cured leaves were not significantly different from the untreated control. Butam residues in cured leaves averaged 0.35 ppm. Bioavailable residues in the field were found for 4 months with UBI-S734 or the combination and for one month with butam. Soil type and organic matter greatly affected herbicide availability. No leaching below 10 cm was detected under field conditions in clayey or organic soils. Weed control, tobacco injury, tobacco characteristics, herbicide bioavailability, leaching.

INTRODUCTION

Where weeds proliferate normal growth and development of tobacco is dramatically decreased, yield and quality are significantly reduced, and chemical composition with smoking and physical properties of cured leaf are altered (Lolas 1981b). In Greece losses in tobacco yield due to weeds are estimated at $20 M yearly (Lolas 1981a). The role and value of herbicides, necessary for a safe, efficient, and economic tobacco production are well established (Collins *et al*, 1971). Among the new herbicides examined for tobacco weed control in Greece are Butam 6E and UBI-S734 (2-[[1-(2,5-dimethylphenyl)ethyl] sulfonyl] pyridine 1-oxide) as a 75 WP. Butam applied preemergent controlled common annual grass and broadleaf weeds in peanuts and soybeans (Coble *et al*, 1978). Butam is registered for annual grasses and certain broadleaf weeds in peanuts, soybeans, tomatoes, and sugarbeets, but not in tobacco (WSSA Herb. Handbook, 1979). UBI-S734 gave good control of most annual grasses and fair control of small seed broadleaf weeds in cotton and soybeans (Crawford *et al*, 1981). Against nutsedge and most annual grasses UBI-S734 was very effective and comparable to commercial standards (Coble *et al* 1981; Harrison *et al*, 1981). Soil organic matter and clay content affect behaviour of some herbicides in soil (Weber and Peter, 1982). The objective of these studies was to evaluate: 1) butam and UBI-S734 efficacy and crop tolerance, 2) effect of these two herbicides on tobacco yield, quality and chemical composition, 3) bioavailability of residues in soil and 4) their soil absorption and leaching.

MATERIAL AND METHODS

Agronomic characteristics : Studies were conducted in Greece during 1980 - 1982 on sandy clay and sandy loam soil with oriental, and in 1981 - 1982 on organic soil (O.M. = 20%) and silty clay soils (SiC) with burley tobacco. Plots were 3 x 10 m with 5 rows in oriental and 4 x 10 m with 4 rows in burley tobacco. Only the middle rows were harvested and used for data collection. A randomized complete block design (RCB), with 3 replications in oriental and 4 in burley tobacco, was used. Butam, UBI-S734 or butam + UBI-S734 in combination were applied preplant incorporated, one day before transplanting, at rates shown in Table 1. Weed control ratings were made at 35 days after transplanting, just before the layby cultivation of all treatments. There were two control treatments. Control A, receiving two cultivations (one about three weeks after transplanting and a second at layby time), represented the standard recommended to tobacco farmers practice. Control B received only the second layby cultivation as did the herbicide plots. Tobacco injury evaluations were made at 35 and 60 days after transplanting as per plant fresh weight from 5 plants per plot. The weights of cured leaf from each plot were recorded and the yields in kg/ha and quality were determined.

Chemical determinations were made on random composite samples of cured leaves from the five primings for each plot in 1980 and 1981. Nicotine as total alkaloids was determined by the Coresta procedure (1969), total N by the Kjeldahl method, and alkalinity number of water soluble ash (Alk. No.) as reported by Ioannidis (1973).

Herbicide residues : In 1980 composite soil samples from 0 - 10, and 10 to 20 cm were taken at 120 and 360 days after herbicide application. In 1981 - 1982 the soil samples were taken from 0 to 10 cm at 30 and 60 days from 0 to 10 and 10 to 20 cm at 90, 120 and 360 days after herbicide application. Soil samples were air-dried for two days, sieved, mixed well and transferred to 15 cm pots. Fifteen oat seeds were planted in each pot and thinned to 10 most uniform seedlings at 10 days. Pots were watered with tap water as needed. Once a week pots were given complete nutrient solution. At 21 days fresh and dry weight per 10 plants were recorded. Only 1980 - 1981 data are presented.

Nitrate reductase (NR) assay : *In vivo* NR activity was measured in 1981 and 1982 for oriental tobacco at 30 and 60 days after herbicide application as described by Lolas (1980).

Leaf herbicide residues : Cured tobacco leaves were analyzed for butam residues by a confidential method in France. (See Acknowledgements).

Smoking panels : Both years, untreated or tobacco treated with either of the two herbicides or their combination was smoked by two different smoking panels for differences in taste and/or flavour.

Herbicide bioassays : Bioavailability of butam at 2.2 or 4.4 kg a.i./ha as affected by soil O.M. was studied in pots using three test species; oat, cucumber and sunflower. Pots were filled with 700 g soil mixed with 1, 6, 12, 18 or 100% black organic soil. Pots were arranged in a RCB design with five replications. Depending on test species 12 or 5 seeds were planted and after 10 days thinned to 8 or 2 most uniform seedlings for oat and cucumber and sunflower respectively. The procedure thereafter was the same as in the herbicide residues section. UBI-S734 bioavailability, at 2 and 4 kg a.i./ha, was studied similarly to butam, using oat as test species. All bioassays were conducted in triplicate.

Soil type and butam bioavailability was studied at 2, 4 and 6 kg a.i./ha in five representative Greek tobacco soils differing in their texture. Oat was used as the bioassay test species. The procedure thereafter was the same as above. Bioassays were conducted twice.

Leaching studies : Butam and UBI-S734 mobility in the field was studied with bioassay, using oat as described above.

Statistical analysis : Data from each individual experiment first, and then over tests, were subjected to analysis of variance. Data averaged over tests or years are given in Tables or plotted.

RESULTS AND DISCUSSION

Agronomic characteristics : In oriental or burley tobacco grown on silty clay soil grass and broadleaf weed control, except nutsedge control with butam alone, was very good with either herbicide or their combination (Table 1). Inversely in burley tobacco grown in black organic soils and despite the increased herbicide rates (circa 50%), only grasses were controlled adequately.

Table 1

Percent weed control with butam and UBI-S734, alone and in combination

Herbicide	Rate kg a.i./ha	Oriental tobacco: Annual Broad-leaves[2]	Oriental tobacco: Cyperus spp.	Oriental tobacco: Annual grasses[3]	Burley tobacco: Annual Broad-leaves[2]	Burley tobacco: Annual grasses[3]
Control A	-	100	100	100	100 - 95[4]	100 - 95[4]
Butam 6E	2.3(3.2)[1]	90	55	95	75 - 85	80 - 90
UBI-S734	2(3)	82	87	90	60 - 70	95 - 90
Butam 6E + UBI-S734	1.8(2.8) + 1.2(2)	92	88	92	65 - 88	95 - 95
LSD, p = .05		19	18	11	30 - 20	30 - 15
C.V. %		6	14	8	31 - 25	28 - 20

[1] In parenthesis, rates used on burley tobacco, grown on organic soil (20% O.M.)
[2] Amaranthus spp; Portulaca spp; [3] Setaria spp; Digitaria spp; Echinochloa spp.
[4] Burley tobacco grown on silty clay soil.

It is suggested that this poorer weed control in burley was due to high organic matter content (20%) of the soil. No crop injury was measured at 35 and 60 days after herbicide application, as indicated by no differences in plant fresh weight, in plots treated with either herbicide or their combination as compared to control A, receiving two cultivations as recommended (Table 2). Tobacco yield, not significantly different, was higher where the herbicides were used, compared to control A. Tobacco receiving only one cultivation (layby), yielded significantly less compared to the herbicide treatments which also received the layby cultivation. These findings suggest that for normal growth and development of oriental tobacco, the grower must control the weeds for 15 to 20 days after transplanting. Tobacco quality was not affected by any treatment (Table 2).

Table 2

Oriental tobacco characteristics following weed control with butam, UBI-S734 and their combination

Herbicide	Rate kg a.i./ha	Yield kg/ha	Quality[2]	Tobacco growth (Fr. wt., g/plant) 35 days	60	Nic. %	N	Alk. no.	NR activity 30 days (μmoles NO_2 g^{-1} Fr.Wt.h^{-1})	60
Control A	Two cultivations	1950	7.6	81	281	1.12	2.35	21	2.883	1.502
Control B	One cult.@ layby	1650	7.3	60	237	1.00	2.10	22	2.726	1.365
Butam 6E	2.2	2250	7.5	66	275	1.30	2.54	21	2.923	1.784
UBI-S734	2.0	2200	7.6	67	293	1.20	2.44	20	2.733	1.477
But. + UBI[1]	1.8 + 1.2	2010	7.6	67	260	1.72	2.82	25	2.777	1.550
LSD p = .05		300	NS	20	45	.28	.30	NS	NS	NS
C.V. %		9	6	17	10	15	8	20	9	12

1. Only 1981 data   2. 0 = Worst, 10 = Best

Table 3

Bioavailability of butam, UBI-S734 applied alone or in combination (Oat Fresh weight, g/10 plants)

Herbicide	Rate kg a.i./ha	Oriental tobacco (Burley tobacco) 0 - 10 cm: 30	60	90	120	10 - 20 cm: 90	120 days
Control A	-	1.06(1.07)	1.45(1.27)	2.12(2.34)	2.62(2.46(	2.05	3.48(2.92)
Control B	-	1.03(1.35)	1.63(1.21)	2.30(2.37)	2.80(2.13)	2.03	3.95(3.19)
Butam 6E	2.2(3.2)	0.63(1.29)	1.32(1.25	1.68(2.25)	2.17(2.29)	2.38	3.00(2.98)
UBI-S734	2(3)	0.36(1.00)	0.26(1.19)	0.52(2.15)	1.54(2.64)	1.75	3.12(3.12)
Butam 6E[1] + UBI-S734	1.8(2.8) + 1.2(2)	0.34(1.45)	0.26(1.04)	1.20(2.14)	2.36(2.29)	1.96	3.04(2.96)
LSD p = .05		.28(NS)	.40(NS)	.69(NS)	.92(NS)	NS	NS(NS)
C.V. %		21(18)	27(21)	23(16)	21(16)	16	16(16)

Chemical characteristics : Butam or UBI-S734, alone or in combination, did not affect chemical characteristics of cured tobacco compared to tobacco receiving two cultivations (Table 2). Although nicotine, and total N, were higher in tobacco treated with the herbicides as compared to controls A and B, the differences are not significant. Note, however, that in control B where tobacco did not receive the first cultivation (weeds left to grow for 5 weeks), chemical composition was significantly altered (Table 2).

Herbicide residues : One of the potential limitations in herbicide use lies in their persistence in soils. Therefore,a better understanding of the actual or potential long-term affect of tobacco herbicide residues in soils from the continued and repeated use of herbicides is needed. In 1980 and 1981 oat bioassays at 120 and 360 days after herbicide application showed bioavailable residues only for UBI-S734 at 120 days (Figure 1). In 1981 bioavailable residues were found for 120 days for UBI-S734 and for 30 days for butam after the herbicide application, only in clay soil where oriental tobacco was grown (Table 3). Inversely, probably due to absorption on the high organic matter content of the soil, no bioavailable residues were found, even one month after herbicide application in the black soil where burley tobacco was grown. One may then conclude that butam presents no problems in crop rotation.

NR Assay : Butam and UBI-S734 alone or in combination had no significant effect on NR activity of tobacco leaves at 30 and 60 days after herbicide application (Table 2).

Leaf herbicide residues : Due to their possible chronic harmful effects on consumers' health, herbicide residues on and within leaves are now considered a factor in tobacco quality in many countries. Residue analysis, in 1980 and 1981, of cured tobacco leaves from plots receiving 2.2 kg a.i./ha showed an average of 0.35 ppm. Maximum permissible residues on tobacco in Germany for Tillam 6E and Paarlane 6E, are 0.5 ppm, (Wittekinat, 1978).

Smoking panels : Presence of residues or metabolites of herbicides in cured tobacco leaf by changing the physical and/or chemical characteristics of cured leaf may also change the composition or taste and flavour of smoke, and therefore the desirability of the manufactured product (cigarettes). In both years no difference was detected in tobacco in which butam, UBI-S734 or their combination had been employed for weed control and untreated tobacco from control A. It is therefore concluded that the two herbicides, alone or in combination, had no adverse effect on smoking properties of cured tobacco.

Herbicide bioassays : Figure 2 shows oat growth as affected by the recommended, and twice the recommended, rate of butam and UBI-S734 in soil containing different amounts of organic matter. Bioavailable herbicide residues were reduced significantly when 12% or more organic matter was incorporated in the soil. No bioavailable residues were detected for 2.2 kg a.i./ha butam in the black soil containing 20% organic matter. These bioassays support and explain the results of poor weed control in burley tobacco above. Cucumber and sunflower were found to be less sensitive in detecting butam bioavailability in these bioassay tests (data not presented).

Soil type and butam bioavailability : Soil type greatly affected butam bioavailability (Figure 2). In high organic matter soil (2 or 4 kg a.i./ha) less than 20% of butam was bioavailable (oat growth 80% or more than that of control). In the clayey tobacco soil (SC in Figure) butam was 60% or more bioavailable. In the sandy soil (S in Figure) almost 100% of butam was bioavailable. It is therefore suggested that butam recommendations on tobacco should consider soil texture.

Fig. 1

Bioavailability of butam and UBI-S734 at 120 (left) and 360 days (right) after application

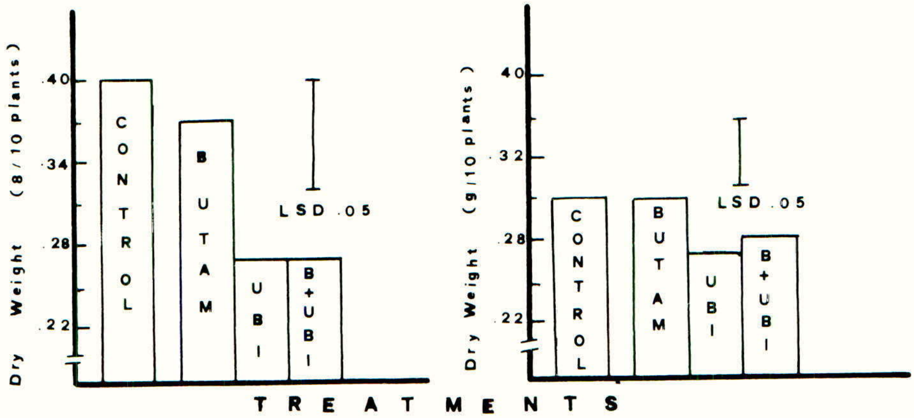
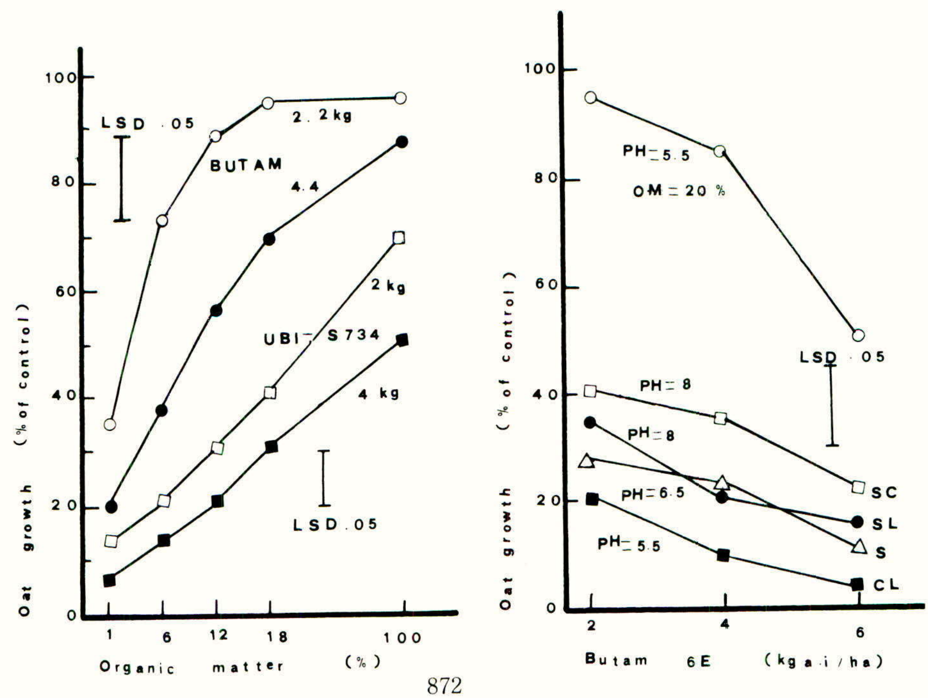


Fig. 2

Effect of organic mater (left) and soil type (right) on bioavailability of butam and UBI-S734



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CHEMICAL CONTROL OF WEEDS IN TRANSPLANTED RICE

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Summary. The post-emergence effects of butachlor (at 2.0 and 3.0 kg a.i./ha), a bentazone/propanil mixture (Basagran PL 2 at 4.0 and 5.0 kg total a.i./ha), NC 20484 (2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate) (at 0.25 and 0.5 kg a.i./ha) and molinate (at 3.6 kg a.i./ha) on weeds in transplanted rice and the influence of these treatments on the crop were investigated on the irrigated basin of River Mombo in Northern Tanzania. The bentazone/propanil mixture at both rates tested gave the best weed control. The performance of the other herbicides was generally poor. Handweeding gave the second best weed control. The treatments had no undesirable effects on crop quality, neither did they have any significant effect on grain yield.

INTRODUCTION

One of the common systems of rice cultivation is transplanting rice seedlings into a puddled field. Soon after transplanting, the field is flooded to a depth of about ten centimetres, which is roughly enough to cover the whole soil surface even if there are minor irregularities in the height of the field (Acland, 1975). Conditions of the puddled field often encourage the growth of aquatic and semi-aquatic weeds. If weed density is high and control measures are not taken, the farmer may suffer heavy losses of grain yield.

Weeds in transplanted rice are usually removed by pulling with hands. The spacing between rice plants is so small (about 20 cm by 20 cm) that hand-hoeing is not practicable. Depending on the extent and type of weed growth, weeding in transplanted rice can be a very tedious task; and it may become even more difficult if the size of the rice farm is several hectares. Nevertheless, weed control in transplanted rice, either by hand or otherwise, is inevitable if higher grain yields are to be realised.

The use of herbicides for the control of weeds in transplanted rice would seem to be more effective than handweeding. Much evidence in the literature is available which shows that herbicides are effective on weeds in transplanted rice. Pereira and Ghosh (1981) tested butachlor at 3 kg/ha in India, among other granular herbicides, and found it generally effective both in terms of weed control and rice yield. Ryang et al (1979) tested several herbicides in Korea, one of which was bentazone (48% a.i.) at over 0.2%. This herbicide controlled *Scirpus maritimus* but not annual weeds. Bisen and Patel (1974) found propanil at 2.5 kg a.i./ha very effective against weeds and was almost as effective as handweeding in terms of weed control and crop yield. Ritoine et al (1980), working in Northern Tanzania, found a mixture of bentazone and propanil at 3.0 + 2.0 kg a.i./ha very effective against weeds, and almost as effective as handweeding in terms of weed control.

A wide range of herbicides that have been claimed to be effective against weeds in transplanted rice are now available, some of which are still at the experimental stage. The aim of the present study, therefore, was to investigate post-emergence effects of some of the recommended and candidate herbicides on weeds in transplanted rice under Tanzanian conditions, and how these herbicides influence the crop.

METHODS AND MATERIALS

The herbicide trial was laid down at Mombo Irrigation Scheme in the basin of River Mombo, Korogwe District, in Northern Tanzania. Soils here are heavy, black loamy clays which crack on drying. The land was ploughed, harrowed and then pre-irrigated to allow water to soak into the soil. Then, the soil was puddled with hoes to a fine tilth, thus thoroughly mixing it with water. Rice seedlings of 15 to 20 centimetres in height and aged 3.5 weeks were transplanted in rows at a spacing of 20 centimetres between plants and 20 centimetres between rows and at a depth of about 5 centimetres. The rice used in this experiment was a selected local variety called 'Kihogo Red'.

The experimental layout was a randomised complete block design, with seven herbicide treatments, one handweeded control and one unweeded control, all replicated three times. Each plot measured 4.5 m by 2.7 m, with bunds in all directions and a space of 0.5 m between plots. There was a space of about one metre between blocks, with a canal supplying water to each plot. Two days before treatment application, all the experimental plots were drained. Herbicide treatments and weeding of control plots were carried out on 7th November, 1979 between 11.55 a.m. and 12.30 p.m. This was 42 days after transplanting the rice seedlings. During that time, it was slightly windy, the sky cloudless and the relative humidity was 55%. The soil was completely drained, but it was still wet at the time of treatments. The herbicides were applied with an Oxford Precision sprayer using 'O' fan jet nozzles at a pressure of 205.3 kPa and a water spray volume of 350 l/ha. All the experimental plots were flooded again three days after treatments, and remained flooded up to just before harvest.

The effect of treatments on weeds was tested 38 and 80 days after herbicide application. This was done by randomly throwing a 30 cm by 30 cm metal quadrat six times in each plot and then counting predetermined individual weed species within the quadrats. The percentage effectiveness of each treatment on all weed species at 38 and 80 days after treatment application was worked out by the method of Abbot (Anon., 1975) and is recorded, along with mean weed densities, in Table 2. The weeds were then classified into three main groups: grass, sedge and broad-leaved. The percentage effectiveness of treatments on the three weed groups, 38 and 80 days after treatment application, was calculated (also by the method of Abbot) and is recorded in Table 3.

The rice was harvested on 8th March, 1980 by cutting the stems at the base with a sickle. All the rice rows in each plot were harvested and piled together. The harvested crop in each plot was threshed with a CeCeCo Foot Thresher (one-man type), the paddy winnowed with a CeCeCo Grain Winnower and dried in the sun for two days. The percentage moisture content of grain from each plot was measured with a Wile 35 Moisture Content Meter, its actual weight recorded and then adjusted to the standard moisture content of 14%. Mean grain yield for each treatment was then calculated and statistically analysed to test the effect of treatments on grain yield. Results for this analysis are recorded in Table 4.

Statistical methods of analysis used in this experiment were the two-way Anovar at $p = 0.05$ and the percentage effectiveness of treatments on weed species by the method of Abbot (loc. cit.). The formula of Abbot states as follows:-

$$\% \text{ effectiveness} = 100 - \frac{\text{Mean weed density in treated plots}}{\text{Mean weed density in untreated plots}} \times 100$$

Common, trade and code names, formulations and the manufacturers of the herbicides tested are given in Table 1.

Table 1

Details of the herbicides tested

Common name	Trade name	Code name	Formulation	Manufacturer
Butachlor	Machete	CP 53619	50% E.C.	Monsanto
Bentazone plus propanil	Basagran PL 2 (Anon., 1979)	BAS 454 02 H	50% E.C.	BASF
(2,3-dihydro-3,3-dimethyl-5-benzofuranyl ethanesulphonate)		NC 20484	40% E.C.	FBC Ltd.
Molinate	Ordram	-	72.7% E.C.	Stauffer

RESULTS

Three uniformly distributed weed groups before treatments were recognised, namely grass, sedge and broad-leaved weeds. The sedges consisted of Cyperus difformis and Pycreus macrostachyos. Grass weeds consisted mostly of Echinochloa colonum. Broad-leaved weeds consisted mainly of Ammania baccifera, Ludwigia abyssinica and Ipomea aquatica.

Thirty eight and eighty days after treatments, mean weed density in all the experimental plots showed a significant difference, suggesting that the treatments were effective on weeds (Table 2). At both 38 and 80 DAT, bentazone/propanil at both 4 and 5 kg a.i./ha was the most effective herbicide on all weed species. All the other herbicide treatments showed poor performance on weeds. Overall weed control by handweeding was good enough, and came next to bentazone/propanil.

A comparison of the percentage effectiveness of treatments on all weed species at 38 and 80 DAT confirmed that bentazone/propanil at both rates tested was the most effective herbicide (over 95%) (Table 2). This was followed by handweeding (52.1 - 70.5%). The percentage effectiveness of all the other treatments was below 26, which is regarded as poor performance of these treatments. On grass, sedge and broad-leaved weeds, the percentage effectiveness of the best treatments was repeated in the same order (Table 3). All the other treatments performed poorly on the three weed groups.

The treatments showed no undesirable effects on crop quality, neither did they have a significant effect on rice grain yield (Table 4).

Table 2

Percentage effectiveness of treatments on mean weed density 38 and 80 days after treatment

Treatment	Rate (kg a.i./ha)	Mean weed density (number/0.54 m^2) 38 DAT	Mean weed density (number/0.54 m^2) 80 DAT	% effectiveness 38 DAT	% effectiveness 80 DAT
Butachlor	2.0	172.0	63.7	-4.2	15.9
Butachlor	3.0	147.0	60.7	10.9	19.8
Bentazone + propanil	4.0	5.0	2.7	97.0	96.4
Bentazone + propanil	5.0	2.7	1.7	98.4	97.8
NC 20484	0.25	179.0	67.0	-8.5	11.5
NC 20484	0.5	124.7	56.7	24.4	25.1
Molinate	3.6	149.7	72.7	9.3	4.0
Handweeded control	-	48.7	36.3	70.5	52.1
Unweeded control	-	165.0	75.7	-	-
S.E.		21.2	7.4		
L.S.D. (p = 0.05)		63.1	22.0		
C.V. (%)		6.4	5.1		

Table 3

Percentage effectiveness of treatments on grass, sedge and broad-leaved weeds

(a) Weed counts

Treatment	Rate (kg a.i./ha)	Weed counts (number/1.62 m^2) 38 DAT G*	38 DAT S*	38 DAT B*	80 DAT G	80 DAT S	80 DAT B
Butachlor	2.0	8	469	39	7	172	12
Butachlor	3.0	0	405	36	9	163	10
Bentazone + propanil	4.0	3	11	1	0	8	0
Bentazone + propanil	5.0	2	6	0	0	5	0
NC 20484	0.25	0	498	40	9	180	12
NC 20484	0.5	9	349	16	12	148	10
Molinate	3.6	5	413	31	9	199	10
Handweeded control	-	0	140	6	1	98	10
Unweeded control	-	3	453	39	10	201	16

* G = Grass weeds; S = Sedge weeds; B = Broad-leaved weeds.

Table 3 (contd.)

(b) % effectiveness

Treatment	Rate (kg a.i./ha)	% effectiveness 38 DAT G	S	B	80 DAT G	S	B
Butachlor	2.0	-166.7	-3.5	0	30.0	14.4	25.0
Butachlor	3.0	100.0	10.6	7.7	10.0	18.9	37.5
Bentazone + propanil	4.0	0	97.6	97.4	100.0	96.0	100.0
Bentazone + propanil	5.0	33.3	98.7	100.0	100.0	97.5	100.0
NC 20484	0.25	100.0	-9.9	-2.6	10.0	10.4	25.0
NC 20484	0.5	-200.0	23.0	59.0	-20.0	26.4	37.5
Molinate	3.6	-66.7	8.8	20.5	10.0	1.0	37.5
Handweeded control	-	100.0	69.1	84.6	90.0	51.2	37.5
Unweeded control	-	-	-	-	-	-	-

Table 4

Effect of treatments on mean grain yield

Treatment	Rate (kg a.i./ha)	Mean grain yield (kg/12.15 m^2)
Butachlor	2.0	4.0
Butachlor	3.0	4.0
Bentazone + propanil	4.0	3.2
Bentazone + propanil	5.0	3.6
NC 20484	0.25	3.4
NC 20484	0.5	3.2
Molinate	3.6	3.5
Handweeded control	-	4.3
Unweeded control	-	2.8
	S.E.	0.4
	L.S.D. ($p = 0.05$)	N.S.
	C.V. (%)	3.8

DISCUSSION

The liquid butachlor used in this experiment has shown unsatisfactory performance on weeds. Granular butachlor would probably be more effective in transplanted rice, as suggested from the high frequency of application by many workers (Jana, 1974; Gidnavar and

Shivanandaiah, 1980; Chang and Datta, 1973; Ryang *et al*, 1979; Chang, 1974). From the results obtained by Baker (1980) in drill-sown and water-sown rice in U.S.A., the performance of liquid butachlor might be improved by mixing it with propanil. Suggested rates of application are butachlor + propanil at (1.8 - 2.2) + (2.2 - 3.6) kg a.i./ha respectively (Anon., 1972).

Results on the effectiveness of NC 20484 on grass weeds are not conclusive. However, its performance on sedge and broad-leaved weeds, although generally poor, is promising. Further trials with NC 20484 are, therefore, recommended so as to improve its effectiveness on grass, sedge and broad-leaved weeds in transplanted rice.

Molinate has displayed poor performance on weeds in this experiment. Probably the herbicide has a higher application potential in direct-sown rice than in transplanted rice, as is implied from the relatively high occurrence of experience with molinate in direct-sown rice reported in the literature (Szilvassy, 1981; Bischof, 1974; Chang, 1973). However, the performance of molinate on weeds in transplanted rice may be improved by applying it in flooded plots so as to minimise loss of herbicide through evaporation (Anon., 1978). Alternatively, the effectiveness of molinate may be improved by using it in combination with simetryne (Chang, 1973).

The percentage effectiveness of handweeding on all weed species seems to decline after 38 days (70.5 - 52.1%). A second handweeding 5 to 6 weeks after the first weeding would probably maintain about 70% weed control up to harvesting. This practice is recommended in situations where labour is cheaply available and the rice plots are small (e.g. up to 1 ha).

Changes in the density of individual weed species after treatments cannot be entirely due to herbicidal activity. Puddling of the field before transplanting and flooding it to a depth of 5 to 15 centimetres up to just before harvest are important factors that help to suppress weed growth throughout the growing season (Acland, 1975; Kaushik and Mani, 1978; Jana, 1974). The field on which this experiment was conducted was prepared and maintained as suggested by the above workers. From the fact that grain yield of unweeded plots did not differ significantly from that of herbicide treated plots, one may conclude that the weed density in all the experimental plots, though significantly different between treatments, was not high enough to provide weed competition with the crop during the entire growing season. Thus, although the herbicide treatments did not significantly improve the rice yield over and above that from unweeded plots and neither did they reduce the yields, one can conclude that the herbicides applied in this experiment are safe to be used in transplanted rice.

The overall results in this experiment suggest that bentazone/propanil could have a high application potential for the control of a broad weed spectrum in transplanted rice. This further suggests that the search for the development and application of herbicides in combination should continue.

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PENDIMETHALIN: A REVIEW OF ITS HERBICIDE POTENTIAL IN THE TROPICS

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Summary. Pendimethalin has become a well known herbicide in temperate and tropical regions. Excellent tolerance has been shown in the following crops: cotton, maize, rice, soybeans, groundnuts, sugarcane, cereals, legumes and a range of minor crops. Pendimethalin controls a wide range of prominent grass and broadleaved weeds. Many weed grass species are particularly well controlled, including Rottboellia exaltata, a major problem weed of increasing significance. STOMP, HERBADOX, cotton, maize, soybeans, groundnuts, sugarcane, rice, cereals, Rottboellia exaltata.

INTRODUCTION

This paper is a survey of the development of pendimethalin (available as commercial formulations under the trademarks STOMP*, PROWL*, HERBADOX*, GO-GO-SAN* and WAY-UP*), over the last 10 years in the following major tropical cultures: cotton, soybeans, groundnuts, maize, rice, cereals and sugarcane. The data sources for the 145 trials covered in this paper include American Cyanamid trials, cooperator trials and published literature.

Technical data on pendimethalin are published (American Cyanamid Co., 1981). Pendimethalin is toxicologically and environmentally a non-hazardous herbicide, and is currently registered in over 50 countries.

Spectrum of susceptible tropical weeds:

Broadleaved weeds		
Abutilon malvifolium	Corchorus tridens	Portulaca oleracea
Abutilon theophrasti	Croton lobatus	Sida alba
Amaranthus hybridus	Eupatorium odoratum	Sida rhombifolia
Amaranthus spinosus	Hibiscus asper	Spermacoce sinensis
Amaranthus viridis	Lucus martinicensis	Talinum triangulare
Aspilia helianthoides	Ludwigia octovalvis	Trianthema monogyna
Boerhaavia repens	Mollugo nudicaulis	Tribulus terrestris
Celosia laxa	Phyllanthus amarus	Verbena bonariensis
Grass weeds and sedges		
Brachiaria deflexa	Digitaria horizontalis	Monochoria vaginalis
Brachiaria lata	Digitaria ischaemum	Panicum maximum
Brachiaria mutica	Digitaria velutina	Paspalum dilatatum
Brachiaria ramosa	Echinochloa colonum	Paspalum orbiculare
Brachiaria reptans	Echinochloa crus-galli	Paspalum urvillei
Bulbostylis sp.	Eleusine africana	Pennisetum purpureum
Cenchrus echinatus	Eleusine indica	Phalaris minor
Chloris gayana	Fimbristylis littoralis	Rottboellia exaltata
Chloris pilosa	Ischaemum rugosum	Setaria viridis
Dactyloctenium aegyptium	Leptochloa filiformis	Setaria verticillata
Digitaria ciliaris	Mariscus umbellatus	Sorghum halepense

* Trademark of American Cyanamid Company.

MATERIALS AND METHODS

The 145 trials reported have been conducted to an internationally acceptable standard. Basically they were small plot replicated research trials where herbicides were applied with knapsack type sprayers. Variations occurred however in the use of trial designs, equipment, assessment techniques, reporting format, etc. The applications were made pre-emergence unless otherwise stated in the tables 1 through 7. The assessments were generally made 30 to 60 days after application. If a choice was available a date between 45 and 60 days was selected. About 50 % of the data were converted, either from the E.W.R.S., or the French C.E.B. systems to a percentage figure.

The data in the tables are expressed as follows: A % crop vigour or stand, B % overall weed control and C % yield. The figures A and B are expressed as a percentage of the untreated control and C as a percentage of the handweeded treatment. Not all 3 figures are available for all trials.

The averages of each trial were used to calculate the overall average (x) and the standard deviation (s) value for each treatment per crop. Due to the large variation between trials in different years, weed infestations and countries, the standard deviation is unavoidably large. Factors such as variety, soil type, amount and timing of precipitation had to be largely ignored, due to the lack of space but salient cases will be discussed.

RESULTS

1. COTTON

Table 1
Results from 54 cotton trials

Country	No. of trials		herbicides and rates kg a.i./ha (in parentheses): pendimethalin (1.5 - 2.0)			pendimethalin (1.4 - 1.8) + fluometuron (1.0 - 2.0)			pendimethalin (1.3 - 1.8) + cyanazine (0.7 - 0.9)			fluometuron (1.6 - 2.4)		
			A	B	C	A	B	C	A	B	C	A	B	C
EGYPT	18		98	79	111	97	81	115	-	-	-	98	78	114
ETHIOPIA	1		-	-	127	-	-	-	-	-	-	-	-	-
IVORY COAST	16		100	88	-	-	-	-	-	-	-	100	73	-
MADAGASCAR	6		-	-	133	-	-	-	-	-	-	-	-	125
SENEGAL	4		-	-	133	-	-	-	-	-	-	-	-	93
SUDAN	5		100	78	102	95	94	103	-	-	-	-	-	-
TOGO	1		-	23	-	-	-	-	-	-	-	-	88	-
ZAMBIA	3		100	72	-	-	-	-	100	86	-	-	-	-
	54	x	99	81	119	98	84	112	100	86	-	98	74	107
		n	19	43	26	9	17	6	3	3	-	11	34	17
		s	3.83	13.02	13.87	3.45	8.12	10.58	0	14.15	-	6.38	16.40	17.35

Pre-emergence applications of pendimethalin at a rate of 2.0 kg a.i./ha in Egypt, Sudan and Madagascar and 1.5 kg a.i./ha in the majority of other countries, have resulted in excellent crop tolerance (99 %), and provided both a reasonable weed control (81 %) and a good yield increase (19 %). In Egypt and Sudan a tank-mixture of pendimethalin with fluometuron improved overall weed control (84 %) and gave a mean yield

Abbreviations used for tables 1 - 7:
A. = % Crop stand/vigour; B. = % Overall weed control, compared with unweeded control plots; C. = % Yield compared with weeded control plots. x = average values; n = number of trials; s = standard deviation.

increase (12 %) but increased yields in Egypt and Sudan. Another tank-mixture, pendimethalin + cyanazine has been evaluated in Zambia and has given encouraging results. Compared with the standard fluometuron, pendimethalin alone and in tank-mixtures with fluometuron, has shown an important increase in weed control and yield. This is explained by the excellent grass control activity of pendimethalin in addition to its ability to control a good range of broadleaved weeds. Commelina benghalensis is one of a few tolerant species.

2. SOYBEANS

Table 2
Results from 11 soybean trials

Country	No. of trials	herbicides and rates in kg a.i./ha (in parentheses): pendimethalin (1.0 - 2.0) A	B	C	metribuzin (0.5) A	B	C	trifluralin (1.0 - 1.4 ppi) A	B	C	butralin (1.9 - 2.9) A	B	C
EGYPT	8	100	74	147	-	64	146	100	71	118	100	70	113
GHANA	1	100	52	100	100	78	109	100	47	100	-	-	-
NIGERIA	1	86	84	-	-	-	-	-	-	-	-	-	-
SENEGAL	1	88	99	-	50	97	-	-	-	-	96	99	-
	11 x	96	76	141	75	72	136	100	63	112	98	80	113
	n	6	11	8	2	6	4	2	3	3	2	3	2
	s	6.74	16.69	87.23	35.36	15.14	32.26	0	15.18	52.60	2.83	18.08	40.31

Eight pre-emergence trials have been carried out in Egypt and one each in Ghana, Nigeria and Senegal. The results with pendimethalin have been favorable. Pendimethalin was more tolerated by the crop than metribuzin in Senegal, both being non-phytotoxic in Ghana. Pendimethalin at 2.0 kg a.i./ha was well tolerated on the heavier soils of Egypt, but on the lighter soils of Senegal 1.2 kg a.i./ha caused light but acceptable crop damage. With respect to weed control, pendimethalin was as effective as metribuzin and butralin, and slightly superior to trifluralin (ppi) in these trials.

The yield data are mainly from Egypt, where pendimethalin and metribuzin gave higher yield increases (47, 46 %) than trifluralin or butralin (18, 13 %).

Cowpea's, beans and peas (not reported here) have also shown good tolerance to pendimethalin.

3. GROUNDNUTS

Table 3
Results from 5 groundnuts trials

Country	No. of trials	herbicides and rates in kg a.i./ha (in parentheses): pendimethalin (1.0 - 2.0) A	B	C	trifluralin (1.2) ppi A	B	C	vernolate (3.0 - 4.0) A	B	C	napropamide (3.0) A	B	C
EGYPT	1	100	92	132	-	-	-	100	68	103	-	-	-
GHANA	2	73	62	104	-	-	-	-	-	-	-	54	93
UPPER VOLTA	1	100	78	120	100	78	130	-	-	-	-	-	-
ZIMBABWE	1	100	90	124	-	-	-	-	-	-	-	-	-
	5 x	93	77	120	100	78	130	100	68	103	-	54	93
	n	4	5	4	1	1	1	1	1	1	-	1	1
	s	13.50	14.80	11.78	0	0	0	0	0	0	-	0	0

The application of pendimethalin in groundnuts has been less well researched than other crops. The 5 trials reported showed good pre-emergence crop tolerance at rates between 0.83 and 2.0 kg a.i./ha, the higher rates being used on heavier soils. Weed control was excellent in Egypt and Zambia, but the product would require tank-mixing with napropamide in Ghana and Upper Volta to improve the overall weed control. The average increase in yield with pendimethalin was 20 %. In these trials trifluralin (ppi) and vernolate performed reasonably, but napropamide was more phytotoxic, as expressed in a lower yield.

In the USA and other countries pendimethalin has been used ppi in groundnuts with success at rates from 0.75 to 1.65 kg a.i./ha.

4. SUGARCANE

Table 4
Results from 12 sugarcane trials

Country	No. of trails		herbicides and rates in kg a.i./ha (in parentheses) pendimethalin (1.5 - 2.0)			pendimethalin (1.3 - 1.5) + atrazine (2.0 - 2.5)			pendimethalin (2.0) + diuron (1.0)			atrazine (2.0) + ametryne (2.0)		
			A	B	C	A	B	C	A	B	C	A	B	C
GHANA	4		97	94	-	-	-	-	-	-	-	-	-	-
IVORY COST	3		100	67	-	100	57	-	-	-	-	100	50	-
PHILIPPINES	3		110	67	-	-	-	-	111	67	-	-	-	-
UPPER VOLTA	2		-	-	-	100	57	-	-	-	-	100	75	-
	12	x	102	78	-	100	57	-	111	67	-	100	67	-
		n	10	10	-	4	4	-	3	3	-	3	3	-
		s	5.81	19.57	-	0	37.27	-	0	0	-	0	19.97	-

Trials in Ivory Coast, Upper Volta, Ghana and the Philippines have shown that pendimethalin can be used pre-emergence alone or combined with atrazine, 2,4-D or diuron. The excellent control of Rottboellia exaltata in newly planted or ratoon sugarcane is of particular importance. The residual activity of the pendimethalin + atrazine mixture was greater than that of the standard atrazine + ametryne (van Hoogstraten, 1981). Crop tolerance of pendimethalin alone or in mixtures was excellent in both newly planted and ratoon cane.

5. MAIZE

Table 5
Results from 43 maize trials

Country	No. of trials		herbicides and rates in kg a.i./ha (in parentheses) pendimethalin (1.2 - 2.0)			pendimethalin (1.0 - 2.0) + atrazine (1.0 - 2.0)			atrazine (1.0 - 3.0)		
			A	B	C	A	B	C	A	B	C
EGYPT	1		100	73	110	100	98	110	100	90	118
GHANA	21		100	45	86	92	93	137	97	86	120
NIGERIA	5		97	71	103	96	81	108	101	5	87
PHILIPPINES	7		100	83	-	100	93	-	-	-	-
TOGO	2		-	84	180	-	89	180	-	-	-
ZAIRE	1		-	71	107	-	-	-	-	-	-
ZAMBIA	5		99	82	150	100	66	117	-	-	-
ZIMBABWE	1		-	91	98	-	-	-	-	-	-
	43	x	99	78	117	97	88	130	100	51	105
		n	9	19	11	12	4	33	4	6	6
		s	2.40	13.02	34.52	7.73	14.61	32.41	5.35	39.80	15.37

A large number of pre-emergence (43) trials have been carried out, especially in Ghana. The crop tolerance of pendimethalin alone or in a tank-mixture with atrazine has always been acceptable. Weed control with pendimethalin alone has been good with some exceptions in Nigeria and Zaire. In Nigeria the addition of 2.0 kg a.i./ha atrazine to pendimethalin improved the overall weed control significantly (71 % to 81 %), and the same responses have been observed in Egypt, Ghana, Philippines and Togo.

Overall yield responses followed the same pattern as weed control, pendimethalin alone gave higher yields (+17 %) than atrazine alone (+5 %). The tank-mixture of both showed the greatest increase (30 %).

As early as 1974, staff at the Henderson Research Station Zimbabwe, discovered in logarithmic trials the potential of pendimethalin to control Rottboellia exaltata in maize. Many trials since then have confirmed this finding.

6. RICE

Table 6
Results from 10 rice trials

Country	No. of trials		pendimethalin (1.3 - 2.0) A	B	C	pendimethalin (1.0) + propanil (2.0) * A	B	C	propanil (3.0 - 5.0) post-em. A	B	C	molinate (4.3) A	B	C
EGYPT	7		90	84	116	-	-	-	-	80	135	-	73	101
GHANA	2		100	65	-	-	-	-	100	45	-	-	-	-
VENEZUELA	1		100	71	-	100	86	-	100	53	-	-	-	-
	10	x	96	78	116	100	86	-	100	61	135	-	73	101
		n	5	8	5	1	1	-	3	5	2	-	1	1
		s	7.43	4.83	53.37	0	0	-	0	23.77	72.83	-	0	0

herbicides and rates in kg a.i./ha (in parentheses)

* early post-emergence.

Direct seeded rice.
Pendimethalin alone is used with success on a commercial scale in Uganda. Pendimethalin/propanil tank-mixtures were used early post-emergence for weed control in direct seeded rice in the tropical regions of Latin America. Propanil controlled the emerged weeds and pendimethalin provided residual activity. Pre-emergence treatments of pendimethalin alone were also used. It is important that rice seeds are well covered by soil, since crop phytotoxicity may occur if seeds come in direct contact with the herbicide.

Transplanted rice.
Studies in the Philippines have shown that good crop tolerance exists if pendimethalin is applied as a granule at rates between 1.0 and 1.5 kg a.i./ha, 3-5 days after transplanting. Excellent control of Monochoria vaginalis, Echinochloa spp., Cyperus difformis and Sphenoclea zeylandica was obtained. Further trials in Japan, Taiwan, Egypt, and India have confirmed the high efficacy of pendimethalin on Echinochloa spp.

7. CEREALS

Table 7
Results from 10 cereal trials

Country	Crop	No. of trials		pendimethalin (1.3 - 2.0) A	B	C	chlortoluron (3.0) A	B	C
EGYPT	Wheat	3		116	84	153	-	-	-
KENYA	Wheat	5		98	86	135	98	84	120
ZAMBIA	Wheat	1		100	68	-	-	-	-
		9	x	101	83	142	98	84	120
			n	7	8	8	5	5	2
			s	6.59	11.15	48.17	1.10	10.74	29.22
KENYA	Barley	1		99	90	124			

herbicides and rates in kg a.i./ha (in parentheses)

Pendimethalin is a successful and widely used product in wheat and barley in Europe. Cereals are grown in specific areas in the sub-tropics. Results from Egypt, Kenya and Zambia have shown that pendimethalin has an important role to play against local weeds, growing under sub-tropical conditions. Control of Setaria spp in cereals has been excellent in Kenya. Crop safety of pendimethalin has been good.

8. ROTTBOELLIA EXALTATA

Rottboellia exaltata is an annual weed which can grow 3-4 m. high before flowering in 100 days. Besides causing major crop competition, it seriously hinders mechanical or hand harvest of crops. Subsequent soil cultivations can become a problem if large amounts of plant residues are present. *Rottboellia exaltata* is widespread in the tropics and may occur in all major crops (Thomas, 1970).

The publications by Akobundu (1981), Edmeades (1981), Laycock (1980, 1981) and Vernon (1976) describe studies on control of this serious weed with pendimethalin:

Specific *Rottboellia exaltata* experiments were carried out in Nigeria (Akobundu, 1981) and in Zambia (Vernon, 1976). A summary of their data is shown in table 8.

Table 8
Effect of pendimethalin on Rottboellia exaltata (R.e.) control and yield of maize.

Treatment	Nigeria			Zambia	
	Rate kg a.i./ha	% R.e. control	% yield	Rate kg a.i./ha	% R.e. control
Unweeded check	-	0	28	-	0
pendimethalin	1.5	86	86	1.0	62
pendimethalin	2.5	92	83	2.0	90
pendimethalin + atrazine	2+2	86	90	1.5+1	86
hand weeding (3 and 8 weeks)	-	100	100	-	-

Studies in Ghana compared tank-mixtures of pendimethalin + atrazine at normal (N) and half dose rate (1/2 N) with hand weeding in maize. Table 9 below shows the weed control and yield data:

Table 9
Effect of hand weeding and pendimethalin + atrazine mixture on Rottboellia exaltata control and maize yields.

	Edmeades		Laycock	
	% control	% yield	% control	% yield
Unweeded	0	62	0	70
1 x handweeded	88	81	-	90
2 x handweeded	97	100	100	100
p. + a. (1/2 N)	91	86	73	106
p. + a. (1/2 N) + 1 late hand weeding	97	97	-	104
p. + a. (N)	94	101	93	93

Edmeades : hand weeding at 3 and 6 weeks. Pendimethalin + atrazine (p.+a.) N rate = (2.0 + 1.25) kg a.i./ha.
Laycock: hand weeding at 2, 3 and 8 weeks. Pendimethalin + atrazine (p.+a.) N rate = (1.5 + 1.0) kg a.i./ha.

These studies confirm that under favourable conditions, even the half rates provide considerable control of *Rottboellia*. The majority of other studies however, indicate that under practical conditions, a rate of at least 1.5 - 2.0 kg a.i./ha pendimethalin is required. The good results obtained in these research trials could be due to pendimethalin application to a moist, firm but fine tilth seed bed. Under such conditions herbicidal activity is optimal. Some soil moisture is essential to activate pendimethalin, like many other pre-emergence herbicides.

DISCUSSION

Weed control in tropical crops demands high performance from a herbicide due to the vigour of the weed flora. In addition, pre-emergence herbicides are often applied to very rough or dry seed beds, which reduces the herbicidal activity. Consequently, pre-emergence applications of herbicides in many tropical regions must be regarded as an aid to the farmer to delay his hand weeding and to make this task lighter and more effective. Deat (1974) reports that fluometuron usage in cotton can reduce hand weeding by 60 %, which allows the farmer more time for other activities. Pendimethalin alone or in mixture with fluometuron will increase this figure even further, possibly even eliminating hand weeding, because of its better overall weed control and its longer persistance in the soil.

Aston (1976) and Kirkland (1979) have pointed out the versatility of pendimethalin in tropical crops and the wealth of data presented here confirms their views. The value of pendimethalin is based on its persistent grass control activity, on Rottboellia exaltata in particular, as well as activity on many broadleaved weeds. The majority of triazine compounds used extensively in developing countries are excellent on many broadleaved weeds but show a weakness on grasses. Therefore the use of pendimethalin in tropical crops can be an answer. Where Rottboellia exaltata is present, a treatment with pendimethalin alone or as an additive to a standard herbicide becomes essential and can fully replace hand weeding. Furthermore Laycock (1981) confirms that the acute shortage of labour for weeding in Ghana in the critical first 6 weeks of crop growth, causes considerable yield loss to the local maize farmers. Weeding if done at all tends to be done late and poorly because of the dense weed growth. Combinations of herbicides with hand weeding have shown their value in terms of increased yields, and have proved more effective than 2 or 3 handweedings alone. In order to demonstrate the possibility of reducing the costs of herbicides to farmers, Laycock (1981) carried out band spraying (25cm.) in maize (row distance 80cm.) with pendimethalin + atrazine mixtures. This was as effective as overall spraying, providing a cost reduction of 70 %. Due to the lack of foreign exchange in many developing countries, which limits the importation of herbicides, this method could be a real answer towards improving national food production and thereby reducing foreign exchange expenditure for agricultural products.

Pendimethalin alone or in mixture has a great potential in many tropical crops to improve yields and to increase agricultural output.

CONCLUSION

The results above have shown the value of pendimethalin in a range of important tropical crops. A number of important additional/general recommendations can be made:

1. Dosages. The maximum rate in most crops is 2.0 kg a.i./ha, but on light soils and for sensitive crops this rate must be reduced to 1.5 or 1.0 kg a.i./ha. The minimum effective rate is determined by the weed spectrum present.
2. Herbicidal efficacy. Soils with high organic matter, 6-10 %,require a dosage increase of 20 %. Efficacy can be improved by providing a firm, but fine tilth seed bed, with no lumps over 5 cm diameter. Adequate soil moisture or rain after pre-emergence applications improves efficacy. Established weeds are not reliably controlled by pendimethalin. In such cases an application of paraquat or glyphosate prior to crop emergence will increase overall efficacy.
3. Crop tolerance. Crop tolerance is reduced in water-logged soils and in certain monocotyledonous crops such as maize, wheat and direct seeded rice if they are not uniformly sown to a depth of 3-5 cm.

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THE POSITION OF HEXAZINONE IN MIXTURES FOR WEED CONTROL IN SUGAR CANE IN SOUTHERN AFRICA

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Summary. The weed spectrum, timing of application, length of control and crop safety of hexazinone are discussed.

It is shown that mixtures with diuron, ametryne and ioxynil + 2, 4-D improve the usefulness of hexazinone by widening the weed spectrum, extending the time of application and increasing residual action. Suggestions for improved control of Cyperaceae are also discussed.

INTRODUCTION

The use of hexazinone ('Velpar Weedkiller') alone in sugar cane is well documented. Since it s introduction into the sugar cane industry of Southern Africa, various mixtures with other herbicides have been tested and applied on a commercial scale. The need for such mixtures was particularly felt where the grower, through a high-season work load, was forced either to apply hexazinone as a pre-season or as a late-season corrective treatment.

Although hexazinone proved itself a versatile herbicide from the point of timing and weed spectrum covered, in the early stages of commercialisation growers exhibited an increasing tendency to apply the product very early in the season, often under suboptimal temperature and moisture conditions.

The use pattern necessitated an investigation into possible mixtures, whereby the residual aspects, post emergence efficacy and the efficacy under pre-seasonal, dry and cool, conditions could be improved.

REVIEW OF TRIAL RESULTS

All trial results referred to have been laid out as randomised block experiments with four replications. Like many soil-applied residual herbicides, hexazinone, used alone, has shown limitations under specific soil/climatic and weed spectrum conditions. The following factors led to the introduction of hexazinone/diuron mixtures:

- Restriction of hexazinone dose rate for crop safety reasons.
- The need for an extended period of weed control as a result of early season applications.
- Improved control of problem weeds.

RESULTS OBTAINED WITH HEXAZINONE/DIURON MIXTURES

A summary of fourteen field trials carried out over two seasons is given in Table 1.

Table 1

A comparison of hexazinone versus hexazinone/diuron mixtures and accepted standard treatment mean percentage weed control

Treatment	(a) Dose Rate (g ai/ha)	Grasses (13 trials) (b) 40-60 days	Grasses (13 trials) 80-100 days	Broadleaves (6 trials) 40-60 days	Broadleaves (6 trials) 80-100 days	Cyperaceae (40-60 days) (b) Cyperus esculentus (4 trials)	Cyperaceae (40-60 days) (b) Cyperus rotundus (1 trial)
Hexazinone	340	86	64	98	98	-	-
	640	95	86	99	99	94	18
Hexazinone + Diuron	225 + 1000	91	73	99	99	90	0
	450 + 2000	98	93	99	99	97	0
Diuron + Actril DS 70EC (ioxynil + 2,4-D)	2000 + 875	92	69	98	97	76	15

a) All treatments were applied at pre-emergence to early post-emergence of weeds.

b) Time of evaluation, days after application.

These trials were all done in the Natal Sugar Cane belt and Swaziland.

For ease of interpretation two sets of dose rates have been chosen to compare hexazinone alone with a hexazinone/diuron mixture. The level of commercially acceptable weed control is set at 90%.

The data show that the addition of diuron to hexazinone improved the control of grasses and the residual effect. Grass species such as Digitaria sanguinalis, Panicum laevifolium, P. maximum and Paspalum vaginatum proved to be better controlled with the mixture. In Mauritius the same applied to Digitaria horizontalis, Paspalum paniculatum and P. urvillei.

The mixtures of hexazinone and diuron gave no improvement on broadleaved control over hexazinone alone.

The listed treatments proved to have a two-times crop safety factor. A single application of 670 g ai/ha of hexazinone did not control Cyperus rotundus, but Cuperus esculentus was controlled well for up to two months after application. Treatments on Cyperaceae were applied post emergence to weeds.

Various investigators found that the hexazinone/diuron mixture applied early season under conditions of low soil moisture and soil temperature gave unacceptable control of some winter weeds and problem grasses. To overcome these shortcomings other combinations were also tested.

RESULTS OBTAINED WITH A MIXTURE OF AMETRYNE ('GESAPAX') AND HEXAZINONE

The control obtained on specific weeds with ametryne and diuron mixtures with hexazinone are given in Table 2.

Table 2

Comparison of hexazinone/ametryne and hexazinone/diuron mixtures

Treatment (a)	Mean percentage weed control, 40-60 days after application					
	Broad-leaves (6 trials)	*Cyperus esculentus* (10 trials)	*Cyperus rotundus* (2 trials)	*Digitaria sanguinalis* (6 trials)	*Panicum maximum* (10 trials)	*Paspalum* spp (2 trials)
Hexazinone (1)	100	90	15	87	94	64
Ametryne (2)	86	62	0	96	54	-
Hexazinone + Ametryne (3)	100	90	20	96	93	88
Hexazinone + Diuron (4)	97	92	0	92	85	66

Dose rate (g ai/ha) = (1) 670 (2) 3000 (3) 450 + 2000 (4) 450 + 2000

a) Timing of application: Pre-emergence to early post-emergence of weeds in growing season.

Under the prevailing trial conditions of a dry and cool early season climate, improved control was obtained with the addition of ametryne to reduced rates of hexazinone, particularly on *D. sanguinalis* and *Paspalum spp*. No benefit was obtained with the addition of ametryne on broadleaf weed control.

Crop safety with the hexazinone/ametryne mixtures proved to be excellent. Acceptable post-emergence control of *C. esculentus* was obtained with the mixtures.

The mixtures of hexazinone with either diuron or ametryne did not control *C. rotundus*, leaving this weed problem still unresolved in ratoon cane. This problem has been solved in plant cane in South Africa by soil incorporation of EPTC or butylate, both with R 25788 safener ('Eptam Super' or 'Sutan Plus', respectively).

An interesting case was reported by Cornu (1982) on the use of hexazinone + ametryne in Reunion island (Indian Ocean). Post-emergence treatments remain popular because high rainfall sometimes necessitates a second application. Certain problem grasses are being selected by popular post-emergence treatments, including *Panicum maximum*, *Rottboelia exaltata* and *Paspalum dilatatum*.

These grasses are all controlled by a single post-emergence application of hexazinone + ametryne at 0.5 + 0.8 kg ai/ha plus a wetter/sticker at registered rates. This mixture is the only used treatment to date to control *P. dilatatum*. The purpose of the addition of a wetter/sticker is to prevent the product being washed from the weed leaves by unpredictable intermittent rains.

CONTROL OF C. rotundus OBTAINED WITH SPLIT APPLICATIONS OF HEXAZINONE MIXTURES

McIntyre et al. (1980) demonstrated under Mauritian conditions that commercially acceptable control was obtained with split applications of mixtures containing hexazinone. These mixtures were:

a) 'Velpar* K4' containing hexazinone and diuron in the ratio of 1:4.

b) 'Velpar* K4' + 'Actril DS' (ioxynil + 2,4-D).

c) 'Velpar* K4' + 2,4-D amine.

The first applications were made late post-emergence of C. rotundus followed up eight weeks later by the same treatments. The results obtained by McIntyre et al. are presented in Table 3. They indicate that hexazinone + diuron used as a split application resulted in acceptable control of C. rotundus.

Table 3

Effect of various post-emergence treatments on C. rotundus growing in ratoon canes

Herbicide	Dose Rate (kg ai or, ae/ha)	Mean % cover of C. rotundus		% Kill
		Before spraying	20 weeks later	
Hexazinone/ Diuron Premix	3.0	46.7	2.3	95.0
Hexazinone/ Diuron Premix + Ioxynil/ 2,4-D Premix	3.0 + 1.2	40.0	2.0	95.0
Hexazinone/ Diuron Premix + 2,4-D Amine Salt	3.0 + 2.0	46.7	2.3	95.0
Ioxynil/ 2,4-D Premix	1.2	46.7	25.7	45.0
Untreated Control	-	50.0	53.0	-

Source: McIntyre (1980)

Following these results, Richardson and English (1982) found a similar effect on C. rotundus in South Africa.

Of various combinations and treatments tested commercially, acceptable control of C. rotundus was found only where the following programme was applied: hexazinone + diuron (450 + 1000 g ai/ha) followed four weeks later by hexazinone (340 g ai/ha) + ioxynil/2, 4-D premix (700 g ai/ha). None of the other programmes listed below, gave acceptable control of C. rotundus.

		Rate (g ai/ha)				Rate (g ai/ha)
1)	Metribuzin	1400	THESE	a)	Ioxynil/2,4-D	875
	+	+	TREATMENTS		+	+
	Diuron	1500	SUPERIMPOSED		Diuron	2100
			BY THE			
2)	Metolachlor	2000	FOLLOWING	b)	Ioxynil/2,4-D	875
	+	+	FOUR WEEKS		+	+
	Ametryne	2000	LATER:-		Ametryne	2000
3.	Alachlor	2300		c)	Ioxynil/2,4-D	700
	+	+			+	+
	Diuron	2100			Hexazinone	340

CONCLUSIONS

1) There is merit in the mixture of hexazinone + diuron and hexazinone + ametryne. Selection of the mixture to be used should be dictated by prevailing soil conditions at time of application.

2) Certain problem grasses such as P. maximum and Paspalum spp. are better controlled with an equivalent hexazinone + ametryne dose rate.

3) Mixtures allow improved crop selectivity through reduction of the hexazinone rate. This is a factor of special importance in lighter soils.

4) Hexazinone + diuron followed by either hexazinone + diuron or hexazinone + ioxynil/2,4-D shows promise for the control of C. rotundus.

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DIFFERENTIAL RESPONSE OF AVENA SPP AND PHALARIS SPP TO SEVERAL PRE- AND POST-EMERGENCE HERBICIDES USED IN CEREALS

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Summary. A series of pot experiments was set up to investigate the differential response of *Phalaris minor* from India, *P. paradoxa* from England and *Avena fatua* and *Avena ludoviciana* from both countries to several grass weed herbicides used in cereals. *P. minor* was several times more susceptible than *P. paradoxa* to chlortoluron, isoproturon and metoxuron in both pre- and post-emergence treatments. Methabenzthiazuron, diclofop-methyl, flamprop-methyl, pendimenthalin and triallate were equally toxic to both species and AC 222293 and chlorsulfuron were more active against *P. paradoxa*. The differences in herbicide response between *Avena* species and biotypes were less pronounced. Methabenzthiazuron and isoproturon were more active on *A. ludoviciana* than *A. fatua* regardless of country of origin, but chlortoluron was more active against biotypes of both species from India, while AC 222293 and diclofop-methyl were slightly more toxic to English biotypes. The better field performance of certain substituted urea herbicides in India, compared with England, is discussed.

INTRODUCTION

Grass weeds are of major importance in cereal growing areas throughout the world and in many situations more than one herbicide is required to control all the species. In Europe substituted ureas such as isoproturon, metoxuron and chlortoluron control *Alopecurus myosuroides* well but do not control *Avena* spp at doses tolerated by the crop (Holroyd *et al*., 1976; Catizone, 1974; Scourey *et al*., 1982). However in India both *A. fatua* and *A. ludoviciana* together with *P. minor* are controlled in wheat by isoproturon, metoxuron, chlortoluron and methabenzthiazuron (Gill *et al*., 1979; Gill and Brar, 1977) at doses of 1-2 kg/ha which are well below those required for satisfactory performance in Europe. Catizone and Viggiani (1980) found *P. minor* was more susceptible than *P. paradoxa* to several herbicides, and since this latter species is of increasing importance in the UK (Anon, 1982) it has been included in our studies.

The differential activity of herbicides may be due to plant, soil and/or climatic factors. This paper describes experiments in which some current herbicides used for grass weed control in cereals are evaluated against wild oats (*A. fatua* and *A. ludoviciana*) from England and India and *P. minor* from India and *P. paradoxa* from England. The same soil was used throughout and environmental conditions were identical within but not between experiments.

MATERIALS AND METHODS

Experimental details are given in Table 1 of a series of pot experiments which were conducted during 1981-1982. Seeds of all the grasses were planted 15 mm deep in 9 cm diameter plastic pots containing Begbroke sandy loam soil supplemented with NPK fertilizer and trace elements. Five seeds were planted in each pot in all experiments and thinned to 3 plants in the studies with post-emergence application of the herbicides. They were watered daily from above, avoiding the foliage.

Table 1

Experimental details

Expt. No.	Species	Origin	Planting date	Spray date growth stage	Assessment date	Location/mean temp. range
1.	P. minor P. paradoxa	India) England)	30.10.81	27.11.81 2½-3 leaf	22.12.81	Glasshouse 14-23°C
2.	P. minor P. paradoxa	India) England)	4.1.82	5.1.82 Pre-em	18.1.82	Glasshouse 13-17°C
3.	P. minor P. paradoxa	India) England)	11.2.82	9.3.82 2-2½ leaf	25.3.82	Glasshouse 15-19°C
4.	A. fatua A. fatua A. ludoviciana	India) England) India)	10.2.82	9.3.82 2-2½ leaf	24.3.82	Glasshouse 13-17°C
5.	A. fatua A. ludoviciana	India) India)	22.6.82	20.7.82 3-3½ leaf	2.8.82	Open air*
	A. fatua A. ludoviciana	England) England)	1.7.82	26.7.82 3-3½ leaf	10.8.82	

* but for 1 week in glasshouse during germination and 1 week in growth room immediately after spraying (16/10°C and 75/86% RH day/night conditions, 100 W/m^2 for 14 h photoperiod).

Herbicides. The rates of application of each herbicide are given in the appropriate tables and the formulations used are included at the first reference. All the herbicides were used as formulated products without adding surfactant, except for AC 222293,≠ which was applied in all but Experiment 1, with 0.25% v/v solution of Agral 90. The herbicides were applied using a laboratory pot sprayer comprising of a single Teejet band spray nozzle (8001E) travelling at 0.7 km/h and delivering 200 l/ha at an operating pressure of 211 kPa.

At the time of assessment the shoots were cut above the soil, dried in an oven and weighed. Four replicate pots were used throughout and the experiments were arranged in a split block design.

Herbicide retention studies. Spray retention on foliage was measured using fluorescein dye (sodium salt at 0.1% concn.) in the herbicide spray solution. The procedure of Merritt (1980) was modified by including AC 222293 at 0.30 kg/ha for Phalaris spp and at 0.20 kg/ha for Avena spp in the spray solution. The dye was washed from the foliage using 50 ml 0.005M NaOH. The plants were dried and weighed after washing.

The amount of spray solution reaching the soil (soil retention) was estimated by covering the soil surface with black plastic beads and washing them after the spray to recover the dye, in the same way as explained above.

The retention studies were done using 10 pots for each species/biotype. The herbicide retention on soil was done only for Phalaris spp.

RESULTS

Effect of herbicides on Phalaris spp. The effect of post-emergence applications on shoot dry weight (Experiments 1 and 3) are shown in Table 2.

≠ as described by Kirkland and Shafer (1982).

Table 2

Effect of herbicides applied post-emergence to Phalaris spp. shoot dry wt. (mg) (Experiments 1 and 3)

Herbicide	kg a.i./ha[a]	Experiment 1 P minor	Experiment 1 P. paradoxa	Experiment 3 P. minor	Experiment 3 P. paradoxa
AC 222293[b]	0.15	360	257	196	63
(50% wp)	0.30	308	177	145	63
	0.60	156	85	116	53
Chlorsulfuron	0.005	-[c]	-	192	188
(20% wp)	0.010	-	-	219	130
	0.015	-	-	217	123
Diclofop-methyl	0.50	226	241	180	172
(38% ec)	1.00	238	207	150	130
	2.00	123	57	104	94
Flamprop-methyl	0.13	309	275	-	-
(10% ec)	0.25	214	208	-	-
	0.50	132	81	-	-
Chlortoluron	0.75	-	-	66	160
(50% flowable)	1.50	-	-	24	144
	3.00	-	-	16	75
Isoproturon	0.50	-	-	57	159
(50% flowable)	1.00	18	229	30	66
	2.00	-	-	23	19
Methabenzthiazuron	1.00	-	-	137	123
(80% wp)	2.00	-	-	22	31
	4.00	-	-	20	18
Metoxuron	1.00	95	254	39	153
(50% flowable)	2.00	41	272	40	120
	4.00	34	216	18	96
Control		339	326	240	211
S.E.		±23.64		±13.09	

[a] Typical retentions were:

		Foliage	Soil
P. minor	42 µl/3 plants	(516 µl/g dry wt)	94 µl
P. paradoxa	48 " "	(528 " " ")	97 µl

[b] In experiment 1 no surfactant; experiment 2 and 3 with 0.25% v/v Agral 90.

[c] Treatment not investigated.

Following application of AC 222293 at 0.3 and 0.6 kg/ha the shoot dry weight of P. paradoxa were decreased much more than those of P. minor and shoot height was very strongly suppressed in the former species. Adding 'Agral 90' surfactant to AC 222293 in Experiment 3 increased its activity on both species but the differentially larger effect on P. paradoxa was maintained at higher doses and increased at 0.15 kg/ha. Chlorsulfuron at 10-15 g/ha showed a similar trend in its effects on the two species with P. paradoxa being much more susceptible. Diclofop-methyl at the highest dose was more damaging to P. paradoxa in Experiment 1, but there was no difference between the species in Experiment 3. Both species were moderately resistant to flamprop-methyl at the doses employed. Methabenzthiazuron also was equally toxic to both species, giving good control at the 2.0 and 4.0 kg/ha doses. The remaining substituted ureas were much more toxic to P. minor than P. paradoxa. Treatment of younger plants (Experiment 3) generally led to greater herbicide toxicity, particularly in the case of isoproturon and metoxuron against P. paradoxa.

The pre-emergence treatments (Table 3) included two additional herbicides.

Table 3

Effect of herbicides applied pre-emergence to Phalaris spp (Experiment 2)

Herbicide	kg ai/ha	Emergence % of planted P.minor	Emergence % of planted P.paradoxa	Plant kill % of emerged P.minor	Plant kill % of emerged P.paradoxa	Shoot dry wt. % of control P.minor	Shoot dry wt. % of control P.paradoxa
AC 222293	0.10	90	90	17	0	96	110
	0.20	95	90	0	0	61	40
	0.40	85	75	12	100	20	0
Chlorsulfuron	0.002	100	70	0	0	106	45
	0.004	100	85	0	0	73	40
Diclofop-methyl	0.10	95	75	0	7	109	96
	0.20	90	95	78	5	92	99
	0.40	45	45	100	100	0	0
Pendimethalin (33% ec)	0.10	85	100	23	5	37	94
	0.20	80	70	81	21	17	41
	0.40	55	95	73	68	17	46
Tri-allate (40% ec)	0.38	100	80	0	31	28	25
	0.75	70	75	78	80	9	4
	1.50	75	70	73	100	1	0
Chlortoluron	0.75	85	80	88	6	5	101
	1.50	95	90	100	0	0	73
	3.00	95	70	100	29	0	27
Isoproturon	0.50	90	85	94	6	4	47
	1.00	80	80	100	19	0	18
	2.00	85	70	100	94	0	4
Methabenz-thiazuron	1.00	70	75	50	0	11	52
	2.00	70	70	100	36	0	10
	4.00	70	70	100	100	0	0
Metoxuron	1.00	90	85	11	0	11	76
	2.00	100	95	95	5	3	55
	4.00	75	65	100	92	0	2
Control		95	95	0	0	100 (62 mg)[a]	100 (52 mg)
S.E.						±11.1	

[a] dry weight/plant

Pendimethalin at 0.4 kg/ha reduced emergence of P. minor by about 46% and over 70% of the emerged plants subsequently died. P. paradoxa suffered the same mortality of emerged plants, but its emergence was unaffected so control of this species was less effective. Tri-allate affected both species similarly and at the 0.75 and 1.5 kg/ha dose gave excellent control. Chlorsulfuron had little effect on emergence and none of the plants in either species was completely killed, but growth of P. paradoxa was about twice as susceptible as P. minor. All the substituted urea herbicides were more phytotoxic to P. minor than P. paradoxa. Complete control of the latter species was only achieved with methabenzthiazuron at 4 kg/ha.

Effect of herbicides on Avena spp. The effect of post-emergence application of herbicides on shoot dry weight (Experiment 4 and 5) are shown in Table 4. Indian Avena fatua was found to be slightly less damaged by AC 222293 than other species and biotypes of wild oats, in both experiments. The slightly poorer control of AC 222293 in Experiment 5 was probably due to the fact that older plants were used. A. fatua and A. ludoviciana from India were slightly more tolerant to diclofop-methyl than their counterparts from England.

Table 4

Effect of herbicides post-emergence on Avena spp from England and India (Shoot dry weight as % of control) (Experiment 4 and 5)

		Experiment 4			Experiment 5			
		Avena fatua		A.ludoviciana	Avena fatua		A.ludoviciana	
Herbicide	(kg ai/ha)	India	England	India	India	England	India	England
AC 222293	0.05	43	32	27	79	56	70	49
	0.10	43	25	28	65	54	51	43
	0.20	41	31	29	54	53	50	47
Diclofop-methyl	0.50	95	57	68	-[a]	-	83	47
	1.00	72	33	31	-	-	63	55
	2.00	42	25	29	-	-	56	37
Chlortoluron	0.75	53	75	48	-	-	58	95
	1.50	30	47	28	-	-	41	50
	3.00	18	31	20	-	-	28	27
Isoproturon	0.50	42	59	37	76	69	51	58
	1.00	25	33	26	47	50	37	30
	2.00	22	19	16	36	42	34	26
Methabenz-thiazuron	1.00	67	79	37	75	73	56	55
	2.00	50	53	19	52	53	39	42
	4.00	18	18	16	36	50	35	38
Metoxuron	1.00	39	33	34	-	-	35	38
	2.00	18	26	23	-	-	36	31
	4.00	20	10	19	-	-	28	24
S.E.			± 4.8			± 7.3[b]		± 5.9[c]
Control dry wt. (g)		0.30g	0.32g	0.30g	0.42g	0.43g	0.41g	0.58g
Typical foliage retentions were:				µl/3 plants	63	81	51	78
				µl/g dry wt.	145	209	150	217

[a] Treatment not investigated; [b] for comparing all means; [c] for comparing A.ludoviciana

Experiments 4 and 5 show that both Avena spp from England were more tolerant than their Indian counterparts to chlortoluron. In contrast, both species regardless of source were equally susceptible to metoxuron. In the case of isoproturon and methabenzthiazuron, A. ludoviciana regardless of source tended to be more susceptible than A. fatua.

DISCUSSION

The results of experiments 1 to 5 taken together show considerable variation in herbicide performance arising mainly from plant factors. With regard to P. minor and P. paradoxa, six out of ten herbicides evaluated showed marked inter-specific selectivity. The substituted ureas, apart from methabenzthiazuron which was equally toxic to both species, were several times more active against P. minor than P. paradoxa. For AC 222293 and chlorsulfuron, the selectivity was reversed. Catizone and Viggiani (1980) reported similar results for chlortoluron and methabenzthiazuron with P. paradoxa and P. minor. These interspecific differences in response to herbicides were apparent in both pre- and post-emergence treatments, but tended to be most marked in the latter. Since these differences were maintained following entry via either the roots or shoots there may be differences in metabolism and/or sensitivity at the site of action to the herbicides in the two species. The contribution of differential spray retention on foliage or soil can be dismissed since it was found to be similar for both species, averaging about 45 μl/3 plants or 522 μl/g dry weight for foliage. The interspecific differences in herbicide response of A. fatua and A. ludoviciana, regardless of source of seed, were less marked than those reported for Phalaris spp, and A. fatua tended to be more tolerant than A. ludoviciana, for example, to isoproturon and methabenzthiazuron.

In addition to these interspecific differences, there were some important contrasts in response to herbicides associated with country of origin of the seed. The Indian A. fatua and A. ludoviciana, by comparison with corresponding English species, were approximately 50% more susceptible to chlortoluron. AC 222293 and diclofop-methyl showed a reverse but less marked trend towards these species. However, metoxuron was equally active on both species of wild oats regardless of source.

In England, multilocation trials suggest that A. fatua was more susceptible than A. ludoviciana to early post-emergence application of isoproturon and chlortoluron (Proctor and Armsby, 1974), and to post-emergence application of metoxuron (Ummel et al., 1974). Variations in soil and climatic conditions in Europe between different sites might have been largely responsible for this response, which is contrary to the results obtained in our experiments.

The wild oats from India (irrespective of their species) germinated more slowly but grew faster after emergence and flowered earlier than those from England. These observations concur with reports by Yamaguchi (1977) on A. fatua biotypes. These differences in growth between biotypes were reflected in differential spray retention on foliage (Table 4).

The greater susceptibility of wild oats in India to ureas as reported by Gill and Brar (1977) and Gill et al. (1979) could be due to plant, soil, climatic and management factors. A limited literature survey suggests that the rather more susceptible A. ludoviciana may be the more dominant species of wild oat in India. Secondly, the vast majority of the wheat area in North-west India is irrigated and the soil surface at the time of herbicide application seldom remains dry which is conducive to good activity of soil acting herbicides. In contrast, in England and elsewhere in Europe the herbicide is occasionally applied to dry soil where it remains inactive until rainfall (Smith, 1981). Longer dry periods may lead to strong establishment of weeds and sometimes variable weed control. In addition, ash from straw burning may contribute to reduced herbicide activity (Nyffeler and Blair, 1978).

In our pot experiments, the soil type used and the consistently high moisture content should also favour the activity of herbicides such as the substituted ureas. The observed differential response, then, could be due to differences between species/biotypes in entry, movement and metabolism and activity of the herbicides at their site of action. Of these, the existence of a detoxifying mechanism and differential rate of degradation in the plant are reported to be the main selective mechanism in many weeds and wheat cultivars to phenyl urea herbicides (Muller and Frahm, 1977; Ryan et al., 1981).

Further investigations are being carried out to widen our understanding of the physiological basis for the differential response found for the two Phalaris spp to some of these herbicides.

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