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THE EFFECT OF TEMPERATURE ON THE PERFORMANCE OF FIVE HERBICIDES USED TO CONTROL AGROPYRON REPENS

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Summary Uniform single shoot plants of *A. repens* were treated with three doses of five herbicides and kept in controlled environment cabinets where all conditions were constant (light 16 h at 4,200 lm; humidity 1.5 mm Hg water vapour deficit leaf/air; soil water at field capacity) except temperature which was set at 6, 16 and 26°C. The time for damage to appear was inversely proportional to temperature and dose, but ultimate kill did not always follow this pattern for temperature. Paraquat at 0.25, 0.5 and 1.0 lb/ac produced damage within 24 h at all temperatures, but all doses killed only at 6°C, regrowth occurring at low rates at higher temperatures. Asulam symptoms did not appear until five days at 26 and two weeks at 6°C at 4 lb/ac and took longer at 0.5 and 2.0 lb/ac. In contrast to paraquat optimum kill was at 26°C and minimal at 6°C. Activated aminotriazole at 1, 3 and 6 lb/ac dalapon and Orga 3045 at 3, 6 and 12 lb/ac performed well at all temperatures, but some regrowth occurred at low rates especially at the high temperature.

INTRODUCTION

A number of herbicides are available for the control of *Agropyron repens* and are used at various times of year. Choice is based on factors such as cost and possible residual effects on the following crop. Rarely are weather conditions considered other than on the day of spraying. However Hammerton (1968) in his review on 'The environment and herbicide performance' stressed that post-application conditions can play a decisive role in the efficiency of chemical weed control. Although weather forecasting leaves much to be desired, general seasonal patterns are predictable. Hence information on the relative performance of herbicides at different levels of a parameter such as temperature can assist decision making where there is choice of product, and possibly explain inconsistencies in field performance.

The experiment reported here examined the effect of three temperature levels on the performance of five herbicides used to control *A. repens*, while other environmental factors were kept constant.

METHOD AND MATERIALS

Single node 1 in. rhizome fragments of *Agropyron repens* L. (Beauv.) clone 31 (Headington clone) were planted in Levington compost in 3.5 in. pots and grown in a glasshouse until they reached the 4-leaf stage. Uniform plants were selected and transferred to Saxcil controlled environment cabinets set up as follows:

Radiation - 16 h at 4,200 lumens
Temperature - 16°C
Humidity - 85% relative humidity

Air Speed - 30 ft per min - vertically from below

The compost was kept at field capacity by automatic sub-irrigation.

Following two days of acclimatization, the temperature and humidity were adjusted gradually to give the following regimes:

Temperature °C	% Relative Humidity	Water vapour pressure deficit (leaf/air) mm. Hg
6	78	1.5
16	89	1.5
26	94	1.5

The same water vapour pressure deficit between the leaves and air was maintained in all cabinets, in order to keep the cuticles hydrated and to avoid variable rates of desiccation of the spray droplets.

The plants in each cabinet were set up in two randomised blocks each containing two replicates.

The herbicides, plus 0.2% v/v Tergitol NPX wetter, were applied at the doses shown in Table 1 with a laboratory pot sprayer operating at 30 lb in^2 and delivering 30.1 gal/ac. Plants were transferred to and from the spray room in a closed box and returned to the cabinet immediately after application to minimise the time the plants were out of the controlled environment. To ensure that only the foliage was treated with herbicide the compost surface was covered with perlite granules before spraying which were then removed subsequently.

The plants were kept in the cabinets for 35 days and then transferred to an outside standing ground where they equilibriated for 60 days. The foliage was then cut at soil level. The rhizomes were removed and replanted in fresh compost in 5 in. pots.

Following spraying, the development of symptoms was recorded every day for the first five days and subsequently each week. The total number of shoots was recorded every seven days while the plants were in the cabinets and 25 days after replanting. The total number of shoots included the main shoot, all tillers and upturned rhizomes over 0.5 in. in length, even if chlorotic or necrotic, as long as they were partially turgid.

RESULTS

In Fig. 1A the growth of the control plants is represented as the number of shoots per pot at each assessment date in the cabinets, and finally 25 days after replanting. The number of shoots per pot on the herbicide treated plants (Fig. 1B-F) are expressed as percentages of the controls at each temperature and each curve represents the mean of the three doses of the herbicide. The most rapid development of visible damage occurred at 26°C and the slowest at 6°C and this is reflected in the shoot assessments. Paraquat acted most rapidly of the chemicals tested, causing the leaves to wilt and become grey green at 6°C and to become yellow brown at 26°C within 24 h. Activated aminotriazole and the sodium salt of dalapon at the high rate and temperature also developed necrosis within 24 h. The sodium salt of 2,2,3,3-tetrafluropropionic acid (Orga 3045) developed chlorosis and necrosis after 48 h at the high temperature and symptom manifestation was slower at all temperatures than with the chemically closely related dalapon. The slowest acting chemical was the sodium salt of asulam at 6°C which took two weeks to cause slight twisting of new growth. At the higher temperatures these symptoms appeared after five to ten days.

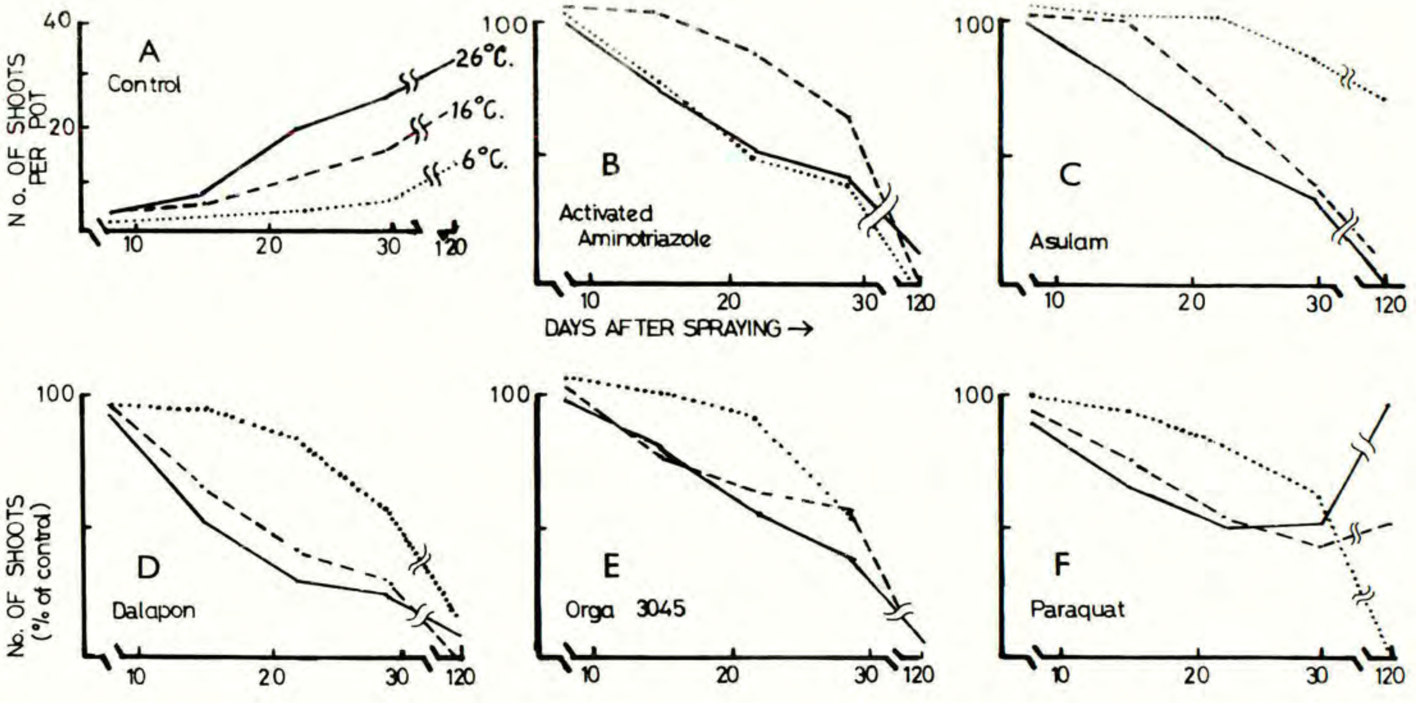

Figure 1

Effect of three temperature regimes on the growth of Agropyron repens, expressed as number of shoots per pot for controls 'A', and number of shoots per pot as a percentage of controls for herbicide treatments B to F (mean of three rates).

The greatest difference in ultimate effect initially lay between 6 and 16°C for all the chemicals except asulam. In the case of Orga 3045 and paraquat, the 6°C treatments eventually achieved the maximum degree of control and activated aminotriazole was almost as good. A notable exception was asulam which showed little activity at this temperature except at the highest rate, but gave a complete kill at 26°C. In complete contrast paraquat obtained maximum final kill in the 6°C regime and minimum at 26°C.

Shoot numbers for all treatments 22 days after spraying are presented in Table 1. The influence of temperature on the dose response of the plants at each temperature is apparent from these figures. There was little difference between doses at low temperature, but the effect of dose on phytotoxicity became highly significant as the temperature regimes were ascended, the greatest difference occurring between low and others. The failure of the means of 3 doses of activated aminotriazole, dalapon and Orga 3045 to give a total kill at 26°C in figure 1 was due to recovery of some of the plants treated with the low rate of herbicide.

Table 1

Shoots per pot 22 days after spraying

	Dose lb a.i./ac	6°C	16°C	26°C
Control		4.5	10.4	14.2
Activated aminotriazole	1	4.6	7.4	13.7
	3	3.3	4.0	4.6
	6	3.3	3.1	3.3
Asulam	0.5	4.7	9.8	8.4
	2	4.6	6.5	4.2
	4	4.0	4.4	3.7
Dalapon	3	4.3	5.2	5.9
	6	3.5	4.0	2.3
	12	3.2	3.4	2.5
Orga 3045	3	4.2	11.0	12.0
	6	3.8	4.3	7.3
	12	4.0	3.6	3.6
Paraquat	0.25	3.1	8.2	11.3
	0.5	2.5	4.8	6.0
	1.0	2.0	3.4	4.7
S.E. control		0.65	0.97	1.70
S.E. rates		0.56	0.84	1.47
S.E. control v. rates		0.33	0.49	0.85

DISCUSSION

A general conclusion that can be drawn from these results is that increased temperature is accompanied by more rapid manifestation of initial damage, but ultimate phytotoxicity does not necessarily follow this trend. Higher temperature in the absence of cuticle dehydration and rapid drying of spray droplets, as in this experiment, generally increases uptake and translocation (Hammerton 1968) and hence the symptoms of phytotoxicity appeared first at 26°C for each chemical and last at

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6°. The failure of this initial advantage at 26°C, especially at low doses, to be maintained through to the death of the plant may be attributed to a number of factors. Rapid growth at 26°C (Fig. 1A), especially from buds free from initial contact action, probably resulted in the same amount of herbicide, in relation to the lower temperature, being translocated further to more cells. In addition to this diluting factor, higher temperatures accelerate biochemical and biophysical processes in the plant (Went and Overland Sheps 1969) and thus herbicide detoxifying mechanisms are likely to be enhanced.

Håkansson (1969) found __A. repens__ grew actively at an average temperature of 5-6°C both in the field and under controlled environment conditions. The control curve for 6°C (Fig. 1A) confirms this for Headington clone and although biochemical and biophysical processes would be relatively slow, all the herbicides except asulam were ultimately lethal to all plants, at the higher rates. The slower speed of plant processes at 6°C probably accounted for the improved performance of paraquat as less herbicide would be trapped in dead tissue at the point of contact, hence allowing more extensive movement, as in dark versus light situations for diquat (Baldwin 1963). A possible explanation for the low activity of asulam at 6°C may be due to slow uptake and translocation coupled with a detoxifying mechanism in __A. repens__ which is efficient at this temperature.

The ultimate kill obtained in this experiment was partly dependent on the conditions after the plants were removed from the cabinet and variations of the time spent in the cabinet and outside would probably alter the detail of some of the results, however, in general, the trends established during the 35 days under controlled conditions are reflected in the final assessment.

In order to understand the principles involved in the response of herbicides to environmental factors it is important to examine one factor at a time. Generally results obtained in this type of work cannot automatically be applied directly to the field situation as other factors apart from the variable being investigated may have a significant effect on herbicide performance. However, in the case of paraquat autumn applications under cool conditions have been observed in the field to be very effective and thus would appear to agree with the 6°C results of this experiment. In the autumn other environmental parameters such as low light intensity (Brian and Headford 1968) favour this herbicide.

The general implications of this experiment are that activated aminotriazole, dalapon and Orga 3045 perform adequately at all three temperatures whereas the activity of asulam at 6°C and paraquat at 26°C was considerably diminished.

__Acknowledgements__

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HERBICIDES FOR THE CONTROL OF AGROPYRON REPENS AND AGROSTIS GIGANTEA

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Summary Agropyron repens in undisturbed barley stubble was very well controlled for at least 8-10 months by early autumn applications of sodium 2,2,3,3-tetrafluoropropionate (Orga 3045) at 4 and 8 lb a.i./ac and aminotriazole plus ammonium thiocyanate at 1, 2 and 4 lb a.i./ac. A. repens and Agrostis gigantea specially planted in the spring were almost completely controlled by pre- and post-emergence applications of Orga 3045 at 4 and 8 lb a.i./ac and a pre-emergence application of TCA at 30 lb a.i./ac. Aminotriazole plus ammonium thiocyanate was less effective under these latter conditions but 4 lb a.i./ac applied post-emergence gave moderate control of A. repens and good control of A. gigantea. Other treatments which gave good control in this experiment were carbetamide at 2 lb a.i./ac on A. repens, 6'-t-butyl-2-chloro-N-(methoxymethyl)-o-acetotoluidide (CP 44939) at 4 lb a.i./ac on A. repens and A. gigantea and EPTC at 4 lb a.i./ac on A. repens and A. gigantea, all mixed into the soil; and dalapon at 8 lb a.i./ac applied post-emergence.

INTRODUCTION

The control of 'couch' (Agropyron repens and Agrostis gigantea) is a major project at the Weed Research Organization and there is a continuing evaluation of potential herbicides for this purpose. Information from the manufacturers and the results of standard greenhouse assessments are used to indicate the more promising compounds.

This report deals with two field evaluation experiments A and B. In experiment A, in the spring of 1969, the activities of four candidate herbicides were compared with those of four standard herbicide treatments on specially planted populations of A. repens and A. gigantea. Experiment B, in autumn 1969, compared the effects of 5 different herbicides on a semi-natural population of A. repens in barley stubble.

METHOD AND MATERIALS

For experiment A a normal seed bed was prepared on a light sandy loam soil at the Weed Research Organization. Furrows were drawn 9 in. apart and approximately 3 in. deep. Four 6 in. rhizome pieces were planted at 9 in. intervals in each furrow in yd^2 plots on 1.4.69, giving 16 rhizome pieces per plot. The rhizome material was cut from clonal material (Headington clone) raised in stock beds. Unbranched and unsprouted rhizomes were selected which appeared healthy. A 9 in. unplanted discard was left around each plot.

In experiment A the candidate herbicides were: carbetamide (as a 30% w/v e.c.), 6'-t-butyl-2-chloro-N-(methoxymethyl)-o-acetotoludide (CP 44939, as a 48% w/v e.c.), 2-chloro-N-(isopropoxymethyl)-(2,6-xylyl)acetamide (CP 52665, as a 48% w/v e.c.) and sodium 2,2,3,3-tetrafluoropropionate (Orga 3045, as a 80.8% w/v aq.c.) and the standard treatments of dalapon-sodium (as a 74% w/w s.p.), EPTC (as a 72% w/v e.c.), aminotriazole plus ammonium thiocyanate (activated aminotriazole as a 20% w/v aq.c.) and TCA-sodium (as a 80.68% w/w pelletised solid). In experiment B the herbicides were: asulam (as a 40% w/v aq.c.), Orga 3045, dalapon, activated aminotriazole and paraquat (as a 20% w/v aq.c.).

Treatments were applied using a special sprayer for small plots fitted with a Teejet 730039, at a volume rate of 20 gal/ac and a working pressure of 30 lb/in^2. Those treatments requiring incorporation were forked in two directions into the top 2-3 in. of soil before planting the rhizomes. Other treatments were applied either immediately after planting on 1.4.69 or when the plants had 3 leaves and were 3-4 in. high on 20.5.69. The experimental design was a randomised block of four replicates, with separate areas of A. repens and A. gigantea.

The experiment was left uncultivated and assessed on 11.6.69 and 4.8.69, by counting the shoots on the centre 2 x 2 ft of each plot. Aminotriazole-treated plots were not assessed at the first date due to the difficulty of distinguishing between live and dead shoots. After the final assessment samples of rhizome from severely affected plots were replanted in fresh soil in pots to determine their viability.

The site of experiment B had been used for an A. repens/spring barley competition experiment in 1968 during which it was planted up with A. repens rhizomes of Headington clone. After normal cultivations in the autumn and spring of 1968-69 a spring barley crop was sown by the farm with normal fertilizer application. By the summer of 1969 the A. repens population was relatively uniform over the whole area and after harvest it was allowed to grow in the stubble to a height of 5-6 in. before treatment.

Treatments were applied on 18.9.69 with an Oxford Precision Sprayer fitted with 8002 Teejets applying 20 gal/ac at 30 lb/in^2. Each treatment was replicated twice, using 6 x 2 yd plots in randomised blocks. In each replicate nine plots were rotary cultivated to a depth of 3-4 in. as cultivated controls.

Plots were assessed on 21.5.70 by harvesting the 'couch' foliage from two 1 ft^2 quadrats randomly placed in each plot.

RESULTS

Table 1 summarises the results from Experiment A. The most effective compound was Orga 3045 which when applied pre-emergence to the soil surface gave a complete kill of both species of 'couch' at a dose of 8 lb a.i./ac; and at 4 lb a.i./ac a complete kill of A. gigantea and almost a complete kill of A. repens. Applied to the foliage post-emergence it was not quite so active particularly on A. gigantea which was not completely killed by 8 lb a.i./ac.

Carbetamide was the second most active compound against A. repens although CP 44939 was slightly more active against the A. gigantea. These compounds were mixed with the soil before planting and did not appear to give a superior result to EPTC used in the same way.

Of the four standard treatments, 30 lb a.i./ac of TCA applied to the soil surface was the most effective, although even this did not give a complete kill. 4 lb a.i./ac of EPTC mixed into the soil and 8 lb a.i./ac of dalapon applied to the foliage were also relatively effective. Activated aminotriazole applied to the foliage at 4 lb a.i./ac had a marked effect particularly on the A. gigantea.

Table 1

Shoot counts of A. repens and A. gigantea

Counts per 4 ft^2 of each plot - mean of 4 replicates

Treated pre-emergence and pre-planting on 1.4.69; post emergence on 20.5.69

	Dose	A. repens		A. gigantea	
Assessment date		11.6.69	4.8.69	11.6.69	4.8.69
Treatment	(lb a.i./ac)				
CP 52665 pre-plant incorp.	1	26	175	35	312
	2	14	127	14	160
	4	5	57	27	176
CP 44939 pre-plant incorp.	1	25	184	43	276
	2	14	138	12	95
	4	3	32	4	24
carbetamide pre-plant incorp.	0.5	19	147	62	386
	1	15	102	35	359
	2	4	53	12	151
EPTC pre-plant incorp.	4	1	47	1	39
TCA surface pre-emergence	30	0	4	0	2
Orga 3045 surface pre-emergence	2	2	37	31	132
	4	0	8	0	0
	8	0	0	2	0
Orga 3045 foliar post-emergence	2	22	88	82	347
	4	22	7	63	27
	8	14	0	42	5
dalapon foliar post-emergence	8	15	6	40	4
activated aminotriazole foliar post-emergence	4	-	96	-	21
Untreated control		34	198	40	477
S.E. treatment mean comp.		± 4.2	19.7	4.7	21.4
S.E. treatment/control comp.		± 4.4	21.5	5.2	23.4

Pieces of rhizome from the A. repens plots treated pre-emergence with 4 and 8 lb a.i./ac of Orga 3045 and post-emergence with 8 lb a.i./ac proved to be dead when transferred to untreated soil, but one or two shoots emerged from similarly treated pieces of A. gigantea rhizome. Rhizomes taken from plots treated with other herbicides all showed some growth.

In experiment B (Table 2) several of the herbicide treatments were preventing the development of aerial shoots on A. repens eight months after application. Activated aminotriazole was the most effective compound under these conditions, although surprisingly the 1 lb a.i./ac treatment had as much effect as the 4 lb a.i./ac treatment. However the 'couch' population was rather variable as shown by the relatively large standard error values.

Table 2

Dry weights (g) of two 2 ft^2 samples/plot

Treated: 18.9.69; Samples: 21.5.70

Herbicide	Dose (lb a.i./ac)	Dry wt (g)
Orga 3045	2	3.74
	4	1.86
	8	0.15
Dalapon	2	8.82
	4	7.18
	8	3.32
Activated aminotriazole	1	0.05
	2	0.13
	4	0.38
Paraquat	0.5	12.56
	1	6.43
	2	2.84
Asulam	2	8.41
	4	8.88
	8	5.35
rotovated control		3.83
untreated control		16.98
S.E. treatment comparison	±	3.84
S.E. treatment / untreated control comparison	±	4.21
S.E. treatment / rotovated control comparison	±	4.10

Orga 3045 was again very effective and the 2 lb a.i./ac treatment had almost as much effect as 8 lb a.i./ac of dalapon. Asulam was relatively ineffective even at 8 lb a.i./ac and on the paraquat-treated plots, although regrowth was delayed, it was very vigorous. Rotary cultivation also reduced the density of the regrowth, but that which was present was very vigorous. At the time of the final visual observation on the 17.7.70 (approx 10 months after treatment) 8 lb a.i./ac of the Orga 3045 and all three doses of activated aminotriazole were still giving almost complete suppression of the aerial growth of the __A. repens__. Examination of portions of the rhizomes on these plots by digging indicated that many were apparently dead.

DISCUSSION

Aelbers et al. (1969) reported the high activity of Orga 3045 on __Agropyron repens__ and the two present experiments demonstrate this strikingly under two very different sets of conditions. In experiment A the rhizomes were disturbed and fragmented but growing conditions were relatively good with adequate soil moisture although temperatures were initially rather low. In experiment B, by contrast the rhizomes were undisturbed, the soil relatively compacted and very dry for the first six weeks. However experiment A in which treatments were applied both pre- and post-emergence does indicate that its effectiveness is likely to be greatest if applied to the soil soon after cultivation to disturb and break up the rhizomes. Aelbers et al. reported the compound to be effective on __Agrostis stolonifera__ in addition to A. repens and experiment A indicates that Agrostis gigantea is also very susceptible. Foliar applications were relatively slow in action and the control given by both dalapon and Orga 3045 improved between the two assessments (Table 1), except for the lowest dose of Orga 3045.

In contrast to the Orga compound, activated aminotriazole was much more effective in experiment B than experiment A but it is difficult to define any one factor such as dry soil conditions, or soil compaction which could account for this difference - almost certainly the effects of the rotary cultivation treatment were enhanced by the early dry conditions.

Both these experiments tested the direct effects of the treatments on the 'couch', with no crop present which under normal conditions could be expected to help suppress the weed by competition.

Soil samples taken in the spring from experiment B and tested by sowing with various crop seeds, indicated that herbicide residues were absent even from the most highly dosed plots. It should be possible therefore to follow the early autumn treatments with a normal spring crop but further work is being done on this aspect at the present time.

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FACTORS INFLUENCING THE EFFECT OF TCA ON GRAMINEOUS SPECIES, WITH SPECIAL REFERENCE TO THE EFFECT ON *Agropyron repens* (L.) BEAUV.

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Summary TCA sodium was applied to the soil in pot experiments. It was shown to be much more effective against *Agropyron repens* in early stages of growth, especially before emergence, than in later stages. This was the result not only for plants developed from the reproductive stems but also for seedlings. The results were similar for seedlings of the annual *Hordeum distichum* and essentially the same for fodder grasses studied. Previous experiments concerning the soil moisture and the TCA effect are discussed. In recent experiments the temperature influence was studied. A temperature increase from a level of 7-10° C to 20-25° C caused a decrease in the effect of TCA, shown both for plants from rhizomes of *Agropyron* and for seedlings of *Hordeum* in different soils. The effect on *Triticum aestivum* was greater at 5-10° C than at 15-20° C. With a temperature increase from 25° C to 30 and 35° C there was a gradual decrease in the rapidity of shoot emergence from rhizome pieces of *Agropyron* but an increase in the effect of TCA. The reason for this is discussed.

INTRODUCTION

The phytotoxic effect and the fate of TCA after application in different ways has been discussed by many authors (literature surveys by Leasure, 1964; and Kearney *et al.*, 1965; more recent original papers by Håkansson, 1969a; Håkansson & Jonsson, 1970; Chow, 1970; and others). In a series of experiments factors influencing the controlling effect of TCA (the sodium salt) on gramineous species after soil application have been studied by the present author and co-workers. One group of experiments has concerned the effect after application in different stages of plant development. In other groups the influence of environmental conditions in the soil has been studied.

MATERIALS AND METHODS

Some trials concerning TCA and the stage of plant development were carried out in the field (Håkansson, 1969a), but otherwise the experiments were performed as pot experiments in growth cabinets, growth chambers and greenhouses. All the TCA experiments were conducted in 0.5-litre plastic pots containing about 450 ml soil. In most experiments the plant material was *Agropyron repens* (L.) Beauv., rhizome pieces of which were planted at a depth of 1.5-2 cm. The piece length and the number of pieces planted per pot were different in different experiments. Five or ten pieces of a length of 8 and 4 cm, respectively, and with one or two buds each were planted. Four to seven TCA doses were used, represented by two to four replication pots with a total of 20-51 buds per dose in a given experimental series. In certain experiments, seeds or kernels of couch, *Agropyron repens*, two-row barley, *Hordeum distichum* L., or wheat, *Triticum aestivum* L., were sown, 25 per pot at a depth of 1.5 cm. TCA was applied in different ways so that a satisfactory distribution in the soil was achieved for the different types of experiments. Alternative application methods were compared in special tests.

In all experiments but those where the purpose was to study the time of application, TCA was applied at the time of planting or sowing. The pots were watered individually, ensuring the desired moisture contents. Other data about the experiments are given with the results.

The phytotoxic effects have been expressed by ED50 values on the basis of number and dry weight of aerial shoots judged to be at least partly alive. The tests were carried out when the shoots in the TCA-free pots in the different experimental series had reached a given stage, usually the 3-4-leaf stage. Special tests showed a good correlation between test values based on all new plant parts and on the aerial shoots only.

RESULTS

From earlier reports (e.g. Stahler, 1950; Bylterud, 1958; Krüger, 1961) it could be suggested that TCA in soil exerts its greatest effect on Agropyron repens in the early stages of plant development from the reproductive stem system, and this was repeatedly shown by the author both in field and laboratory investigations (Håkansson, 1969a).

Pot experiments were later performed in the greenhouse to study the TCA effect on seedlings of the perennial Agropyron repens and the annual Hordeum distichum. The results, summarized in Table 1, show that the best controlling effect was achieved when the herbicide was present in the soil from the start of germination. The effect then decreased gradually with delayed application, particularly after the shoots had emerged above soil.

Table 1

Effect of TCA expressed on the basis of the dry weight of aerial shoots

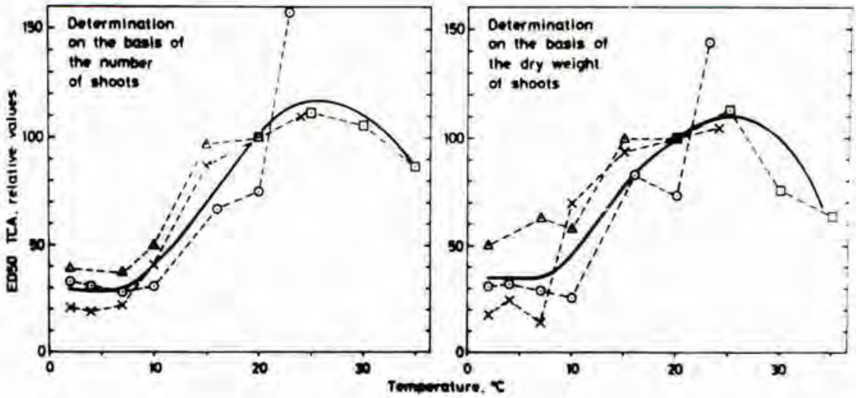
Time of TCA application	ED50 TCA, mg/litre soil	
	Agropyron	Hordeum
Before emergence above soil		
At start of germination	2.3	1.5
Near emergence	2.5	4.0
After emergence above soil		
Shoots with 1 foliage leaf	4.1	6
Shoots with 2 foliage leaves	16	>16

The results obtained suggest that, as a general rule, TCA exerts its greatest controlling effect when taken up by the plant in the earliest developmental stages before emergence. This conclusion is further supported by the results of greenhouse experiments with different perennial fodder grasses: Poa pratensis L., Bromus inermis Leyss., Festuca rubra L. and Lolium perenne L.

From field and laboratory experiments with Agropyron repens it is concluded that, for most effective results, TCA should be applied to the soil at times suitable for bringing it into contact with the reproductive stem system (1) when growth starts in the spring in areas with a pronounced winter or (2) whenever an intense regrowth can start after soil cultivation causing a destruction of the aerial shoots (Håkansson, 1969a). The question is now in which seasons factors such as the soil moisture content or soil temperature could be supposed to prevent a satisfactory TCA effect in different climatic regions.

In pot experiments Håkansson & Jonsson (1970) found only small differences in the effect of TCA on Agropyron in soil with a moisture content varying from near the wilting point up to the maximum content of water at free drainage of the pots. At contents around and below the wilting point, TCA was probably

Fig. 1. Temperature influence on the effect of TCA on Agropyron repens as shown in four experiments, the relative ED50 values from which are designated by different symbols. The ED50 values for 20° C, or for the average of those near 20° C with this temperature being the mean, have been given the value 100. An Uppland clone in a sandy loam was used in three experiments (o, x, □) whereas a Blekinge clone in an organogenic soil was studied in one experiment (△). After 5-6 weeks material kept at experimental temperatures below 10° C was transferred to temperatures of 15-20° C, where the final plant development before the determination of the TCA effect was completed. Unbroken curved lines are drawn to show the type of relationship between the TCA effect and the temperature that is hypothetically concluded from the experiments.



only taken up to a slight extent, or not at all, by the plant tissues. Thus, the surviving plant material showed no, or only slight, damage from TCA after having been kept in dry soil for a period and then washed and transplanted into a TCA-free soil with a moisture content sufficient for growth. Although a satisfactory effect of TCA on Agropyron will be achieved even at rather low moisture contents when the herbicide, as in the experiments, is well distributed in the soil, there are problems in practice. Even at moderately low moisture contents there are often difficulties with the cultivation of the soil and thus with the distribution of the herbicide. The difficulties with low moisture contents must be strongly dependent on the soil type. The problems with leaching of the highly water-soluble herbicide in periods with excess of water are wellknown.

The temperature influence on the effectiveness of TCA on Agropyron repens, Hordeum distichum and Triticum aestivum was studied in recent experiments in growth cabinets and chambers. Some of the material grown in the greenhouse, but otherwise similar to that placed in growth cabinets, was involved in the experimental comparisons after it had been shown that comparable results were obtained from rooms with alternating and constant temperatures with the same diurnal temperature sums and with light intensity differences over a wide range.

The results of experiments with Agropyron repens at different temperatures are summarized in Fig. 1. They indicate a considerable decrease in the TCA effect with a temperature increase from 7-10° C up to about 25° C. In this temperature region the sprouting and shoot growth rapidity increases strongly with increased temperature.

A temperature influence of the same kind as that described in Fig. 1 was noted for the TCA effect on Hordeum distichum in a clay and an organogenic soil (Table 2) and on Triticum aestivum in an unsterilized and a sterilized sandy loam (Table 3).

Table 2

TCA effect on Hordeum distichum at three temperatures in two soils

Temperature	ED50 TCA, mg/litre soil			
	Clay soil		Org. soil	
	Number of shoots	Dry weight of shoots	Number of shoots	Dry weight of shoots
2° C (35 days, then 16-21°)	2.1	1.4	3.2	1.8
10° C	2.6	2.1	3.2	2.4
20° C (var. 16-21°)	8.3	9.0	11.0	7.3

Table 3

TCA effect on Triticum aestivum at two temperatures in unsterilized soil and soil sterilized in autoclave at 127° C for 1 hour

Temperature	Values determined on the basis of the number of shoots		Values determined on the basis of the dry weight of shoots	
	Unsterilized soil	Sterilized soil	Unsterilized soil	Sterilized soil
	ED50 TCA, mg/litre soil			
9° C	1.3	2.3	1.2	1.4
18° C	1.8	4.9	1.8	2.8
	Ratio: ED50 for 18° C to ED50 for 9° C			
	1.4	2.1	1.5	2.0

The results of the experiment with Triticum do not indicate that differences in the microbiological activity and TCA breakdown could have been the reason for the different TCA effect at the higher and lower temperatures. However, on soils previously treated with TCA, without a pronounced lag phase, a more rapid biological degradation might occur at the higher temperature and thus contribute to reduce the effect.

A temperature optimum was registered for the Uppland clone of Agropyron in the region around 25° C. (Cf. Meyer & Buchholtz, 1963; Håkansson, 1969c.) Increasing temperature above the optimum caused a decreasing bud activity and rapidity of shoot growth, and the TCA effect increased (Fig. 1). There was thus a negative correlation between the TCA effect and the shoot growth both in the temperature regions below and above the region of maximum growth rapidity. The situation in the region of the lowest temperatures is somewhat obscure. There might have been a pronounced increase in the effect with a temperature decrease even below 7-10° C if the plant material had not been transferred to a higher temperature (15-20° C) as early as 5 to 6 weeks after the start of the experiment.

DISCUSSION

To be able to explain the described temperature influence on the TCA effect, further extensive investigation is required. However, a hypothetical explanation will be given here under the assumption that the differences in the TCA effect at different temperatures are a result of differences in the amount of TCA taken up by the plant within defined stages in the early phase of shoot growth. According to the descriptions in the previous section, the uptake in the pre-emergence phase is decisive for the phytotoxic effect of TCA. In an experiment with Cynodon dactylon (L.) Pers., Rochecouste (1962) demonstrated that there was no effect from uptake of TCA via the roots when the shoots were in the bud stage and there was no transpiration. The results of preliminary experiments with wheat carried out by the present author support Rochecouste's results. From these facts it might be suggested that the absorption of TCA from the soil and uptake into sensitive tissues is dependent only to a lesser extent on the plant activity in early stages. Recent experiments by Chow (1970) concerning the root uptake by plants in later stages than those under discussion here do not contradict this suggestion. In many steps, the movements of TCA in connection with the uptake in early stages will be of the type of diffusion, both outside and inside the plant surfaces. On the whole, the uptake per time-unit and plant surface unit could be suspected to change more slowly with a temperature change than the rapidity of the development and growth of plant tissues. The uptake in the period between given stages of early development will then decrease with an increasing rapidity of growth, and this will lead to the type of changes in effect with changes of the temperature that are shown in Fig. 1.

The strong effect of TCA at low temperatures may be one of the reasons why TCA application in early spring gives the relatively good control of Agropyron repens that is experienced in Scandinavia. Experiences from field trials in Sweden suggest a better average effect of TCA after application in the very early spring than after application later in the growing season in connection with the soil cultivation before the sowing of a brassica crop in the spring or in the stubble field in late summer. The control by treatment in late summer is, however, favoured by other factors, which will sometimes weigh strongly against the disadvantage of the higher soil temperatures, the daily averages of which are seldom above 16-17° C in Sweden. The underground reproductive stems are thus concentrated more to the upper soil layers in the later part of the growing season than they are in the spring after ploughing in the previous autumn. (Cf. Håkansson, 1969b). This makes it easier to bring the herbicide into good contact with the stems, which, in addition, can be broken to a great extent even by fairly shallow soil operations. Hence the good effect of combined rotavation and TCA application often obtained (Cf. Hamand et al., 1968). In large parts of Sweden there are much lesser risks of unfavourable leaching with application in the summer than with very early spring application, when there are also risks of transportation by surface water because the herbicide can seldom be mixed into the soil by cultivation. In the summer, on the other hand, there are greater chances of low moisture contents in the soil with possible disadvantages according to the previous discussions.

Under certain climatic and other conditions TCA may also be applied in the autumn, and even in the winter, in order that the favourable influence of low temperatures would be used. According to the results of recent experiments (Håkansson, unpubl.) periods of temperatures below 0° C do not reduce the effect of TCA taken up by the plants at temperatures above 0° C before or after the frost periods.

Acknowledgements

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A STUDY OF THE COMPETITION BETWEEN AGROPYRON REPENS (L.) BEAUV. AND SPRING SOWN BARLEY, WHEAT AND FIELD BEANS

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Summary **A. repens** at two population levels was planted into land that was later sown to spring field beans, wheat and two varieties of barley. The crops had a greater effect on the growth of A. repens than vice versa The cereal crops were much more suppressive than field beans. Yield of field beans was reduced by 43% in the presence of the low population and 79% by the high population. Cereal yields were not affected by the low population of 45 primary shoots/yd^2. The high population of 180 primary shoots/yd^2 reduced yield of the cereal crops by around 20%. Crop dry weight on A. repens infested plots relative to that on weed free plots declined continuously through the life of all the crops. This was most marked in the case of spring wheat.

INTRODUCTION

Previous work reported in 1968 had indicated the importance of competition from a crop in modifying the development of A. repens. Spring sown barley and wheat were found to be much more effective in suppressing and delaying the formation of new rhizome than were field beans. Of the two former crops, barley was more suppressive in the 1967 season.

It seemed reasonable to infer from these results that crops which most effectively suppressed weed growth would suffer least from weed competition. It also appeared possible that there might be differences between crop varieties as well as between species. Accordingly, an experiment was set up in 1968 to examine the effects of the weed on the crops as well as vice versa.

METHOD AND MATERIALS

The treatments were all combinations of four crops:

Beans	var.	Maris Bead
Wheat	var.	Kloka
Barley	var.	Impala
"	"	Deba abed

and three population levels of Agropyron repens:

Nil
18 rhizome pieces/yd^2
72 " " /yd^2

The low population of A. repens was also included without a crop.

The experiment was sited at Begbroke Hill Farm on a sandy loam soil. A randomised block design was used. Each main plot was 40 ft long by 9.5 ft wide, the plots were separated by pathways 2.5 ft wide. The main plots were sub divided into areas 10 ft by 9.5 ft of which the central 4.5 ft^2 was planted to A. repens, where required. All assessments were made on the central 3 ft^2 of this area. There were four of these sample plots within each main plot. Each main plot was drilled continuously with the crop, as appropriate, there being 19 crop rows 6 in. apart across each plot. Rhizome pieces 6 in. long were cut from clonal material of A repens obtained from an area planted for this purpose in 1967. Unbranched and unsprouted pieces were selected and the material was chosen so as to avoid rhizomes with damaged buds or with abnormal internode length or diameter. (The mean dry weight of a 6 in. planted section was 0.36 g). The rhizome pieces were placed by hand into the bottoms of shallow furrows. The furrows were levelled off immediately after planting and the crops drilled as soon afterwards as possible (always within 24 hours). Final depth of rhizome in settled soil was from 2-3 in. One replicate was planted on the 29th February and two on the 7th and 8th March.

The whole area received an application of 2½ cwt/ac of a compound fertilizer containing N.P.K. in the ratio 13:13:20. All plots except those sown to beans received an additional application of 1½ cwt/ac of an ammonium sulphate nitrate product containing 26% nitrogen.

All plots were sprayed with dinoseb for control of broadleaved weeds on the 25th April; the wheat and barley plots with an amine formulation and the bean plots with an acetate formulation. The herbicide was applied on a day which started cool and humid but shortly after spraying was complete the temperature rose to a maximum of 66°F.

The herbicide treatment had no visible effect on wheat or Agropyron repens. The barley however was severely scorched (estimated at 30-40% defoliation) although recovery was rapid. The beans were very severely scorched (estimated at 90% defoliation) and took longer to recover. There was little plant mortality and the surviving plants grew very strongly although they were reduced in height. The final yield, on weed free plots, of nearly 43 cwt/ac of seed beans indicated a high degree of recovery from this damage.

Foliar disease did not become noteworthy on any crops and the beans remained free from aphid attack. The spring wheat was, however, attacked by the grain aphis, Sitobium avenae.

Sample plots selected at random were assessed at intervals throughout the season. On the first three occasions, 10, 15 and 19 weeks after planting, the crops were assessed for dry weight, plant number/yd^2, tillers/plant and leaves/plant. A. repens was completely excavated and assessed for numbers of primary shoots and tillers, leaves and flower heads, where present. Dry weight of the original rhizome piece and of the various components of the new growth were also recorded.

The remaining assessment plots were assessed in two stages because of the widely disparate dates of maturity of the different crops. Of the cereal crops Impala barley ripened shortly before Deba Abed barley and both were ripe well before Kloka wheat. Total dry weight of above ground parts of the crop and of grain were determined for these plots on the 22nd August. At this time only the above ground parts of A. repens were assessed on these plots. The beans ripened much later and were assessed on the 30th September. Complete assessment of A. repens on all plots was also made on this date.

RESULTS

1. The growth of Agropyron repens

On average each 6 in. piece of planted rhizome produced 3 primary or rhizome axillary shoots, regardless of the competing crop.

Table 1

Mean shoots and tillers on each 6 in. piece of A. repens in the lower population

Competing crop.		Assessed on 15th May	26th June	21st Aug.	30th Sept.
No crop		7.73	39.5		38.6
Beans		4.61	23.0		35.8
Wheat		3.33	2.6	4.6	
Barley - Impala		3.30	3.0	8.4	
Barley - Deba Abed		3.23	3.2	6.9	
	S.E.	0.54	1.6		

Table 1 shows that tiller formation in the lower population was very much affected by crop competition. Fewer tillers were formed in the plots sown to wheat than in those sown to barley. There was profuse tillering on the plots sown to beans and even more on the uncropped plots.

The shoot count on the uncropped plots had reached a very high level in June; but no further increase was recorded at the end of September. It would seem that production of new tillers and senescence of old ones kept pace at a level of around 39 shoots on each rhizome section or about 600 tillers/yd^2. By the end of September this level had almost been reached on the plots sown to beans.

Table 2

Mean dry weight per plant of A. repens

Competing crop	A. repens level	Assessed on 15th May	26th June	22nd July	21st Aug.*	30th Sept.
No crop	Low	1.23	22.0	41.0	-	59.7
Beans	Low	0.73	12.0	13.7	-	38.4
	High	0.83	7.4	10.6	-	19.3
Wheat	Low	0.93	2.3	3.0	2.2	4.5
	High	0.93	2.2	3.2	2.4	4.2
Barley Impala	Low	0.87	3.1	4.1	3.4	7.4
	High	0.83	2.7	4.0	2.8	6.1
Barley Deba Abed	Low	0.83	2.6	3.9	3.0	7.0
	High	1.00	2.9	4.9	3.5	6.8
	S.E.	0.079	0.55	0.72		2.5

*Applies only to foliage removed at crop harvest

Table 3

Dry weight of new rhizome g per "plant"

Competing crop	*A. repens* level	Assessed on 15th May	26th June	22nd July	30 Sept.
No crop	Low	0.07	7.65	17.05	36.2
Beans	Low	0.01	3.74	4.24	11.4
	High	Not measured separately			6.7
Wheat	Low	Nil	0.02	0.08	1.0
	High	Not measured separately			0.7
Barley Impala	Low	trace	0.04	0.45	2.3
	High	Not measured separately			1.8
Barley Deba Abed	Low	trace	0.32	0.60	2.3
	High	Not measured separately			1.8
S.E.				0.35	1.06

Table 2 gives total dry weights for all structures of *A. repens* recovered (including the original piece) and Table 3 gives dry weight of new rhizome only. It can be seen that, on the uncropped plots, growth was slow at first but very rapid later in the season. By July new rhizome made up 41.5% of the total dry weight. By the end of September, the dry weight of 36.2 g of new rhizome per plant on these uncropped plots represents an hundredfold increase on the weight of rhizome planted

A repens also produced a great deal of new rhizome growth in the plots sown to beans, the level of production being considerably greater than that recorded in 1967. At the later dates of assessment an increasing difference was recorded between the weight per plant of *A. repens* at the different population levels. By early October the weight per plant on the "high" population plots was around a half of that recorded on the low population plots, an indication of the high level of intra-specific as well as inter-specific competition on the dense plots.

Growth of *A. repens* was very much poorer in the plots cropped to wheat and barley. There appeared to be very little difference between the barley varieties Impala and Deba Abed in respect of suppression of *A. repens*. It was notable that spring wheat was more suppressive than barley in this experiment, a reversal of the result obtained in 1967.

2. Crop growth

The crop populations were within the normal limits for field practice. Table 4 gives details of crop population and degree of tillering in the early stages of the experiment. Only flowering tillers were recorded in June, the number of non-flowering tillers being negligible.

Between May and June there was a reduction in plant numbers and in tillers per plant of wheat and barley. Tiller numbers of beans increased slightly during this period. Similar changes took place in the 1967 experiment.

Table 4

Crop establishment and tillering

Crop	A. repens level	Plants/yd^2 15th May	Plants/yd^2 26th June	Total shoots/plant 15th May	Total shoots/plant 26th June
Beans	Nil	42	27	1.06	1.33
	Low	36	24	1.07	1.33
	High	35	33	1.00	1.08
Wheat	Nil	409	297	1.96	1.20
	Low	579	327	2.30	1.25
	High	415	385	2.10	1.12
Barley Impala	Nil	274	242	3.05	2.40
	Low	284	257	3.40	2.25
	High	295	240	2.79	1.95
Barley Deba Abed	Nil	243	243	3.69	2.10
	Low	286	285	3.95	1.68
	High	273	272	3.47	1.85
S.E.		36.9	24.8	0.13	0.14

Table 5 shows the effects of two levels of A. repens infestation on the dry weight above ground of the crops. At the time of the first harvest on 15th May there was no evidence of a damaging effect on crop dry weights due to the presence of A. repens. Conversely the dry weight of wheat and barley was significantly higher on the plots planted to the low level of weed.

The effect of A. repens on the crops increased as the season progressed. By 22nd July the higher population of A. repens had significantly reduced yields of all the crops, the effect on beans being most severe. It appeared that the variety Impala suffered to a greater extent than Deba Abed and, at this stage, the effect of A. repens on wheat was less severe than on either of the two barley varieties. By the time of crop maturity this difference was reversed, so that the yield of wheat was reduced to a slightly greater extent than that of either variety of barley.

At the lower population level, the yield of beans was 43% below that of the weed free control plots and at the higher population level it was reduced by 80%

Table 5

Crop dry weight (above ground) as a percentage of that on weed-free plots

Crop	A. repens level	Assessed 15th May	26th June	22nd July	At Maturity
Beans	Low	114 ± 63	63 ± 14	57 ± 5	57 ± 5
	High	103	49	26	21
Wheat	Low	130 ± 5	107 ± 3	102 ± 3	99 ± 5
	High	112	93	91	78
Barley Impala	Low	132 ± 6	100 ± 3	107 ± 4	95 ± 6
	High	104	81	77	80
Barley Deba Abed	Low	122 ± 8	106 ± 4	104 ± 4	99 ± 6
	High	99	97	89	84

Table 6

Crop yields at maturity (cwt/ac at 15% moisture)

Crop	A. repens level	Total yield of aerial growth	Grain yield
Beans	Nil	71.7	42.6
	Low	40.9	26.8
	High	14.8	9.0
Wheat	Nil	74.2	30.9
	Low	73.3	27.5
	High	58.2	18.7
Barley Impala	Nil	66.0	34.6
	Low	62.6	33.0
	High	52.7	29.1
Barley Deba Abed	Nil	63.7	37.6
	Low	62.8	37.0
	High	53.8	30.8
S.E.		3.8	2.7

The ratio of grain yield to total (above ground) dry weight was little affected by competition in beans or barley. In the case of spring wheat this ratio, which was already low on the control plots, was decreased with increasing population of A. repens.

Wheat was apparently affected to a greater degree than barley in the later stages of grain development. In addition to the steep fall in the relative yields of the infested plots between July and August, this difference between wheat and barley is reflected in the 1000 corn weights in Table 7. The grain weight of barley showed no change but the reduction in wheat could account for over half the total yield reduction.

Table 7

1000 corn weights in grams dry matter

A. repens level	Beans	Wheat	Barley (var. Impala)
Nil	354.6	33.0	31.6
High	314.3	28.7	31.6

DISCUSSION

The spring and early summer of 1968 were relatively warm at Begbroke and a (calculated) moisture deficit of 1½ in. was recorded on only 15 days. Conditions were thus very favourable to crop growth on this light loam soil. In many respects however, the results obtained in this experiment were similar to those obtained in the much drier 1967 season.

The aerial growth and new rhizome growth of A. repens was very much suppressed and delayed by competition from crop plants, the cereals being more efficient than spring beans in this respect. In complete contrast to 1967 the spring wheat in this experiment was more suppressive than either variety of barley. This was an exceptionally vigorous wheat crop, but it seems possible that the check to growth of the barley caused by dinoseb application may have affected the balance of competition. This check was of short duration, but occurred at a crucial time, i.e. just as the cereal crops were establishing a complete leaf cover.

When considering loss of crop yield due to the presence of A. repens the effect on beans needs little discussion. This crop which was the least effective at suppressing the growth of A. repens was the most severely affected by it. Yield was severely reduced by the lowest population, which appeared to have no adverse effect on the cereal crops.

On 15th May dry weight of all three cereal crops was considerably higher on the plots planted to the low population than on the plots free of A. repens. A similar result has been recorded in another experiment. It is difficult to find a convincing explanation for this increase. The plots planted to A. repens may be rather more compacted than the weed free plots, but the difference is not likely to be great.

An anomalous result that is easier to explain was that spring wheat, which was the most effective suppressor of the weed grass, was, none the less, more severely affected by its presence than was barley. This effect occurred mainly during the later stages of crop growth. It seems quite probable that spring wheat is inherently more susceptible to stress at this time; it does have a reputation for not "finishing" well on sandy soils. In addition, the crop was later to mature than either barley variety in this experiment. It is logical that late maturing crops should be more severely affected. At this time of the season the A. repens is tillering rapidly, and extending its root zone whereas the crop is becoming senescent and presumably its root zone is relatively static. In short, the later a crop matures, the more A. repens it will have to compete with. It has been suggested that, during the early stages of the A. repens/crop association, the most intense competition is for light. A. repens is drawn up to the height of the competing crop. Conversely at later stages of crop development it is unlikely that light is the prime factor. Only the flag leaves and ears of the crop are carrying on photosynthesis and these are rarely overshadowed by the weed. At this stage an increasing proportion of A. repens foliage is at the lower horizons, to which light has been admitted by senescence of crop leaves.

Of the two barley varieties, Deba Abed was slightly less affected by A. repens competition than was Impala, the differences being much more marked at the earlier assessments. Deba Abed was later to ripen but the margin was only one of a few days The habit of growth of this variety is unusual. It remains very low for a large part of the season, being less than 2/3 of the height of Impala during late May. After ear emergence a rapid stem elongation occurs and the final height of the two varieties is similar. It has been suggested that these two varieties of barley represent the extremes of competitive ability within the current range. If this is so then the range does not appear to be very great, judging from the results of this experiment. Varieties and indeed crops can vary in their performance under different conditions, and it would be unwise to draw hard and fast conclusions on these critical points from limited evidence.

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CULTURAL AND CHEMICAL TREATMENTS FOR THE CONTROL OF AGROPYRON REPENS AND AGROSTIS GIGANTEA IN BARLEY

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Summary The results are reported of a series of experiments started after cereal harvest in 1968. The effects of rotary cultivation and TCA, sodium chlorate and paraquat, alone and with rotary cultivation, were recorded.

When followed by mouldboard ploughing, the greatest reduction in emergence of shoots of *A. repens* and *A. gigantea* was produced by combinations of a single cultivation and a herbicide. A single rotary cultivation was more effective than the use of herbicide without cultivation.

INTRODUCTION

In the current economic situation, the intensive cereal grower has relatively little money available for perennial grass control. Two contrasting approaches which take this into account merit investigation; one involves a drastic reduction of the weed quickly and the other involves a lesser reduction repeated over several years. The latter must be sufficiently cheap to allow of annual treatment during two to three years.

With these two approaches in view, the activity of three herbicides against *A. repens* and *A. gigantea* was studied.

The recommendation for the use of TCA (Fryer and Evans, 1968) current in 1967 was considered laborious and expensive by many farmers as it involved a split application of 40 lb/ac TCA in association with an involved pattern of cultivation. Two pilot experiments carried out in the autumn of 1967 indicated that cheaper and simpler ways of using the chemical might be possible.

The results obtained by Turner (1969) suggested that repeated applications of low doses of paraquat would be more effective than a single higher dose.

Fail (1956) and Proctor (1961) affirmed the value of stubble cultivations for perennial grass control. The experiments described here examined some complementary applications of cultivation and herbicide.

METHOD AND MATERIALS

Experiments were conducted at 8 sites, details of which appear in Table 1.

Each experiment was laid out on barley stubble in randomised blocks with three replicates. Plot size was 70 ft by 25 ft. Discard strips, 5 ft wide, between plots reduced the effective plot width to 20 ft. These received additional rotary cultivation to minimise carry over of rhizomes from plot to plot.

Table 1

Details of experiments

Site No.	County	Weed spp.	Soil type	Date 1st treatment	No. of repeated paraquat applications	Plot harvest method
1.	Oxon.	A.repens	Sandy loam	6 Sept.	3	Combine 16 Aug.
2.	Oxon.	A.repens	Loam over limestone	30 Aug.	4	Combine 3 Sept.
3.	Northants.	Both spp.	Clay over limestone	27 Aug.	3	Combine 29 Aug.
4.	Northants.	Both spp.	Clay loam	28 Aug.	3	Hand 27 Aug.
5.	Worcs.	Both spp.	Silty clay loam	18 Sept.	3	Yields not recorded
6.	Worcs.	A.repens	Loamy sand	26 Aug.	4	Hand 7 Aug.
7.	Devon	A.gigantea	Loam	10 Sept.	3	Yields not recorded
8.	Cornwall	A.gigantea	Loam	11 Sept.	4	Yields not recorded

Herbicides were applied at 24 gal/ac and 30 lb/in^2 by a Land Rover mounted sprayer. Doses are expressed in terms of a.i. throughout. Cultivation was by a "two blade" Howard Series E Rotovator, with rotor and tractor speeds adjusted to give one cut/5 in. of forward travel. With the rear shield raised, this gave the soil a coarse tilth. Where applicable, repeated treatments were applied approximately every three weeks when regrowth had reached 1-2 leaves/shoot. The farmer ploughed, cultivated and drilled all sites to spring barley in the normal manner, except for site 5, where spring oats were planted.

The initial effects of the treatments were observed in the autumn of 1968, but the main assessments involved shoot counts in the following spring. Where both species were present, Agropyron repens and Agrostis gigantea were counted separately. The size of quadrat and numbers thrown were selected so that at least 100 shoots were counted on each control plot. The first count was in late April to early May; the crop, which had just emerged, was also counted at this time. Couch shoots were again counted later in May after the crop had commenced tillering.

At 3 sites, grain samples were harvested by combine, a swath 8.5 ft by 65 ft from each plot being taken. Two experiments were sampled by hand by the following method: 10 samples, each two rows by 3 ft were taken from each plot by cutting off the heads with a serrated breadknife. These samples were subsequently threshed, dressed, dried at 100°C to zero moisture and weighed.

After harvest, the population of couch shoots was assessed, either by quadrat counts or by subjective scoring. Shoot counts at three sites were made easier by counting the regrowth from burnt stubble. These autumn assessments were not differentiated according to species.

All TCA applications had an additional 1 oz/ac of paraquat to give more consistent scorch of foliage under a range of weather conditions. These and the applications of 2 oz/ac paraquat received additional wetting agent, 'Agral' at the rate of 1/10 fl oz per gallon (1/8th pint/ac).

RESULTS

Effects on weed population

Tables 2 and 3 give the results for *A.repens* and *A.gigantea* respectively obtained at the second spring assessment. Table 4 gives results of the stubble assessments, which were counts of primary shoots (exclusive of tillers) at sites 1-4 and subjective scores at sites 5-8. From the spring shoot counts it appeared that the two species were similar in reaction. Site to site variability within each species was greater than any differences noted between species at a single site.

Table 2

Agropyron repens Shoot numbers as % controls May 1969

Treatments	Site No. 1.	2.	3.	4.	5.	6.	Mean
TCA 15 lb/ac*							
On surface	31	54	30	6	56	27	34
#Incorporated	8	7	4	8	18	6	9
#Applied to regrowth	12	6	2	3	10	2	6
TCA 30 lb/ac*							
On surface	27	27	35	7	44	16	26
#Incorporated	16	3	6	10	10	3	8
Sodium chlorate 50 lb/ac							
On surface	42	79	30	75	78	12	53
#Incorporated	17	2	35	10	18	3	14
Sodium chlorate 100 lb/ac							
On surface	26	34	20	17	30	35	27
#Incorporated	12	9	3	2	13	2	7
Paraquat							
8 oz/ac single dose	34	27	60	19	35	13	31
2 oz/ac repeated as necessary	26	10	13	20	51	16	23
Cultivation with paraquat (2 oz/ac)							
#Pqt - cults - pqt	17	5	28	14	21	9	16
#Cults - pqt - pqt	13	5	37	8	29	2	16
Cultivation only							
#Once	27	15	27	11	26	4	18
Twice	17	3	12	6	16	10	10
"Standard" - Dalapon 12 lb/ac	18	4	1	8	36	12	13
Control population - shoots/yd^2	102	67	56	49	72	30	
S.E. as % control	10	8	23	15	11	11	

* With 1 oz/ac paraquat

\# All plots marked thus received the same standard cultivation.

The effects on shoot emergence in spring and primary shoot population recorded after harvest were similar, and at every site there was a significant correlation between the two. In many cases, however, there was some increase between spring and harvest in shoot numbers on treated plots relative to those on untreated plots. This must indicate a tendency for some treatments to delay emergence of surviving shoots. This tendency had been noted during the assessment programme but it was assumed that emergence would be completed by the time of the final spring assessment. The assumption was nearly but not absolutely sound.

Cultivation had an overriding influence over all other treatments. One rotary cultivation without chemical gave on average over 80% reduction in spring shoot emergence, even though the implement was set to leave a very coarse finish and not to achieve the maximum rhizome fragmentation. A second rotary cultivation increased this average effect to over 90% reduction.

Table 3

Agrostis gigantea Shoot numbers as % controls May 1969

Treatments	Site No. 3.	4.	5.	7.	8	Mean
TCA 15 lb/ac*						
On surface	13	12	45	31	66	33
#Incorporated	5	4	12	11	8	8
#Applied to regrowth	5	3	5	4	9	5
TCA 30 lb/ac*						
On surface	31	7	10	15	9	14
#Incorporated	9	5	19	4	17	11
Sodium chlorate 50 lb/ac						
On surface	8	4	82	20	29	29
#Incorporated	14	2	26	3	12	11
Sodium chlorate 100 lb/ac						
On surface	2	5	16	11	38	14
#Incorporated	tr	3	10	3	10	5
Paraquat						
8 oz/ac single dose	19	6	22	6	70	25
2 oz/ac repeated as necessary	8	14	30	9	20	16
Cultivation with paraquat (2 oz/ac)						
#Pqt - cults - pqt	5	6	29	Not applied		
#Cults - pqt - pqt	24	10	28	5	4	14
Cultivations only						
#Once	8	10	37	8	22	17
Twice	5	5	10	Not applied		
"Standard" - Dalapon 12 lb/ac	1	6	8	30	38	16
Control population - shoots/yd^2	22	139	24	108	288	
S.E. as % control	12	5	22	5	11	

* With 1 oz/ac paraquat

\# All plots marked thus received the same standard cultivation.

Without cultivation, dalapon was the most effective treatment. The greatest shoot reductions were obtained from combinations of cultivations and herbicide, TCA and sodium chlorate being much more effective in this situation than paraquat.

The dose of 30 lb/ac of TCA was only marginally more effective than 15 lb/ac. There was relatively little difference in effect between the two methods of use of TCA which involved cultivation.

At three sites there was a marked improvement in the activity of paraquat by repeated applications of 2 oz/ac compared with a single application of 8 oz/ac. There was no such improvement at the other sites. Combinations of cultivation and paraquat were more effective than applications of paraquat without cultivation.

Table 4

A. repens and A. gigantea in stubble-Autumn 1969

Treatments	Shoots as % controls				Shoot numbers scored/10			
	1.	2.	3.	4.	5.	6.	7.	8.
TCA 15 lb/ac*								
On surface	45	62	52	35	5	6	5	7
#Incorporated	8	13	11	14	2	2	2	2
#Applied to regrowth	9	12	5	5	2	1	2	1
TCA 30 lb/ac*								
On surface	31	38	33	22	3	2	3	3
#Incorporated	16	9	12	12	2	2	1	3
Sodium chlorate 50 lb/ac								
On surface	37	64	40	25	5	4	3	4
#Incorporated	21	15	42	14	4	2	1	2
Sodium Chlorate 100 lb/ac								
On surface	22	36	31	24	2	3	3	6
#Incorporated	12	13	9	10	2	3	1	3
Paraquat								
8 oz/ac single dose	49	31	51	19	2	1	2	7
2 oz/ac repeated as necessary	21	16	21	30	4	3	2	3
Cultivation with paraquat (2 oz/ac)								
#Pqt - cults - pqt	16	12	40	19	3	2	Not applied	
#Cults - pqt - pqt	9	12	26	19	2	1	1	2
Cultivations only								
#Once	34	30	47	30	4	2	1	5
Twice	10	6	20	13	3	1	Not applied	
"Standard" - Dalapon 12 lb/ac	25	13	12	18	3	2	4	5
Control	100	100	100	100	10	10	10	10
Control population shoots/yd^2	69	104	95	196				
S.E. as % control	9	7	17	5				

* With 1 oz/ac paraquat.

\# All plots marked thus received the same standard cultivation.

Effects on crop growth

The assessments of crop emergence showed that standard errors were low and there were no apparent effects due to any of the treatments.

Table 5 gives yields of barley for the five sites which were assessed for yield.

Table 5

Yield of barley cwt/ac at 85% D.M.

Treatments	Sites 1.	2.	3.	4.	6.
TCA 15 lb/ac					
On surface	40.0	39.9	31.5	29.0	53.3
Incorporated	41.3	41.6	39.7	27.8	59.4
Applied to regrowth	44.4	38.3	39.8	28.3	59.4
TCA 30 lb/ac					
On surface	38.1	41.6	36.7	28.9	57.4
Incorporated	39.2	43.8	36.3	30.3	54.6
Sodium chlorate 50 lb/ac					
On surface	37.8	37.2	37.3	29.1	52.6
Incorporated	36.4	42.5	31.1	31.0	54.5
Sodium chlorate 100 lb/ac					
On surface	44.5	41.8	34.1	29.2	55.4
Incorporated	44.2	43.0	34.1	25.0	53.7
Paraquat					
8 oz/ac single dose	38.8	37.0	33.4	28.1	50.1
2 oz/ac repeated as necessary	40.9	42.5	37.5	26.4	57.5
Cultivation with paraquat (2 oz/ac)					
Pqt - cults - pqt	41.2	42.1	36.7	30.1	56.6
Cults - pqt - pqt	42.8	41.0	31.8	29.5	57.2
Cultivations					
Once	39.2	38.9	32.2	27.8	51.9
Twice	43.3	40.5	33.5	29.2	59.4
Controls and standards					
No treatment	30.4	37.7	35.7	27.6	49.2
Standard dose of dalapon (12 lb/ac)	43.2	44.5	38.2	29.0	57.2
S.E.	2.95	1.55	2.34	1.32	2.26
Mean of all treatments	41.0	41.0	35.3	28.7	55.6

The standard errors in Table 5 are too high to allow detailed comments on the cost effectiveness of various treatments. In some experiments none of the differences reached significance. Generally there was a marked increase in yield after any treatment but differences between treatments are more difficult to interpret and more likely to be due to error.

Comparing the control yield with the mean yield of all treatments, there is no obvious connection between the magnitude of yield response and level of weed population or control yield.

Site 3 appeared to be anomalous in that there was, overall, a negative yield response. The weed distribution at this site was reasonably uniform within replicates but there was a very striking difference between replicates. On two replicates the mean population of shoots (predominantly of *A. gigantea*) was 22/yd² on the control plots. These control plots out yielded the comparable treated plots. On the third replicate the control shoot population was 190/yd². On this replicate the mean yield of all treated plots was 6 cwt/ac higher than control yield.

At site 6, although yield levels were very high and weed population low, there was a marked response to treatment. The weed at this site was *Agropyron repens*, noted in spring 1969 as being of a vigorous strain.

DISCUSSION

The most striking result of these experiments was the degree of weed control obtained by a single rotary cultivation. Although a rotary cultivator was used for the sake of uniformity, it was not used to achieve maximum fragmentation of the rhizomes. The setting used, a blade cut for every 5 in. of forward travel, contrasts with the commonly recommended setting, a blade cut for every 2 in. of forward travel.

At all sites this cultivation treatment did not look impressive in the late autumn of the treatment year due to the large amount of regrowth. This foliar growth did not result in appreciable new rhizome growth whereas the number of viable rhizome buds must have been greatly reduced by sprouting. The shoots were ultimately buried by winter ploughing. In the damp warm autumn of 1968 the loss of rhizome reserves by rotting must also have been of major importance.

The results obtained with TCA showed a very marked interaction between the activity of this herbicide and cultivation. The relative timing of herbicide application and cultivation did not seem important. Application to the regrowth three weeks after cultivation was slightly more effective than incorporation of the herbicide by cultivation. It was also notable that the activity of TCA was very high in these experiments. Over a range of soil types the dose of 30 lb/ac showed very little improvement in result over the dose of 15 lb/ac. The autumn of 1968 was a relatively wet one, it may be that in a drier season the general level of activity would be lower and there would be a response to incorporation (as opposed to prior cultivation). It seems reasonable to deduce that the primary role of cultivation in augmenting the activity of TCA is in fragmenting the rhizome system. Vertical distribution of the herbicide may play a minor role in many cases.

The addition of 1 oz/ac of paraquat was made to all TCA treatments. A further experiment has indicated that this addition of paraquat is not likely to have made a significant contribution to the results.

The high and low doses of TCA are of the same order of cost as the high and low doses of sodium chlorate used in these experiments. On this basis the cost/effectiveness of the two herbicides was similar when incorporated by rotary cultivation. Sodium chlorate was not tested as an application to the regrowth after cultivation. In addition to its soil activity sodium chlorate is an effective desiccant and this method of application might prove interesting.

Repeated applications of oz/ac of paraquat were not always more effective than single applications of 6 oz/ac. In practical terms, however, the repeated applications of 2 oz/ac have a lot to commend them. Each single application is quite cheap. In a system involving thorough cultivation after harvest and repeated treatments regularly thereafter, the repeat treatments could involve cultivation or paraquat according to the weather, pressure of other work etc. In this way the

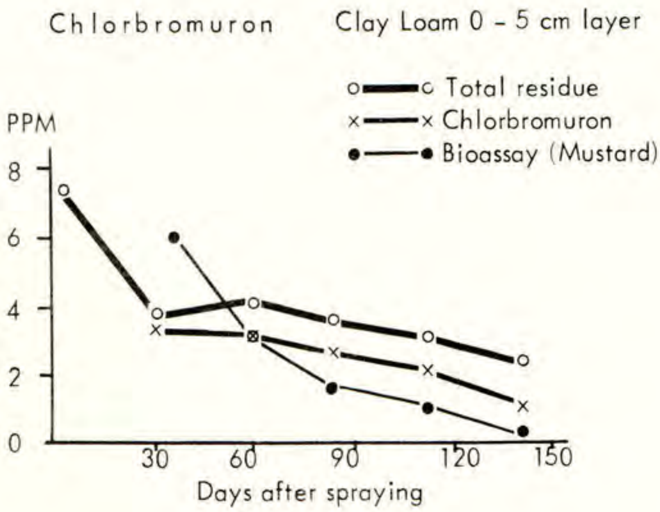

Fig. 2. Rate of dissipation of chlorbromuron in the 0-5 cm layer of a plant-free soil (Otterbach) under field conditions. Rate of application: 4 kg a.i./ha.

MECHANISM OF DEGRADATION

The present scheme of biochemical degradation of urea herbicides includes stepwise demethylation/demethoxylation, deamination-decarboxylation and binding of metabolites to certain plant and soil constituents (Geissbuhler, 1969).

Photochemical degradation mainly results in the formation of desmethyl- or desmethoxy-compounds and p-hydroxylated derivatives of the parent herbicide. (Rosen & Strusz, 1968; Rosen et al., 1969; Crosby & Li, 1969; Crosby & Tang, 1969)

The bulk of degradation and /or conjugation products formed by biochemical and photochemical processes still contains the aniline-moiety of the original phenylurea structure. Consequently, the standard residue method, which is based on colorimetric or gaschromatographic (Baunok & Geissbuhler, 1968) measurement of the aniline, after alkaline hydrolysis of the unextracted plants or soil, represents a valid procedure for examining contaminants in various materials.

In recent model experiments, carried out with unrealistically high concentrations of anilines and anilide-type herbicides applied to soil samples, the formation of small amounts of azobenzene derivatives was observed (Bartha & Pramer, 1967; Bartha, 1968; Kearney et al., 1969). This observation has precipitated numerous speculations on the formation of such azo compounds in soils treated with urea herbicides. Extended laboratory and field experiments conducted by both Du Pont (Belasco & Pease, 1969) and CIBA indicate that upon application of normal doses of urea herbicides, no detectable quantities of azobenzene derivatives accumulate in soils.

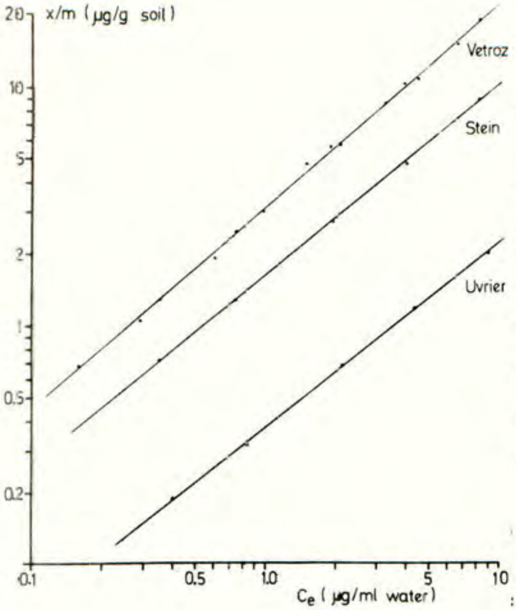

Fig. 3.

Freundlich adsorption isotherms of fluometuron obtained with three different soil types. The concentrations of herbicide fixed on the soil (x/m) have been plotted against the equilibrium concentration in soil solution (Ce) on a log x log scale.

Admitting the concentrations of the herbicide in the soil solution to be 1.0 µg/ml, the concentrations of compound fixed on the soil (µg/g) are the following:-

soil Vetroz = 3.2

soil Stein = 1.6

soil Uvrier = 0.4

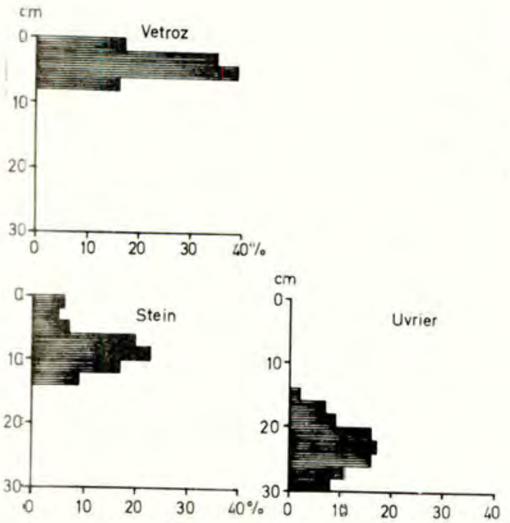

Fig. 4.

Leaching of fluometuron in three different soil types. Amount of artificial rain: 200 mm.

Rate of application: 5 kg. a.i./ha.

Formulation: 50 % wettable powder.

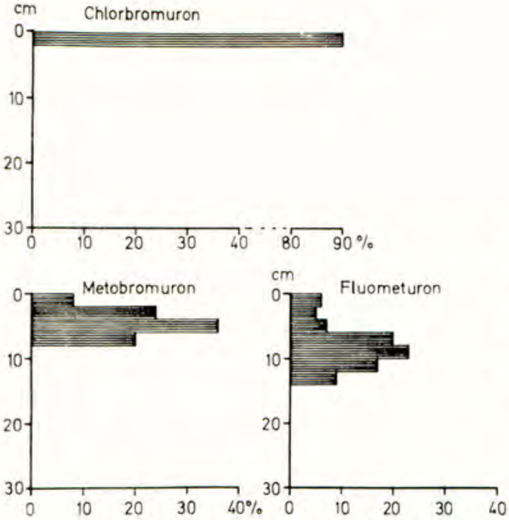

Fig. 5.

Leaching of fluometuron, metobromuron and chlorbromuron in soil Stein.

Amount of artificial rain: 200 mm.

Rate of application: 5 kg a.i./ha.

Formulation: 50% wettable powder.

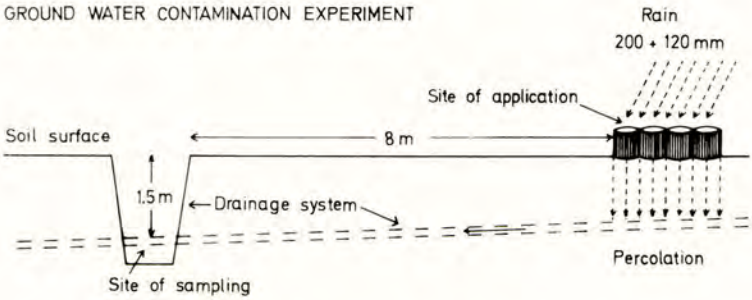

Fig. 6. Schematic diagram of a ground water contamination experiment with fluometuron.

Rate of application: 20 kg a.i./ha.

Amount rainfall: 320 mm.

Formulation: 50% wettable powder

Time of sampling: 0, 1, 3, 7, 14 and 32 days after application; samples were taken at 8.00, 12.00 and 16.00 hours each day.

ADSORPTION AND LEACHING

Possible contamination of ground and run-off water by urea herbicides depends on the adsorption and leaching behaviour of these compounds in soils. Freundlich adsorption isotherms obtained, for example, with fluometuron in standardized soil samples indicated that herbicide adsorption is suffuciently strong to prevent rapid movement through the soil profile (Fig. 3.). This indication was confirmed by actual leaching experiments in which 200 mm of artificial rain was applied to 30-cm soil columns (Figs. 4 and 5.). With this amount of rain, which corresponds to the average quantity received during the growing season, none of the compounds examined moved below the 30-cm soil level.

CONTAMINATION OF GROUND AND RUN-OFF WATER

To further verify potential contamination hazards, the most easily leached urea compound, fluometuron. was subjected to an actual ground water experiment under field conditions, (Fig. 6.). All drainage water samples, which were collected at different time intervals after application, were found to be free of fluometuron residues (less than 0.05 ppm).

RESIDUES IN FISH

In preliminary experiments, gold fish were maintained for a period of 4 days in water containing various concentrations of the urea herbicide chlortoluron. Results of analyses of fish tissue indicated that some accumulation of residues occurred when compared with the herbicide concentration of the surrounding water. However, this accumulation was too small to suggest any obvious toxicological effects on fish in water containing several ppm of the herbicide.

CONCLUSIONS

Present results of a number of field dissipation, adsorption, leaching and degradation experiments carried out according to the guidelines of the U.S. Department of Agriculture do not indicate that urea herbicide residues represent a significant hazard with regard to contamination of the environment.

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PRELIMINARY STUDIES INTO THE BIOLOGY AND CULTURAL CONTROL OF POA TRIVIALIS IN CEREAL AND GRASS SEED CROPS

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Summary Trials have suggested that spring barley can be used as a cleaning crop on land infested with dormant seed of Poa trivialis provided over-wintering plants are destroyed by good seed bed preparations. Under spring barley, Poa trivialis germinates but is incapable of producing seed in the year of germination.

In grass seed crops infested with Poa trivialis, delaying stubble cultivations for three months following harvest allows the seed to germinate on the surface and thus prevents the incorporation of viable seeds into the soil where a proportion become dormant. Growing spring barley between two ryegrass seed crops is also likely to reduce the infestation still further.

INTRODUCTION

This investigation is divided into three parts:-

1. An investigation into the value of using spring barley as a cleaning crop on land infested with dormant seed of Poa trivialis. Work done by Cooper and Calder (1964) and Budd (1970,a) has shown that Poa trivialis plants need exposure to winter conditions in order to produce seed the following year; spring germinating plants may therefore be incapable of producing seed in the year of germination. This being so, it should be possible to use spring barley as a cleaning crop, provided the seed bed cultivations are sufficiently thorough to destroy any over-wintering plants. Observations on a number of barley crops during 1969 and 1970 are reported.

2. An assessment of the dormancy and survival of Poa trivialis seed, following periods of burial in the ground. Milton (1936) has shown that some Poa trivialis seeds were still viable after being buried in soil for at least 5 years. Similar work has been carried out on Poa annua by Roberts (1967), on Avena fatua and A. ludoviciana by Thurston (1966) and on Alopecurus myosuroides by Wellington and Hitchings (1965), and Lewis (1961).

3. The results are given of a three year, mainly cultural experiment designed to reduce the field infestation of Poa trivialis in a grass seed crop. The technique has been suggested by Budd (1970,a). Other cultural techniques for weed control in seed crops were suggested by Hitchings (1970).

METHOD AND MATERIALS

1. In 1969 and 1970 nine farm sites were chosen, on which to observe the behaviour of Poa trivialis plants in spring barley crops. Five of the sites were in fields known to have a history of Poa trivialis infestation. On each of these, the farmer took particular care to destroy any over-wintering plants by good autumn and

spring cultivations. This ensured that all the Poa trivialis plants found in the spring barley had germinated with or after the crop. The remaining sites were sown experimentally and included four spring barley crops and one winter wheat crop, on each of which, seed of Poa trivialis was broadcast onto the clean seed bed. On all ten sites the Poa trivialis plants were recorded for growth and seed production immediately before the cereal crops were harvested.

2. To observe the survival of Poa trivialis following burial in soil, seed was enclosed in elongated terylene mesh bags buried three and six inches deep. Each bag consisted of a 0.3 mm woven mesh which prevented any loss of the enclosed seed, but allowed the free entry of small insects, soil particles, roots, air and moisture. The bags measuring 9 in. x $1\frac{1}{2}$ in. were buried lengthwise, with the seed spread evenly along the bottom to ensure close contact with the soil. Some of these seed bags were buried in the spring, in ground freshly sown to spring barley, others were buried in the autumn under a timothy crop sown the previous spring. Each experiment was replicated four times and every bag contained 150 seeds of known germination. After five months burial the seed was recovered from the ground and immediately subjected to a germination test in a Copenhagen Tank.

3. The infestation of Poa trivialis in an old seed crop of S.24 perennial ryegrass, following a cultural treatment was assessed and compared with the infestation in a new crop three years later. The sequence of events was as follows: In July, 1967, from a seed crop of S.24 perennial ryegrass twenty sample areas were cut at random immediately before harvest. Each sample was examined and the number of seed heads of Poa trivialis and ryegrass compared giving an estimate of the field contamination. After harvest, the following measures were carried out to prevent the incorporation into the soil of the numerous Poa trivialis seeds present in the combined straw and lying on the ground. First, the straw was burnt in the swath to kill as much seed as possible and the stubbles were left uncultivated until October to allow the seed on the ground to germinate. Three weeks after harvest the crop regrowth was sprayed with paraquat to kill the old crop and suppress the growth of any Agropyron repens. Three to four weeks later, the dead foliage was sufficiently dry to be set on fire. A very efficient burn was achieved which killed the remainder of the old crop, Agropyron repens regrowth, Poa trivialis seedlings and some of the ungerminated seed. The scorched ground was then left until late October before ploughing. During this period any remaining viable seed would be expected to have had a further opportunity of germinating on the soil surface, moisture conditions now being adequate for germination. In the spring of 1968 a barley crop was sown on the field, particular care again being taken to ensure that no over-wintering plants of Poa trivialis survived the spring cultivations. After harvest, the stubbles were immediately cultivated in order to expose and germinate dormant seed contained in the soil and to control any Agropyron repens. In the spring of 1969 the field was again sown with S.24 perennial ryegrass under spring barley. At seed harvest in July 1970, the crop was sampled as in 1967 to determine whether the treatments described had been successful in reducing the level of Poa trivialis infestation.

RESULTS

Figure 1 shows the field infestation of Poa trivialis in 1967 and 1970.

Table 1 shows the results of examining the behaviour of Poa trivialis in winter and spring cereals.

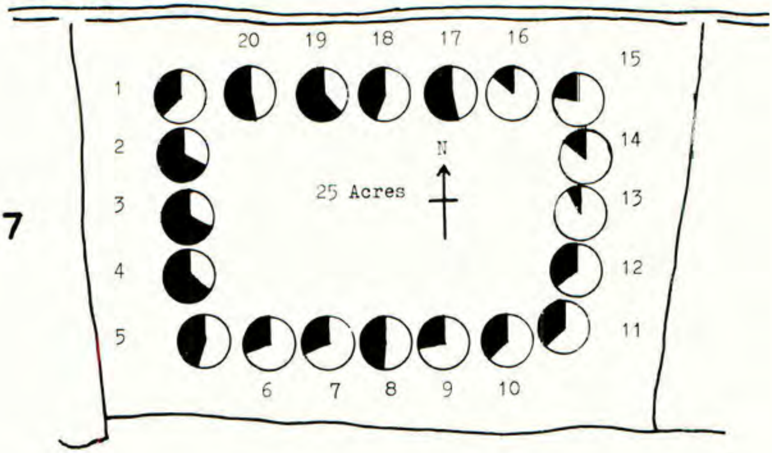
Table 2 shows the results of dormancy studies on buried seed of Poa trivialis

Figure 1

<u>Field reduction of Poa trivialis infestation in S.24 Perennial ryegrass following Spring barley crops in 1968 and 1969</u>

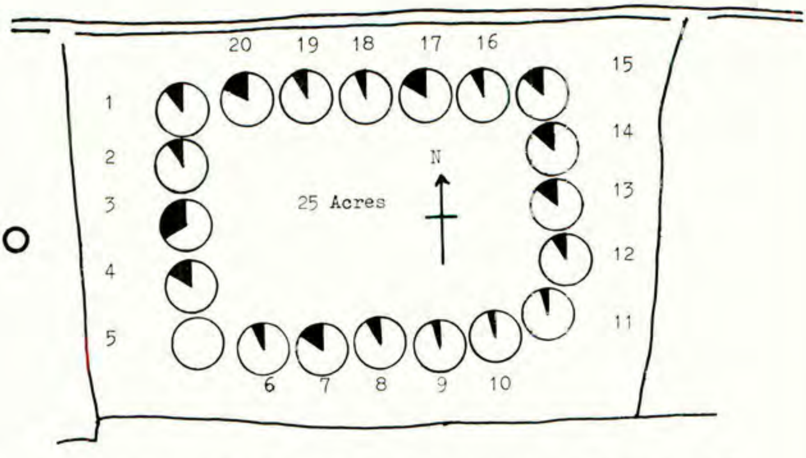
<u>KEY</u> Sample area of 1 yd.^{2} — Percentage of Perennial ryegrass seed heads
" " <u>Poa trivialis</u> " "

1967



Mean = 1,386 Perennial ryegrass + 929 <u>Poa trivialis</u> seed heads/yd.^{2}
Ratio = 100 " " : 67 " " " "

1970



Mean = 1,731 Perennial ryegrass + 213 <u>Poa trivialis</u> seed heads/yd.^{2}
Ratio = 100 " " : 12 " " " "

Table 1

Behaviour of Poa trivialis in cereal crops

Site	Crop	Sown	No. of plants examined	No. of plants producing seed	Mean number tillers/plant
1	Spring barley	March 1969	50	0	2.7
2	" "	" "	50	0	3.4
3	" "	" "	100	0	3.0
4	" "	" "	320	1	1-3
5	" "	" "	320	0	1-3
6	Spring barley	March 1970	50	0	4.5
7	" "	" "	50	0	3.0
8	" "	" "	300	0	2.3
9	" "	" "	200	0	1.5
10	Winter wheat	Nov. 1969	100	1	6.5

Table 2

Survival of Poa trivialis seed following burial in soil under spring barley and timothy

Site	Soil type	Crop	Duration of burial	Percentage reduction in the viability of seed buried at:		
				$\frac{1}{2}$ in.	3 in.	6 in.
Cambridge	Clay	Spring barley	March-August '69	-	9	3
Hampshire	Loam	" "	" " "	-	36	2
Hampshire	Loam	Spring barley	March-August '70	-	9	42
Hampshire	Loam	Timothy	October-March '70	21	26	40

DISCUSSION

1. The results show that Poa trivialis plants in the ten cereal crops failed to produce seed heads during 1969 and 1970 and that the addition of new seed to that already present in the soil was prevented. The single winter wheat crop observed gave the same result as the nine spring barley crops, despite the probability of the plants being fully vernalized. Budd (1970,a) showed that single spaced plants grown from seed germinating during the period November to March are fully vernalized, and therefore, those germinating in the winter wheat should have produced seed heads. The Poa trivialis, however, did not germinate until December and failure to head could have been due to intense competition from the strong wheat crop, accentuated by the late germination of the weed. The wheat crop in this case yielded over 40 cwt/ac. It has also been observed in spring cereals, that old plants of Poa trivialis which have survived autumn cultivations and overwintered, are capable of producing seed heads because they are vernalized and more competitive. It is important, therefore, that these and all autumn germinating seedlings must be destroyed by good cultivations if spring barley is to be regarded as a cleaning crop.

2. From the burial of Poa trivialis seed for 5 months no clear pattern emerges to show whether season, soil type, depth or duration of burial influences the degree of survival. The results show, however, that at least 60% of the seed can survive 5 months burial. Roberts and Dawkins (1967) working on Poa annua and Thurston (1966)

on Avena fatua and A. ludoviciana, found exponential decreases of 21% to 26% per year in the viability of buried indigenous seed. Assuming an exponential decrease of 25% per year the viability of the initial population would still be 1% after 16 years.

3. Examination of the samples taken from the grass seed crop in 1970, when compared with those taken in 1967 showed an average reduction of 77% in the number of Poa trivialis heads and an increase of 20% in the ryegrass. The crop seed yield also increased by 14%. It is reasonable to assume, therefore, that the cultural treatment imposed on this field since harvest in 1967 reduced the infestation of Poa trivialis and may have increased the grass seed yield. However, as under this type of field experiment it was not possible to leave untreated controls, the assumption cannot be proved. If the cultural sequence described is the reason for this improvement, then the main factor responsible is the change in the farmer's practice of treating the stubbles. Prior to 1967 it was customary to break up and rotovate the stubbles of an old grass seed crop immediately after harvest in July to control Agropyron repens. Unfortunately in doing this, the viable seed of Poa trivialis on the ground became incorporated into the soil where a proportion became dormant. Figure 1 shows the presence of 929 heads of Poa trivialis per square yard in the 1967 seed crop. Since such heads can produce a mean of 1,100 seeds per head, with a viability of 95% soon after shedding (Budd unpublished), incorporation into the soil can soon lead to a large build up of dormant seed. Work done by Budd (1970,a) has shown that given suitable weather conditions Poa trivialis seed on the ground in July can all germinate by the end of August and that cultivations could then be carried out without risk of incorporating potentially dormant seed. Agropyron repens can also be suppressed by spraying the seed crop aftermath three weeks after harvest, with paraquat and then burning the dead dry foliage after another three weeks. This leaves at least another month for any viable seeds to germinate before cultivating in October. Spring barley following a grass seed crop will further reduce the viable population of Poa trivialis seed in the soil and, provided the barley stubbles are cultivated immediately after harvest, Agropyron repens can also be controlled.

In conclusion, it is hoped that the cultural sequence described will prevent the increase of Poa trivialis seed in the soil and also clean out dormant seed already present, without encouraging the ingress of other weed species such as Agropyron repens. Such treatments could complement herbicide controls as outlined by Budd (1970,b).

Acknowledgments

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THE EFFECT OF TEMPERATURE ON THE PERFORMANCE OF FIVE HERBICIDES USED TO CONTROL AGROPYRON REPENS

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__Summary__ Uniform single shoot plants of __A. repens__ were treated with three doses of five herbicides and kept in controlled environment cabinets where all conditions were constant (light 16 h at 4,200 lm; humidity 1.5 mm Hg water vapour deficit leaf/air; soil water at field capacity) except temperature which was set at 6, 16 and 26°C. The time for damage to appear was inversely proportional to temperature and dose, but ultimate kill did not always follow this pattern for temperature. Paraquat at 0.25, 0.5 and 1.0 lb/ac produced damage within 24 h at all temperatures, but all doses killed only at 6°C, regrowth occurring at low rates at higher temperatures. Asulam symptoms did not appear until five days at 26 and two weeks at 6°C at 4 lb/ac and took longer at 0.5 and 2.0 lb/ac. In contrast to paraquat optimum kill was at 26°C and minimal at 6°C. Activated aminotriazole at 1, 3 and 6 lb/ac dalapon and Orga 3045 at 3, 6 and 12 lb/ac performed well at all temperatures, but some regrowth occurred at low rates especially at the high temperature.

INTRODUCTION

A number of herbicides are available for the control of __Agropyron repens__ and are used at various times of year. Choice is based on factors such as cost and possible residual effects on the following crop. Rarely are weather conditions considered other than on the day of spraying. However Hammerton (1968) in his review on 'The environment and herbicide performance' stressed that post-application conditions can play a decisive role in the efficiency of chemical weed control. Although weather forecasting leaves much to be desired, general seasonal patterns are predictable. Hence information on the relative performance of herbicides at different levels of a parameter such as temperature can assist decision making where there is choice of product, and possibly explain inconsistencies in field performance.

The experiment reported here examined the effect of three temperature levels on the performance of five herbicides used to control __A. repens__, while other environmental factors were kept constant.

METHOD AND MATERIALS

Single node 1 in. rhizome fragments of __Agropyron repens__ L. (Beauv.) clone 31 (Headington clone) were planted in Levington compost in 3.5 in. pots and grown in a glasshouse until they reached the 4-leaf stage. Uniform plants were selected and transferred to Saxcil controlled environment cabinets set up as follows:

Radiation - 16 h at 4,200 lumens
Temperature - 16°C
Humidity - 85% relative humidity

Air Speed - 30 ft per min - vertically from below

The compost was kept at field capacity by automatic sub-irrigation.

Following two days of acclimatization, the temperature and humidity were adjusted gradually to give the following regimes:

Temperature °C	% Relative Humidity	Water vapour pressure deficit (leaf/air) mm. Hg
6	78	1.5
16	89	1.5
26	94	1.5

The same water vapour pressure deficit between the leaves and air was maintained in all cabinets, in order to keep the cuticles hydrated and to avoid variable rates of desiccation of the spray droplets.

The plants in each cabinet were set up in two randomised blocks each containing two replicates.

The herbicides, plus 0.2% v/v Tergitol NPX wetter, were applied at the doses shown in Table 1 with a laboratory pot sprayer operating at 30 lb in^2 and delivering 30.1 gal/ac. Plants were transferred to and from the spray room in a closed box and returned to the cabinet immediately after application to minimise the time the plants were out of the controlled environment. To ensure that only the foliage was treated with herbicide the compost surface was covered with perlite granules before spraying which were then removed subsequently.

The plants were kept in the cabinets for 35 days and then transferred to an outside standing ground where they equilibriated for 60 days. The foliage was then cut at soil level. The rhizomes were removed and replanted in fresh compost in 5 in. pots.

Following spraying, the development of symptoms was recorded every day for the first five days and subsequently each week. The total number of shoots was recorded every seven days while the plants were in the cabinets and 25 days after replanting. The total number of shoots included the main shoot, all tillers and upturned rhizomes over 0.5 in. in length, even if chlorotic or necrotic, as long as they were partially turgid.

RESULTS

In Fig. 1A the growth of the control plants is represented as the number of shoots per pot at each assessment date in the cabinets, and finally 25 days after replanting. The number of shoots per pot on the herbicide treated plants (Fig. 1B-F) are expressed as percentages of the controls at each temperature and each curve represents the mean of the three doses of the herbicide. The most rapid development of visible damage occurred at 26°C and the slowest at 6°C and this is reflected in the shoot assessments. Paraquat acted most rapidly of the chemicals tested, causing the leaves to wilt and become grey green at 6°C and to become yellow brown at 26°C within 24 h. Activated aminotriazole and the sodium salt of dalapon at the high rate and temperature also developed necrosis within 24 h. The sodium salt of 2,2,3,3-tetrafluropropionic acid (Orga 3045) developed chlorosis and necrosis after 48 h at the high temperature and symptom manifestation was slower at all temperatures than with the chemically closely related dalapon. The slowest acting chemical was the sodium salt of asulam at 6°C which took two weeks to cause slight twisting of new growth. At the higher temperatures these symptoms appeared after five to ten days.

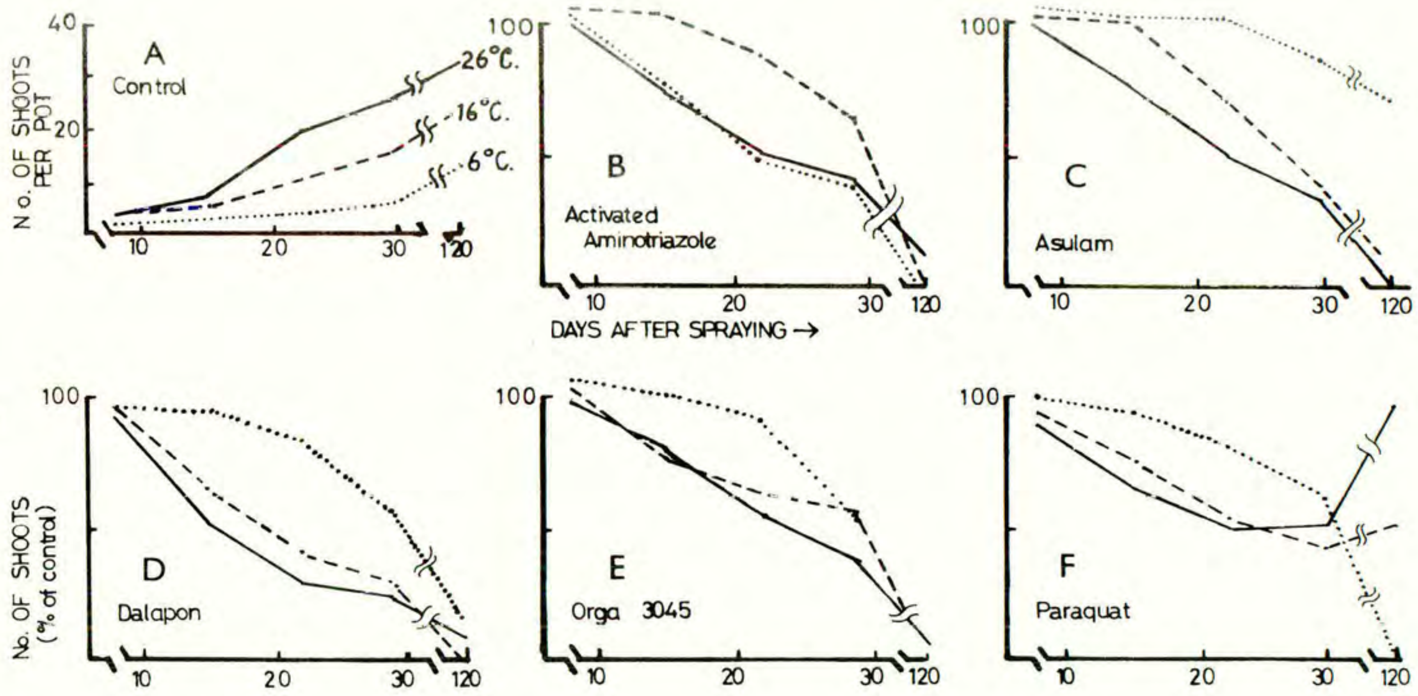

Figure 1

<u>Effect of three temperature regimes on the growth of Agropyron repens, expressed as number of shoots per pot for controls 'A', and number of shoots per pot as a percentage of controls for herbicide treatments B to F (mean of three rates).</u>

The greatest difference in ultimate effect initially lay between 6 and 16°C for all the chemicals except asulam. In the case of Orga 3045 and paraquat, the 6°C treatments eventually achieved the maximum degree of control and activated aminotriazole was almost as good. A notable exception was asulam which showed little activity at this temperature except at the highest rate, but gave a complete kill at 26°C. In complete contrast paraquat obtained maximum final kill in the 6°C regime and minimum at 26°C.

Shoot numbers for all treatments 22 days after spraying are presented in Table 1. The influence of temperature on the dose response of the plants at each temperature is apparent from these figures. There was little difference between doses at low temperature, but the effect of dose on phytotoxicity became highly significant as the temperature regimes were ascended, the greatest difference occurring between low and others. The failure of the means of 3 doses of activated aminotriazole, dalapon and Orga 3045 to give a total kill at 26°C in figure 1 was due to recovery of some of the plants treated with the low rate of herbicide.

Table 1

Shoots per pot 22 days after spraying

	Dose lb a.i./ac	6°C	16°C	26°C
Control		4.5	10.4	14.2
Activated aminotriazole	1	4.6	7.4	13.7
	3	3.3	4.0	4.6
	6	3.3	3.1	3.3
Asulam	0.5	4.7	9.8	8.4
	2	4.6	6.5	4.2
	4	4.0	4.4	3.7
Dalapon	3	4.3	5.2	5.9
	6	3.5	4.0	2.3
	12	3.2	3.4	2.5
Orga 3045	3	4.2	11.0	12.0
	6	3.8	4.3	7.3
	12	4.0	3.6	3.6
Paraquat	0.25	3.1	8.2	11.3
	0.5	2.5	4.8	6.0
	1.0	2.0	3.4	4.7
S.E. control		0.65	0.97	1.70
S.E. rates		0.56	0.84	1.47
S.E. control v. rates		0.33	0.49	0.85

DISCUSSION

A general conclusion that can be drawn from these results is that increased temperature is accompanied by more rapid manifestation of initial damage, but ultimate phytotoxicity does not necessarily follow this trend. Higher temperature in the absence of cuticle dehydration and rapid drying of spray droplets, as in this experiment, generally increases uptake and translocation (Hammerton 1968) and hence the symptoms of phytotoxicity appeared first at 26°C for each chemical and last at

4

6°. The failure of this initial advantage at 26°C, especially at low doses, to be maintained through to the death of the plant may be attributed to a number of factors. Rapid growth at 26°C (Fig. 1A), especially from buds free from initial contact action, probably resulted in the same amount of herbicide, in relation to the lower temperature, being translocated further to more cells. In addition to this diluting factor, higher temperatures accelerate biochemical and biophysical processes in the plant (Went and Overland Sheps 1969) and thus herbicide detoxifying mechanisms are likely to be enhanced.

Håkansson (1969) found **A. repens** grew actively at an average temperature of 5-6°C both in the field and under controlled environment conditions. The control curve for 6°C (Fig. 1A) confirms this for Headington clone and although biochemical and biophysical processes would be relatively slow, all the herbicides except asulam were ultimately lethal to all plants, at the higher rates. The slower speed of plant processes at 6°C probably accounted for the improved performance of paraquat as less herbicide would be trapped in dead tissue at the point of contact, hence allowing more extensive movement, as in dark versus light situations for diquat (Baldwin 1963). A possible explanation for the low activity of asulam at 6°C may be due to slow uptake and translocation coupled with a detoxifying mechanism in A. repens which is efficient at this temperature.

The ultimate kill obtained in this experiment was partly dependent on the conditions after the plants were removed from the cabinet and variations of the time spent in the cabinet and outside would probably alter the detail of some of the results, however, in general, the trends established during the 35 days under controlled conditions are reflected in the final assessment.

In order to understand the principles involved in the response of herbicides to environmental factors it is important to examine one factor at a time. Generally results obtained in this type of work cannot automatically be applied directly to the field situation as other factors apart from the variable being investigated may have a significant effect on herbicide performance. However, in the case of paraquat autumn applications under cool conditions have been observed in the field to be very effective and thus would appear to agree with the 6°C results of this experiment. In the autumn other environmental parameters such as low light intensity (Brian and Headford 1968) favour this herbicide.

The general implications of this experiment are that activated aminotriazole, dalapon and Orga 3045 perform adequately at all three temperatures whereas the activity of asulam at 6°C and paraquat at 26°C was considerably diminished.

Acknowledgments

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Proc. 10th Br. Weed Control Conf. 1970

HERBICIDES FOR THE CONTROL OF AGROPYRON REPENS AND AGROSTIS GIGANTEA

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Summary **Agropyron repens** in undisturbed barley stubble was very well controlled for at least 8-10 months by early autumn applications of sodium 2,2,3,3-tetrafluoropropionate (Orga 3045) at 4 and 8 lb a.i./ac and aminotriazole plus ammonium thiocyanate at 1, 2 and 4 lb a.i./ac. **A. repens** and **Agrostis gigantea** specially planted in the spring were almost completely controlled by pre- and post-emergence applications of Orga 3045 at 4 and 8 lb a.i./ac and a pre-emergence application of TCA at 30 lb a.i./ac. Aminotriazole plus ammonium thiocyanate was less effective under these latter conditions but 4 lb a.i./ac applied post-emergence gave moderate control of **A. repens** and good control of **A. gigantea**. Other treatments which gave good control in this experiment were carbetamide at 2 lb a.i./ac on **A. repens**, 6'-t-butyl-2-chloro-N-(methoxymethyl)-o-acetotoluidide (CP 44939) at 4 lb a.i./ac on **A. repens** and **A. gigantea** and EPTC at 4 lb a.i./ac on **A. repens** and **A. gigantea**, all mixed into the soil; and dalapon at 8 lb a.i./ac applied post-emergence.

INTRODUCTION

The control of 'couch' (**Agropyron repens** and **Agrostis gigantea**) is a major project at the Weed Research Organization and there is a continuing evaluation of potential herbicides for this purpose. Information from the manufacturers and the results of standard greenhouse assessments are used to indicate the more promising compounds.

This report deals with two field evaluation experiments A and B. In experiment A, in the spring of 1969, the activities of four candidate herbicides were compared with those of four standard herbicide treatments on specially planted populations of **A. repens** and **A. gigantea**. Experiment B, in autumn 1969, compared the effects of 5 different herbicides on a semi-natural population of **A. repens** in barley stubble.

METHOD AND MATERIALS

For experiment A a normal seed bed was prepared on a light sandy loam soil at the Weed Research Organization. Furrows were drawn 9 in. apart and approximately 3 in. deep. Four 6 in. rhizome pieces were planted at 9 in. intervals in each furrow in yd^2 plots on 1.4.69, giving 16 rhizome pieces per plot. The rhizome material was cut from clonal material (Headington clone) raised in stock beds. Unbranched and unsprouted rhizomes were selected which appeared healthy. A 9 in. unplanted discard was left around each plot.

In experiment A the candidate herbicides were: carbetamide (as a 30% w/v e.c.), 6'-t-butyl-2-chloro-N-(methoxymethyl)-o-acetotoludide (CP 44939, as a 48% w/v e.c.), 2-chloro-N-(isopropoxymethyl)-(2,6-xylyl)acetamide (CP 52665, as a 48% w/v e.c.) and sodium 2,2,3,3-tetrafluoropropionate (Orga 3045, as a 80.8% w/v aq.c.) and the standard treatments of dalapon-sodium (as a 74% w/w s.p.), EPTC (as a 72% w/v e.c.), aminotriazole plus ammonium thiocyanate (activated aminotriazole as a 20% w/v aq.c.) and TCA-sodium (as a 80.68% w/w pelletised solid). In experiment B the herbicides were: asulam (as a 40% w/v aq.c.), Orga 3045, dalapon, activated aminotriazole and paraquat (as a 20% w/v aq.c.).

Treatments were applied using a special sprayer for small plots fitted with a Teejet 730039, at a volume rate of 20 gal/ac and a working pressure of 30 lb/in^2. Those treatments requiring incorporation were forked in two directions into the top 2-3 in. of soil before planting the rhizomes. Other treatments were applied either immediately after planting on 1.4.69 or when the plants had 3 leaves and were 3-4 in. high on 20.5.69. The experimental design was a randomised block of four replicates, with separate areas of A. repens and A. gigantea.

The experiment was left uncultivated and assessed on 11.6.69 and 4.8.69, by counting the shoots on the centre 2 x 2 ft of each plot. Aminotriazole-treated plots were not assessed at the first date due to the difficulty of distinguishing between live and dead shoots. After the final assessment samples of rhizome from severely affected plots were replanted in fresh soil in pots to determine their viability.

The site of experiment B had been used for an A. repens/spring barley competition experiment in 1968 during which it was planted up with A. repens rhizomes of Headington clone. After normal cultivations in the autumn and spring of 1968-69 a spring barley crop was sown by the farm with normal fertilizer application. By the summer of 1969 the A. repens population was relatively uniform over the whole area and after harvest it was allowed to grow in the stubble to a height of 5-6 in. before treatment.

Treatments were applied on 18.9.69 with an Oxford Precision Sprayer fitted with 8002 Teejets applying 20 gal/ac at 30 lb/in^2. Each treatment was replicated twice, using 6 x 2 yd plots in randomised blocks. In each replicate nine plots were rotary cultivated to a depth of 3-4 in. as cultivated controls.

Plots were assessed on 21.5.70 by harvesting the 'couch' foliage from two 1 ft^2 quadrats randomly placed in each plot.

RESULTS

Table 1 summarises the results from Experiment A. The most effective compound was Orga 3045 which when applied pre-emergence to the soil surface gave a complete kill of both species of 'couch' at a dose of 8 lb a.i./ac; and at 4 lb a.i./ac a complete kill of A. gigantea and almost a complete kill of A. repens. Applied to the foliage post-emergence it was not quite so active particularly on A. gigantea which was not completely killed by 8 lb a.i./ac.

Carbetamide was the second most active compound against A. repens although CP 44939 was slightly more active against the A. gigantea. These compounds were mixed with the soil before planting and did not appear to give a superior result to EPTC used in the same way.

Of the four standard treatments, 30 lb a.i./ac of TCA applied to the soil surface was the most effective, although even this did not give a complete kill. 4 lb a.i./ac of EPTC mixed into the soil and 8 lb a.i./ac of dalapon applied to the foliage were also relatively effective. Activated aminotriazole applied to the foliage at 4 lb a.i./ac had a marked effect particularly on the A. gigantea.

Table 1

Shoot counts of A. repens and A. gigantea

Counts per 4 ft^2 of each plot - mean of 4 replicates

Treated pre-emergence and pre-planting on 1.4.69; post emergence on 20.5.69

	Dose	A. repens		A. gigantea	
Assessment date		11.6.69	4.8.69	11.6.69	4.8.69
Treatment	(lb a.i./ac)				
CP 52665 pre-plant incorp.	1	26	175	35	312
	2	14	127	14	160
	4	5	57	27	176
CP 44939 pre-plant incorp.	1	25	184	43	276
	2	14	138	12	95
	4	3	32	4	24
carbetamide pre-plant incorp.	0.5	19	147	62	386
	1	15	102	35	359
	2	4	53	12	151
EPTC pre-plant incorp.	4	1	47	1	39
TCA surface pre-emergence	30	0	4	0	2
Orga 3045 surface pre-emergence	2	2	37	31	132
	4	0	8	0	0
	8	0	0	2	0
Orga 3045 foliar post-emergence	2	22	88	82	347
	4	22	7	63	27
	8	14	0	42	5
dalapon foliar post-emergence	8	15	6	40	4
activated aminotriazole foliar post-emergence	4	-	96	-	21
Untreated control		34	198	40	477
S.E. treatment mean comp.		± 4.2	19.7	4.7	214
S.E. treatment/control comp.		± 4.4	21.5	5.2	234

Pieces of rhizome from the A. repens plots treated pre-emergence with 4 and 8 lb a.i./ac of Orga 3045 and post-emergence with 8 lb a.i./ac proved to be dead when transferred to untreated soil, but one or two shoots emerged from similarly treated pieces of A. gigantea rhizome. Rhizomes taken from plots treated with other herbicides all showed some growth.

In experiment B (Table 2) several of the herbicide treatments were preventing the development of aerial shoots on A. repens eight months after application. Activated aminotriazole was the most effective compound under these conditions, although surprisingly the 1 lb a.i./ac treatment had as much effect as the 4 lb a.i./ac treatment. However the 'couch' population was rather variable as shown by the relatively large standard error values.

Table 2

Dry weights (g) of two 2 ft^2 samples/plot

Treated: 18.9.69; Samples: 21.5.70

Herbicide	Dose (lb a.i./ac)	Dry wt (g)
Orga 3045	2	3.74
	4	1.86
	8	0.15
Dalapon	2	8.82
	4	7.18
	8	3.32
Activated aminotriazole	1	0.05
	2	0.13
	4	0.38
Paraquat	0.5	12.56
	1	6.43
	2	2.84
Asulam	2	8.41
	4	8.88
	8	5.35
rotovated control		3.83
untreated control		16.98
S.E. treatment comparison	±	3.84
S.E. treatment / untreated control comparison	±	4.21
S.E. treatment / rotovated control comparison	±	4.10

Orga 3045 was again very effective and the 2 lb a.i./ac treatment had almost as much effect as 8 lb a.i./ac of dalapon. Asulam was relatively ineffective even at 8 lb a.i./ac and on the paraquat-treated plots, although regrowth was delayed, it was very vigorous. Rotary cultivation also reduced the density of the regrowth, but that which was present was very vigorous. At the time of the final visual observation on the 17.7.70 (approx 10 months after treatment) 8 lb a.i./ac of the Orga 3045 and all three doses of activated aminotriazole were still giving almost complete suppression of the aerial growth of the A. repens. Examination of portions of the rhizomes on these plots by digging indicated that many were apparently dead.

DISCUSSION

Aelbers et al. (1969) reported the high activity of Orga 3045 on Agropyron repens and the two present experiments demonstrate this strikingly under two very different sets of conditions. In experiment A the rhizomes were disturbed and fragmented but growing conditions were relatively good with adequate soil moisture although temperatures were initially rather low. In experiment B, by contrast the rhizomes were undisturbed, the soil relatively compacted and very dry for the first six weeks. However experiment A in which treatments were applied both pre- and post-emergence does indicate that its effectiveness is likely to be greatest if applied to the soil soon after cultivation to disturb and break up the rhizomes. Aelbers et al. reported the compound to be effective on Agrostis stolonifera in addition to A. repens and experiment A indicates that Agrostis gigantea is also very susceptible. Foliar applications were relatively slow in action and the control given by both dalapon and Orga 3045 improved between the two assessments (Table 1), except for the lowest dose of Orga 3045.

In contrast to the Orga compound, activated aminotriazole was much more effective in experiment B than experiment A but it is difficult to define any one factor such as dry soil conditions, or soil compaction which could account for this difference - almost certainly the effects of the rotary cultivation treatment were enhanced by the early dry conditions.

Both these experiments tested the direct effects of the treatments on the 'couch', with no crop present which under normal conditions could be expected to help suppress the weed by competition.

Soil samples taken in the spring from experiment B and tested by sowing with various crop seeds, indicated that herbicide residues were absent even from the most highly dosed plots. It should be possible therefore to follow the early autumn treatments with a normal spring crop but further work is being done on this aspect at the present time.

Acknowledgments

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FACTORS INFLUENCING THE EFFECT OF TCA ON GRAMINEOUS SPECIES, WITH SPECIAL REFERENCE TO THE EFFECT ON *Agropyron repens* (L.) BEAUV.

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Summary TCA sodium was applied to the soil in pot experiments. It was shown to be much more effective against *Agropyron repens* in early stages of growth, especially before emergence, than in later stages. This was the result not only for plants developed from the reproductive stems but also for seedlings. The results were similar for seedlings of the annual *Hordeum distichum* and essentially the same for fodder grasses studied. Previous experiments concerning the soil moisture and the TCA effect are discussed. In recent experiments the temperature influence was studied. A temperature increase from a level of 7-10° C to 20-25° C caused a decrease in the effect of TCA, shown both for plants from rhizomes of *Agropyron* and for seedlings of *Hordeum* in different soils. The effect on *Triticum aestivum* was greater at 5-10° C than at 15-20° C. With a temperature increase from 25° C to 30 and 35° C there was a gradual decrease in the rapidity of shoot emergence from rhizome pieces of *Agropyron* but an increase in the effect of TCA. The reason for this is discussed.

INTRODUCTION

The phytotoxic effect and the fate of TCA after application in different ways has been discussed by many authors (literature surveys by Leasure, 1964; and Kearney *et al*., 1965; more recent original papers by Håkansson, 1969a; Håkansson & Jonsson, 1970; Chow, 1970; and others). In a series of experiments factors influencing the controlling effect of TCA (the sodium salt) on gramineous species after soil application have been studied by the present author and co-workers. One group of experiments has concerned the effect after application in different stages of plant development. In other groups the influence of environmental conditions in the soil has been studied.

MATERIALS AND METHODS

Some trials concerning TCA and the stage of plant development were carried out in the field (Håkansson, 1969a), but otherwise the experiments were performed as pot experiments in growth cabinets, growth chambers and greenhouses. All the TCA experiments were conducted in 0.5-litre plastic pots containing about 450 ml soil. In most experiments the plant material was *Agropyron repens* (L.) Beauv., rhizome pieces of which were planted at a depth of 1.5-2 cm. The piece length and the number of pieces planted per pot were different in different experiments. Five or ten pieces of a length of 8 and 4 cm, respectively, and with one or two buds each were planted. Four to seven TCA doses were used, represented by two to four replication pots with a total of 20-51 buds per dose in a given experimental series. In certain experiments, seeds or kernels of couch, *Agropyron repens*, two-row barley, *Hordeum distichum* L., or wheat, *Triticum aestivum* L., were sown, 25 per pot at a depth of 1.5 cm. TCA was applied in different ways so that a satisfactory distribution in the soil was achieved for the different types of experiments. Alternative application methods were compared in special tests.

In all experiments but those where the purpose was to study the time of application, TCA was applied at the time of planting or sowing. The pots were watered individually, ensuring the desired moisture contents. Other data about the experiments are given with the results.

The phytotoxic effects have been expressed by ED50 values on the basis of number and dry weight of aerial shoots judged to be at least partly alive. The tests were carried out when the shoots in the TCA-free pots in the different experimental series had reached a given stage, usually the 3-4-leaf stage. Special tests showed a good correlation between test values based on all new plant parts and on the aerial shoots only.

RESULTS

From earlier reports (e.g. Stahler, 1950; Bylterud, 1958; Krüger, 1961) it could be suggested that TCA in soil exerts its greatest effect on Agropyron repens in the early stages of plant development from the reproductive stem system, and this was repeatedly shown by the author both in field and laboratory investigations (Håkansson, 1969a).

Pot experiments were later performed in the greenhouse to study the TCA effect on seedlings of the perennial Agropyron repens and the annual Hordeum distichum. The results, summarized in Table 1, show that the best controlling effect was achieved when the herbicide was present in the soil from the start of germination. The effect then decreased gradually with delayed application, particularly after the shoots had emerged above soil.

Table 1

Effect of TCA expressed on the basis of the dry weight of aerial shoots

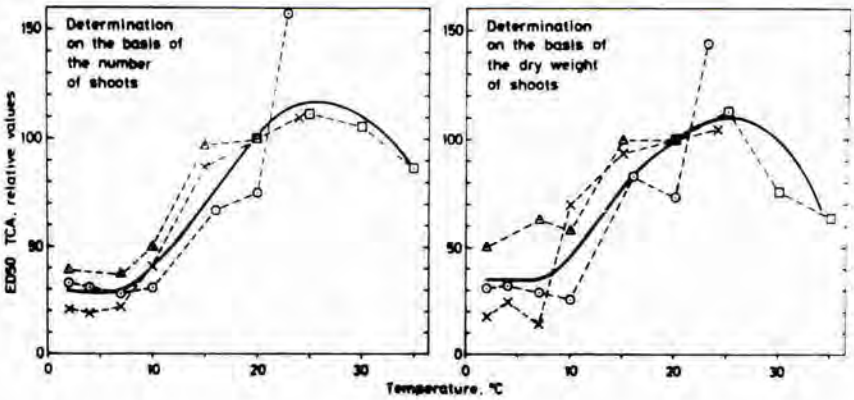
Time of TCA application	ED50 TCA, mg/litre soil	
	Agropyron	Hordeum
Before emergence above soil		
At start of germination	2.3	1.5
Near emergence	2.5	4.0
After emergence above soil		
Shoots with 1 foliage leaf	4.1	6
Shoots with 2 foliage leaves	16	>16

The results obtained suggest that, as a general rule, TCA exerts its greatest controlling effect when taken up by the plant in the earliest developmental stages before emergence. This conclusion is further supported by the results of greenhouse experiments with different perennial fodder grasses: Poa pratensis L., Bromus inermis Leyss., Festuca rubra L. and Lolium perenne L.

From field and laboratory experiments with Agropyron repens it is concluded that, for most effective results, TCA should be applied to the soil at times suitable for bringing it into contact with the reproductive stem system (1) when growth starts in the spring in areas with a pronounced winter or (2) whenever an intense regrowth can start after soil cultivation causing a destruction of the aerial shoots (Håkansson, 1969a). The question is now in which seasons factors such as the soil moisture content or soil temperature could be supposed to prevent a satisfactory TCA effect in different climatic regions.

In pot experiments Håkansson & Jonsson (1970) found only small differences in the effect of TCA on Agropyron in soil with a moisture content varying from near the wilting point up to the maximum content of water at free drainage of the pots. At contents around and below the wilting point, TCA was probably

Fig. 1. Temperature influence on the effect of TCA on Agropyron repens as shown in four experiments, the relative ED50 values from which are designated by different symbols. The ED50 values for 20° C, or for the average of those near 20° C with this temperature being the mean, have been given the value 100. An Uppland clone in a sandy loam was used in three experiments (o, x, □) whereas a Blekinge clone in an organogenic soil was studied in one experiment (Δ). After 5-6 weeks material kept at experimental temperatures below 10° C was transferred to temperatures of 15-20° C, where the final plant development before the determination of the TCA effect was completed. Unbroken curved lines are drawn to show the type of relationship between the TCA effect and the temperature that is hypothetically concluded from the experiments.



only taken up to a slight extent, or not at all, by the plant tissues. Thus, the surviving plant material showed no, or only slight, damage from TCA after having been kept in dry soil for a period and then washed and transplanted into a TCA-free soil with a moisture content sufficient for growth. Although a satisfactory effect of TCA on Agropyron will be achieved even at rather low moisture contents when the herbicide, as in the experiments, is well distributed in the soil, there are problems in practice. Even at moderately low moisture contents there are often difficulties with the cultivation of the soil and thus with the distribution of the herbicide. The difficulties with low moisture contents must be strongly dependent on the soil type. The problems with leaching of the highly water-soluble herbicide in periods with excess of water are wellknown.

The temperature influence on the effectiveness of TCA on Agropyron repens, Hordeum distichum and Triticum aestivum was studied in recent experiments in growth cabinets and chambers. Some of the material grown in the greenhouse, but otherwise similar to that placed in growth cabinets, was involved in the experimental comparisons after it had been shown that comparable results were obtained from rooms with alternating and constant temperatures with the same diurnal temperature sums and with light intensity differences over a wide range.

The results of experiments with Agropyron repens at different temperatures are summarized in Fig. 1. They indicate a considerable decrease in the TCA effect with a temperature increase from 7-10° C up to about 25° C. In this temperature region the sprouting and shoot growth rapidity increases strongly with increased temperature.

A temperature influence of the same kind as that described in Fig. 1 was noted for the TCA effect on Hordeum distichum in a clay and an organogenic soil (Table 2) and on Triticum aestivum in an unsterilized and a sterilized sandy loam (Table 3).

Table 2

TCA effect on Hordeum distichum at three temperatures in two soils

Temperature	ED50 TCA, mg/litre soil			
	Clay soil		Org. soil	
	Number of shoots	Dry weight of shoots	Number of shoots	Dry weight of shoots
2° C (35 days, then $16-21^{\circ}$)	2.1	1.4	3.2	1.8
10° C	2.6	2.1	3.2	2.4
20° C (var. $16-21^{\circ}$)	8.3	9.0	11.0	7.3

Table 3

TCA effect on Triticum aestivum at two temperatures in unsterilized soil and soil sterilized in autoclave at 127° C for 1 hour

Temperature	Values determined on the basis of the number of shoots		Values determined on the basis of the dry weight of shoots	
	Unsteril-ized soil	Steril-ized soil	Unsteril-ized soil	Steril-ized soil
	ED50 TCA, mg/litre soil			
9° C	1.3	2.3	1.2	1.4
18° C	1.8	4.9	1.8	2.8
	Ratio: ED50 for 18° C to ED50 for 9° C			
	1.4	2.1	1.5	2.0

The results of the experiment with Triticum do not indicate that differences in the microbiological activity and TCA breakdown could have been the reason for the different TCA effect at the higher and lower temperatures. However, on soils previously treated with TCA, without a pronounced lag phase, a more rapid biological degradation might occur at the higher temperature and thus contribute to reduce the effect.

A temperature optimum was registered for the Uppland clone of Agropyron in the region around 25° C. (Cf. Meyer & Buchholtz, 1963; Håkansson, 1969c.) Increasing temperature above the optimum caused a decreasing bud activity and rapidity of shoot growth, and the TCA effect increased (Fig. 1). There was thus a negative correlation between the TCA effect and the shoot growth both in the temperature regions below and above the region of maximum growth rapidity. The situation in the region of the lowest temperatures is somewhat obscure. There might have been a pronounced increase in the effect with a temperature decrease even below $7-10^{\circ}$ C if the plant material had not been transferred to a higher temperature ($15-20^{\circ}$ C) as early as 5 to 6 weeks after the start of the experiment.

DISCUSSION

To be able to explain the described temperature influence on the TCA effect, further extensive investigation is required. However, a hypothetical explanation will be given here under the assumption that the differences in the TCA effect at different temperatures are a result of differences in the amount of TCA taken up by the plant within defined stages in the early phase of shoot growth. According to the descriptions in the previous section, the uptake in the pre-emergence phase is decisive for the phytotoxic effect of TCA. In an experiment with Cynodon dactylon (L.) Pers., Rochecouste (1962) demonstrated that there was no effect from uptake of TCA via the roots when the shoots were in the bud stage and there was no transpiration. The results of preliminary experiments with wheat carried out by the present author support Rochecouste's results. From these facts it might be suggested that the absorption of TCA from the soil and uptake into sensitive tissues is dependent only to a lesser extent on the plant activity in early stages. Recent experiments by Chow (1970) concerning the root uptake by plants in later stages than those under discussion here do not contradict this suggestion. In many steps, the movements of TCA in connection with the uptake in early stages will be of the type of diffusion, both outside and inside the plant surfaces. On the whole, the uptake per time-unit and plant surface unit could be suspected to change more slowly with a temperature change than the rapidity of the development and growth of plant tissues. The uptake in the period between given stages of early development will then decrease with an increasing rapidity of growth, and this will lead to the type of changes in effect with changes of the temperature that are shown in Fig. 1.

The strong effect of TCA at low temperatures may be one of the reasons why TCA application in early spring gives the relatively good control of Agropyron repens that is experienced in Scandinavia. Experiences from field trials in Sweden suggest a better average effect of TCA after application in the very early spring than after application later in the growing season in connection with the soil cultivation before the sowing of a brassica crop in the spring or in the stubble field in late summer. The control by treatment in late summer is, however, favoured by other factors, which will sometimes weigh strongly against the disadvantage of the higher soil temperatures, the daily averages of which are seldom above 16-17° C in Sweden. The underground reproductive stems are thus concentrated more to the upper soil layers in the later part of the growing season than they are in the spring after ploughing in the previous autumn. (Cf. Håkansson, 1969b). This makes it easier to bring the herbicide into good contact with the stems, which, in addition, can be broken to a great extent even by fairly shallow soil operations. Hence the good effect of combined rotavation and TCA application often obtained (Cf. Hamand et al., 1968). In large parts of Sweden there are much lesser risks of unfavourable leaching with application in the summer than with very early spring application, when there are also risks of transportation by surface water because the herbicide can seldom be mixed into the soil by cultivation. In the summer, on the other hand, there are greater chances of low moisture contents in the soil with possible disadvantages according to the previous discussions.

Under certain climatic and other conditions TCA may also be applied in the autumn, and even in the winter, in order that the favourable influence of low temperatures would be used. According to the results of recent experiments (Håkansson, unpubl.) periods of temperatures below 0° C do not reduce the effect of TCA taken up by the plants at temperatures above 0° C before or after the frost periods.

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A STUDY OF THE COMPETITION BETWEEN AGROPYRON REPENS (L.) BEAUV. AND SPRING SOWN BARLEY, WHEAT AND FIELD BEANS

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Summary A. repens at two population levels was planted into land that was later sown to spring field beans, wheat and two varieties of barley. The crops had a greater effect on the growth of A. repens than vice versa The cereal crops were much more suppressive than field beans. Yield of field beans was reduced by 43% in the presence of the low population and 79% by the high population. Cereal yields were not affected by the low population of 45 primary shoots/yd^2. The high population of 180 primary shoots/yd^2 reduced yield of the cereal crops by around 20%. Crop dry weight on A. repens infested plots relative to that on weed free plots declined continuously through the life of all the crops. This was most marked in the case of spring wheat.

INTRODUCTION

Previous work reported in 1968 had indicated the importance of competition from a crop in modifying the development of A. repens. Spring sown barley and wheat were found to be much more effective in suppressing and delaying the formation of new rhizome than were field beans. Of the two former crops, barley was more suppressive in the 1967 season.

It seemed reasonable to infer from these results that crops which most effectively suppressed weed growth would suffer least from weed competition. It also appeared possible that there might be differences between crop varieties as well as between species. Accordingly, an experiment was set up in 1968 to examine the effects of the weed on the crops as well as vice versa.

METHOD AND MATERIALS

The treatments were all combinations of four crops:

Beans	var.	Maris Bead
Wheat	var.	Kloka
Barley	var.	Impala
"	"	Deba abed

and three population levels of Agropyron repens:

Nil
18 rhizome pieces/yd^2
72 " " /yd^2

The low population of A. repens was also included without a crop.

The experiment was sited at Begbroke Hill Farm on a sandy loam soil. A randomised block design was used. Each main plot was 40 ft long by 9.5 ft wide, the plots were separated by pathways 2.5 ft wide. The main plots were sub divided into areas 10 ft by 9.5 ft of which the central 4.5 ft^2 was planted to A. repens, where required. All assessments were made on the central 3 ft^2 of this area. There were four of these sample plots within each main plot. Each main plot was drilled continuously with the crop, as appropriate, there being 19 crop rows 6 in. apart across each plot. Rhizome pieces 6 in. long were cut from clonal material of A repens obtained from an area planted for this purpose in 1967. Unbranched and unsprouted pieces were selected and the material was chosen so as to avoid rhizomes with damaged buds or with abnormal internode length or diameter. (The mean dry weight of a 6 in. planted section was 0.36 g). The rhizome pieces were placed by hand into the bottoms of shallow furrows. The furrows were levelled off immediately after planting and the crops drilled as soon afterwards as possible (always within 24 hours). Final depth of rhizome in settled soil was from 2-3 in. One replicate was planted on the 29th February and two on the 7th and 8th March.

The whole area received an application of 2½ cwt/ac of a compound fertilizer containing N.P.K. in the ratio 13:13:20. All plots except those sown to beans received an additional application of 1½ cwt/ac of an ammonium sulphate nitrate product containing 26% nitrogen.

All plots were sprayed with dinoseb for control of broadleaved weeds on the 25th April; the wheat and barley plots with an amine formulation and the bean plots with an acetate formulation. The herbicide was applied on a day which started cool and humid but shortly after spraying was complete the temperature rose to a maximum of 66°F.

The herbicide treatment had no visible effect on wheat or Agropyron repens. The barley however was severely scorched (estimated at 30-40% defoliation) although recovery was rapid. The beans were very severely scorched (estimated at 90% defoliation) and took longer to recover. There was little plant mortality and the surviving plants grew very strongly although they were reduced in height. The final yield, on weed free plots, of nearly 43 cwt/ac of seed beans indicated a high degree of recovery from this damage.

Foliar disease did not become noteworthy on any crops and the beans remained free from aphid attack. The spring wheat was, however, attacked by the grain aphis, Sitobium avenae.

Sample plots selected at random were assessed at intervals throughout the season. On the first three occasions, 10, 15 and 19 weeks after planting, the crops were assessed for dry weight, plant number/yd^2, tillers/plant and leaves/plant. A. repens was completely excavated and assessed for numbers of primary shoots and tillers, leaves and flower heads, where present. Dry weight of the original rhizome piece and of the various components of the new growth were also recorded.

The remaining assessment plots were assessed in two stages because of the widely disparate dates of maturity of the different crops. Of the cereal crops Impala barley ripened shortly before Deba Abed barley and both were ripe well before Kloka wheat. Total dry weight of above ground parts of the crop and of grain were determined for these plots on the 22nd August. At this time only the above ground parts of A. repens were assessed on these plots. The beans ripened much later and were assessed on the 30th September. Complete assessment of A. repens on all plots was also made on this date.

RESULTS

1. The growth of Agropyron repens

On average each 6 in. piece of planted rhizome produced 3 primary or rhizome axillary shoots, regardless of the competing crop.

Table 1

Mean shoots and tillers on each 6 in. piece of A. repens in the lower population

Competing crop.		Assessed on 15th May	26th June	21st Aug.	30th Sept.
No crop		7.73	39.5		38.6
Beans		4.61	23.0		35.8
Wheat		3.33	2.6	4.6	
Barley - Impala		3.30	3.0	8.4	
Barley - Deba Abed		3.23	3.2	6.9	
	S.E.	0.54	1.6		

Table 1 shows that tiller formation in the lower population was very much affected by crop competition. Fewer tillers were formed in the plots sown to wheat than in those sown to barley. There was profuse tillering on the plots sown to beans and even more on the uncropped plots.

The shoot count on the uncropped plots had reached a very high level in June; but no further increase was recorded at the end of September. It would seem that production of new tillers and senescence of old ones kept pace at a level of around 39 shoots on each rhizome section or about 600 tillers/yd^2. By the end of September this level had almost been reached on the plots sown to beans.

Table 2

Mean dry weight per plant of A. repens

Competing crop	A. repens level	15th May	26th June	Assessed on 22nd July	21st Aug.*	30th Sept.
No crop	Low	1.23	22.0	41.0	-	59.7
Beans	Low	0.73	12.0	13.7	-	38.4
	High	0.83	7.4	10.6	-	19.3
Wheat	Low	0.93	2.3	3.0	2.2	4.5
	High	0.93	2.2	3.2	2.4	4.2
Barley Impala	Low	0.87	3.1	4.1	3.4	7.4
	High	0.83	2.7	4.0	2.8	6.1
Barley Deba Abed	Low	0.83	2.6	3.9	3.0	7.0
	High	1.00	2.9	4.9	3.5	6.8
	S.E.	0.079	0.55	0.72		2.5

*Applies only to foliage removed at crop harvest

Table 3

Dry weight of new rhizome g per "plant"

Competing crop	A. repens level	15th May	Assessed on 26th June	22nd July	30 Sept.
No crop	Low	0.07	7.65	17.05	36.2
Beans	Low	0.01	3.74	4.24	11.4
	High	Not measured separately			6.7
Wheat	Low	Nil	0.02	0.08	1.0
	High	Not measured separately			0.7
Barley Impala	Low	trace	0.04	0.45	2.3
	High	Not measured separately			1.8
Barley Deba Abed	Low	trace	0.32	0.60	2.3
	High	Not measured separately			1.8
S.E.				0.35	1.06

Table 2 gives total dry weights for all structures of A. repens recovered (including the original piece) and Table 3 gives dry weight of new rhizome only. It can be seen that, on the uncropped plots, growth was slow at first but very rapid later in the season. By July new rhizome made up 41.5% of the total dry weight. By the end of September, the dry weight of 36.2 g of new rhizome per plant on these uncropped plots represents an hundredfold increase on the weight of rhizome planted

A repens also produced a great deal of new rhizome growth in the plots sown to beans, the level of production being considerably greater than that recorded in 1967. At the later dates of assessment an increasing difference was recorded between the weight per plant of A. repens at the different population levels. By early October the weight per plant on the "high" population plots was around a half of that recorded on the low population plots, an indication of the high level of intra-specific as well as inter-specific competition on the dense plots.

Growth of A. repens was very much poorer in the plots cropped to wheat and barley. There appeared to be very little difference between the barley varieties Impala and Deba Abed in respect of suppression of A. repens. It was notable that spring wheat was more suppressive than barley in this experiment, a reversal of the result obtained in 1967.

2. Crop growth

The crop populations were within the normal limits for field practice. Table 4 gives details of crop population and degree of tillering in the early stages of the experiment. Only flowering tillers were recorded in June, the number of non-flowering tillers being negligible.

Between May and June there was a reduction in plant numbers and in tillers per plant of wheat and barley. Tiller numbers of beans increased slightly during this period. Similar changes took place in the 1967 experiment.

Table 4

Crop establishment and tillering

Crop	A. repens level	Plants/yd² 15th May	Plants/yd² 26th June	Total shoots/plant 15th May	Total shoots/plant 26th June
Beans	Nil	42	27	1.06	1.33
	Low	36	24	1.07	1.33
	High	35	33	1.00	1.08
Wheat	Nil	409	297	1.96	1.20
	Low	579	327	2.30	1.25
	High	415	385	2.10	1.12
Barley Impala	Nil	274	242	3.05	2.40
	Low	284	257	3.40	2.25
	High	295	240	2.79	1.95
Barley Deba Abed	Nil	243	243	3.69	2.10
	Low	286	285	3.95	1.68
	High	273	272	3.47	1.85
S.E.		36.9	24.8	0.13	0.14

Table 5 shows the effects of two levels of A. repens infestation on the dry weight above ground of the crops. At the time of the first harvest on 15th May there was no evidence of a damaging effect on crop dry weights due to the presence of A. repens. Conversely the dry weight of wheat and barley was significantly higher on the plots planted to the low level of weed.

The effect of A. repens on the crops increased as the season progressed. By 22nd July the higher population of A. repens had significantly reduced yields of all the crops, the effect on beans being most severe. It appeared that the variety Impala suffered to a greater extent than Deba Abed and, at this stage, the effect of A. repens on wheat was less severe than on either of the two barley varieties. By the time of crop maturity this difference was reversed, so that the yield of wheat was reduced to a slightly greater extent than that of either variety of barley.

At the lower population level, the yield of beans was 43% below that of the weed free control plots and at the higher population level it was reduced by 80%

Table 5

Crop dry weight (above ground) as a percentage of that on weed-free plots

Crop	A. repens level	Assessed 15th May	Assessed 26th June	Assessed 22nd July	Assessed At Maturity
Beans	Low	114 ± 63	63 ± 14	57 ± 5	57 ± 5
	High	103	49	26	21
Wheat	Low	130 ± 5	107 ± 3	102 ± 3	99 ± 5
	High	112	93	91	78
Barley Impala	Low	132 ± 6	100 ± 3	107 ± 4	95 ± 6
	High	104	81	77	80
Barley Deba Abed	Low	122 ± 8	106 ± 4	104 ± 4	99 ± 6
	High	99	97	89	84

Table 6

Crop yields at maturity (cwt/ac at 15% moisture)

Crop	A. repens level	Total yield of aerial growth	Grain yield
Beans	Nil	71.7	42.6
	Low	40.9	26.8
	High	14.8	9.0
Wheat	Nil	74.2	30.9
	Low	73.3	27.5
	High	58.2	18.7
Barley Impala	Nil	66.0	34.6
	Low	62.6	33.0
	High	52.7	29.1
Barley Deba Abed	Nil	63.7	37.6
	Low	62.8	37.0
	High	53.8	30.8
S.E.		3.8	2.7

The ratio of grain yield to total (above ground) dry weight was little affected by competition in beans or barley. In the case of spring wheat this ratio, which was already low on the control plots, was decreased with increasing population of A. repens.

Wheat was apparently affected to a greater degree than barley in the later stages of grain development. In addition to the steep fall in the relative yields of the infested plots between July and August, this difference between wheat and barley is reflected in the 1000 corn weights in Table 7. The grain weight of barley showed no change but the reduction in wheat could account for over half the total yield reduction.

Table 7

1000 corn weights in grams dry matter

A. repens level	Beans	Wheat	Barley (var. Impala)
Nil	354.6	33.0	31.6
High	314.3	28.7	31.6

DISCUSSION

The spring and early summer of 1968 were relatively warm at Begbroke and a (calculated) moisture deficit of 1½ in. was recorded on only 15 days. Conditions were thus very favourable to crop growth on this light loam soil. In many respects however, the results obtained in this experiment were similar to those obtained in the much drier 1967 season.

The aerial growth and new rhizome growth of A. repens was very much suppressed and delayed by competition from crop plants, the cereals being more efficient than spring beans in this respect. In complete contrast to 1967 the spring wheat in this experiment was more suppressive than either variety of barley. This was an exceptionally vigorous wheat crop, but it seems possible that the check to growth of the barley caused by dinoseb application may have affected the balance of competition. This check was of short duration, but occurred at a crucial time, i.e. just as the cereal crops were establishing a complete leaf cover.

When considering loss of crop yield due to the presence of A. repens the effect on beans needs little discussion. This crop which was the least effective at suppressing the growth of A. repens was the most severely affected by it. Yield was severely reduced by the lowest population, which appeared to have no adverse effect on the cereal crops.

On 15th May dry weight of all three cereal crops was considerably higher on the plots planted to the low population than on the plots free of A. repens. A similar result has been recorded in another experiment. It is difficult to find a convincing explanation for this increase. The plots planted to A. repens may be rather more compacted than the weed free plots, but the difference is not likely to be great.

An anomalous result that is easier to explain was that spring wheat, which was the most effective suppressor of the weed grass, was, none the less, more severely affected by its presence than was barley. This effect occurred mainly during the later stages of crop growth. It seems quite probable that spring wheat is inherently more susceptible to stress at this time; it does have a reputation for not "finishing" well on sandy soils. In addition, the crop was later to mature than either barley variety in this experiment. It is logical that late maturing crops should be more severely affected. At this time of the season the A. repens is tillering rapidly, and extending its root zone whereas the crop is becoming senescent and presumably its root zone is relatively static. In short, the later a crop matures, the more A. repens it will have to compete with. It has been suggested that, during the early stages of the A. repens/crop association, the most intense competition is for light. A. repens is drawn up to the height of the competing crop. Conversely at later stages of crop development it is unlikely that light is the prime factor. Only the flag leaves and ears of the crop are carrying on photosynthesis and these are rarely overshadowed by the weed. At this stage an increasing proportion of A. repens foliage is at the lower horizons, to which light has been admitted by senescence of crop leaves.

Of the two barley varieties, Deba Abed was slightly less affected by A. repens competition than was Impala, the differences being much more marked at the earlier assessments. Deba Abed was later to ripen but the margin was only one of a few days The habit of growth of this variety is unusual. It remains very low for a large part of the season, being less than 2/3 of the height of Impala during late May. After ear emergence a rapid stem elongation occurs and the final height of the two varieties is similar. It has been suggested that these two varieties of barley represent the extremes of competitive ability within the current range. If this is so then the range does not appear to be very great, judging from the results of this experiment. Varieties and indeed crops can vary in their performance under different conditions, and it would be unwise to draw hard and fast conclusions on these critical points from limited evidence.

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CULTURAL AND CHEMICAL TREATMENTS FOR THE CONTROL OF AGROPYRON REPENS AND AGROSTIS GIGANTEA IN BARLEY

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Summary The results are reported of a series of experiments started after cereal harvest in 1968. The effects of rotary cultivation and TCA, sodium chlorate and paraquat, alone and with rotary cultivation, were recorded.

When followed by mouldboard ploughing, the greatest reduction in emergence of shoots of *A. repens* and *A. gigantea* was produced by combinations of a single cultivation and a herbicide. A single rotary cultivation was more effective than the use of herbicide without cultivation.

INTRODUCTION

In the current economic situation, the intensive cereal grower has relatively little money available for perennial grass control. Two contrasting approaches which take this into account merit investigation; one involves a drastic reduction of the weed quickly and the other involves a lesser reduction repeated over several years. The latter must be sufficiently cheap to allow of annual treatment during two to three years.

With these two approaches in view, the activity of three herbicides against *A. repens* and *A. gigantea* was studied.

The recommendation for the use of TCA (Fryer and Evans, 1968) current in 1967 was considered laborious and expensive by many farmers as it involved a split application of 40 lb/ac TCA in association with an involved pattern of cultivation. Two pilot experiments carried out in the autumn of 1967 indicated that cheaper and simpler ways of using the chemical might be possible.

The results obtained by Turner (1969) suggested that repeated applications of low doses of paraquat would be more effective than a single higher dose.

Fail (1956) and Proctor (1961) affirmed the value of stubble cultivations for perennial grass control. The experiments described here examined some complementary applications of cultivation and herbicide.

METHOD AND MATERIALS

Experiments were conducted at 8 sites, details of which appear in Table 1.

Each experiment was laid out on barley stubble in randomised blocks with three replicates. Plot size was 70 ft by 25 ft. Discard strips, 5 ft wide, between plots reduced the effective plot width to 20 ft. These received additional rotary cultivation to minimise carry over of rhizomes from plot to plot.

Table 1

Details of experiments

Site No.	County	Weed spp.	Soil type	Date 1st treatment	No. of repeated paraquat applications	Plot harvest method
1.	Oxon.	A.repens	Sandy loam	6 Sept.	3	Combine 16 Aug.
2.	Oxon.	A.repens	Loam over limestone	30 Aug.	4	Combine 3 Sept.
3.	Northants.	Both spp.	Clay over limestone	27 Aug.	3	Combine 29 Aug.
4.	Northants.	Both spp.	Clay loam	28 Aug.	3	Hand 27 Aug.
5.	Worcs.	Both spp.	Silty clay loam	18 Sept.	3	Yields not recorded
6.	Worcs.	A.repens	Loamy sand	26 Aug.	4	Hand 7 Aug.
7.	Devon	A.gigantea	Loam	10 Sept.	3	Yields not recorded
8.	Cornwall	A.gigantea	Loam	11 Sept.	4	Yields not recorded

Herbicides were applied at 24 gal/ac and 30 lb/in^2 by a Land Rover mounted sprayer. Doses are expressed in terms of a.i. throughout. Cultivation was by a "two blade" Howard Series E Rotovator, with rotor and tractor speeds adjusted to give one cut/5 in. of forward travel. With the rear shield raised, this gave the soil a coarse tilth. Where applicable, repeated treatments were applied approximately every three weeks when regrowth had reached 1-2 leaves/shoot. The farmer ploughed, cultivated and drilled all sites to spring barley in the normal manner, except for site 5, where spring oats were planted.

The initial effects of the treatments were observed in the autumn of 1968, but the main assessments involved shoot counts in the following spring. Where both species were present, Agropyron repens and Agrostis gigantea were counted separately. The size of quadrat and numbers thrown were selected so that at least 100 shoots were counted on each control plot. The first count was in late April to early May; the crop, which had just emerged, was also counted at this time. Couch shoots were again counted later in May after the crop had commenced tillering.

At 3 sites, grain samples were harvested by combine, a swath 8.5 ft by 65 ft from each plot being taken. Two experiments were sampled by hand by the following method: 10 samples, each two rows by 3 ft were taken from each plot by cutting off the heads with a serrated breadknife. These samples were subsequently threshed, dressed, dried at 100°C to zero moisture and weighed.

After harvest, the population of couch shoots was assessed, either by quadrat counts or by subjective scoring. Shoot counts at three sites were made easier by counting the regrowth from burnt stubble. These autumn assessments were not differentiated according to species.

All TCA applications had an additional 1 oz/ac of paraquat to give more consistent scorch of foliage under a range of weather conditions. These and the applications of 2 oz/ac paraquat received additional wetting agent, 'Agral' at the rate of 1/10 fl oz per gallon (1/8th pint/ac).

RESULTS

Effects on weed population

Tables 2 and 3 give the results for A.repens and A.gigantea respectively obtained at the second spring assessment. Table 4 gives results of the stubble assessments, which were counts of primary shoots (exclusive of tillers) at sites 1-4 and subjective scores at sites 5-8. From the spring shoot counts it appeared that the two species were similar in reaction. Site to site variability within each species was greater than any differences noted between species at a single site.

Table 2

Agropyron repens Shoot numbers as % controls May 1969

Treatments	Site No. 1.	2.	3.	4.	5.	6.	Mean
TCA 15 lb/ac*							
On surface	31	54	30	6	56	27	34
#Incorporated	8	7	4	8	18	6	9
#Applied to regrowth	12	6	2	3	10	2	6
TCA 30 lb/ac*							
On surface	27	27	35	7	44	16	26
#Incorporated	16	3	6	10	10	3	8
Sodium chlorate 50 lb/ac							
On surface	42	79	30	75	78	12	53
#Incorporated	17	2	35	10	18	3	14
Sodium chlorate 100 lb/ac							
On surface	26	34	20	17	30	35	27
#Incorporated	12	9	3	2	13	2	7
Paraquat							
8 oz/ac single dose	34	27	60	19	35	13	31
2 oz/ac repeated as necessary	26	10	13	20	51	16	23
Cultivation with paraquat (2 oz/ac)							
#Pqt - cults - pqt	17	5	28	14	21	9	16
#Cults - pqt - pqt	13	5	37	8	29	2	16
Cultivation only							
#Once	27	15	27	11	26	4	18
Twice	17	3	12	6	16	10	10
"Standard" - Dalapon 12 lb/ac	18	4	1	8	36	12	13
Control population - shoots/yd^2	102	67	56	49	72	30	
S.E. as % control	10	8	23	15	11	11	

* With 1 oz/ac paraquat

\# All plots marked thus received the same standard cultivation.

Table 2

Effects of post-emergence application[x] of herbicides on percentages of protein, oil, calcium, phosphorous and iodine number of soybean seeds

Herbicide	Rate (a.i.) kg/ha	Protein %	Oil %	Iodine Number	Calcium %	Phosphorous %
chloramben	2.0	34.46	21.33	130.16		
	3.0	32.19	21.87	127.46	0.25	0.90
	4.0	33.06	22.18	122.01		
chloroxuron	3.0	32.48	22.42	130.55		
	4.0	33.01	22.11	130.63	0.26	0.85
	5.0	30.53	23.18	127.56		
dichlobenil	2.5	32.63	22.42	120.94		
	5.0	34.29	20.98	129.12	0.24	0.85
	7.5	32.23	22.43	125.54		
diphenamid	1.5	31.32	22.81	128.19		
	3.0	32.20	21.92	128.52	0.25	0.84
	6.0	32.75	21.56	130.12		
linuron	0.5	34.01	20.74	135.92		
	1.0	32.27	21.18	134.68	0.24	0.8
	1.5	30.96	22.79	128.41		
propachlor	4.0	29.79	23.15	129.14		
	6.0	32.43	22.55	128.55	0.25	0.84
	8.0	31.42	22.59	127.43		
sulfallate	3.0	34.34	21.97	129.52		
	5.0	32.10	22.21	131.83	0.28	0.87
	7.0	34.18	21.22	134.55		
trifluralin	1.0	34.74	21.94	129.39		
	1.5	33.94	21.97	127.47	0.24	0.82
	2.0	32.98	22.97	127.71		
Handweeded		34.12	22.51	128.43	0.25	0.87
Unweeded		33.10	22.33	128.35	0.24	0.82
L.S.D. 5% level		2.17	N.S.	6.03	N.S.	N.S.
r value		-0.67	-0.54			

[x] Applied on June 27, 1968, two months after planting

DISCUSSION

It has been noted that no significant difference was observed between the chemical composition of soybean seeds harvested from handweeded and unweeded plots (Table 1 and 2). This may suggest that weed competition had no influence on the nutritional characteristics studied. Therefore, differences which were observed in the percentages of protein and oil, as well as in the amount of unsaturation of certain treated seeds, could be due to the direct effects of herbicides used.

In general, it was observed that herbicides which caused a reduction in the protein percentage resulted in an increase in the oil percentage, and vice versa (Tables 1 and 2). This was clearly manifested in the pre-emergence application of diphenamid at 6.0 kg/ha where a significant increase in protein percentage was counterbalanced with a decrease in oil content (Table 2); in addition, the changes in the degree of unsaturation were negatively correlated with the oil percentages (Tables 1 and 2).

In a recent experiment, we observed that three of the herbicides which were used in this study, namely chloramben, chloroxuron and linuron, applied as pre-emergence sprays in soybeans, resulted in effective weed control and caused a significant increase in yield. Based on the data presented in Table 1, chloramben at 3.0 kg/ha and chloroxuron at 4.0 kg/ha could be recommended for the selective control of weeds in soybeans since they showed no detrimental effect on the chemical composition of the seeds.

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WEED CONTROL IN GROUNDNUTS IN ISRAEL*

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Summary The problem of weeds in groundnuts became severe with the progress of mechanization and the increasing scarcity of labour. Formerly weeding required as many as 160 working days/ha for one season of growth; this was prohibitive from the growers' standpoint, especially as groundnuts is one of Israel's best export crops. The main weeds in groundnuts are those common in arable land, i.e., *Amaranthus* spp., *Portulaca oleracea*, *Solanum villosum*, *Digitaria sanguinalis*, *Echinochloa colonum* and *Eleusine indica*. Other important weeds of limited distribution are *Tribulus terrestris*, *Cyperus rotundus* and *Cynodon dactylon*. Crop losses caused by weeds, especially by delayed control, are assessed at 20-50% according to the time between emergence and weeding; weeds also interfere with harvesting.

INTRODUCTION

Groundnuts (*Arachis hypogaea*, peanuts) is one of Israel's best export crops. In 1970 approximately 45,000 dunams (1 dunam = 1,000 m^2 = 1/10 ha = 1/4 ac) were under groundnuts in the three main growing regions: the Negev, the Sharon Plain and the reclaimed Hula Lake area, with sand and sandy loess, sandy loam, and highly organic (peat) types of soils, respectively.

The most common commercial varieties grown in Israel are Shulamit (X-30), Virginia and N.C.2. The first is quite popular, having a relatively short growth period (120 days) which avoids the hazards of early rainfall.

Planting is carried out mechanically in the early spring (mid-April to late May), with simultaneous application of a nitrogen-fixing bacteria suspension into the planting slit. Sprinkler irrigation is employed by most of the growers except in the Hula area, where subsurface irrigation is used.

In 1969, average yields reached 300-350 kg pods per dunam, but yields vary from 200 to 500 kg/dunam according to the field conditions, grower's skill, and degree of weed infestation.

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WEEDS OF GROUNDNUT FIELDS

The weeds of groundnut fields are typical of summer weed societies of irrigated fields. Annual weeds such as Amaranthus retroflexus, A. lividus (and other species), Portulaca oleracea, Solanum villosum, Digitaria sanguinalis, Echinochloa colonum and Eleusine indica are found in all the groundnut-growing areas, while Dactyloctenium aegypticum, Eragrostis sp. (annual), Tribulus terrestris, Chenopodium spp., Crozophora tinctoria and Heliotropium europaeum are less common and constitute only a regional problem.

The most common perennial weeds in groundnuts are Cyperus rotundus and Cynodon dactylon.

DAMAGE TO GROUNDNUTS BY WEEDS

Groundnuts are rather susceptible to weed competition. Hauser et al. (1970) cite a number of workers who found that yield reductions may reach 50%, depending on weed density and time of weeding. Similar data were obtained by Lifshitz (1968a), who found that postponement of the first weeding from 10 to 23 days after crop emergence resulted in a yield reduction of 23%; a delay to 65 days after emergence resulted in a 77% reduction. These results show the importance of early weed control measures.

Besides reducing yields, weeds, especially late-season weeds, may inteffere with harvesting procedures. Particularly noxious in this respect are annual grasses which form a net of stems and roots like Digitaria or grow in rigid clumps, like Eleusine.

WEED CONTROL

Most groundnut growers in Israel apply herbicides at planting time or immediately afterwards, but always before the first, or 'emergence' irrigation. It is common practice to carry out a light cultivation (e.g. with a rotary hoe) several days later, to control whatever weed seedlings escaped the herbicide treatment.

In 1970, however, many growers seemed to prefer the recently introduced pre-planting herbicides. The main reasons appear to be that the herbicides can be incorporated in the soil during one of the last cultivations for seed-bed preparation and the independence of such timing from planting.

CHEMICAL WEED CONTROL RECOMMENDATIONS

The 1970 Weed Control Recommendations for groundnut issued by the Israel Ministry of Agriculture are summarised in Table 1.

EXPERIMENTAL RESULTS

The recommendations in Table 1 are based on a decade of weed control research. The first herbicides used commercially in groundnuts in Israel were the contact, pre-emergence, substituted-phenol compounds (DNOC, PCP, dinoseb). An early trial with

Table 1

Summary of weed control recommendations for groundnuts (1970)

Time of application	Herbicide, and weeds controlled	Rate (g a.i./ha)	Important weeds not controlled
Pre-planting soil incorporation	vernolate[1] - Cyperus rotundus Cynodon dactylon Annual weeds	2160-2880	S. villosum
	benfluralin - Tribulus terrestris and other annual weeds	1350	S. villosum
Pre-emergence to crop & weeds	diphenamid[2] - Annual weeds	3600-4800	S. villosum T. terrestris
	terbutryne - broadleaved annual weeds	750-1250	Annual grasses T. terrestris
	alachlor[3] - Annual weeds	1900-2850	---
Post-emergence to crop, pre-emergence to weeds	diphenamid	3600-4800	S. villosum T. terrestris
Post-emergence to weeds, pre-emergence to crop	paraquat/diquat combination	1000 ml of commercial product	Portulaca oleracea (unless very early)

[1]vernolate - S-propyl NN-dipropyl thiolcarbamate

[2]with diphenamid, irrigation should be limited to 300-400m^3/ha at one time; nine months should be allowed to pass before another crop is planted.

[3]alacholor - 2-chloro -2,6 -diethyl-N-(methoxymethyl) acetanilide

residual herbicides (simazine, diuron) was carried out by Lifshitz (1959). Further trials with many different herbicides have since been carried out by several workers (Amir, 1964; Horowitz and Amir, 1965; Elal and Luz, 1965; Kleifeld, 1965; Luz et al., 1968).

1. Trials for the control of annual weeds

Most of the field trials were conducted in a randomized blocks design, with treatments replicated 4-6 times. The results were compared with weeded and (sometimes) with unweeded control plots. Individual plots usually consisted of four rows, of which the centre two were used for counting and sampling. Alachlor, ametryne, benfluralin, chloramben, chloroxuron, chlorthal dimethyl, dichlobenil, diphenamid, linuron, nitrofen, noruron, prometryne and terbutryne have been tested so far.

Simazine was injurious to the crop and not sufficiently effective (at up to 500 g/ha) against Digitaria sanguinalis. Diuron (as the liquid suspension, at up to 750 g/ha) gave slightly better weed control than simazine, without causing any visible damage to the crop (Lifshitz, 1959).

Chlorthal dimethyl was studied by Horowitz and Amir (1965), Lifshitz (1963) and in detail, by Kleifeld (1965). This herbicide caused the very extraordinary effect of a profuse and lush vegetative growth, with severe crop losses and pod deformation. The amount of hay obtained from plots treated with chlorthal dimethyl was about twice that obtained from control plots.

Dichlobenil, applied post-emergence (at 1500-2500 g/ha) was not toxic to the groundnuts while proving to be a relatively efficient herbicide (Lifshitz, 1963; Lifshitz, 1968a.)

The trials carried out by Horowitz and Amir (1965), Lifshitz (1963-66), Lifshitz et al. (1968), Lifshitz (1968a) and Elal and Luz (1965) showed prometryne and diphenamid to be the best materials. Elal and Luz (1965) found that diphenamid was capable of preventing the re-emergence of Echinochloa colonum for a period of 5 months under irrigated conditions. Both herbicides showed remarkable residual effects and controlled most of the annual weeds present, although prometryne was not sufficiently active against grasses and diphenamid did not affect Solanum villosum. In practice, however, it soon became apparent that prometryne had a narrow margin of safety to the crop, particularly in the light soils of the Negev, and that Solanum villosum was becoming a menace in several fields.

Subsequent work showed that terbutryne had a wider margin of safety to the crop than prometryne. Lifshitz found that while prometryne at 1250 g/ha in sandy loam (1968a) and 600 g/ha in the Negev sand and sandy loess tended to injure groundnuts (1963, 1964), terbutryne, even at the excessive rate of 4500 g/ha in sandy loam caused only the typical vein chlorosis.

Luz et al. (1968), working with benfluralin, a pre-planting soil-incorporated herbicide, found that it will control most of the common annual weeds except Solanum villosum, without injuring the crop, when applied at the rate of 720-1800 g/ha. However, preliminary data suggest that the depth of incorporation in the soil may be crucial to the herbicidal activity of the chemical (Lifshitz, 1968b).

Alachlor, recently introduced, has been under field evaluation for two seasons. It has shown a high degree of herbicidal effectiveness, a moderate residual effect and a reasonable margin of safety in groundnuts (Lifshitz, 1969, 1970). Alachlor controlled both grasses and broadleaved weeds at 1900-2800 g/ha, with no adverse effects to the crop even when applied at a rate of 3800 g/ha.

Solanum villosum was satisfactorily controlled with alachlor and with terbutryne in a trial carried out in 1968 (Lifshitz, 1969). Tribulus terrestris was satisfactorily controlled commercially by benfluralin. Good control was also obtained in a series of trials carried out by Lifshitz (1969, 1970) with terbutryne at 2250 and 4500 g/ha, nitrofen at 750 and 1125 g/ha, and a 1:1 combination of terbutryne and 2-chloro-4-ethylamino-6-tert. butylamino-S-triazine at 2250 and 4500 g/ha. Terbutryne at the higher rate caused some vein chlorosis (typical of the chemical), while the terbutryne combination was fatal to the crop. Further trials showed that the same combination at other proportions (750:250, 500:250, 750:375, and 1500:375 g/ha) showed promise for improved general weed control (including grasses) but did not control Tribulus satisfactorily. Alachlor at 3800 g/ha controlled Tribulus without harming the crop; 1900 g/ha was not sufficient to control Tribulus, but gave good control of other weeds.

2. Trials for the control of perennial weeds

Luz *et al*. (1968) obtained efficient control of *Cyperus rotundus* for 60 days with vernolate, applied pre-planting and incorporated into the soil. It is claimed also, that vernolate is capable of controlling *Cynodon dactylon* (at least the Negev variety or ecotype), but recent (unpublished) results show this to be rather erratic (Amir *et al*., 1969).

3. Crop Response

Some of the data on crop response to various chemicals are summarized in the following Tables.

Table 2

Groundnut pod yields (kg/ha) under different treatments and times of application (Lifshitz, 1968a).

Time of Application	Hand weeding	Diphenamid (3600 g/ha)	Prometryne (1250 g/ha) + diphenamid (3600 g/ha)	Prometryne (1250 g/ha) + diphenamid (2500 g/ha)	Dichlobenil (2500 g/ha)
PE	4344	4396	4925[1]	4363[1]	4188[2]
EPE	3344	4802	4763	4531	4802
LPE	1188	4573	5213	4469	4698

PE - Pre-emergence application, or the earliest possible weeding.
EPE - Early post-emergence (28-30 days after planting)
LPE - Late post-emergence (65-70 days after planting)

[1] Prometryne alone was applied at PE. Diphenamid and dichlobenil were added respectively, at EPE and LPE.

[2] PE plots were hand-weeded. Dichlobenil was applied at EPE and LPE only.

Further tests showed that differences in treatment or application time did not affect essential yield components. The data are given in Table 3.

Table 3

Average pod weight, 1000-seed weight and seed/shell ratio of groundnuts following different herbicide treatments (Lifshitz, 1968a)

Treatments & Time of Application[x]		Mean pod weight[1] (g)			1000-seed weight (g)			Seed/shell ratio		
		A[2]	B	C	A	B	C	A	B	C
Hand weeding	PE	2.5	1.5	1.0	943	898	753	2.3	2.6	1.8
	EPE	2.6	1.5	1.2	922	883	729	2.2	2.2	1.8
	LPE	2.5	1.4	1.0	939	924	761	1.8	1.8	1.3
Diphenamid 3600 g/ha	PE	2.5	1.5	1.1	994	883	781	2.5	2.7	2.0
	EPE	2.6	1.5	1.1	926	908	791	2.4	2.6	1.9
	LPE	2.5	1.4	1.2	939	882	817	2.3	2.4	2.1

Table 3 (cont).

Treatments & Time of Application[x]		Mean pod weight[1] (g)			1000-seed weight (g)			Seed/shell ratio		
		A[2]	B	C	A	B	C	A	B	C
Prometryne	PE	2.5	1.4	1.1	913	910	706	2.2	2.5	2.0
1250 + diph.	EPE	2.6	1.4	1.2	985	919	805	2.5	3.4	2.3
3600 g/ha	LPE	2.5	1.5	1.0	939	943	792	2.4	2.5	1.9
Prometryne	PE	2.6	1.5	1.1	949	922	734	2.4	3.0	1.7
1250 + dichlo-	EPE	2.5	1.4	1.2	926	900	799	2.4	2.0	1.8
benil 2500 g/ha	LPE	2.5	1.4	1.0	921	899	781	2.2	2.5	1.9
Dichlobenil	PE	2.6	1.5	1.1	934	912	889	2.3	2.3	2.1
2500 g/ha	EPE	2.5	1.5	1.1	913	886	799	2.4	2.6	2.0
	LPE	2.5	1.4	1.0	901	894	741	2.3	2.6	1.9

[x]See footnote to Table 2.

[1]All data are taken from samples of 1 kg of pods per replication.

[2]Grade A pods - > 25mm length of pod; grade B - < 25mm but marketable; grade C - unmarketable.

The lowest values were obtained with grade C pods. The lowest seed/shell ratios of grades A and B pods were obtained where weed competition existed for the longest time; otherwise, there were no inter-grade differences due to type or time of treatment. This is especially noteworthy, since prometryne, when applied pre-emergence at the rate of 1250 g/ha, caused some initial injury to the groundnuts.

Crop response data pertaining to other herbicides, are presented in Tables 4-7.

Table 4

Effect of vernolate, incorporated in the soil prior to planting, on groundnut yield in 1966 (Luz et al., 1968)

Rate (g/a.i./ha)	Soil type	Pod yield (kg/ha)	Hay:Pod ratio	Mean pod weight (g)	1000-seed weight (g)	Seed/shell ratio
2150	Sandy loam	5036	1.3	2.8	1013	2.3
2870	"	5143	1.3	2.8	1038	2.5
Control	"	4321	1.4	2.8	1022	2.5
1650	Loess sand	4251	-	2.3	-	3.2
2798	"	4668	-	2.3	-	2.8
Control	"	3751	-	2.5	-	3.2
2150	Sandy-loam	5857	1.2	2.7	951	1.8
2870	"	5429	1.4	2.4	828	1.4
Control	"	4786	1.2	2.4	857	1.0

Vernolate, as well as diphenamid and benfluralin, at the recommended rates did not hinder the inoculation of groundnuts by nitrogen-fixing bacteria (Luz _et al_. 1968).

Table 5

Effect of terbutryne on the yields of groundnuts in 1967 and 1968 (Lifshitz, 1968b, 1969)

Rate (g/a.i./ha)	Year & soil type	Pod yield (kg/ha)	Hay/Pod ratio	Mean pod weight (g)	1000-seed weight (g)	Seed/shell ratio
1000	1967, heavy	3680	1.3	2.0	761	1.9
2000		5230	1.1	2.2	811	2.0
Control (weeded)		4067	0.9	2.1	775	2.0
Control (unweeded)		2758	1.3	1.9	744	1.7
750	1967, light	4760	1.2	1.9	792	2.8
1500		4174	1.4	2.0	819	2.8
Control (weeded)		4126	1.3	2.0	809	2.8
Control (unweeded)		2766	1.2	1.9	898	2.8
1500	1968, heavy	5300	1.9	-	-	-
Control (weeded)		3790	2.0	-	-	-
1000	1968, light	5320	1.9	-	-	-
Control (weeded)		5170	1.9	-	-	-

Terbutryne was also applied at 2250 and 4500 g/ha with satisfactory results, but the yields were not recorded.

Table 6

Effects of alachlor on the yield of groundnuts in 1968 and 1969 (Lifshitz, 1969, 1970)

Rate (g/a.i./ha)	Year & soil type	Pod yield (kg/ha)	Hay/Pod ratio
1200	1968, light	4740	1.8
2400		5380	1.7
Control (weeded)		3790	2.0
1450	1968, heavy	5610	1.8
2860		4850	1.8
Control (weeded)		5170	1.9
1900	1969, light	4790	-
3800		5660	-
Control (weeded)		5500	-

Table 7

Effects of benfluralin on the yield of groundnuts in 1966 (Luz et al., 1968 and 1968 (Lifshitz, 1969)

Rate (g/a.i./ha)	Year & Soil type	Pod yield (kg/ha)	Hay/Pod ratio	Mean pod weight (g)	1000-seed weight (g)	Seed/shell ratio
788	Loess sand, 1966	5334	--	2.4	--	2.9
1180		4418	--	2.5	--	3.1
1772		4501	--	2.4	--	2.9
Control		3751	--	2.5	--	3.2
1253	Sandy loam, 1966	4962	1.4	2.9	999	1.9
1790		5426	1.2	2.8	986	2.0
Control		5341	1.2	2.7	984	1.9
1340	Sandy loam, 1968	4620	1.5	-	--	-
2148		4490	1.8	-	--	-
Control		2860	1.5	-	--	-

DISCUSSION

It was our aim to review the situation of weed control in groundnuts in Israel, present some of the research data on which official recommendations and agricultural practice are based, and to discuss briefly the properties of the herbicides that are in common use by groundnut growers. We have come a long way from the time of hand weeding and cultivations, or when PCP was used for chemical weed control. However, not all the problems have been solved. What is most needed is a herbicide that will be safe for the crop, with sufficient residual effect to keep the field clean throughout the season but not persistent enough to be carried over to the next season. We hope that research and industry will provide us with such compound.

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HERBICIDES ON COTTON - RESULTS OF THE TRIALS CARRIED OUT IN MOZAMBIQUE FROM 1963 TO 1970

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Summary The results are presented of trials carried out in Mozambique during the past seven years on different types of soil, under different climatic conditions and employing different cultural practices, both on dry and irrigated lands.

The conclusion is reached that the best treatment consists of a combination of trifluralin at 0.50-0.75 kg/ha, incorporated into the soil pre-sowing, with fluometuron at 1.6 kg/ha, incorporated or pre-emergence or with prometryne at 1.0 kg/ha pre-emergence. Such combinations do not control Commelina benghalensis, Tridax procumbens nor Cyperus spp. In plantations where such are expected to occur, a post-emergence application of noruron + MSMA (0.5 + 1.5 kg/ha) is better as a supplement to the trifluralin treatment, or alternatively diuron applied pre-emergence at 1.6 kg/ha, which kills the two first species.

INTRODUCTION

In spite of differences from region to region it can be said that, in general, the prevailing weeds in the north of Mozambique, in the first months after sowing, are grasses, of which Digitaria spp. (D. pentzii and D. perrottetti), Echinochloa colonum, Eragrostis spp. (E. aethiopica, E. aspera, E. arenicola and E. ciliaris), Panicum maximum and Dactyloctenium aegypticum are of the greatest importance; to a lesser extent Eleusine indica and Brachiaria deflexa are to be found. Partially dominated by these are the dicotyledons, which rapidly take over the soil when the competing grasses are eliminated. The commonest are Acanthospermum hispidum, Tridax procumbens, Boerhaavia diffusa and Amaranthus spp. (A. spinosus, A. gracilis and A. blitum). Trichodesma zeylanicum, Ocimum americanum, Mollugo nudicaulis, Vernonia cinerea, Jacquemontia tamnifolia and Commelina benghalensis may sometimes be fairly important.

The main weed problem in the irrigated cotton grown in the south is Cyperus spp., the commonest being C. rotundus and C. esculentus. Besides Cyperus, dicotyledons prevail, amongst which Commelina benghalensis, Corchorus spp. (C. trilocularis and C. olitorius), Acalypha segetalis, Amaranthus spp. (A. gracilis and A. spinosus) and Portulaca oleracea are conspicuous. As minor infestants Ipomoea spp., Indigofera spp., Sida alba, Oxalis semiloba, Chenopodium album and Phyllanthus nummularaefolius must be mentioned. As far as grasses are concerned, the frequency of Leptochloa panicea, Echinochloa colonum, Panicum maximum and Sorghum spp. (S. halepense and S. verticilliflorum) must be emphasised, and to a lesser extent, the occurrence of Urochloa mossambicensis.

METHOD AND MATERIALS

Experiments on chemical weed control of cotton fields were conducted at three Experimental Stations in the north of Mozambique, where the crop is grown under dry farming conditions, and in two in the south, situated in regions where, due to scarce and irregular rainfall, the cotton is irrigated.

Two of the Experimental Stations in the north are situated on yellowish-brown to reddish fersiallitic soils and the other on ferrallitic soils, predominantly reddish. They are of a clay-sand to sandy-clay texture, poor to very poor in organic matter and of a neutral to slightly acid reaction (Casimiro, 1969).

Constituting the main climatic features two well-defined seasons occur, a dry winter with mild temperatures (Min. = 15°C; Max = 30°C), followed by a rainy summer with higher ones (Min. = 17°C; Max. = 35°C). Annual rainfall is in the order of 1000 mm. In the course of its vegetative cycle the crop disposes of some 800 mm rainfall, the potential evapotranspiration ranging between 170 and 130 mm. In the first two months after cotton germination the mean minimum temperature never falls below 20°C (Freixo, 1969).

The two southern Experimental Stations lie on the Limpopo and Umbeluze rivers, on alluvial soils where cotton is irrigated. They are clay-sand to clayey soils and are also poor in organic matter and of neutral to slightly acid reaction. The annual rainfall is 700 to 800 mm, of which about 500 mm falls during the growing period. However, owing to rainfall being most irregular, it is usually necessary to assist the crop by resorting to irrigation.

RESULTS

In the first years of experimentation the following products were tried, either applied with normal or logarithmic-sprayers: noruron, fluometuron, chloroxuron, linuron, prometryne and diuron, applied pre- and post-emergence, the mixture of chloranocryl + DSMA only post-emergence, trifluralin and bensulide incorporated before sowing.

Chloroxuron and chloranocryl + DSMA were found to be toxic to cotton and for this reason were rejected (Almeida and Carvalho, 1966). Even at the maximum dosages (15 kg/ha) bensulide did not give good control of the weeds in the trials where it was applied with a logarithmic sprayer. Linuron and diuron revealed a very low selective factor to cotton, i.e. the lowest dosage necessary to obtain efficient weed control differed to a very small extent from the highest dosage the crop could tolerate, thus it was recommended to reserve its use for controlling species that could not be controlled by other means (Almeida, 1968b).

The dose of 0.5 kg/ha of trifluralin was insufficient on the heavy soils of the north and on the alluvial ones of the south but in the experiments carried out on the lighter soils it controlled grasses efficiently, as well as Amaranthus; nevertheless it had no effect on the remaining dicotyledons which, free from competition, developed vigorously and infested the plots.

On all types of soil a dosage of 1.5 kg/ha of prometryne, applied pre-emergence, clearly showed good selectivity to cotton; dosages of 2.5 kg/ha were excessive on the sandy-clay soils, causing foliar spots and growth retardation. Application post-emergence of 1.5 kg/ha caused burning and chlorotic spots on the leaves but did not affect the cotton's yield. Fair weed control was attained by the elimination of most of the dicotyledons and annual grasses, while the growth of those species not eradicated was retarded.

Fluometuron and noruron, both when used pre- and post-emergence, were very selective in cotton. However, noruron controls fewer species than fluometuron which, at 2.4 kg/ha, either pre- or post-emergence, was the best herbicide controlling cotton weeds (Almeida, 1967 and 1968a).

As the products used until that time did not control weeds satisfactorily, each herbicide always favouring some resistant species which then grew luxuriantly as soon as the competition from the other species was eliminated. It was, therefore, decided to test some combinations of the more promising products in an effort to enlarge the number of weeds individually controlled by them. These comprised fluometuron, prometryne and diuron, as combined pre- and post-emergence treatments and also trifluralin, incorporated before sowing followed by diuron, fluometuron and prometryne, pre- and post-emergence, and with noruron + MSMA only post-emergence. Rather high dosages were used, while minimum dosages of the more promising combinations were left for further investigation.

In the southern irrigated trials Cyperus constituted 60% of the weeds and the only successful treatment was the mixture of noruron + MSMA (0.5 + 1.5 kg/ha) applied post-emergence. Although it did not eradicate this weed, destruction of the aerial part was achieved and regeneration temporarily hindered. This product also gave some control of the remaining weeds, except Echinochloa colonum and Boerhaavia diffusa, which were however affected (Almeida, 1969a).

Fluometuron (1.6 kg/ha), prometryne (1.2 kg/ha), and diuron (2.4 kg/ha) combinations pre- and post-emergence, killed practically all the weeds except Digitaria pentzii, which was, however, much affected by them; this weed, very common in the north, was controlled by a combination of trifluralin at 1.5 kg/ha, incorporated in the soil, followed by an application of fluometuron at 1.6 kg/ha or prometryne at 1.2 kg/ha, these treatments being the best in the trials (Almeida, 1969b).

Because such good results were obtained with noruron + MSMA in controlling Cyperus, and because some species susceptible to fluometuron were not eradicated, it was decided in 1968/69 to test mixtures of fluometuron and MSMA to try, simultaneously, to eradicate Cyperus and a wider range of other weeds as well. A trial

Table 1

Minimum doses required to control various species

Weed species	fluometuron	prometryne	fluometuron + prometryne	asulam	chlorthal	fluometuron + MSMA (1.5:1)	fluometuron + MSMA (1:1)	fluometuron + MSMA (1:1.5)	MSMA	noruron + MSMA (1:2.2)
Echinochloa colonum	3.0	2.5	3.0	4.0	18	2.0	3.0	2.5	1.5	-
Leptochloa panicea	1.2	2.0	2.0	4.0	18	1.5	3.0	2.0	1.5	1.5
Sorghum halepense	3.0	2.5	3.0	4.0	-	3.0	5.0	5.0	-	-
Corchorus trilocularis	2.0	2.0	2.5	7.0	10	3.0	5.0	5.0	-	-
Indigofera sp.	1.2	2.0	2.0	4.0	r	1.3	2.0	-	1.5	2.0
Amaranthus spp.	3.0	2.0	-	6.0	14	3.0	2.5	2.5	1.5	1.5
Ipomoea sp.	3.0	3.0	3.0	7.0	18	4.0	5.0	-	1.5	-
Sida alba	2.0	3.0	1.5	5.0	r	-	6.0	4.8	2.5	2.5
Portulaca oleracea	1.2	3.0	2.0	5.0	8	3.0	2.5	5.0	-	1.5
Datura stramonium	2.0	1.5	1.5	4.0	-	-	1.1	2.0	1.5	1.5
Euphorbia hirta	3.0	1.5	-	4.0	4	1.3	-	2.0	1.5	1.5

was therefore laid down at the southern stations to compare the fluometuron, prometryne and noruron + MSMA (tested previously) with three mixtures of fluometuron + MSMA, fluometuron + prometryne, and two further products, asulam and chlorthal. The application, post-emergence, was made by a logarithmic sprayer.

It was found that either in mixture or individually MSMA satisfactorily controls *Cyperus* at doses between 0.8 and 1.0 kg/ha; selectivity is however very poor and its use is only justified until another product is found which is capable of controlling *Cyperus* with less risk of injuring cotton.

With respect to the remaining species infesting the trial plots, the minimum dosages required are given in Table 1, however, these must be accepted with some reserve, as the results for some species need to be confirmed.

In order to recommend the most economical treatments for practical use, other trials were carried out to determine the minimum dosages at which trifluralin,can be combined with fluometuron and prometryne without losing the good herbicidal characteristics shown in the previous trials.

Table 2

Percentage of weeds resistant to treatment 50 days after sowing cotton

		trifluralin 0.50 kg/ha							trifluralin 0.75 kg/ha			
Species		fluometuron			prometryne			noruron + MSMA	fluometuron		prometryne	
	Control	inc	pre	post	inc	pre	post	post	pre	post	pre	post
LIGHT SOILS												
Digitaria spp.	23	2	8	16	21	6	-	8	-	-	-	-
Portulaca quadrifida	20	-	-	-	-	7	5	-	-	-	-	-
Boerhaavia diffusa	14	-	-	-	3	3	1	2	-	-	3	2
Commelina benghalensis	14	12	15	17	47	47	3	5	30	21	10	5
Vernonia cinerea	9	-	-	-	-	-	-	-	-	-	-	-
Mollugo nudicaulis	7	2	-	3	-	-	-	-	-	-	-	-
Amaranthus spp.	4	2	-	-	-	-	-	-	-	-	-	-
Mucuna coriacea	4	-	2	-	2	-	-	2	3	2	-	2
Celosia trigyna	4	2	-	-	12	3	-	3	3	3	3	3
Others	1	2	2	2	10	9	4	2	7	8	5	1
	100	24	27	38	95	75	14	22	42	34	21	13
HEAVY SOILS												
Digitaria spp.	50	5	3	11	9	7	7	2	9	11	2	6
Amaranthus spp.	31	2	3	-	10	2	-	2	1	-	1	-
Eragrostis ciliaris	7	1	1	-	1	-	-	1	-	-	-	-
Echinochloa colonum	4	3	4	10	16	16	6	2	9	6	2	1
Tridax procumbens	1	-	1	1	7	3	-	2	3	3	3	2
Others	7	1	-	1	3	7	1	4	3	2	1	2
	100	12	12	24	46	35	14	13	25	22	9	11

At the northern Experimental Stations combinations were tried of trifluralin at 0.5 and 0.75 kg/ha, incorporated into the soil, pre-sowing, with fluometuron at 1.6 kg/ha and prometryne at 1.0 kg/ha, incorporated, pre- and post-emergence, and with noruron + MSMA (0.5 + 1.5 kg/ha) post-emergence only.

The combinations of trifluralin at 0.5 kg/ha were fairly efficient against grasses growing on the light soils, but on the heavier soils, even at a dose of 0.75 kg/ha, they were unable to control Echinochloa colonum. As for dicotyledons, Table 2 shows that Commelina benghalensis is tolerant of combinations of trifluralin with fluometuron and prometryne but susceptible to noruron + MSMA. None of the treatments seem to have affected Tridax procumbens. The best results were those obtained with combinations of trifluralin, incorporated at 0.5 or 0.75 kg/ha, according to soil texture, with fluometuron at 1.6 kg/ha incorporated or pre-emergent or with prometryne 1.0 kg/ha pre- or post-emergent, or with noruron + MSMA (0.5 + 1.5 kg/ha), post-emergent (Almeida, 1970).

It was also found in this trial that a correlation exists between the mean number of weeds which infest the soil per m^2 during the first twenty days after cotton emergence, and the cotton yield, a correlation that could be expressed by the regression function $y = 1753.5 - 14.7\ x$.

This led to the conclusion that as it is necessary to wait at least one week for the weeds to emerge, and that as the eradication should not be delayed for more than possibly 10 to 15 days, the optimum period for the post-emergence treatments is reduced to less than one week. This is a requirement too difficult to meet in practice; hence, post-emergence applications should be chosen only when weed problems cannot be solved by other methods.

Nevertheless, it has been observed that farmers experience some difficulty in incorporating the products into the soil; this difficulty accounts for the failures already recorded, which are often wrongly attributed to the herbicides.

In order to avoid incorporated treatments, as well as post-emergent treatments (because of the inconveniences already stressed) another trial was made in 1969/70 at the northern stations to compare mixtures of trifluralin incorporated with fluometuron and prometryne with the products appearing in Table 3. The aim was to find a pre-emergence treatment which controlled weeds as well as the incorporated mixtures.

The prevailing species were Digitaria pentzii and, to a lesser extent, Tragus berteronianus, Amaranthus spp., Corchorus trilocularis and Mollugo nudicaulis. They were practically eradicated by CP 53619 (5 kg/ha), alachlor (2 kg/ha), fluorodifen (4 kg/ha) and prometryne (2 kg/ha). There was no advantage in mixing the latter with fluorodifen, TCA and trifluralin.

Diuron at 2.5 kg/ha and fluometuron at 2.4 kg/ha did not eradicate Digitaria; Amaranthus also showed resistance to diuron. At the doses tested, however, CP 53619, alachlor and prometryne, caused temporary symptoms of phytotoxicity to cotton leaves, but without affecting the yield. Mixtures including TCA were also found to be phytotoxic as well as causing the decreases in cotton production.

Good though they were, the results recorded for these new products need to be confirmed by further investigations.

Table 3

Percentage of weeds surviving, 30 and 60 days after the application of the herbicides

	No. days after application	CP 53619 (5.0)	alachlor (2.0)	fluorodifen (4.0)	nitrofen (2.0)	prometryne (2.0)	fluometuron (2.4)	diuron (2.5)	fluorodifen + prometryne (3 + 1.5)	fluorodifen + fluometuron (3 + 1.6)	TCA + prometryne (10 + 1.5)	TCA + fluometuron (10 + 1.6)	trifluralin + prometryne (0.75 + 1.5)	trifluralin + fluometuron (0.75 + 1.6)	control
Digitaria pentzii	30	-	2	-	7	-	6	18	1	9	-	4	1	3	85
	60	1	8	1	7	-	7	19	3	16	1	10	1	2	79
Amaranthus spp.	30	-	-	-	-	-	-	2	-	-	-	-	-	-	6
	60	-	-	-	-	-	-	1	-	1	-	-	-	-	3
Corchorus trilocularis	30	-	-	-	1	-	-	-	-	-	-	-	-	-	1
	60	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Mollugo nudicaulis	30	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tragus berteronianus	30	-	-	-	-	-	-	-	-	-	-	1	-	-	2
	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	30	-	1	-	1	-	1	-	-	2	-	1	-	1	5
	60	-	1	-	14	-	2	2	-	2	-	1	-	1	17
Total	30	-	3	-	9	-	7	20	1	11	-	6	1	4	100
	60	1	9	1	22	1	9	22	4	19	1	11	1	3	100

CONCLUSIONS

From trials carried out during the past seven years on different types of soil, under different climatic conditions and employing different cultural practices in dry and irrigated cotton in the north and south of Mozambique, and in which several herbicides were tried individually or in mixtures and combinations, the following conclusions can be drawn:

a) - linuron, diuron and asulam, have poor selectivity for the crop. Their utilization is, therefore, only justified for controlling weeds which cannot be controlled by other more selective herbicides.

b) - bensulide, nitrofen, chlorthal and noruron, with a good selective factor do not control effectively the prevailing weeds in Mozambique's cotton fields.

c) - CP 53619, alachlor and fluorodifen, when applied pre-emergence, proved to be quite efficient in controlling weeds, but the first two caused temporary phytotoxicity on the cotton plant. More detailed observations are therefore needed.

d) - pre-emergence applications of prometryne, at rates higher than 1.5 kg/ha in light soils, 2.0 kg/ha in sandy-clay-loam soils, and 2.5 kg/ha in clay soils, or post-emergence, using dosages higher than 1.5 kg/ha, cause temporary symptoms of phytotoxicity on the cotton leaves. It controls well a large number of dicotyledons and annual grasses, but Echinochloa colonum, Digitaria spp., Sorghum spp., Amaranthus spp. and Ipomoea spp. are only controlled when higher doses are used.

e) - fluometuron, one of the more selective herbicides amongst those tested on cotton, controls satisfactorily the more common weeds but, as was the case with prometryne, only the highest doses are efficient on the more common grasses of cotton fields.

f) - trifluralin, a very selective herbicide, controls well annual and perennial grasses and Amaranthus spp., even at low rates; however, it has no effect on most dicotyledons.

g) - post-emergence applications of noruron + MSMA provide good weed control, including Cyperus spp. burning the leaves and retarding the growth of those it does not eliminate.

h) - post-emergence treatment with mixtures of fluometuron + MSMA is effective against Cyperus and, generally speaking, against the remaining weeds; its selectivity to cotton is, however, very low.

i) - the pre-emergence use of fluometuron + prometryne, although controlling a very wide range of species is not effective against grasses, when economic rates are considered.

j) - combinations of trifluralin at 0.5-0.75 kg/ha, incorporated into the soil before sowing, with fluometuron at 1.6 kg/ha or with prometryne at 1.0 kg/ha, either incorporated or applied pre-emergence gave the best weed control, both in the irrigated cotton fields of the south and the dry fields in the north.

k) - the above combinations do not kill Commelina benghalensis, Tridax procumbens nor Cyperus spp. In fields where these weeds are expected, post-emergence applications of noruron + MSMA at 4.0 kg/ha or, for the two first-mentioned species, a pre-emergence application of diuron at 1.6 kg/ha, are advisable as a supplement to the trifluralin treatment.

l) - weed competition is most harmful to cotton during the first twenty days of the crop's life and a decrease in production of the order of 140 kg/ha can be expected for each ten weeds per m^2 occurring in the soil during this period.

m) - for this reason post-emergence treatments must be applied during the interval between the first and second week after crop emergence, which limits its applicability; on the other hand, herbicide incorporation is not advisable as a great number of farmers, on account of the present state of their development, are unable to do this efficiently; pre-emergence application of herbicides seems, therefore, to be more practicable in Mozambique.

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APPLICATION OF THIOCARBAMATE HERBICIDES INTO IRRIGATION WATER

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Summary Techniques are described for the application of thiocarbamate herbicides, with emphasis on EPTC, through flood, furrow or sprinkler irrigation systems. Constant flow devices have been constructed which accurately meter EPTC into irrigation water. EPTC-treated water has been applied safely to lucerne, ladino clover, potatoes, sugarbeets and to almond, walnut and citrus orchards mainly for the control of annual and perennial grasses and sedges, such as *Cynodon dactylon*, *Cyperus esculentus* and *Cyperus rotundus*.

INTRODUCTION

Thiocarbamate herbicides developed since 1959 have been successfully used for weed control in beans, maize, potatoes, rice, sugarbeets and other crops. These herbicides are characterized by relatively low water-solubility and high vapour pressures. Loss by vaporization occurs readily from moist soil surfaces (Gray 1965); to prevent this various soil-incorporation techniques have been utilized such as rotovation, cross-discing and the use of sub-surface sweeps or injector tines. Under conditions where irrigation is an integral part of the cultural practice, thiocarbamate herbicides can be moved into the soil to the site of susceptible germinating weed seeds, rhizomes or bulbils by irrigation water. This technique also permits the application of thiocarbamate herbicides in established crops without soil disturbance.

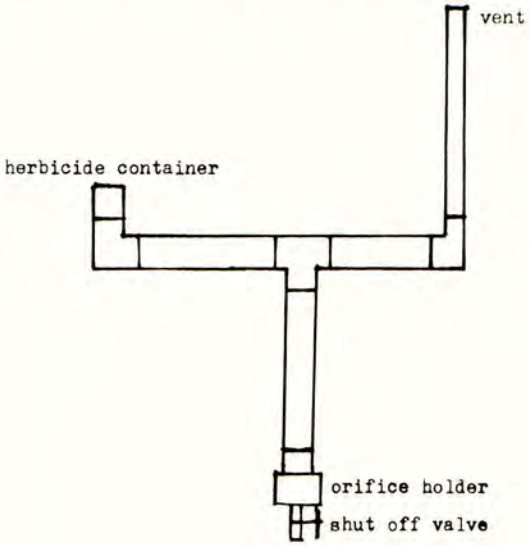
METHOD AND MATERIALS

Flood and furrow irrigation systems. In systems which utilize flood and furrow watering, EPTC is applied throughout the period of the water run. A constant head, zero pressure metering device is attached to the $\frac{3}{4}$ in. orifice of the herbicide container. This device can be constructed from plumbing supplies. Recent work has utilized a metering device with an adjustable flow rate. Once a metering device is attached to the container, it is calibrated to deliver the correct quantity of EPTC. Use of different sized Tee Jet orifices allows the delivery of the required rate of herbicide for water runs of varying time intervals.

Sprinkler irrigation systems. In sprinkler systems, EPTC is applied to the field after application of untreated water to the cultivated field. The herbicide is metered into the system at the required rate by means of the constant head device shown in Figure 2. The vacuum side of the booster pump is the site of herbicide introduction.

EPTC is applied in the first irrigation after planting; established and recently germinated weeds being destroyed by cultivation. Water without EPTC is sprinkled on to the cultivated field and, during the last 2 hours of the run, the herbicide is

Figure 1. Constant head, zero pressure metering device for thiocarbamate application in flood and furrow irrigation systems.



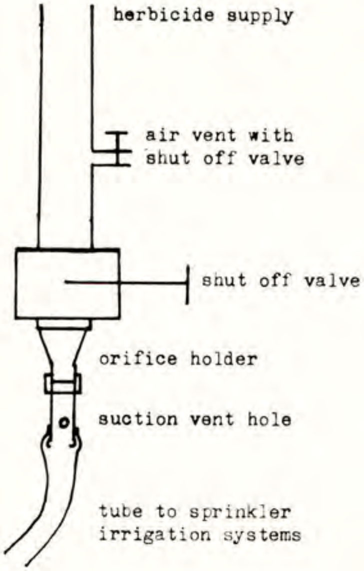


Figure 2. Constant head metering device for thiocarbamate application in sprinkler irrigation systems.

metered into the system. On medium textured soils, this timing will ensure penetration of EPTC-treated water to a depth of 3 to 4 inches, while on lighter textured soils 1 to 1½ hours application is sufficient. No irrigation using untreated water should follow herbicide application.

RESULTS

Weed control using water-applied thiocarbamates is commercial practice in the United States and has been utilized in Spain. Results with EPTC on annual grasses, susceptible broadleaves and perennial grasses and sedges such as *Cynodon dactylon*, *Cyperus esculentus* and *Cyperus rotundus* have been the equal of those obtained using conventional mechanical incorporation. These techniques should be applicable to various agricultural production areas where weeds susceptible to the thiocarbamate herbicides are found.

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WEED CONTROL IN PLANTATION RUBBER

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Summary Weed control aims and practices in Malayan rubber plantations are outlined and current recommendations are given for the use of herbicides.

The crop

Hevea brasiliensis, the source of natural rubber, is a tall tree with a spreading canopy grown in plantation conditions normally at spacings in the range 20 ft x 12 ft to 30 ft x 8 ft. The tree takes about 6 years from planting to attain a sufficient size for it to be brought into bearing and its productive life thereafter is around 30 years. The harvest is taken by hand, by making bark incisions every few days throughout the year, and collecting the latex produced. Some 5 gallons of latex may be collected per acre each harvest and it is carried to nearby factories for processing. Basic managerial objectives in weed control are: the protection of the young rubber from smothering during establishment, the reduction of competition by interrow growths before maturity and the maintenance of open conditions to ease latex harvesting and carrying during maturity. Subsidiary but vital objectives are the protection of the soil against erosion, the destruction of cover for pests and vermin, the maintenance of good ventilation around the trees with a view to reducing disease incidence and the easing of field supervision.

Cultural requirements

The 70 years of growing plantation rubber in the Orient have been marked by progressive developments in managerial attitudes towards the attainment of such objectives. In the euphoria of the early planting days, nothing less than clean weeding was acceptable and planters went to great lengths to keep the interrows bare. The consequent erosion was severe and this, combined with financial stringency in the subsequent long years of depression in rubber, led to a relaxation of attitudes to the point that a partial simulation of the tropical rain forest, which is the habitat of wild Hevea brasiliensis became recognised practice. Interrow cover constituents were classified on field experience of their competitiveness with rubber as:

(a) those, the encouragement of which was recommended
(b) those considered generally useful but requiring some measure of control
(c) those, whose characteristics on the whole were rated as undesirable.

Class (c) weeds normally were selectively eradicated in the interrows, class (b) were controlled by periodic slashing to 3-4 ft; only the access paths along the tree rows were kept clear.

Creeping legumes became the preferred interrow covers for the vast programme of replanting with higher yielding cultivars that has featured the past 20 years of rubber growing in Malaysia. Such covers are readily supervised and controlled, and they fix considerable amounts of nitrogen and mobilise other plant nutrients in their litter, for the benefit of young rubber on land that has become impoverished through prior cropping. Non-legumes were considered less satisfactory and were weeded out assiduously by legume-advocates. In particular the climbing composite Mikania cordata has been shown to exude phenols and flavones from its roots and these suppress soil nitrification and microbiological activity and impair the growth of young rubber. It is now known that the enhanced growth of rubber associated with the maintenance of pure legume covers can be matched where the covers are grass, if more fertiliser is given to the young trees. Once the trees mature, yields level out as the plantation moves into full production, provided an adequate nutrient supply is maintained. Hence a new flexibility of managerial attitude has been generated: pure creeping legumes are preferred wherever they can be established and maintained economically, but subsequent non-legume encroachment is accepted with equanimity in the confidence that an acceptable increase in manuring will sustain growth of the rubber. Again hillsides, the steepness of which makes them too prone to erosion to permit cultivation in preparation for sowing legume covers, may now be handled efficiently by associating selective weeding of natural regeneration in the interrow with judicious enhancement of manuring.

Weed control objectives

Weed control in rubber is particularly onerous in the first 3-4 years after planting, before the crowns of the young trees meet and shade out the ground vegetation. Thus, surveys reported in 1967 show annual weeding costs from clearing to maturity to average:

Cost £/ha

Year	Replant	New planting
Preplanting	0.3	4.1
1st	33.3	23.0
2nd	24.8	31.4
3rd	20.8	19.2
4th	15.0	24.1
5th	9.2	17.1
6th	6.2	10.5
7th	2.4	-
Total	111.8	129.4
Average per year	14.0	18.5

The weed control policy adopted depends on the aims of interrow management. Where pure legume covers are maintained, a seed mixture (usually of Pueraria phaseoloides, Centrosema pubescens and Calopogonium mucunoides) is sown into a prepared seedbed down the middle of the interrow shortly before planting the rubber. Every effort is made to clean up the plantation before preparing the land and to keep the covers clean-weeded afterwards, until the rubber shades out unwanted vegetation. Weeds ahead of the spreading covers are readily controlled with contact herbicides, but close to the trees, weeding normally is by hand as the bark of young rubber is thin and easily damaged. The legumes themselves are herbicide-sensitive: out of 33 commercial and experimental products screened, only neburon applied pre-emergence was tolerated; however, the application of paraquat to well established covers will kill newly emergent sensitive weeds without causing lasting harm to the legumes. The covers are kept back from the trees by keeping rings around each tree, or strips along the planting rows, free of vegetation, initially by hand but later, as the rubber bark thickens and hardens, by spraying. The legumes commonly lose their leaf during dry weather, hence providing an opening for weed invasion, but where early weedings are rigorous and legume growth is kept active by manuring, their dominance is maintained and the comparatively high initial weeding costs are compensated by reduced expenditure later in immaturity.

Where legume covers are sown but are not nurtured so rigidly and where natural growths are maintained in the interrows, weed control is confined to keeping the planting strips clear and to selective removal of undesirable species from the planting strip. Survivors from weed control in previous cropping make up the interrows where natural growths are maintained and, their survival being a consequence of their resistance to weed control measures, their control is correspondingly more exacting than where the interrows originally were sown with legumes.

Interrows sometimes are used during the immaturity of the rubber for growing short term cash-crops. The intercrop requirements then set the patterns of weed control.

Whatever interrow management is adopted, young growths are much more readily controlled than old and weeding rounds initially need to be at least monthly, becoming less frequent as infestations are mastered and the rubber starts to shade out the ground vegetation. The extent of the canopy of well-grown rubber suppresses ground vegetation so effectively that estate surveys show weeds need controlling on average only at 1½ year intervals in mature plantations. Concern to have some cover on the ground in fact leads some planters to plant shade-tolerant class (a) species, notably the fern Nephrolepis biserrata, in the interrows where the soil is bare. The grass Ottochloa nodosa may be used similarly and promises to be less competitive. Ground vegetation rapidly becomes prolific whenever a break in the canopy occurs and in practice, although rubber remains dominant, there is a shift towards an increase in the abundance and variety of the ground cover. Hence it is common practice to intensify weed control during the last years of a planting, so as to ease it in the following replant.

Chemical control

Weeds commonly occurring in ground cover in rubber in Malaysia have been described and illustrated in publications of the R.R.I. The use of chemicals to aid their control dates from pre-war attempts to restore rubber that had been abandoned in the depths of the depression. Sodium chlorate and an alkaline solution of sodium arsenite proved useful adjuncts to manual methods; the rank grass Imperata cylindrica in particular is susceptible to sodium arsenite, and this compound has been widely used to aid reclamation of properties that had been neglected during the wartime Japanese occupation. Sodium arsenite then found such wide application that its use, and subsequently the use of all arsenicals, in agriculture was brought under legislative control. Official anxiety to entirely discontinue the use of sodium arsenite, combined with unwillingness on the part of users to abandon it generated a major programme of screening possible alternatives. This was placed on a systematic basis to determine the susceptibilities, power of recovery and colonisation abilities of a wide variety of cover constituents under a range of canopy condition after treatment with commercial and experimental herbicides and mixtures. Recovery of sprayed vegetation was shown to be related exponentially with time:

$$C \propto A^t$$

where C is the ground coverage of the recovering vegetation at a time t from the start of observation and A is the recovery rate. Rain accelerated recovery and both translocated and contact herbicides were more persistent in the shade than in the open. The cost of the high rates of application found necessary for adequate kills of the grasses that commonly dominate interrow growth and the limited spectra and duration of control obtained combined to rule out the substitution of sodium arsenite by any of the test chemicals. Cost-competitiveness was first obtained by using sub-lethal doses of translocated herbicides to disorganise plant metabolism (but not to kill the plants) followed by subsequently burning off the leaves with paraquat. Such sequential spraying proved effective against most of the common grasses. Sodium chlorate proved an effective alternative to paraquat for burning off the leaf.

Single sprays with mixtures of 2,4-D (alkyl amines) with MSMA and/or sodium chlorate have proved equally successful and have gained popularity over the sequential treatments on account of the simpler supervision required. Other recommendations have been published by the R.R.I. and the current position is summarised in Table 1. The control recommended (Column 3) relates to the weeds shown opposite them in Columns 1 and 2. Thus, in Nurseries and new plantings, grasses are controlled by Treatments (1)-(4), but only Treatments (1) and (2) are effective in dealing with general weeds. Again, General weeds in Immature rubber may be controlled with Treatment (11) (which is effective also on *Axonopus compressus*, *Paspalum conjugatum* and *Ottochloa nodosa* but not on the other grasses listed) or with Treatments (13)-(14) which are effective also on *Ischaemum muticum* and *Paspalum commersonii*. Treatment (15) is effective against the 4 grasses only while Treatments (14) (16) and (17) control *Sporobulus indica*, *Digitaria* spp. and *Eleusine indica* as well.

Except for aromatic oil and dieseline, which are used undiluted for wiping sporadic *Imperata cylindrica*, all formulations are diluted with water. The rates of dilution all relate to the commercial concentrates, not the active ingredient. Unless already incorporated in the formulations used, spreaders need adding to the herbicides indexed[a] and stickers to those indexed[b]. The higher volumes of spray application relate to heavy weed infestations, the higher rates of herbicide application to open canopy conditions.

Field tests have shown that effective year-round weed control in immature rubber can be achieved both by paraquat-based sequential sprayings and by single rounds of a mixture of MSMA/2,4-D selected according to the particular weed situation. The differences in year-round cost of such alternatives for sodium arsenite are marginal and depend largely on the difficulty of the terrain and the availability of water on the site. On flat bottom-land with water available nearby, the cheapness of the chemical favours sodium arsenite, but where remoteness of supply or steepness of terrain makes water supply more difficult the alternatives are cheaper.

Spraying costs, £(s)/ha of rubber

Weed control programme	Easy terrain, water locally available	Steep land, no water on site
Mature rubber, per annum		
sodium arsenite	1.62	3.24
paraquat	2.06	2.60
sodium chlorate	1.92	3.00
MSMA	2.07	2.88
Immature rubber, overall		
sodium arsenite	18.86	37.64
paraquat	20.92	26.57
sodium chlorate	23.16	38.28
MSMA	17.97	24.98

Pre-emergence herbicide application to the tree row is only effective against germinating seeds and will not control encroachment from the interrows. Association of a pre-emergence treatment with contact herbicide control of encroachment holds greater promise: over 2 years, 2 applications at 5 month intervals of 25 ml/m^2 1.25% diuron followed by 25 ml/m^2 application of 0.14% paraquat to the fringe on average every 7-8 weeks, has sustained a 20% improvement in growth over hand-weeding, attributed to the conservation of nutrients in the mulch formed by the repeated paraquat treatment. Weed encroachment of up to 60% in early growth was shown to be tolerated.

The effectiveness and persistence of weed control depends on the herbicide used, the weather at spraying and the openness of the canopy. Rain at any time before sodium arsenite has destroyed the leaf laminae grossly impairs its effectiveness and necessitates a respray. The recognised alternatives generally are effective provided the sprayed foliage escapes being washed with rain for 2-4 hours after application. Where spraying has been successful, about 2 months of weed control are expected from a herbicide application when conditions are open, extending to 6 months or more as the canopy closes in. Rounds of herbicide application usually are linked with rounds of manuring, with the intention of reducing the competition of the ground covers with the rubber for the applied nutrients. Weed control is more persistent in dry season than in wet and is more reliably obtained in well-drained upland situations than in wet low-lying localities where regeneration is favoured by prevailing moisture.

Conclusion

By the very nature of the culture and management requirement, rubber offers a variety of weed situations that probably is unique in crop production. Fortunately the acreage on which it is grown is sufficiently extensive and the pressures towards the solution of the weed problems have been sufficient for great official and private efforts to have been devoted towards their solution. The investment in such investigation has been generous; industry gains further as the low price of sodium arsenite on the world market helps to keep down the price of other weedkillers. Cost-competitiveness limits prospects for refinements of current practices until major advances are achieved in the persistence with which weed emergence and encroachment is controlled.

Acknowledgements

I am grateful for this opportunity to acknowledge the contributions so many people and organizations have made towards devising weed control methods in rubber and to the Director R.R.I.M. for his permission to present this report.

Table 1

<table>
<tr><th colspan="2">Weed situation</th><th>Control</th></tr>
<tr><td colspan="3">Nurseries and new plantings</td></tr>
<tr><td>General weeds</td><td rowspan="2">Grasses</td><td>(1) Spray frequently, 1.25% paraquat with minimal wetting of rubber foliage.
or
(2) Spray 3-monthly, 110 ml/m^2 0.25-0.5% diuron or simazine with protection of rubber and with avoidance of subsequent soil tillage.</td></tr>
<tr><td></td><td>(3) Spray 1% dalapon[(a)] with minimal rubber foliage wetting
or
(4) Spray frequently, 1% MSMA[(b)]</td></tr>
</table>

Immature rubber

Mikania cordata		(5) Spray 11 ml/m^2 2.5% paraquat or (6) Spray 22 ml/m^2 1.25% paraquat + 0.25% 2,4-D (Na salt or alkyl amine) or (7) Wet thoroughly, 0.15% picloram/2,4-D (triisopropanolamine) or (8) Wet thoroughly 0.1% 2,4-D (Na salt) or (9) Spray 0.15 ml/m^2 2,4-D (alkyl amine)
	Paspalum conjugatum	(10) Spray 45 ml/m^2 0.6% MSMA + 0.3% 2,4-D (alkyl amine)
Axonopus compressus General weeds	Ottochloa nodosa	(11) Spray 45 ml/m^2 0.6% MSMA + 1.25% sodium chlorate + 0.3% 2,4-D (alkyl amine) away from rubber
Ischaemum muticum Paspalum commersonii Axonopus compressus	Ottochloa nodosa	(12) Spray 45-65 ml/m^2 4-5% sodium chlorate + 0.2% 2,4-D (alkyl amine)[a][b] away from rubber or (13) Spray 45-65 ml/m^2 0.4% dalapon + 0.2% 2,4-D (alkyl amine)[a] followed in 2-3 weeks by 45-65 ml/m^2 2.5% sodium chlorate[a][b] away from rubber or (14) Spray 45 ml/m^2 0.6% MSMA + 0.5-1% dalapon + 0.3% 2,4-D (alkyl amine)[a][b] away from rubber
		(15) Spray 35-45 ml/m^2 0.8% MSMA + 1.5-2% sodium chlorate[b] away from rubber or + 0.4% MCPA/TBA
Sporobulus indicus Digitaria spp. Eleusine indica		(16) Wet thoroughly, 1% dalapon
General weeds		(17) Spray 22 ml/m^2 1-2% dalapon followed in 3-4 weeks by 22 ml/m^2 0.6-1.2% paraquat or (14) Spray 45 ml/m^2 0.6% MSMA + 0.5-1% dalapon + 0.3% 2,4-D (alkyl amine)[a][b] away from rubber

	Paspalum conjugatum	(18) Spray 35-45 ml/m^2 1% MSMA[b] or (19) Spray 35-45 ml/m^2 2% Amitrole-T
General weeds		(20) Spray 45 ml/m^2 0.3% Amitrole-T followed in 2-4 weeks by 45-65 ml/m^2 1.5% sodium chlorate[a][b] away from rubber or (21) Spray 22 ml/m^2 0.6% Amitrole-T followed in 3-4 weeks by 22 ml/m^2 0.6-1.2% paraquat
		(22) Spray 22 ml/m^2 1% dalapon + 0.6% Amitrole-T[a] followed in 3-4 weeks by 22 ml/m^2 0.6-1.2% paraquat or
	Paspalum commersonii *Eleusine indica* *Digitaria* spp. *Axonopus compressus*	(23) Spray 65-90 ml/m^2 1% sodium arsenite[a] with protection of rubber
	Brachiaria mutica	(24) Spray 65-90 ml/m^2 1% dalapon + 0.2% 2,4-D (alkyl amine)[a] followed in 2-3 weeks by 65-90 ml/m^2 1.75% sodium chlorate[a][b] away from rubber

Mature rubber

General weeds		(25) Spray 22 ml/m^2 1% paraquat or (26) Spray 35-45 ml/m^2 1% MSMA + 0.3% 2,4-D (Na salt or alkyl amine)[b]
General weeds with broad-leaved herbaceous species dominant		or (27) Spray 45-65 ml/m^2 3-4% sodium chlorate + 0.2% 2,4-D (alkyl amine[a][b] away from rubber or (23) Spray 65-90 ml/m^2 1% sodium arsenite[a] with protection of rubber
		(28) Spray 22 ml/m^2 0.6% paraquat + 0.3% 2,4-D (Na salt or alkyl amine) or (29) Wet thoroughly 0.3% picloram/2,4-D (triisopropanolamine)

Brush

Woody species		(30) Wet thoroughly 1% picloram/2,4-D (triisopropanolamine)
	Dicranopteris linearis	(31) Wet thoroughly 1.5% sodium arsenite[a] and spray regrowth similarly
	Lygodium spp.	(32) Wet thoroughly 0.5% 2,4-D/2,4,5-T (low volatile ester)
	Cyclosorus sp. Pteris vittata Pityrogramma calomalensis	(33) Wet thoroughly 1.5% sodium chlorate + 0.1% 2,4-D (alkyl amine)[a][b]
	Aroids	(34) Spray 0.3 ml/m^2 2,4-D (alkyl amine)
Tetracera scandens		(35) Spray 50-100 ml/m^2 0.5% 2,4,5-TP
		(36) Spray 50-100 ml/m^2 0.5% 2,4-D/2,4,5-T (low volatile ester)
Mature Musa spp.		(37) Slash and soak cut stump surface, 5% 2,4-D (na salt) or (38) Inject 30 ml 1% 2,4-D (na salt) 7-10 cm into stem base from 2-3 scattered points
Young Musa spp.		(39) Wet leaves thoroughly 0.2% 2,4-D (na salt)
Eugeissona tristes		(40) Slash and wet thoroughly 10% dalapon[a] when regrowths are 1 m tall

Imperata cylindrica		(41) Spray 110 ml/m^2 1.5% dalapon[a] (optionally + 0.25% MSMA to control invading weeds) or (42) Spray 110 ml/m^2 1% dalapon[a] followed in 4 weeks by 45 ml/m^2 0.6% paraquat or (43) Spray 45 ml/m^2 0.6% paraquat followed at 3-week intervals by 22 ml/m^2 0.6% paraquat until the infestation is contained. Apply N fertiliser to rubber to encourage canopy development or (44) Spray 65-100 ml/m^2 1-1.5% sodium arsenite every 9-10 days until the infestation is contained
Sporadic Imperata cylindrica		(45) Wipe aromatic oil, dieseline or 1-1.5% dalapon or (46) Spot spray 1-1.5% dalapon

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POSSIBLE USES OF PICLORAM FOR RANGELAND IMPROVEMENT IN KENYA

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Summary A series of experiments was conducted in arid to semi-arid areas of Kenya to test the effects of picloram + 2,4-D amines, and other picloram formulations, in comparison with longer established herbicides on a range of bush species of importance in rangeland. On *Acacia drepanolobium* and *Tarchonanthus*, picloram + 2,4-D was more effective than 2,4,5-T ester, there was little difference between picloram + 2,4-D and 2,4,5-T + 2,4-D on *Commiphora* and various associated species, while 2,4-D alone controlled *Lippia*. Effective foliar treatment was shown to be dependent on stage of growth at application. Injection or stump treatment make more economical use of chemical and are recommended for trees of suitable growth habit. The cost of chemical treatment is discussed in relation to the economics of ranching in Kenya.

INTRODUCTION

Bush has been estimated to limit forage production on 25,000,000 ac of rangeland in the semi-arid areas of Kenya (Heady 1960). In addition to its influence on the grazing potential, it also forms a habitat for tsetse on an estimated 35,000,000 ac (Glover *et al*. 1960). A wide range of trees and shrubs is involved, the most important genera being *Acacia*, *Commiphora*, *Combretum*, *Tarchonanthus*, *Euclea*, *Aspilia* and *Lippia*. One of the principal objectives of the research section of the UNDP/FAO Range Management Project, established in 1966, has been to investigate methods of controlling bush, and the work has included studies on the effects of fire, cutting and herbicides.

A considerable amount of information on the effects of 2,4-D and 2,4,5-T on East African bush species is available from experiments conducted over the last 20 years (Little and Ivens 1965), but only limited practical usage has developed in rangeland. Picloram represents the first major advance in arboricide development since the introduction of 2,4-D and 2,4,5-T evaluation began in Kenya in 1964, when both commercial (Twiga 1967) and official (Pratt 1966) trials were laid down. Similar work was started in Uganda in 1965, and reported at the last British Weed Control Conference (Harrington 1968). The aim of the present paper is to report recent progress with picloram formulations and to attempt an assessment of their potential in relation to current plans for rangeland development.

METHOD AND MATERIALS

The experiments described were conducted in various parts of the rangeland area of Kenya, at altitudes ranging from 1,000 to 6,000 ft, with average annual rainfall varying between 20 and 30 in., mostly distributed in two distinct rainy seasons. Under the rangeland classification proposed by Pratt *et al*. (1966), the experimental sites would be included in Ecological Zones IV (semi-arid) and V (arid).

The principal picloram formulation tested was a 1:4 mixture of triisopropanolamine salts of picloram and 2,4-D (Tordon 101). Because of its high cost and the fact that it was not destined for sale in East Africa, little work has been done with picloram, potassium salt (Tordon 22K), but several comparisons have been made between picloram + 2,4-D and an experimental formulation of 1:4 picloram + 2,4,5-T amines (Tordon 105). In most trials picloram formulations were compared with 2,4-D (2-ethylhexyl ester), 2,4,5-T ester (either propylene glycol butylether or 2-ethylhexyl esters), 2,4,5-T amine (Dow Veon 2,4,5) or a 2:1 mixture of 2,4-D and 2,4,5-T esters.

Foliar sprays were applied either with a 'Policlair' Knapsack sprayer equipped with a solid cone 'Birchmeier' Helico-sapphire nozzle or with a portable 'Fontan' motorised mist-blower. Injection was done with a 'Jim-Gem' tree-injector (obtained from Forestry Supplies Inc., U.S.A.). High-volume stump treatments were applied by spraying, low-volume by direct application from a graduated measure.

Unless otherwise stated, final assessments were made at least 2 years after treatment and trees were recorded as dead when the bark had dried to ground level and there were no signs of regrowth from below.

RESULTS

I. Acacia drepanolobium

A. drepanolobium (whistling thorn) is the most widespread bush problem of the more productive rangelands in Ecological Zone IV. In a date of spraying experiment, the effectiveness of high-volume foliar application of picloram + 2,4-D and 2,4,5-T was shown to be closely related to rainfall and stage of growth, the highest kills being obtained from treatments applied towards the end of the long rains (late May). At this time, shoot growth was slowing down after the phase of rapid extension resulting from the onset of the rains and the new leaves were fully expanded but not yet senescent. At an a.e. concentration of 0.3% (equivalent to a dose of 1.4 lb/ac) picloram + 2,4-D gave a kill of 82% of the trees at the most susceptible period, compared with 56% using 2,4,5-T. During the early part of the long rains, and also during the November short rains, kills were considerably lower, while during the dry season, when partial defoliation occurred, there was a further reduction in effectiveness. Further details of this experiment, and of other work on A. drepanolobium are given in Ivens (1970).

Supplementary experiments testing a range of concentrations of picloram + 2,4-D at a single (high) volume, and a range of volumes at a single dose, suggest that, at the susceptible growth stage, the dose can be reduced to half of the above without reducing effectiveness, and that mistblower application at 5 gal/ac can give very similar results to spraying at 50 gal/ac. A picloram + 2,4,5-T formulation has also been found very similar in effectiveness to picloram + 2,4-D.

Injection of 15-30% total a.e. picloram + 2,4-D (half strength or undiluted Tordon 101) at the base of the trunk has proved very effective on larger A. drepanolobium 12-20 ft high. Using 0.5 ml per injection with cuts spaced 3 in. apart, 90-95% kills were obtained; with 0.75 or 1 ml applied at 4.5 or 6 in. spacing the percentage kill was reduced. In this experiment picloram + 2,4,5-T gave similar results to picloram + 2,4-D and 2,4,5-T amine alone was also promising at a similar concentration range. In another experiment 36% of 2,4,5-T amine was more effective than 15% picloram + 2,4-D, while 2,4,5-T ethyl hexyl ester was entirely ineffective.

Treatment of freshly cut stumps by spraying with 0.5-1.5% total a.e. picloram + 2,4-D in water has been very effective in some experiments and ineffective in others (Ivens 1970, Twiga 1967). Application of small volumes of the concentrated

mixture has so far given more consistently successful results (Little 1970). ...o
was started in 1969 to compare the effectiveness and reliability of picloram + 2
as low-volume concentrate and high-volume spray treatments, and of 2,4,5-T ester
sprayed in oil, in an experiment with applications at 6 dates during the year.
Results are as yet inconclusive, but suggest that seasonal variations do occur.
available evidence suggests that picloram + 2,4-D gives better results on
A. drepanolobium stumps than 2,4,5-T ester sprayed in oil or amine applied in
concentrate form.

Picloram has been tested as a soil treatment, both in the form of 10% pelle
(Tordon 10K) and 2% granules based on disodium tetraborate (Borolin), applied to
small trees shortly before a period of heavy rain. The two formulations gave
considerably higher percentage kills than other materials tested, including fenu
bromacil and prometon, but the dose required, of the order of 1 g a.e. per tree,
high in comparison with the 0.05-0.1 g picloram + 0.2-0.4 g 2,4-D per tree givin
control with injection and foliar application.

II. Other tree Acacia spp.

On A. hockii, the main bush species in Uganda and also important in western
Kenya, Harrington (1970) reports poor control from foliar spraying with picloram
but more promising results from stump application of picloram or picloram + 2,4-
The mixture applied to regrowth of A. gerrardii has given only moderate control
doses up to 2 g total a.e. per tree (Outram 1970). Foliar application of 0.125%
picloram and up to 0.5% picloram + 2,4,5-T have also failed to give satisfactory
kills of A. seyal in Kenya (Parker, unpublished results).

III. Acacia brevispica

This multi-stemmed, sometimes scandent shrub is one of the most troublesome
bush species, as it frequently grows to a height of 12 ft in impenetrable thicke
For the same reason it is one of the most difficult to control by chemical or ot
methods. Foliar treatment from the ground is usually impracticable without
preliminary cutting and has not been tested. Picloram has been tested on 6 ft h
regrowth, however, and at 0.25-0.5% (1.3-2.0 lb/ac) gave kills of 70-90%, while
kill with 2,4,5-T ester at up to 2% did not exceed 20% (Parker, unpublished resu
More critical work with picloram + 2,4-D is required on regrowth of this species

Treatment of freshly cut stumps with picloram + 2,4-D concentrate was teste
recently, the chemical being applied with a paintbrush. There were from 5-40 st
on the plants treated and an average of 1 g total a.e. per plant was used.
Preliminary results are promising, only 30% of the treated plants having resprou
to an average height of 5 in. after 4 months, while untreated plants had reached
average of 30 in., but further observations will clearly be needed. A. brevispi
represents a type of bush on which granule application would be the most conveni
form of treatment. Picloram 10% pellets applied during a poor rainfall season h
caused defoliation, but little kill, at doses of 2-4 g/plant and would be expect
to be more effective under more favourable conditions.

IV. Tarchonanthus camphoratus

In rangeland Tarchonanthus normally grows in the form of numerous shoots
arising from a large lignotuber. Foliar spraying is generally the only type of
treatment possible, and a date of spraying experiment similar to that described
A. drepanolobium was conducted in 1967-8. Picloram + 2,4-D again proved superio
2,4,5-T ester, maximum kills with a concentration of 0.3% (equivalent to 1.2 lb/
being 80 and 54% respectively, and effectiveness was again related to rainfall.
Shoots of the plants studied continued to grow throughout the year, the rate
gradually reducing, but not to zero, during the dry season, and the susceptible
period was later in relation to the rainy season than with the Acacia, i.e. earl

dry season rather than late, long rains. The susceptible period also appeared to be more prolonged with this species. With a mistblower application of picloram + 2,4-D in June 1967, a dose of 1 lb/ac in 5 gal water gave a kill in excess of 90%.

V. Commiphora and associated species

Commiphora species, especially *C. africana* and *C. riparia* are the dominant trees over extensive areas of bushland in Ecological Zone V. In a large-scale trial started in September 1967 a comparison was made between the effects of picloram + 2,4-D (1 part picloram K + 4 parts 2,4-D amine) and 2,4,5-T + 2,4-D esters (1:2) applied with mistblowers to trees 6 ft high or less. With both materials at a total a.e. dose of 1.5 lb/ac in 5 gal water approximately 80% of *C. africana* and 100% of *C. riparia* were killed. Some associated species (e.g. *Lannea alata*) were affected more by the picloram than the 2,4,5-T mixture, others (e.g. *Grewia* spp.) were more susceptible to the 2,4,5-T mixture. There was little difference between the two treatments in overall effect on the total bush population.

In the same trial picloram + 2,4-D in water and 2,4,5-T + 2,4-D in diesel oil were tested on larger trees, either as stump sprays (on trunks less than 4 in. diameter) or on frilled trunks above 4 in. diameter as basal bark sprays. Kills were generally higher than with the foliar treatment, 90-100% on *Commiphora* spp., and again there was little difference in overall effectiveness between the two mixtures. Injection of picloram + 2,4-D has been equally effective on *Commiphora* and most associated species, and has been found quicker and more convenient than stump or basal bark treatment. It is also cheaper than spraying 2,4,5-T + 2,4-D in diesel oil.

VI. Combretum species

The multi-stemmed shrub *C. volkensii* is a major problem in the coast hinterland region and has proved highly resistant to herbicides. Directed foliar sprays of picloram + 2,4-D at up to 0.2% (0.5 lb/ac) and 2,4,5-T or 2,4-D esters up to 0.5% (1.3 lb/ac) on regeneration at two stages of growth caused only temporary dieback. Kills with the same chemicals (2,4,5-T and 2,4-D in diesel oil) applied to stumps at three times the above doses did not exceed 20%.

Two species of *Combretum* also occurred in the trial described in section (V). *C. exalatum* was one of the most resistant bushes present, though stump treatment gave a moderate degree of control. *C. contractum*, on the other hand, was one of the more susceptible species, both to foliar and stump treatment; equally effective control was obtained with 2,4,5-T + 2,4-D and picloram + 2,4-D.

VII. Lippia species

The small shrubs *L. javanica*, and the closely related *L. ukambensis* with which it is frequently associated, are common invaders of rangeland at medium altitudes. In an experiment in which picloram + 2,4-D at 1 lb total a.e./ac and 2,4,5-T ester at 2 lb/ac were applied to *L. javanica* in 5 gal water/ac by mistblower in June 1969, 80 and 70% respectively were dead a year later. During the intervening period the plots were affected by an accidental grass fire, though this had only temporary effects on unsprayed plants. *L. javanica* was also found susceptible to foliar application of 2,4-D or 2,4,5-T at the same time of year in work by Hocombe (unpublished results), and complete kill after spraying stumps with picloram + 2,4-D is recorded by Outram (1970).

DISCUSSION

It is clear from the results described that, as has been found in other parts of the world, picloram formulations are more effective than 2,4,5-T or 2,4-D on some Kenyan bush species and similar in effectiveness on others. The current approximate costs per lb a.e. of these herbicides in Kenya are as follows: 2,4-D ester K. Shs 8/00, 2,4,5-T ester 20-25/00, picloram + 2,4-D (total a.e.) 48/00, picloram K. Shs 180/00. Obviously the cheaper chemicals will be used where they give satisfactory results. With Lippia, for example, it appears possible to obtain control at lower cost with 2,4-D than picloram + 2,4-D, and 2,4-D is also a successful treatment on Aspilia mossambicensis (Ivens, unpublished results) and Solanum incanum (Brzostowski 1960). Likewise, with Commiphora and a number of associated species, foliar treatment with 2,4,5-T + 2,4-D is as effective and cheaper than picloram + 2,4-D, though on larger trees, stump or injection treatment with picloram + 2,4-D is cheaper than with 2,4,5-T + 2,4-D, because of the added cost of oil carrier with the latter. On those Acacias tested, and on Tarchonanthus, however, the increased cost of picloram + 2,4-D over 2,4,5-T is offset by its greater effectiveness as a foliar spray. Further work is needed on Acacias to determine whether 2,4,5-T amine can be developed into a lower cost injection treatment.

Different methods of application are needed for different types of bush. The methods permitting the most economic use of chemicals are injection and low-volume stump treatment, with both of which there is none of the wastage associated with spraying whereby a proportion of the liquid applied fails to contact the target. Injection is suitable for single-stemmed trees with trunks above about 2 in. diameter, while stump treatment is an obvious choice for species which can be utilised for charcoal. For many smaller types of bush, however, especially multi-stemmed species and clumps of regenerating shoots, there is no real alternative to foliar application. It has been shown on several species that mistblower application can give good results and mistblowers permit the treatment of large areas in a relatively short time. The importance of stage of growth in the application of foliar treatments has been demonstrated and determination of the most susceptible stage of a wider range of species growing under a wider range of conditions should be an important objective of future research.

The key factor in the acceptance of chemical bush control in rangeland is the cost of treatment in relation to the increased production made possible. In the absence of experimental evidence on this point from Kenya only very approximate estimates can be made. On relatively high-potential rangeland the gross annual return is estimated to be of the order of K. Shs 20/00 per ac. If half this potential is lost through the presence of bush, as must frequently occur in moderately dense infestations, the expense of control treatments costing 10-20/00 per ac would be repaid in 1-2 years, assuming effective utilisation of the increased forage produced. Thus application of 1-2 lb/ac 2,4-D to control Lippia or other susceptible species can be considered economically practicable. This cost would also cover injection of up to about 800 trees/ac with picloram + 2,4-D. The chemical cost of low volume application to stumps would be of the same order and, although the cost of cutting makes stump treatment more expensive, this can often be offset by utilising suitable trees for charcoal. For foliar application of picloram + 2,4-D it is doubtful whether doses in excess of about 0.5 lb total a.e./ac can be considered practical under present economic conditions, except on a limited scale.

In less productive rangelands, which include the majority of the areas where new ranching development is taking place, returns are likely to be considerably lower, so that only the cheapest chemical treatments could be considered at present. As the standard of development improves, however, and the costs of alternative control measures rise, it seems likely that, even in these areas, the advantages of chemical bush control will increasingly come to outweigh its expense.

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A 3-YEAR EXPERIMENT WITH GRANULAR HERBICIDES IN VINEYARDS

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Summary An experiment was carried out in a vineyard in Attica (Greece) in which the same dose of six different granular herbicides (chlorthiamid, dichlobenil and different mixtures of triazines and dichlobenil) were applied annually for 3 years. The herbicidal action of all was good, in varying degree. Since the third year of application, however, phytotoxic symptoms (marginal leaf chlorosis) of varying severity has appeared on the vines.

The herbicides had no effect on the yield. There was a marked difference in the effect of all the herbicides on Cyperus rotundus.

INTRODUCTION

Most of the Greek vineyards are found in arid regions and on slopes, where the transport of water and tools is difficult. These special conditions have helped the introduction of granular herbicides in the Greek market, as did their easier handling. In order to determine the efficacy of each granular product in controlling weeds, and their residual action and the possibility of phytotoxicity, the Vine Institute of the Greek Ministry of Agriculture has undertaken an extensive study in different viticultural regions of Greece, such as Attica, Creta, Peloponnesus and Thessaly. The two commercial products chlorthiamid and dichlobenil, as well as several experimental mixtures of triazines and dichlobenil were tested.

In recent years an extensive investigation was initiated on the application of granular herbicides in vineyards. Julliard and Ancel (1967) have noted in Alsace that chlorthiamid and dichlobenil did not cause a decrease in grape production after three years of application; however, they observed some phytotodicity on vines treated with chlorthiamid on permeable soil. Vergnes et al. (1967/8), in Southern France, have observed phytotoxic symptoms (marginal leaf chlorosis) after the application of chlorthiamid at a dose of 12 kg a.i./ha. Lider and Leonard (1968) used dichlobenil and chlorthiamid to control Convolvulus arvensis in Californian vineyards; they found that subsurface, banded applications were more effective than surface applications and that the more soluble chlorthiamid was more effective than dichlobenil in surface applications. Agulhon (1968) observed some necrosis on vine leaves after the application of chlorthiamid in Southern France. These symptoms, which were observed in vineyards on light soils, did not result in decreased yields.

We have observed (Daris, 1968) in Attica a selection of Cyperus rotundus in all the experimental plots two years after applying chlorthiamid, dichlobenil and mixtures of dichlobenil and triazines. Julliard and Huglin (1968) reported that chlorthiamid gave better weed control than dichlobenil but chlorthiamid was more toxic to the vines. They attributed the lower phytotoxicity of dichlobenil to the significant losses of this compound from the soil surface.

Agulhon (1969) in his general report on weed control in France for 1968, states that chlorthiamid has been more efficient than dichlobenil but it induced phytotoxic symptoms on vines in many regions (Alsace, Champagne, Bourgogne and Midi). The symptoms varied from marginal leaf chlorosis to necrosis of the leaf blade and premature leaf-fall. However, the symptoms observed did not influence grape production or the vigour of the vines. Agulhon et al. (1969) found that applications of chlorthiamid, on a light sandy soil, resulted in the formation of a decomposition product: 2,6-dichlorobenzamide (B.A.M.) in the soil zone of 0-40 cm below the surface. It remains to be investigated if the accumulation of B.A.M. in the deeper zones will have an unfavourable effect on the development of the grapevine. In the vineyards of the Midi (France) Amphoux et al. (1970) observed that dichlobenil or chlorthiamid at 12 kg a.i./ha can eliminate Cynodon dactylon, but both products induced necroses on the leaf margin which in certain cases were extended to the greater part of the leaf blade.

METHOD AND MATERIALS

Since 1967 an experiment with granular herbicides has been conducted in one of the experimental vineyards of the Vine Institute in Attica, near Athens.

The soil of the vineyard is a sandy-clay loam and the variety cultivated is Muscat of Hambourg, a table grape, grafted on American rootstocks. The vineyard was planted in March 1958 and the planting distances are 1.5 x 1.5 m. The vineyard was divided into experimental plots of 100 m^2 each and six different granular herbicides were applied pre-emergence. The treatments are given in Table 1.

Table 1

Treatments

	Chemical composition	Dose kg a.i./ha
A	cultivated control	
B	chlorthiamid 7.5%	9
C	dichlobenil 7.5%	9
D	atrazine 2% + dichlobenil 3%	5 + 7.5
E	atrazine 2% + dichlobenil 2%	5 + 5
F	simazine 2% + dichlobenil 2%	5 + 5
G	simazine 2% + dichlobenil 3%	5 + 7.5

The weeds found in the vineyard are:

Anagallis arvensis
Anthemis chia
Avena fatua
Calendula arvensis
Capsella bursa-pastoris
Chenopodium sp.
Convolvulus arvensis
Cynodon dactylon
Cyperus rotundus
Fumaria officinalis
Hordeum murinum
Inula viscosa
Lamium amplexicaule
Malva silvestris
Matricaria chamomilla
Reseda alba
Sisymbrium irio
Sonchus oleraceus
Trifolium sp.

Monthly observations were made on the efficacy of each product, the percentage of each plot covered by weeds, resistant weeds and on phytotoxic symptoms of the vines. The controls were cultivated 2-3 times per year with an ordinary small viticultural motocultivator.

During harvesting the grapes produced on each plot were weighed separately; the branches removed during the pruning were also weighed, in order to see the influence of the herbicides on the vigour of the vines.

RESULTS

Since the first year of application, satisfactory control of the annual broad-leaved weeds has been obtained with all products. Differences in the weed cover are given in Table 2.

Table 2

Percent weed cover

Dates of observation	A	B	C	D	E	F	G
+ 15. 3.67	0	0	0	0	0	0	0
4. 5.67	85	40	35	25	25	25	25
+ 18. 3.68	90	50	45	20	15	15	10
15. 5.68	95	15	20	10	15	15	15
+ 30.12.68	90	30	35	10	10	10	10
3. 2.69	98	10	12	0	0	2	0
1. 3.69	99	1	4	0	0	1	1
14. 6.69	99.5	15	18	35	35	35	30
3. 2.70	100	10	15	2	4	6	5

Treatments and rates as in Table 1

+ = dates of application during the three years of experimentation. The entire vineyard was cultivated just before the first application (15.3.67).

Since the second year of treatment Cyperus rotundus has been selected out in all the treated plots. It emerges in April and in a short time covers the entire plot. It is interesting to note that the plots treated with chlorthiamid and dichlobenil did not show any increase of the population of Cyperus between the second and third year (the area covered varying between 15-20%). On the other hand plots treated with the four different mixtures of triazines and dichlobenil exhibited a very significant increase in Cyperus in the same period, rising from 10-15% in the second year to 30-35% in the third year. Other resistant weeds found in the plots are Convolvulus arvensis and Cynodon dactylon. The two weeds were present since the beginning of the experiment but they did not create any problem because of their limited numbers.

Neither the fruit, nor the wood production at the time of pruning, gave statistically significant differences, however, we must reserve judgement on these results as the yield and the wood production varied significantly between the vines in the same plots.

Phytotoxic symptoms did not appear in the first two years of the experiment, but in the third year and during observation in June, marginal leaf chlorosis of varying degrees was observed in all the treated plots. The symptoms caused are given in Table 3.

Table 3

Phytotoxic symptoms on grapevine

Herbicide used	Symptoms	Extent of symptoms in the plots
chlorthiamid	Marginal leaf chlorosis, 1 cm around the leaf blade	On all the vines of the plot
dichlobenil	Marginal leaf chlorosis covering 0.5 cm around the leaf blade	On most of the vines of the plot
dichlobenil + atrazine	Chlorosis of the teeth of the blade. Later the leaves appear more circular, as the necrotic teeth fall off	On certain vines of the plot
dichlobenil + simazine	Very light chlorosis on the teeth of the leaf blade	Only on certain vines of weak growth

Remark: No differences were observed between the symptoms caused by the mixtures of atrazine and dichlobenil used at different doses, or between mixtures of dichlobenil (5 and 7.5 kg a.i./ha) and simazine.

DISCUSSION

The results obtained in this investigation show that the granular herbicides tested gave very satisfactory control of annual weeds. This has also been observed in other parts of Greece. The more resistant weeds were controlled better by chlorthiamid than dichlobenil, as can be seen by the retardation of growth of Cynodon dactylon. This effect has also been observed in the experimental vineyards of Larissa (Central Greece) and Helia (Southern Greece) and by Amphoux et al. (1970) in Southern France. The suppression of Cyperus rotundus to a certain level by chlorthiamid and, to a lesser degree, by dichlobenil during the second year after treatment must also be noted. This weed is one of the most resistant to all the herbicides we have tested (over 40).

The problem of phytotoxicity that arose after the third year of application in the vineyard studied needs discussing in more detail. The most intense symptoms were caused by chlorthiamid. Similar effects on the vine foliage have been observed in other experimental vineyards in Attica. Everywhere chlorthiamid caused more severe damage than dichlobenil. We have noticed in another vineyard in Attica a variation in the phytotoxicity of chlorthiamid according to the situation of the experimental plots on the slope. The inclination of the vineyard is 25-30°; plots on the top of the slope showed more severe symptoms than plots in the lower part of the vineyard.

No differences were observed in the yield between treated plots with symptoms and cultivated plots. Similar results were also reported by Julliard and Ancel (1967) and Agulhon (1968). We must, however, stress that our observations, as well as those of other investigators, were made after two or three years of application (Agulhon, 1968 and 1969; Agulhon et al., 1969; Amphoux et al., 1970; Daris, 1968; Julliard and Ancel, 1967). More time is needed to confirm that the symptoms observed do not affect the following year's production or the vigour of the vines.

All the mixtures of dichlobenil with atrazine or simazine gave less severe phytotoxic symptoms than chlorthiamid and dichlobenil alone. The mixtures of simazine and dichlobenil were the least harmful. In all the plots where mixtures of triazines and dichlobenil were applied, Cyperus rotundus increased markedly.

Two years ago, we initiated a study of other granular herbicides. These are mixtures of a chlorotriazine with a methoxytriazine and of a chlorotriazine with dichlobenil. Both mixtures have given good weed control and no phytotoxicity as yet.

We have noted before the importance of granular herbicides for arid and mountainous regions, however, the phytotoxicity observed and the high cost of these products have been obstacles to their use on a wider scale. New low-cost formulations must be developed, which will control more weeds and will not be phytotoxic.

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Proc. 10th Br. Weed Control Conf. 1970

HERBICIDE INFLUENCE ON THE ARSENIC UPTAKE OF GRAPES. A STUDY BY NEUTRON ACTIVATION ANALYSIS

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Summary A 4-year experiment with paraquat and atrazine, carried out in a vineyard in S. Greece, resulted in *Sorghum halepense* being selected out. To control this remaining weed we then applied monosodium acid methylarsonate (MSMA), with success.

In order to investigate the uptake of arsenic from MSMA by the vines, grape samples were analyzed using neutron activation analysis. For this purpose dried grapes were irradiated with neutrons for 10 hours at the Democritos Nuclear Reactor. The arsenic content was calculated from the induced activity of As-76 after a radiochemical separation. The results show that the quantity of As in grapes taken from a vineyard treated with MSMA, after a 4-year application of atrazine, is five times higher than in the control (0.24-0.28 µg As/g dry matter instead of 0.04-0.07), whereas in plots treated with MSMA after a 4-year application of paraquat the arsenic content of the fruit was twice as high as in the control (0.08-0.11 µg As/g). Consequently it would seem that atrazine increases the uptake of As by the vine.

INTRODUCTION

Continuous application of the same herbicides in vineyards in the southern part of the Greek peninsula has resulted in the selection of *Sorghum halepense*. In order to control this resistant weed, arsenical herbicides like MSMA were used with satisfactory results. The efficacy of MSMA in controlling *Sorghum halepense* in cotton fields has also been noted by Rea (1964), in young citrus groves and in vineyards by Lange *et al*. (1968 and 1969). Outstanding control of the same weed was also obtained in orchards in California (Elmore *et al*., 1966 and 1967) and Southern Spain (Anon, 1968).

The question raised after the application of arsenical herbicides was to determine if the arsenic absorbed by the plant would be dangerous to the consumer. Lange *et al*. (1968) have found that when the foliage was sprayed with MSMA, residues of arsenic appeared in the fruits. The levels were extremely low, but the presence of traces of As constitutes an added obstacle to the registration of MSMA in U.S.A., for use in vineyards.

The authors of the present article have shown previously (Grimanis *et al*., 1970) that during the time of harvesting in the hot and dry climate of Attica, there was no difference between the quantity of arsenic in the grape berries (pulp, juice, seeds and skin analyzed separately) from vineyards treated with MSMA and those from untreated vineyards. The present work was undertaken to evaluate the absorption of As by the vine under different climatic conditions, and to determine the possible influence of the previous treatments with other herbicides on the uptake of arsenic.

In each case we used neutron activation analysis as a method of determining the arsenic content. In general this method (Bowen and Gibbons, 1963; Fer and Fourcy, 1969; Fourcey et al., 1966; Lyon, 1964) consists of determining an element present in a sample by measuring the induced radioactivity of the element, after irradiating the samples with thermal neutrons from a reactor, and by comparing this radioactivity with that of a known quantity of the same element irradiated under identical conditions.

METHOD AND MATERIALS

(a) In the vineyard

Since 1966 an experiment on weed control has been carried out in a vineyard in the region of Amalias (Southern part of the Greek peninsula). The variety cultivated is Black Corinth, used for the production of dried raisins. The age of the vines is 70-75 years.

Distance of planting: 1.5 x 1.5 m
Total area for experimentation: 4000 m^2. This area is divided in three randomized blocks of 4 experimental plots each. Plot area = 333 m^2.
Treatments: 1. cultivation (without herbicides)
2. paraquat (twice per year)
3. atrazine (six plots)

For 3 consecutive years the same doses of herbicides were applied as follows:

paraquat - 2 kg a.i./ha per year
atrazine - 5 kg a.i./ha per year

The weeds found in this vineyard are:

Calendula arvensis	Muscari comosum	Hypericum crispum
Euphorbia sp.	Sorghum halepense	Picris spinulosa
Anthemis chia	Agropyron repens	Papaver rhoeas
Cynodon dactylon	Ornithogalum nanum	Chrysanthemum segetum
Fumaria officinalis	Sonchus oleraceus	Equisetum sp.
Anemone coronaria	Trifolium stellatum	Allium vineale
Dracunculus vulgaris	Avena fatua	Amaranthus blitum
Ranunculus sp.	Hordeum murinum	Veronica persica

After the 3rd year of application, in all the plots treated with herbicides, Sorghum halepense was the main weed and covered around 75% of the vineyard. In order to control it an arsenical herbicide was applied on the 19th May 1969 in all the experimental plots, except for 3 plots treated with atrazine. The dose applied was 4.3 kg a.i./ha.

In a period of 20-30 days all the plants of Sorghum halepense were destroyed and up until the time of harvesting no regrowth has been observed. The harvesting was done on the 18th August 1969 and samples of grapes from all the experimental plots (two samples per plot) were taken for analysis.

(b) In the nuclear laboratory

The grape samples were washed many times with water, rinsed with distilled water and ground with a mixer. The resulting pulp was transferred to Petri dishes and dried at 75°C for 40 hours. The dried samples were ground in a Perspex mill.

The samples, weighing 100-150 mg each, were placed in polyethylene tubes (10 x 30 mm). Alliquots of 0.5 ml of a standard arsenic solution, containing 50 μg As/ml, were transferred in identical polyethylene tubes. The tubes were heat-sealed and irradiated in the Democritos reactor, using the rotation system of the reactor, for 10 hours in a thermal flux of about 2.2×10^{12} neutrons/cm^2/sec. A second irradiation, using the pneumatic transfer (rabbit) system of the reactor was performed to determine the chemical yield correction for arsenic isolated by the proposed radiochemical procedure (Grimanis, 1969).

After irradiation each of the samples was transferred into a 100 ml beaker containing 1 ml of arsenic carrier solution, 1 ml of each of the holdback carrier solution of copper, manganese and sodium, 3 ml of concentrated nitric acid and 2 ml of 80% perchloric acid. The beakers were heated until white vapours of perchloric acid were evolved, then they were cooled in an icebath to room temperature and the residues were diluted with a mixture of 7 M perchloric acid and 1 M hydrobromic acid, and finally transferred to a separatory funnel containing an equal volume of benzene.

The As-76 and the arsenic carrier were extracted quantitatively into benzene, as arsenic tribromide, back extracted into water, precipitated as metallic arsenic by reduction with sodium hypophosphate and dissolved in 2 ml of nitric acid. The solution was transferred into a 5 ml volumetric flask and diluted to volume with distilled water. The arsenic standard was processed in an identical manner.

The volumetric flasks containing the As-76 from the irradiated grape samples or from the arsenic standard were counted in a sodium iodide (thallium activated) well-type γ scintillation counter (2 x 2.375 in.) for 3 minutes. The radiochemical purity of the isolated arsenic was checked in a 400 channel pulse-height analyser, but contaminants were absent.

The recovery of arsenic averaged 80%. This determination was made by the reactivation method previously reported (Grimanis, 1969).

RESULTS

The arsenic found in the samples of berries is given in the following table. All the results are expressed in μg of arsenic per g of dry matter of the berries.

Randomized blocks	Number of samples	cultivated plots (control)	paraquat and MSMA	atrazine	atrazine and MSMA
1st	1	0.07	0.08	0.05	0.25
	2	0.04	0.11	0.04	0.28
2nd	1	0.04	0.09	0.06	0.24
	2	0.04	0.08	0.05	0.25
3rd	1	0.05	0.11	0.04	0.27
	2	0.04	0.10	0.05	0.28
Mean		0.047	0.095	0.048	0.261

Least statistically significant difference (L.S.D.) (5%) = ± 0.016
(L.S.D.) (1%) = ± 0.030

No differences were found between the cultivated control and those treated only with atrazine.

The coefficient of variability (C.V.) was 1.06% which means that the samples from the different plots, treated identically, were extremely uniform in As-content.

DISCUSSION

The results show that the quantity of arsenic in grapes taken from the plots in which no herbicides were used was around 0.047 µg/g of dry matter. The quantity of arsenic in the grapes taken from the plots treated for 3 consecutive years only with triazine (atrazine) was also on the same level (0.048 µg/g). In the plots treated with paraquat, for 3 consecutive years, and the last year also with MSMA, the quantity of As in the grapes doubled reaching 0.096 µg/g. This augmentation is considered to be due only to the added MSMA, as the paraquat is immediately inactivated in contact with the soil.

These results seem to be in contrast to those stated in our previous article (Grimanis et al., 1970), where the applied MSMA had not increased the quantity of As in the grape berries, but on looking more closely at the problem we can give an explanation: the influence of soil and rainfall. In the region of Attica, where no differences were found between plots treated with MSMA and untreated plots, the soil is heavy and the season is completely dry from June (when MSMA was applied) until September (harvesting period). On the contrary in the region of Amalias where the present work was carried out, the soil is light and permeable and in the period from the application of MSMA till harvesting rain fell on 4 occasions, so that the arsenic reached the root level (around 60 cm below soil surface) in a short time and the uptake of As was high.

In the plots treated with atrazine for 3 consecutive years, and in the last year also with MSMA, the uptake of arsenic is quite high, the As in berries reaching 0.26 µg/g of dry matter. This proves that atrazine, which has a residual action in the soil of several months, facilitates the uptake of arsenic by the plant. It can be seen that the dose of arsenic found in the berries is much lower than the maximum tolerable dose of As, which is 4 µg/g of dry matter (Comar, 1955) and therefore the consumer is in no danger from these grapes.

The experiment has not finished, as it remains to find out after how many years of continuous application of MSMA, the uptake of As by the grapes will exceed the tolerable limits. This danger is unlikely to be realised as total control of Sorghum halepense can be achieved in 2-3 years, with two applications per year; furthermore MSMA is very soluble in water, hence the winter rainfall will probably leach the compound below the root system of the vine.

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THE EFFECT OF CHEMICAL AND MECHANICAL WEED CONTROL ON THE GROWTH OF YOUNG CITRUS CV. MARSH GRAPEFRUIT

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Summary Several chemical and mechanical treatments were applied around young budded citrus plants cv. Marsh grapefruit in Trinidad and growth measurements made over a period of 12 months. Treatments which resulted in bare ground, whether by chemical or mechanical means, produced growth increases very highly significantly superior to those where weed covers were maintained throughout the year.

INTRODUCTION

Weed growth is very rapid in a warm, moist climate like Trinidad and if weed control is inadequate, a crop can become completely smothered by weeds in a short space of time. Tree crops in Trinidad are usually planted after a minimum of land preparation followed by an occasional cutlassing immediately around the plants. This method of weed control is insufficient to eliminate competition for nutrients, moisture and sunlight by weeds.

Several herbicide experiments have been carried out in Trinidad on young and mature citrus and in nursery plants (Kasasian, 1964; University of the West Indies, 1969). In nursery plants mixtures of TCA with diuron, simazine, atrazine, atraton and neburon gave very promising results and in bearing citrus, dalapon, 2,4-D, 2,4,5-T, diuron, bromacil and isocil were effective. The more effective of these herbicides have been recommended for use in citrus (Kasasian and Seeyave, 1968).

In the present trial, 4 mechanical and 5 chemical treatments were compared in young citrus plants.

METHOD AND MATERIALS

In September 1967, nursery plants of nucellar Marsh grapefruit budded on sour orange stock were planted at a spacing of 20 ft x 15 ft along the centres of cambered beds 20 ft wide. Girth measurements of the stock two inches below the bud union and of the scion two inches above the union were made at two-monthly intervals for six months before the differential treatments were applied. During this period the whole area was brushcut every month. The treatments were applied on March 22nd 1968.

The plots consisted of four experimental plants along the bed and were separated from the adjacent plots by single guard plants. There were five replicates arranged in a randomized block design.

Hoeing was done manually, brushcutting by means of an Allen autoscythe and chemicals were applied by knapsack sprayers fitted with a "Dorman" no-drift nozzle to

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minimize drift on to the crop. The mechanical treatments were applied over the entire area of the plot; in addition, for the annual brushcutting treatments, it was found necessary to trample the weeds growing in the immediate vicinity of the plants every 3 months to allow some sunlight to reach the crop. The herbicide treatments were repeated as necessary either as overall sprays or as spot treatment.

The main weed species were _Paspalum fasciculatum_, _P. virgatum_, _P. conjugatum_ and _Pennisetum purpureum_ among the monocotyledons and _Borreria verticillata_, _Euphorbia hirta_, _Pueraria phaseoloides_ and _Laportea aestuans_ among the dicotyledons. The grass species were more abundant.

Girth measurements of stock and scion were made every 2 months for 12 months after treatment. At the end of the trial, on 25th March, 1969, a volume index was obtained for each tree by measuring the height, the maximum diameter of the foliage and the width of foliage at right angles to the latter; the product gives the approximate size of the plant.

RESULTS

Growth Measurements

(a) Girth There were no significant differences in pre-treatment girth increases or in girths at the time of treatment. The mean net increases in girth over the 12 months of the trial and the final girths are shown in Table 1. As there was very little difference between girth of stock and of scion only those of stock are presented here.

Table 1

Mean net increase in girth and final mean girth (mm)

	Treatment	Increase*	Final Girth*
A	Hoeing monthly	89 c	128 bc
B	Brushcut annually	35 a	81 a
C	Brushcut monthly	62 b	107 ab
D	Brushcut three-monthly	48 ab	91 ab
E	Dalapon (broadleaves cut occasionally)	65 b	110 ab
F	2,4-D (brushcut every 3 months)	54 ab	98 ab
G	Dalapon + 2,4-D	65 b	111 ab
H	Diuron + bromacil + brushcut	116 d	165 c
I	Diuron + bromacil overall	120 d	163 c
	S.E.	± 7	± 9

* Values followed by the same letter in the same column are not statistically different at the 1% level by Duncan's Multiple Range Test.

1 = sprayed 10 ft square; unsprayed area brushcut 3-monthly

Girths over the 18 months duration of the experiment for treatments A, B, E and H are presented in graphical form in Figure 1.

(b) Volume of Tree Table 2 shows the average volume index (height x longest diameter x width) at the end of the experiment.

Fig. 1. Stock girths for 4 treatments during the experiment

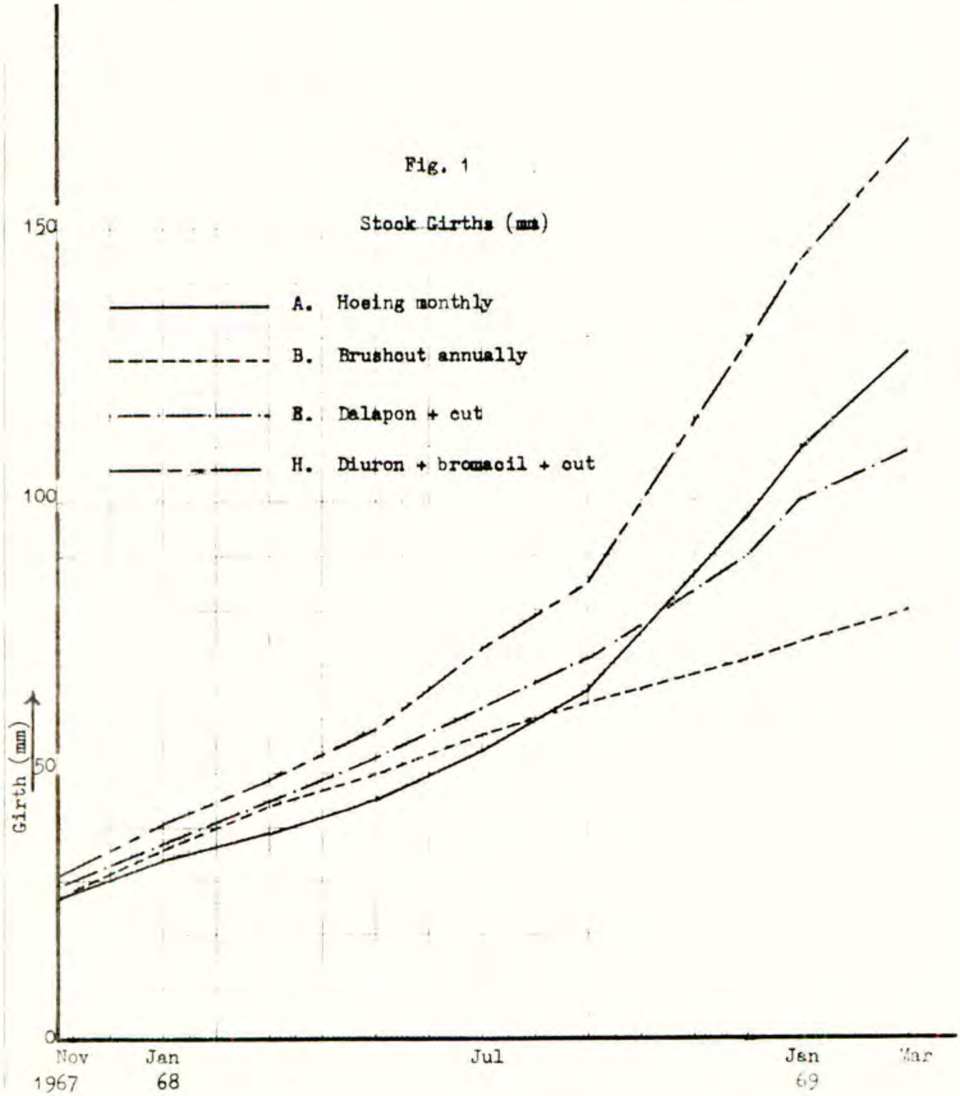

Table 2

Mean Volume index at end of trial (ft^3)

Treatment	Volume Index
A. Hoeing monthly	190 b
B. Brushcut annually	39 a
C. Brushcut monthly	56 a
D. Brushcut three-monthly	40 a
E. Dalapon	69 a
F. 2,4-D	61 a
G. Dalapon + 2,4-D	80 a
H. Diuron + bromacil + brushcut	305 c
I. Diuron + bromacil overall	327 c
S.E.	± 22

* Values followed by the same letter or letters are not statistically different from each other at the 1% level of significance by Duncan's Multiple Range Test.

Weed Control

Table 3 shows the frequency of treatments and the percentage weed cover estimated visually at the end of the Experiment.

Table 3

Number of weed control applications and % weed cover at end

Treatment	Number of applications	% Weed Cover
A. Hoeing monthly	13	17
B. Brushcut annually	1	72
C. Brushcut montly	13	100
D. Brushcut 3-monthly	4	92
E. Dalapon	4	68
F. 2,4-D	2	87
G. Dalapon + 2,4-D	4	60
H. Diuron + bromacil + cut	2	2*
I. Diuron + bromacil overall	2	7

* Refers to sprayed area; 100% weed cover outside

DISCUSSION

The maximum increase in growth was obtained by the treatments resulting in bare ground. Among the latter, chemical weeding was significantly better than mechanical weeding in the case of increase in girth and volume index but not in the case of final girth. The depth of hoeing was restricted to the top inch or so of soil but this superficial treatment may nevertheless have caused enough damage to the feeder root system of the crop to produce less growth than where the soil was not disturbed.

Among the treatments that did not result in complete weed control, dalapon with or without 2,4-D was equivalent to monthly brushcutting in the growth parameters measured and were in general better (but not always significantly so) than the three remaining treatments. Among the former treatments, those containing dalapon resulted in an almost pure stand of broad-leaved species except in two plots where Paspalum conjugatum, resistant to dalapon, was abundant. In the monthly cutting treatments on the other hand, the original weed cover, which was predominantly grass species, was maintained. It would seem therefore that the type of weed cover was immaterial and that crop growth was directly related to the degree of total weed control.

In conclusion, the experiment has shown that under the climatic conditions prevailing in Trinidad:- (1) Weed competition is a limiting factor in the growth of newly planted citrus, (2) complete elimination of the weed flora in the immediate vicinity of the crop, especially by herbicide application, leads to maximum growth, and (3) this may be achieved by spraying a mixture of 5 lb/ac diuron + 5 lb/ac bromacil around the tree with an occasional brushcutting of the unsprayed areas. It should be mentioned that this method of weed control, apart from being cheaper than an overall spray or hoeing at monthly intervals, would also reduce soil erosion which is liable to occur on slopes with bare ground.

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UNIVERSITY OF THE WEST INDIES (1969) Department of Crop Science, Herbicide Section, Report October 1967-August 1968. PANS, 15, 381-398.

RECENT DEVELOPMENTS IN CHEMICAL WEED CONTROL IN BANANAS

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Summary Chlorbromuron was very promising as a highly selective herbicide in bananas. MCPA was effective on vines and was safe on the crop if drift was prevented. The addition of a wetter did not improve the efficiency of paraquat. Mechanical clean weeding gave significantly better yields than other treatments where weeds were merely cut back.

Old banana mats were eradicated by injecting dicamba and replanting of bananas was possible 2 weeks after treatment.

The results of previous herbicide trials in bananas in the West Indies have been reported upon (Kasasian and Seeyave, 1968). The present paper summarizes the results of trials subsequently laid down in St. Lucia.

In a pre-emergence trial, average bunch weight and yield over the first 18 months was not affected by 1.5 lb/ac pyriclor, 3 lb/ac simazine, ametryne and diuron and 3 and 6 lb/ac chlorbromuron, whereas 7.4 lb/ac dalapon plus 2 lb/ac 2,4,5-T produced a marked but not significant reduction in yield. Chlorbromuron gave extremely good weed control and was safe even at 6 lb/ac. Subsequently, 3, 6, 12 and 24 lb/ac chlorbromuron and diuron were compared post-emergence to weeds and bananas in a 3-month old plant crop and in a second ratoon crop. Other treatments included 3.4 lb/ac MSMA, 0.5 lb/ac paraquat, 2 lb/ac MCPA and 2 lb/ac 2,4-D + 2,4,5-T. Chlorbromuron gave excellent control of weeds (mainly Brachiaria mutica) at the lowest rate and no symptoms developed on the plants at the highest rates. Diuron was comparable to the former in effectiveness of weed control but phytotoxic symptoms were apparent on the leaf at rates of 6 lb/ac and higher in the plant crop but was safe even at the highest rate in the ratoon crop. The other treatments also gave good results but where the base of the plant and followers were deliberately sprayed, the following treatments produced a moderate to severe effect on the followers: diuron 6 lb/ac and higher, MCPA and brushkiller. There was only a slight and temporary effect on the followers receiving MSMA spray and none on those receiving chlorbromuron.

Several large scale observation plots using chlorbromuron were laid down in various locations in the Windward Islands and the following remarks summarize the results:

1. Chlorbromuron is safe in bananas as a pre-emergence treatment on light and heavy soils.

2. It is safe where bullheads and sword suckers are used as planting material but where corms are split into pieces, there is a slight retardation in growth, possibly due to absorption of chemical through the cut surface.

3. Its post emergence effect on weeds is considerably enhanced by the addition of 0.25 lb/ac paraquat.

4. It is largely ineffective when the top soil has dried out.

5. As a post-emergence treatment in plant and ratoon crops, 0.5 lb/ac chlorbromuron plus 0.25 lb/ac paraquat controlled weeds for at least twice as long as 0.5 lb/ac paraquat alone.

Broadleaved weeds e.g. Commelina elegans and vines are not controlled adequately by paraquat. In one post-emergence trial, 0.5 and 1 lb/ac MCPA were sprayed on Ipomoea sp. climbing on banana plants. Where directed application was used to prevent the spray from coming into contact with the crop, no phytotoxicity was observed but where the chemical was sprayed directly on the crop and weeds, acute phytotoxicity symptoms appeared, including toppling of the pseudostem. The higher rate gave a complete kill of Ipomoea sp. and Commelina elegans. However, with the present system of poor management and consequent carelessness in spraying, the use of MCPA would be rather limited in banana fields.

The addition of 0.5, 1 and 2 pints per acre of a wetting agent ("Agral 90") did not enhance the activity of 0.125, 0.25 and 0.5 lb/ac paraquat on weeds at either 40 or 80 gallons of spray per acre. The minimum dosage for good control was 0.25 lb/ac paraquat with or without wetter.

In one weed competition trial, monthly clean weeding induced more rapid growth and resulted in earlier cropping than all other treatments, including monthly cutlassing. It would seem therefore that complete elimination of weeds is essential for maximum growth and that the usual practice of chopping weeds or spraying a contact herbicide, even at frequent intervals, is not entirely adequate, (Seeyave and Phillips 1969). The use of a safe and effective pre-emergence herbicide which would give complete weed control for the first 3-4 months of the banana crop would therefore achieve ideal conditions for maximum growth.

ERADICATION OF OLD MATS

Kasasian and Seeyave (1968) found that picloram injected into the pseudostem of banana plants gave a complete kill of the mat but its persistence in the soil prevented its use where bananas had to be replanted almost immediately.

In one trial, 4, 8 and 12 ml of undiluted dicamba (40.6% a.e.) and 2,4-D + 2,4,5-T (24% a.e. of each) were injected into pseudostems or corms. Corm injection gave slightly better kill but was impractical. Brushkiller failed to give a complete kill but the two higher rates of dicamba were highly effective. Growth of corm pieces planted around the dicamba treatments two weeks after application was not affected, which would indicate that dicamba may be useful in the eradication of old mats before planting.

In conclusion, the present recommendations for weed control in bananas in the Windward Islands are:-

(1) Pre-planting: 2 lb a.e./ac 2,4,5-T for brush control and 10 lb/ac dalapon for grass control.

(2) Pre-emergence: 3 lb/ac diuron, linuron, chlorbromuron, atrazine or simazine as an overall spray with the addition of 0.25 lb/ac paraquat if weeds have emerged.

(3) Post-emergence: (a) As (2) above once a year,

(b) paraquat 0.5 lb/ac as required,

(c) paraquat 0.25 lb/ac plus 0.5 - 0.1 lb/ac of above soil acting chemicals 2 or 3 times a year,

(d) 5-10 lb/ac dalapon or 3-4 lb/ac MSMA post-emergence on grasses and

(e) 1-2 lb/ac MCPA or 2,4-D (amine) on vines and broadleaved weeds as a spot treatment with great care being taken to avoid drift.

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A NEW HERBICIDE - 17623 RP: PRELIMINARY STUDIES IN SOME TROPICAL CROPS

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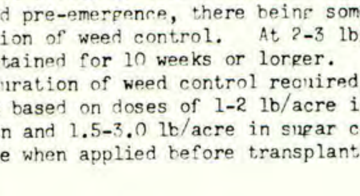
Summary The results are reported of preliminary field experiments with 2-tertiary butyl-4-2'-4'-dichloro-5'-isopropyloxyphenyl-1,3,4-oxadiazolin-5-one (17,623 RP) in groundnuts, cotton, sugar cane and paddy rice (transplanted). Useful levels of herbicidal activity lie between 1 and 3 lb/acre applied pre-emergence, there being some correlation between dose and duration of weed control. At 2-3 lb/acre good levels of control can be maintained for 10 weeks or longer. Considerations of crop selectivity and duration of weed control required, suggest that further work should be based on doses of 1-2 lb/acre in groundnuts, 1-1.5 lb/acre in cotton and 1.5-3.0 lb/acre in sugar cane. In rice, 1-1.5 lb is appropriate when applied before transplanting or 5-10 days after transplanting.

INTRODUCTION

In 1965, a new herbicidal compound, coded 17,623 RP, was prepared in the laboratories of Société des Usines Chimiques Rhône-Poulenc:-



17,623 RP

2-tertiary butyl-4-2'-4'-dichloro-5'-isopropyloxyphenyl-1,3,4-oxadiazolin-5-one.

Field and laboratory screening trials were carried out in 1965/6 and the reactions of a very wide range of weeds and crops were obtained. From 1967, trials were extended to include initial tests on a field scale in a number of tropical and temperate situations to establish the tolerance of important crops to herbicidal doses and to compare its activity with established standards in the various areas. A review of the initial results and practical uses of the herbicide was reported by L. Burgaud et al. (1969).

Initial studies showed the activity and selectivity of pre-emergence treatments to be greater than those applied post-emergence on both broadleaved and grass weeds in most situations and subsequent work was concentrated on pre-emergence use.

The experiments reported here were carried out in countries where the various crops are of importance, in an attempt to establish recommendations for the use of this herbicide in practice.

METHOD AND MATERIALS

All experiments were based on treatments of 17,623 RP applied after sowing or planting of the crop, i.e. pre-emergence of both crop and weeds, except in the case of rice where treatments were applied before or after transplanting.

Liquid formulations were applied with wheeled machines in the logarithmic experiments, but otherwise with knapsack sprayers modified to facilitate accurate application over small plots. Volume rates in the majority of cases were between 20-40 gal/acre. Applications of granular formulations in rice were made with small portable machines of the type commonly used by the small farmer in Japan.

The formulations of 17,623 RP used were a 40% w/v emulsifiable concentrate (Vt 2569) in groundnuts, cotton and sugar cane, and 2, 4 and 7.5% granules in rice.

As the experiments were carried out by several organisations, assessments have been recorded in different ways. The nature of assessments are, however, given in the corresponding tables of results. In all cases treatments were replicated three or more times and the results given are the simple means of replicates. Weed assessments were made on the basis of quadrat counts or visual assessments of per cent ground cover by one or more observers.

RESULTS

Groundnuts The experiments in the Sudan and the U.S.A. (Tables 1 and 2) show high levels of weed control and excellent crop tolerance obtained with 17,623 RP at 1-3 lb/acre applied after sowing. These preliminary field experiments indicate that 1-2 lb/acre of 17,623 RP would provide adequate weed control for at least the first 10 weeks of the crop, enabling it to become well established. The Sudan figures also show that yields comparable with hand-weeded areas are obtained with these treatments. In fact in the Sudan, the experiments of the Agricultural Research Corporation showed 17,623 RP to be the most promising herbicide for use in groundnuts.

Cotton Screening trials in the Sudan (Tables 3 and 4) have indicated that up to 5.5 lb/acre of 17,623 RP is tolerated by cotton without visible signs of phytotoxicity and that a dose of around 1.5 lb/acre provides satisfactory weed control for 13-14 weeks. In the one experiment in which crop weights and seed yields were determined, however, there were slight reductions in crop weight at 5, 9 and 14 weeks after treatment and in seed yield at harvest with 1 lb/acre as compared with the hand-weeded plots. With the higher doses there were greater reductions, but without a marked dose response as between 3 and 5.5 lb/acre.

Several screening trials in the U.S.A. with 17,623 RP at doses from 0.5 to 3.0 lb/acre gave similar results for weed control although crop tolerance was more variable even at low doses. It is suggested that relatively cool conditions and hence slower germination of the cotton may have resulted in the germinating shoots being exposed for a longer time to the herbicide in the soil surface.

Sugar cane Table 5 shows the results obtained by Mongelard and McIntyre (1970) at the Mauritius Sugar Industry Research Institute from two logarithmic screening screening experiments using 17,623 RP pre-emergence. Doses of around 3 lb/acre held weed cover below 20% for 86 and 111 days respectively in the two experiments, and measurements in Experiment 1 showed no harmful effects on cane germination and dewlap height.

Table 1

Groundnuts: Sudan. Weed control and crop tolerance 1968/69

	Assessments		17,623 RP lb/ac 1.0	1.3	1.7	2.2	3.0	Hand-weeded	Non-weeded
Weed control:	Experiment 1. Cumulative weed control. Means of assessments over 6 weeks after treatment. As number of weeds per 5 x $1m^2$ quadrats.			10.5	1.8	0.3		168	
	Experiment 1. Means of all assessments up to harvest. As % of untreated.			0.6	0.1	0.2		10.3	100
	Experiment 2. Weeds at harvest as % of untreated			6	5	3		15	100
	Experiment 3. Weed control at intervals after treatment. As % of hand-weeded.	4 weeks	38				19	100	
		9 weeks	98				41	100	
		14 weeks	91				47	100	
Weed tolerance:	Experiment 2. Crop plants in '000s/ac. at harvest.			55.9	50.1	58.2		58.1	53.5
	Experiment 3. Crop row width as % of hand-weeded at intervals after treatment.	4 weeks	105				88		
		9 weeks	86				117		
		14 weeks	105				97		
	Experiment 1. Yield in lb/ac.			2829	2780	3225		2706	891
	Experiment 2. Yield in lb/ac.			3053	2763	3251		3047	1914
	Experiment 3. Yield as % of untreated		128				181		100

Experiments 1, 2, 3. Treatment immediately after sowing. Variety: Ashford

Table 2

Groundnuts: U.S.A. Weed control and crop yield

Experiments 1 and 2. Pre-emergence application 1968

Assessments	17,623 RP lb/acre 1.0	1.5	2.0	3.0	Untreated control
Expt. 1: % control of broadleaved weeds	85.6	-	97.6	100	0
Expt. 2: % control of broadleaved weeds (After 51 days)	92.0	-	95.0	-	0
Expt. 2: % control of grass weeds (After 51 days)	80.0	-	92.0	-	0
Expt. 1: Crop stand as % of untreated	98.3	-	100	100.6	100
Expt. 2: Crop stand as % of untreated	96.0	98.6	97.3	-	100
Expt. 2: % crop injury (51 days)	0	-	0	-	0
Expt. 1: Yield in lb/acre	-		3023	2726	2777
Expt. 2: Yield in lb/acre		2169	2631	-	2107

Varieties: Expt. 1 - Starr Spanish. Expt. 2 - NC-2.

Table 3

Cotton: Sudan. Experiment 1: Weed control and seed yield 1969

17,623 RP lb/acre	Weed control Period of treatment 5 weeks A*	5 weeks B*	9 weeks A	9 weeks B	14 weeks A	14 weeks B	Mean crop weight as % of clean weeded control 5 wks	9 wks	14 wks	Seed cotton yield as % of clean weeded control	Seed cotton yield as % of non-weeded control
1	14	18	8	22	9	36	97	89	96	94.5	111.6
3	4	20	11	29	10	24	88	90	89	87.2	103.8
5.5	2	11	6	15	4	9	87	90	83	88.0	97.7

* A = % ground cover of weeds

* B = ground cover of weeds in treated plots as % of that in unweeded control

Table 4

Cotton: Sudan. Experiment 2. Crop and weed tolerance (logarithmic) 1969

17,623 RP dose range tested	Crop cotton	Maximum dose tolerated (crop)(lb a.i./acre) 4 wks	8 wks	13 wks	Minimum dose for weed control (lb a.i./acre) 4 wks	8 wks	13 wks
0.5 to 6.5 lb/ acre	Early sown	5.0	5.8	5.7	1.45	1.84	1.49
	Late sown	6.5	6.5	-	1.18	1.23	-

Table 5

Sugar cane: Mauritius. Weed control and crop tolerance (logarithmic) 1968/69

Dose range of herbicide in lb/acre	1.25-1.65	1.65-2.15	2.15-3.80	2.85-3.80	3.80-5.00	Untreated control	Days after spraying
% ground cover by weeds							
Expt. 1 17,623 RP	30.0	38.5	23.0	18.0	6.5	100	86
Expt. 2 17,623 RP	26.4	25.7	18.6	18.6	17.9	100	111
Expt. 2 diuron	33.4	26.1	21.6	19.1	16.4	100	111
Dewlap height as % of untreated							
Expt. 1 17,623 RP	97	94	97	103	98	100	86
Cane germination as % of untreated							
Expt. 1 17,623 RP	95	100	108	115	104	100	86

These two experiments were in the Super-humid zone (>100 in. rainfall per year)

Table 6

Sugar cane: Mauritius. Fixed dose experiments 1969

Experiment No. Zone Cane variety	Ground cover of weeds as % of untreated: 17,623 RP lb/ac 2	3	4	diuron 3	4	3	TCA + Na chlorate + 2,4-D 7½+3+1½	Days after spraying
3: Humid M.377/56 (Plant)	-	22.6	16.1	-	-	-	-	120
4: Super-humid M.202/46 (Plant)	-	-	27.7	45.6	33.5	-	-	74
5: Humid M.147/44 (Ratoon)	29	20	9	-	-	12	18	64
6: Super-humid M.93/48 (Ratoon)	25.7	21.6	-	37.8	-	-	-	96

No cane damage was observed with 17,623 RP in any of these experiments.

Subsequent experiments (Table 6) by the M.S.I.R.I. with fixed dose plots in humid (50 - 100 in. rainfall per year) and super-humid (100 - 150 in. rainfall per year) zones confirmed that 17,623 RP at 3 lb/acre was well tolerated by plant (virgin) and ratoon crops and retained weed cover at around 20% of the untreated for periods of 64 to 120 days after treatment. Residual weed cover indicated that the sedges Cyperus rotundus and Kyllinga monocephala, and Bothriospermum tenellum (Boraginaceae) were resistant.

Results of our own experiments in the Caribbean are presented in Table 7. Assessments at 31-35 days after treatment indicated good weed control with 1 lb/acre (79% control) and very good control with 2 and 3 lb/acre (89 and 91% respectively) - equivalent to that obtained with a relatively high rate of atrazine (4.2 lb a.i./acre). At 56-76 days after spraying the 2 and 3 lb/acre rates still gave good control of grass weeds - substantially better than atrazine at 4.2 lb/acre - but control of broadleaved weeds was only moderate (63 and 67% respectively). Weeds which appeared resistant at this stage included Croton lobatus, Cassia multiflora, Ipomoea sp., and Cyperus rotundus. At the later assessments there was some evidence of compensatory spread of broadleaved weeds, and to some extent Cyperus rotundus, in 17,623 RP treated plots where competitive grass weeds had been largely eliminated. This was particularly so in Experiment 4, in which there were virtually only grass weeds in the untreated plots at 67 days, whereas there were substantial populations of Ipomoea sp. and Croton lobatus in the 17,623 RP plots.

In none of these experiments were any visible signs of crop damage recorded, although it is recognised that yield experiments should be undertaken to determine whether 17,623 RP has any effect on cane development or sugar production.

In the Caribbean experiments, rainfall over the three months in which the work was carried out was 30 - 50 inches.

In other experiments not reported here, post-emergence applications of 17,623 RP have caused extensive leaf scorch and local necrosis on sugar cane at rates as low as 1 lb/acre. Post-emergence applications are therefore considered inappropriate, unless directed spraying techniques are used.

Rice. Table 8 presents the results of extensive series of experiments organised by the Nissan Chemical Co. in Japan over 1967, 1968 and 1969 using granular formulations of 17, 623 RP. Essentially, they show that 17,623 RP applied at 0.9 - 1.3 lb/acre before transplanting or at 1.0 - 2.5 lb/acre after transplanting gives excellent weed control and good crop selectivity for periods of 30 days or more after treatment. Pre-transplanting treatments were incorporated in the soil to prevent physical removal during subsequent flooding of the paddy.

Owing to the practice of transplanting, these techniques achieve a situation where the treatment is made pre-weed-emergence but post-crop-emergence. In other areas of the world there is an increasing preference for direct sowing of rice and investigations of appropriate application techniques for 17,623 RP have yet to be considered.

From the results it appears that 0.9 lb/acre is adequate for pre-transplanting treatments and that 1.0 - 1.5 lb/acre is required for treatments applied 5-10 days after transplanting. If treatment is delayed until 11-16 days after transplanting a slightly higher rate may be required to achieve control of emerging or emerged weeds.

Most common rice weeds of Japan are controlled with these rates: only Scirpus hotarii having appeared to be resistant from the information obtained so far.

Table 7

Sugar cane: Caribbean. % weed control based on ground cover assessments 1970

(Figures in 'Untreated' column are actual levels of ground cover recorded)

Treatments and dose lb/acre		Grass weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)	Broad-leaved weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)	All weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)
Expt. No.	Days after treatment															
1	33	82	94	94	82	16	42	84	95	95	19	57	85	90	88	39
2	33	55	82	72	63	11	77	97	99	99	62	74	95	95	92	75
3	31	94	94	94	94	47	100	100	100	100	1	93	93	93	93	53
4	32	70	96	100	81	42	73	82	100	97	33	70	88	98	89	80
5	34	73	100	91	-	4	85	89	91	-	30	78	82	81	-	37
6	35	97	98	98	-	37	92	99	100	-	17	94	97	97	-	64
7	35	100	100	100	-	13	100	100	100	-	10	90	84	88	-	31
Mean	31-35	81	94	92	80	23	81	95	97	97	24	79	89	91	90	54
1	60	80	77	73	23	34	0	86	76	92	50	25	48	74	59	90
2	76	0	50	55	0	20	18	82	87	89	78	11	65	69	52	100
3	66	45	63	53	44	98	-	-	-	-	-	42	57	47	42	98
4	67	29	55	74	11	99	0	0	0	100	1	2	13	23	10	100
5	63	49	76	78	-	15	42	70	69	-	48	40	64	66	-	67
6	56	87	87	86	-	75	28	54	76	-	17	74	77	82	-	97
7	56	99	100	98	-	57	92	85	95	-	13	83	72	47	-	87
Mean	56-76	55	72	74	19	57	30	63	67	94	35	39	56	58	40	91

No crop injury was recorded in any of these experiments.
Varieties of cane: Expts: 1 Cu 87/51, 2 B.42231, 3,4 B.4362, 5 CP.52/43, 6,7 PR.980

Table 8

Rice: Japan. Weed control and crop tolerance 1967-69

The figures in these tables give the number of experimental sites in which the specified levels of weed control or crop phytotoxicity were obtained.

A. Application 1-2 days before transplanting.
Assessment made about 35 days after treatment (1967-8).

% weed control	17,623 RP lb/ac 0.9 lb	1.3 lb
90 - 100	16	17
80 - 100	2	4
80 - 90	1	2
60 - 80	2	0
40 - 60	1	0

Phytotoxicity	17,623 RP lb/ac 0.9 lb	1.3 lb
None	11	9
Slight	11	11
Noticeable	0	3
Severe	0	0

B. Application 5-10 and 11-16 days after transplanting.
Assessments made 20-30 days after treatment (1968)

% weed control	17,623 RP lb/ac 1.9 lb 5-10 days	11-16 days	2.5 lb 5-10 days	11-16 days
90 - 100	6	4	7	4
80 - 100	1	1	2	2
80 - 90	3	2	2	5
60 - 80	1	4	0	0
40 - 60	0	0	0	0

Phytotoxicity	17,623 RP lb/ac 1.9 lb 5-10 days	11-16 days	2.5 lb 5-10 days	11-16 days
None	9	9	9	9
Slight	2	2	2	2
Noticeable	0	0	0	0
Severe	0	0	0	0

C. Application 5-10 and 11-16 days after transplanting.
Assessments made 20-30 days after treatment (1969)

% weed control	17,623 RP lb/ac 1 lb 5-10 days	11-16 days	1.4 lb 5-10 days	11-16 days
90 - 100	10	6	6	5
80 - 100	1	1	1	1
80 - 90	0	2	0	2
60 - 80	0	0	1	2

Phytotoxicity	17,623 RP lb/ac 1 lb 5-10 days	11-16 days	1.4 lb 5-10 days	11-16 days
None	4	4	3	2
Slight	6	5	4	7
Noticeable	1	0	1	0
Severe	0	1	0	1

A range of rice varieties including temperate and near tropical types, were included in these experiments and no differences in susceptibility were noted. Younger plants appear more susceptible and it is suggested that transplants should have 6-7 leaves and be about 20 cm high at transplanting to minimise reaction to 17,623 RP.

DISCUSSION

Burgaud et al. (1969) reported that 17,623 RP migrates very little in the soil and remains in the top few centimetres. Its pre-emergence herbicidal effect then becomes manifest at germination as shoots penetrate the soil layer containing herbicide. Large-seeded plants exhibit tolerance probably owing to the relatively high ratio of shoot volume to shoot surface in contact with treated soil. A faster rate of penetration through the herbicide layer may also contribute to the apparent tolerance. A connection may also be inferred with the reserves status of the plant as most bulbous, rhizomatous and deep-rooted weeds are resistant to 17,623 RP (with the important exception of the bindweeds, Convolvulus arvensis, and Calystegia sepium). Crops which can be regarded as resistant to pre-emergence applications on the basis of having large seeds or large reserves include sugar cane, groundnuts and cotton.

Many Gramineae are relatively resistant to 17,623 RP applied at doses up to 2 lb/acre post-emergence. Varying degrees of leaf scorch or local necrosis may occur, particularly with liquid formulations but the use of granules minimises this. Thus the use of 17,623 RP granules in rice before or after transplanting provides a situation where the crop is tolerant whilst the weeds will be subject to the pre-emergence effect of the herbicide.

The experiments reported here indicate that sugar cane and groundnuts tolerate 17,623 RP at doses of 3 lb/acre and over. Results from a number of areas show that at 2-3 lb/acre good levels of weed control are maintained for 8-14 weeks, and more in some cases. However, the sugar cane experiments in particular, suggest that after about 6-7 weeks the control of certain broadleaved species tends to deteriorate. In cotton, rates of up to 6.5 lb/acre caused no visible crop phytotoxicity although a yield experiment suggested slight depression with 1 lb/acre of 17,623 RP and more with higher doses. Up to 2.5 lb/acre were tolerated by transplanted rice, but lower doses have caused slight phytotoxic symptoms in some experiments. On the other hand, doses in the range 0.9 - 1.5 lb/acre in rice provided adequate control for periods of 30 days or more after transplanting, sufficient to obviate 2 or 3 hand-weedings.

It is concluded that 17,623 RP is an extremely promising pre-emergence herbicide for use in groundnuts (1-2 lb/acre), sugar cane (1.5 - 3.0 lb/acre), cotton (1.0 - 1.5 lb/acre) and in rice (1.0 - 1.5 lb/acre).

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THE PERFORMANCE OF ALACHLOR ON SOME ANNUAL SUMMER CROPS AND WEEDS IN SOUTH AFRICA

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Summary A series of trials, under a wide variety of conditions in summer crops in South Africa, demonstrated the exceptional reliability of both gran. and e.c. formulations of alachlor (CP 50144) for control of the major annual grasses. Some broadleaves, especially *Amaranthus hybridus* the most important, were effectively controlled, while control of others such as *Tagetes minuta*, *Schkurhia pinnata*, *Cleome monophylla* and *Datura spp.* was often unreliable. The addition of low rates of 2,4-D or atrazine to alachlor resulted in improved broadleaved weed control. The effect on *Cyperus esculentus* has often been acceptable to good, although unreliable in some conditions. Maize and groundnuts have shown excellent tolerance to alachlor, and under normal conditions the addition of low rates of 2,4-D appeared fairly safe to both crops. In one trial alachlor and alachlor + 2,4-D appeared safe to potatoes, while cotton (under adverse conditions) and field beans were damaged initially with good recovery later.

INTRODUCTION

Amongst the weeds encountered in trials and demonstrations in summer crops of the summer rainfall area of South Africa, the following were the most abundant in order of importance: *Eleusine africana*, *Panicum leavifolium* (moist eastern areas), *Amaranthus hybridus*, *Cyperus esculentus* and in some areas *Tagetes minuta* and *Schkurhia pinnata*. The other weeds, *Portulaca oleracea*, *Cleome monophylla*, *Physalis angulata*, *Bidens pilosa* and *Commelina sp.* assume importance in isolated areas. *Datura sp.* is scattered in distribution, but can be particularly important in the drier western and northern summer cropping areas. *Digitaria sanguinalis* is common on heavier soils (fairly high in clay), while *Brachiaria eruciformis* and *Urochloa panicoides* are the dominant grasses on sandy clays high in montmorillonite and/or illite (Margallitic forms). Other weeds, not encountered in trials, which assume some importance are *Xanthium spp.*, *Cosmos bipinnatus*, *Acanthospermum australe*, *Panicum maximum* and *Convolvulus arvensis*.

The value of alachlor alone or in combination with other herbicides was demonstrated on some summer crops, particularly maize and groundnuts, under a wide variety of conditions. Some of these results are presented here.

METHOD AND MATERIALS

All trials and demonstrations were carried out in the Orange Free State, Natal and Eastern areas of the Transvaal (Tvl) highveld on a variety of soil types ranging from sands to sandy clays.

Demonstrations 1968/69

These were unreplicated plots ranging in size from 0.25 to 2 ac. Alachlor e.c. and/or gran. was applied on all sites at planting with tractor and planter mounted sprayers or granular applicators giving a band of 12-14 in. over the crop row.

Weed control was assessed visually into categories outlined in table 2.

Replicated trials

All trials were sprayed on small plots (1/200 to 1/100 ac) in randomised block design with 3 to 4 replicates. All treatments were applied pre-emergence within two days after soil preparation and planting. Details of sites are given in table 1. E.c. and w.p. formulations were sprayed by knapsack sprayer at 25 to 30 lb/in.^{2} at a volume rate of 20 gal/ac using 3 x 8003 T-jet fan nozzles mounted on a hand lance and boom.

Weed control was assessed by counting weeds in 5 to 20 random placements of quadrates varying in size from 1.5 to 4 ft^2. The area assessed was based on the density of the weed population. For the sake of convenience all counts were converted to an area of 10 ft^2.

Weed assessments listed in the tables, unless specified, were undertaken from 4-8 weeks after planting and spraying, at a time when the crop (3 ft rows) was considered sufficiently competitive not to be affected adversely by further weed germination.

Product formulations were as follows :

Alachlor alone : e.c. - 4.8 lb a.i./imp gal.

Formulated mixtures :

Alachlor + 2,4-D e.c. - 3.6 lb a.i. + 1.2 lb a.e.
gran. - 10% a.i. + 3.3% a.e.
or 5.0% a.e.

2,4-D as the iso-octyl ester.

Tank mixtures :

Alachlor e.c. as above with atrazine 80% w.p. or 2,4-D iso-propyl/butyl esters.

Table 1

Details of trial sites

Site No.	Year	Location	Soil type	Rain 1st week	Rain 1st 3 weeks
1	1967/68	Eastern Tvl.	Sandy clay	Adequate for herbicides	Adequate for herbicides
2	1967/68	Eastern Tvl.	Sandy clay loam	Adequate for herbicides	Adequate for herbicides
3	1968/69	Eastern Tvl.	Sandy clay loam	7.9 mm	34.8 mm
4	1968/69	Orange Free	Sandy loam	0 mm	27.4 mm
5	1969/70	Eastern Tvl.	Sandy loam	14.3 mm	94.8 mm
6	1969/70	Eastern Tvl.	Sandy clay loam	15.0 mm	76.8 mm
7	1969/70	Eastern Tvl.	Sandy clay loam	22.6 mm	86.4 mm
8	1969/70	Eastern Tvl.	Sandy loam	32.5 mm	49.0 mm
9	1969/70	Eastern Tvl.	Sandy loam	15.7 mm	48.2 mm
10	1969/70	Northern Tvl.	Sandy clay loam	82.6 mm	262.9 mm
11	1969/70	Orange Free State	Sand	Adequate for herbicides	Adequate for herbicides
12	1969/70	Orange Free State	Sand	8.0 mm	89.0 mm

Organic matter content less than 2% on all sites.
Sites 3 and 7 were on same farm in different years.

RESULTS

Summarized results of demonstrations and replicated trials on weeds and crops are presented in the following tables.

Table 2

The affect of alachlor on weed species on 16 demonstration sites conducted in groundnuts and maize

	Alachlor 1 to 1.2 lb a.i./ac No. of Sites showing			Alachlor 1.8 to 2.2 lb a.i./ac No. of Sites showing		
WEED SPECIES	Total Sites/ Weed	+Accept. control	Good con-trol	Total Sites Weed	+Accept. control	Good con-trol
Eleusine africana and *Panicum laevifolium*	13	2	11	16	1	15
Digitaria sanguinalis	3	0	3	4	0	4
Cyperus esculentus	10	4	2	13	3	6
Amaranthus spp.	10	1	8	12	1	10
Tagetes minuta	6	0	0	7	1	0
Commelina sp.	2	0	0	3	0	0
Schkurhia pinnata	4	0	0	4	0	0
Bidens pilosa	5	3	0	5	2	1
Datura sp.	4	1	0	5	2	0
Portulaca oleracea	2	1	1	3	1	2
Physalis angulata	1	0	1	2	0	2

+Acceptable control = commercially acceptable to grower.
No visible crop damage was recorded at any of the above sites.

Table 3

Replicated trials with alachlor formulations and mixtures on *Cyperus esculentus* and the annual grass *Brachiaria eruciformis* (weeds/10 ft^2.

Treatments a.i. or a.e./ac	*Cyperus esculentus*			*Brachiaria eruciformis*
Site No. :	1	5	6	1
Untreated	100 a	103 a	124 a	39 a
atrazine 2.0 w.p.	-	75 a	146 a	-
3.0 w.p.	102 a	-	-	15 a
propachlor 4.0 w.p.	41 b	-	-	1 b
alachlor 2.0 e.c.	43 b	-	28 b	0 b
2.0 gran.	-	13 b	-	-
alachlor e.c. 1.5 + 2,4-D 0.5	-	13 b	-	-
gran. 1.5 + 0.5	-	15 b	-	-
alachlor e.c. 2.0 + 2,4-D 0.67	-	-	26 b	-
gran. 2.0 + 0.67	-	11 b	-	-
C.V.% (Based on logarithmic transformation of count)	8.62	17.09	23.89	-

Absence of a common letter indicates significant difference at P = .05 based on the logarithmic transformation. Log (Count + 1) alachlor/2,4-D mixtures were formulated materials.

Table 4

Replicated trials with alachlor formulations and mixtures for control of broadleaved weeds
Weeds/10 ft^2

Treatments, lb a.i./ac	Amaranthus hybridus				Physalis angulata	Cleome monophylla	Schkuhria pinnata
Site No.	2	3	5	7	3	6	4
Untreated	246 a	109 a	145 a	105	27 a	62	22 a
atrazine 2.0 w.p.	52 b	-	0 d	0	-	1	-
MCPA 1.5 e.c.	49 b	5 bc	-	-	4 b	-	-
2.0 e.c.	-	4 c	-	-	4 b	-	-
alachlor 1.5 e.c.	-	12 bc	-	-	5 b	-	24 a
2.0 e.c.	37 b	9 bc	-	-	3 b	30	22 a
alachlor 1.5 gran.	-	18 b	-	-	7 b	-	28 a
2.0 gran.	-	8 bc	28 b	1	8 b	-	22 a
alachlor 1.0 e.c.+atrazine 1.0 w.p.	15 b	-	-	-	-	-	-
1.5 e.c.+atrazine 1.0 w.p.	-	-	0 d	0	-	-	-
alachlor 1.0 e.c.+ 2,4-D 1.0 e.c.	15 b	-	-	-	-	-	-
1.0 e.c.+ 2,4-D 0.5 gran.	-	9 bc	-	-	5 b	-	6 b
alachlor 1.5+2,4-D 0.5 e.c.	-	-	5 d	0	-	-	-
1.5+ 0.5 gran.	-	-	17 bc	0	-	-	-
alachlor 2.0+ 0.67 e.c.	-	-	-	-	-	2	-
2.0+ 0.67 gran.	-	-	7 cd	0	-	-	-
C.V.%(based on log.transf.)	24.24	24.79	30.75	-	36.03	-	16.86

Absence of a common letter indicates significant difference at P = .05 based on the logarithmic transformation. Log (Count + 1).

NOTE: alachlor + atrazine and alachlor 1.0 e.c. + 2,4-D 1.0 e.c. were tank mixtures while all other alachlor + 2,4-D treatments were formulated mixtures.

Table 4 (cont'd)

Replicated trials with alachlor formulations and mixtures for control of broadleaved weeds
Weeds 10 ft^2

Treatments, lb a.i./ac		*Tagetes minuta*		
Site No.:	2	3	5	7
Untreated	471 a	146 a	87 a	116 a
atrazine 2.0	74 bc	-	0 d	1 d
MCPA 1.5	25 d	20 c	-	-
2.0	-	9 d	-	-
alachlor 1.5 e.c.	-	68 b	-	-
2.0 e.c.	218 ab	77 b	-	-
alachlor 1.5 gran.	-	62 b	-	-
2.0 gran.	-	70 b	77 ab	22 b
alachlor 1.0 e.c.+atrazine 1.0	70 bc	-	-	-
1.5 e.c.+ 1.0	-	-	5 c	1 cd
alachlor 1.0 + 2,4-D 1.0 e.c.	14 d	-	-	-
1.0 + 2,4-D 0.5 gran.	-	16 c	-	-
alachlor 1.5 + 2,4-D 0.5 e.c.	-	-	28 ab	5 cd
1.5 + 0.5 gran.	-	-	20 bc	7 bc
alachlor 2.0 + 0.67 gran.	-	-	17 bc	3 cd
C.V.%(based on log.transf.)	17.06	12.66	37.87	32.47

Absence of a common letter indicates significant difference at P= .05 based on the logarithmic transformation. Log.(Count + 1).

NOTE: alachlor + atrazine and alachlor 1.0 + 2,4-D 1.0 were tank mixtures while all other alachlor + 2,4-D treatments were formulated mixtures. Atrazine was applied as w.p., 2,4-D and MCPA as liquid formulations.

DISCUSSION

Alachlor has proved to be one of the most consistent herbicides for control of annual grasses, the major weed problem in South Africa. Amongst those controlled were *Eleusine africana*, *Panicum laevifolium*, *Digitaria sanguinalis* and *Brachiaria eruciformis*.

The efficiency of this compound on annual grasses, even under relatively dry conditions was demonstrated in a number of trials in sugar cane in Natal conducted over four years (Richardson, 1970). Amongst the grasses controlled at rates of 2-4 lb a.i./ac were *Digitaria adscendens*, *D.sanguinalis* and *Eleusine indica.*

Control of *Cyperus esculentus*, a weed of increasing importance, was often acceptable to good in trials and demonstrations (table 2 & 3) however, some variability did occur. Commercial applications of alachlor in maize during the 1969/70 season indicated that deep seed bed preparation, combined with early effective rain after application were important requirements for control of this weed. Activity on *Cyperus esculentus* was reported in sugar cane trials in Natal (Richardson, 1970) although it was generally considered that alachlor could not be recommended where this weed was dominant.

Table 5

Vigor assessments and crop yields in cultivated conditions+

Treatments lb a.i. or a.e./ac	Maize		Field (dry) beans Michigan pea (Var. Sanilac)	
	Site 5	Site 7	Site 8	
	Yields 200 lb/ac	Yields 200 lb/ac	Health 57 days	Yield 200 lb/ac
atrazine 2.0 w.p.	15.18	13.48	-	-
alachlor 1.5 e.c.	-	-	1.67	5.30
2.0 e.c.	-	-	3.00	5.00
alachlor 2.0 gran.	14.60	11.70	-	-
alachlor 1.5 e.c.+atrazine 1.0 w.p.	15.53	13.61	-	-
alachlor 1.5+2,4-D 0.5 e.c.	16.03	14.19	3.33	4.29
1.5+ 0.5 gran.	16.89	15.11	-	-
alachlor 2.0+2,4-D 0.67 e.c.	-	-	4.00	3.72
2.0+ 0.67 gran.	15.60	13.38	-	-
Cultivated check	14.71	12.10	1.33	5.27
S.E. of means	1.09	0.96	-	0.29
LSD P = .05	N.S.	2.81	-	0.95

Treatments lb a.i. or a.e./ac	Potatoes	Groundnuts	
	Site 9	Site 11	Site 12
	Yield 150 lb/ac	Yield 200 lb/ac	Yield 200 lb/ac
alachlor 1.5 e.c.	96.87	3.69	4.32
2.0 e.c.	94.78	3.64	5.32
alachlor 1.5+2,4-D 0.5 e.c.	95.49	3.88	4.40
alachlor 2.0+2,4-D 0.67 e.c.	91.75	4.00	3.86
Cultivated check	89.20	4.15	3.57
S.E. of means	4.56	-	-
LSD P = .05			

Treatments lb a.i. or a.e./ac	Cotton	
	Site 10	
	Health 15 days	Yield lb/ac
alachlor 1.5 e.c.	2.75	1243
2.0 e.c.	4.00	1321
2.5 e.c.	4.00	1174
Cultivated check	1.25	1227
S.E. of means	-	53
LSD P = .05	-	148

+ In all sites above, excluding those for groundnuts (Sites 11 & 12) weeds were removed by cultivation. On groundnut sites only the check was cultivated. Vigor assessments are only included where damage was evident at some stage and are based on a scale 1 (no damage) - 10 (complete crop kill).

Acceptable to good control of some broadleaved weeds, including Amaranthus hybridus, the most important, Portulaca oleracea and Physalis angulata was obtained (tables 2 & 4). The addition of low rates of 2,4-D and atrazine (table 4) resulted in improved control of other broadleaves. Alachlor/atrazine mixtures proved to be the most effective, however, combinations with 2,4-D at rates as low as 0.5 to 0.67 lb a.e./ac usually gave acceptable control of Cleome monophylla, Schkurhia pinnata and early germinating Tagetes minuta. Commercial applications of alachlor + 2,4-D at the above rates, have confirmed generally acceptable to good control of the above broadleaved weeds, plus Bidens pilosa. Early, shallow-germinating Datura stramonium has also been controlled.

In all trials granular formulations of alachlor have proved as effective as the emulsifiable concentrates.

In trials, demonstrations and commercial applications, pre-emergence sprays of alachlor have proved completely safe to maize and groundnuts at recommended rates. Under abnormally cold conditions recommended rates of 2,4-D (1.5 to 2.5 lb a.e./ac) can cause varying degrees of damage to maize and groundnuts when applied within three days of planting. In two trials under weed-free conditions (table 5) alachlor/2,4-D mixtures at 1.5 + 0.5 and 2.0 + 0.67 lb a.i. or a.e./ac respectively, did cause malformation of a few maize plants (less than 1%) on one site where spring conditions were cold, however, this did not affect yield (table 5). Groundnuts under warm spring conditions have shown good tolerance to the above rates of alachlor/2,4-D.

In one trial potatoes showed good tolerance to alachlor and alachlor/2,4-D, while cotton and beans were damaged initially with good recovery later. In the cotton trial, spring conditions were abnormally cold, and cotton germination was slow. Under adverse conditions, resulting in slow emergence, cotton has been damaged in South-eastern U. S. A. (Monsanto 1969/70), however, under normal warm conditions good selectivity has been obtained.

Acknowledgements

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RESULTS OBTAINED WITH PRYNACHLOR* IN SOYA BEANS, SORGHUM AND MAIZE

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Summary The report describes the herbicidal efficacy and the selectivity of prynachlor (proposed common name of 2-chloro-N-(1-methyl-2-propynyl)-acetanilide) based on the results of approximately 200 field trials on maize, sorghum and soya beans. The results obtained may be summarised as follows:

The herbicide prynachlor can be applied to weed-free soil in the pre-emergence period, i.e. up to 3 days after sowing maize, sorghum and soya beans. The finer the tilth of the seed-bed, the better the weed control. Adequate moisture for the germination of weeds is a prerequisite for efficient control with prynachlor.

Prynachlor is tolerated well by maize, sorghum and soya bean crops, even at a rate of 8 lb a.i./ac.

Prynachlor controls both annual dicotyledonous and monocotyledonous weeds, but is at its most effective in the eradication of grasses such as Echinochloa, Digitaria and Setaria species.

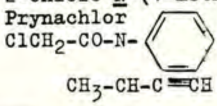
Prynachlor remains effective for only 6-8 weeks, which precludes the possibility of damage to the next crop in rotation.

INTRODUCTION

Prynachlor is a new herbicide from the acetanilide group, which has been tested in recent years as part of a world-wide trial programme under the code names BAS 2900 H, BAS 2901 H, BAS 2902 H and BAS 2903 H. The results obtained are discussed in the following report.

METHOD AND MATERIALS

Chemical name: 2-chloro-N-(1-methyl-2-propynyl)acetanilide
Proposed common name: Prynachlor
Formula:



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* proposed common name of 2-chloro-N-(1-methyl-2-propynyl)-acetanilide (originally chloretin)

Prynachlor is formulated as an emulsifiable concentrate (500 g/l) bearing the trade mark Butisan. *

Toxicological details of the formulated product:

Rat p.o.	LD 50	ca. 1950 ml/kg
Rabbit p.o.	" "	ca. 750 ml/kg
Mouse i.p.	" "	ca. 320 ml/kg
Rat dermal	" "	ca. 1550 ml/kg

The results for herbicidal efficacy and selectivity were obtained from over 200 field trials using randomised plots replicated 3-4 times. The product was applied pre-emergence: i.e. up to 3 days after sowing. It was not incorporated.

Crop tolerance and herbicidal efficacy were assessed according to a scale ranging from 1 to 10, i.e.

1 = no injury to crop or weeds

10= complete eradication

RESULTS

Prynachlor is a distinctive soil herbicide working chiefly through the weed roots. The germinating weeds absorb the active ingredient and usually die shortly before or shortly after emergence. The product remains active for 6-8 weeks, depending on soil type and rainfall.

The following table shows crop tolerance in maize, sorghum and soya beans.

Table 1

Crop tolerance

	Prynachlor lb/ac			
Crop	3	4	5	8
Maize	1.2 (1.5) n=37	1.1 (2) n=98	1.2 (1.3) n=43	1.1 (0.3) n=31
Sorghum	1.1 (1) n=17	1.2 (1.5) n=24	1.5 (1.2) n=3	1.2 (0.6) n=8
Soya beans	1.3 (1.5) n=24	1.6 (2.6) n=31	1.5 (1.7) n=13	-

( ) = Range = Highest rating minus lowest rating

n = Number of trials

*(R)Butisan = Registred Trade Mark of BASF AG, Ludwigshafen, Germany

The product showed good selectivity in these crops. Even application rates of 5 and 8 lb active ingredient per acre, twice the recommended rate, were tolerated. The soil types varied from loamy sand to clay, with varying organic matter contents.

The type of soil has very little influence on prynachlor's efficacy if the soil is moist enough. The weed control is, however, increased if the tilth of the seed-bed is very fine, and if adequate moisture is present for germination of the weeds, thus enabling prynachlor to take effect.

The herbicidal efficacy is also improved if rapid germination of the weeds follows treatment with the compound.

The efficacy against weeds and grasses is summarised in Table 2. The assessments were made approximately 40 days after treatment.

Table 2

Herbicidal efficacy in %

	Prynachlor lb/ac			
Crop	3	4	5	8
Maize	86 n=44	88 n=104	89 n=49	92 n=32
Sorghum	92 n=17	95 n=25	90 n=3	95 n=9
Soya beans	79 n=25	85 n=32	92 n=13	97 n=2

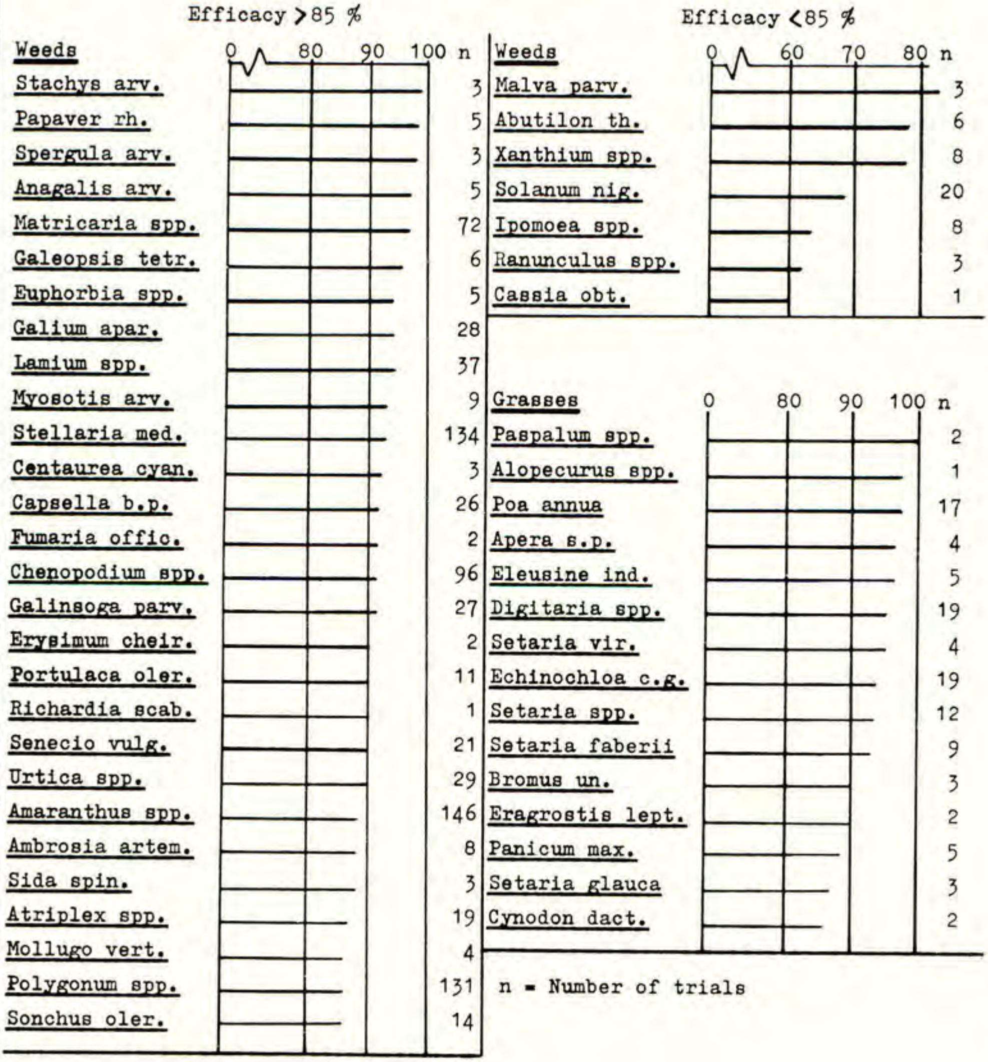
n = Number of trials

The table shows that an application rate of 4 lb prynachlor per acre destroys 85-95 % of the weeds. The recommended application rates lie between 3 and 4 lb per acre.

The weed spectrum of prynachlor, including results from trials with other crops (peanuts, cotton), takes the following form:

Table 3

Weed spectrum of prynachlor 3 lb/ac



n = Number of trials

Prynachlor is especially effective against common grasses such as _Echinochloa crus-galli_, _Digitaria_ and _Setaria_, even at a low rate of application.

It is also highly effective against _Amaranthus_, _Euphorbia_, _Galinsoga_, _Galeopsis_, _Lamium_, _Matricaria_, _Portulaca_, _Stellaria_ and _Veronica_. Its effect on _Ipomoea_, _Malva_, _Sesbania_, and _Solanum_ is limited and it has no effect at all on root-propagated weeds.

DISCUSSION

Prynachlor is effective against both annual broadleaved weeds and annual grasses. The marked selectivity and the broad weed spectrum make prynachlor an effective herbicide for use in maize, sorghum and soya beans, especially where years of broadleaved weed control have favoured the development of grasses. If the predominating weeds are species on which prynachlor has only a limited effect, another herbicide must be added. A mixture of prynachlor with a urea or triazine derivative is particularly suitable. As prynachlor breaks down fairly rapidly in the soil and loses its effectiveness after 6-8 weeks, there is no danger to later crops.

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Table 3

Phytotoxic symptoms on grapevine

Herbicide used	Symptoms	Extent of symptoms in the plots
chlorthiamid	Marginal leaf chlorosis, 1 cm around the leaf blade	On all the vines of the plot
dichlobenil	Marginal leaf chlorosis covering 0.5 cm around the leaf blade	On most of the vines of the plot
dichlobenil + atrazine	Chlorosis of the teeth of the blade. Later the leaves appear more circular, as the necrotic teeth fall off	On certain vines of the plot
dichlobenil + simazine	Very light chlorosis on the teeth of the leaf blade	Only on certain vines of weak growth

Remark: No differences were observed between the symptoms caused by the mixtures of atrazine and dichlobenil used at different doses, or between mixtures of dichlobenil (5 and 7.5 kg a.i./ha) and simazine.

DISCUSSION

The results obtained in this investigation show that the granular herbicides tested gave very satisfactory control of annual weeds. This has also been observed in other parts of Greece. The more resistant weeds were controlled better by chlorthiamid than dichlobenil, as can be seen by the retardation of growth of Cynodon dactylon. This effect has also been observed in the experimental vineyards of Larissa (Central Greece) and Helia (Southern Greece) and by Amphoux et al. (1970) in Southern France. The suppression of Cyperus rotundus to a certain level by chlorthiamid and, to a lesser degree, by dichlobenil during the second year after treatment must also be noted. This weed is one of the most resistant to all the herbicides we have tested (over 40).

The problem of phytotoxicity that arose after the third year of application in the vineyard studied needs discussing in more detail. The most intense symptoms were caused by chlorthiamid. Similar effects on the vine foliage have been observed in other experimental vineyards in Attica. Everywhere chlorthiamid caused more severe damage than dichlobenil. We have noticed in another vineyard in Attica a variation in the phytotoxicity of chlorthiamid according to the situation of the experimental plots on the slope. The inclination of the vineyard is 25-30°; plots on the top of the slope showed more severe symptoms than plots in the lower part of the vineyard.

No differences were observed in the yield between treated plots with symptoms and cultivated plots. Similar results were also reported by Julliard and Ancel (1967) and Agulhon (1968). We must, however, stress that our observations, as well as those of other investigators, were made after two or three years of application (Agulhon, 1968 and 1969; Agulhon et al., 1969; Amphoux et al., 1970; Daris, 1965; Julliard and Ancel, 1967). More time is needed to confirm that the symptoms observed do not affect the following year's production or the vigour of the vines.

All the mixtures of dichlobenil with atrazine or simazine gave less severe phytotoxic symptoms than chlorthiamid and dichlobenil alone. The mixtures of simazine and dichlobenil were the least harmful. In all the plots where mixtures of triazines and dichlobenil were applied, Cyperus rotundus increased markedly.

Two years ago, we initiated a study of other granular herbicides. These are mixtures of a chlorotriazine with a methoxytriazine and of a chlorotriazine with dichlobenil. Both mixtures have given good weed control and no phytotoxicity as yet.

We have noted before the importance of granular herbicides for arid and mountainous regions, however, the phytotoxicity observed and the high cost of these products have been obstacles to their use on a wider scale. New low-cost formulations must be developed, which will control more weeds and will not be phytotoxic.

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HERBICIDE INFLUENCE ON THE ARSENIC UPTAKE OF GRAPES. A STUDY BY NEUTRON ACTIVATION ANALYSIS

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Summary A 4-year experiment with paraquat and atrazine, carried out in a vineyard in S. Greece, resulted in Sorghum halepense being selected out. To control this remaining weed we then applied monosodium acid methyl-arsonate (MSMA), with success.

In order to investigate the uptake of arsenic from MSMA by the vines, grape samples were analyzed using neutron activation analysis. For this purpose dried grapes were irradiated with neutrons for 10 hours at the Democritos Nuclear Reactor. The arsenic content was calculated from the induced activity of As-76 after a radiochemical separation. The results show that the quantity of As in grapes taken from a vineyard treated with MSMA, after a 4-year application of atrazine, is five times higher than in the control (0.24-0.28 μg As/g dry matter instead of 0.04-0.07), whereas in plots treated with MSMA after a 4-year application of paraquat the arsenic content of the fruit was twice as high as in the control (0.08-0.11 μg As/g). Consequently it would seem that atrazine increases the uptake of As by the vine.

INTRODUCTION

Continuous application of the same herbicides in vineyards in the southern part of the Greek peninsula has resulted in the selection of Sorghum halepense. In order to control this resistant weed, arsenical herbicides like MSMA were used with satisfactory results. The efficacy of MSMA in controlling Sorghum halepense in cotton fields has also been noted by Rea (1964), in young citrus groves and in vineyards by Lange et al. (1968 and 1969). Outstanding control of the same weed was also obtained in orchards in California (Elmore et al., 1966 and 1967) and Southern Spain (Anon, 1968).

The question raised after the application of arsenical herbicides was to determine if the arsenic absorbed by the plant would be dangerous to the consumer. Lange et al. (1968) have found that when the foliage was sprayed with MSMA, residues of arsenic appeared in the fruits. The levels were extremely low, but the presence of traces of As constitutes an added obstacle to the registration of MSMA in U.S.A., for use in vineyards.

The authors of the present article have shown previously (Grimanis et al., 1970) that during the time of harvesting in the hot and dry climate of Attica, there was no difference between the quantity of arsenic in the grape berries (pulp, juice, seeds and skin analyzed separately) from vineyards treated with MSMA and those from untreated vineyards. The present work was undertaken to evaluate the absorption of As by the vine under different climatic conditions, and to determine the possible influence of the previous treatments with other herbicides on the uptake of arsenic.

In each case we used neutron activation analysis as a method of determining the arsenic content. In general this method (Bowen and Gibbons, 1963; Fer and Fourcy, 1969; Fourcey et al., 1966; Lyon, 1964) consists of determining an element present in a sample by measuring the induced radioactivity of the element, after irradiating the samples with thermal neutrons from a reactor, and by comparing this radioactivity with that of a known quantity of the same element irradiated under identical conditions.

METHOD AND MATERIALS

(a) In the vineyard

Since 1966 an experiment on weed control has been carried out in a vineyard in the region of Amalias (Southern part of the Greek peninsula). The variety cultivated is Black Corinth, used for the production of dried raisins. The age of the vines is 70-75 years.

Distance of planting: 1.5 x 1.5 m
Total area for experimentation: 4000 m^2. This area is divided in three randomized blocks of 4 experimental plots each. Plot area = 333 m^2.
Treatments: 1. cultivation (without herbicides)
2. paraquat (twice per year)
3. atrazine (six plots)

For 3 consecutive years the same doses of herbicides were applied as follows:

paraquat - 2 kg a.i./ha per year
atrazine - 5 kg a.i./ha per year

The weeds found in this vineyard are:

Calendula arvensis	Muscari comosum	Hypericum crispum
Euphorbia sp.	Sorghum halepense	Picris spinulosa
Anthemis chia	Agropyron repens	Papaver rhoeas
Cynodon dactylon	Ornithogalum nanum	Chrysanthemum segetum
Fumaria officinalis	Sonchus oleraceus	Equisetum sp.
Anemone coronaria	Trifolium stellatum	Allium vineale
Dracunculus vulgaris	Avena fatua	Amaranthus blitum
Ranunculus sp.	Hordeum murinum	Veronica persica

After the 3rd year of application, in all the plots treated with herbicides, Sorghum halepense was the main weed and covered around 75% of the vineyard. In order to control it an arsenical herbicide was applied on the 19th May 1969 in all the experimental plots, except for 3 plots treated with atrazine. The dose applied was 4.3 kg a.i./ha.

In a period of 20-30 days all the plants of Sorghum halepense were destroyed and up until the time of harvesting no regrowth has been observed. The harvesting was done on the 18th August 1969 and samples of grapes from all the experimental plots (two samples per plot) were taken for analysis.

(b) In the nuclear laboratory

The grape samples were washed many times with water, rinsed with distilled water and ground with a mixer. The resulting pulp was transferred to Petri dishes and dried at 75°C for 40 hours. The dried samples were ground in a Perspex mill.

The samples, weighing 100–150 mg each, were placed in polyethylene tubes (10 x 30 mm). Alliquots of 0.5 ml of a standard arsenic solution, containing 50 μg As/ml, were transferred in identical polyethylene tubes. The tubes were heat-sealed and irradiated in the Democritos reactor, using the rotation system of the reactor, for 10 hours in a thermal flux of about 2.2×10^{12} neutrons/cm^2/sec. A second irradiation, using the pneumatic transfer (rabbit) system of the reactor was performed to determine the chemical yield correction for arsenic isolated by the proposed radiochemical procedure (Grimanis, 1969).

After irradiation each of the samples was transferred into a 100 ml beaker containing 1 ml of arsenic carrier solution, 1 ml of each of the holdback carrier solution of copper, manganese and sodium, 3 ml of concentrated nitric acid and 2 ml of 80% perchloric acid. The beakers were heated until white vapours of perchloric acid were evolved, then they were cooled in an icebath to room temperature and the residues were diluted with a mixture of 7 M perchloric acid and 1 M hydrobromic acid, and finally transferred to a separatory funnel containing an equal volume of benzene.

The As-76 and the arsenic carrier were extracted quantitatively into benzene, as arsenic tribromide, back extracted into water, precipitated as metallic arsenic by reduction with sodium hypophosphate and dissolved in 2 ml of nitric acid. The solution was transferred into a 5 ml volumetric flask and diluted to volume with distilled water. The arsenic standard was processed in an identical manner.

The volumetric flasks containing the As-76 from the irradiated grape samples or from the arsenic standard were counted in a sodium iodide (thallium activated) well-type γ scintillation counter (2 x 2.375 in.) for 3 minutes. The radiochemical purity of the isolated arsenic was checked in a 400 channel pulse-height analyser, but contaminants were absent.

The recovery of arsenic averaged 80%. This determination was made by the reactivation method previously reported (Grimanis, 1969).

RESULTS

The arsenic found in the samples of berries is given in the following table. All the results are expressed in μg of arsenic per g of dry matter of the berries.

Randomized blocks	Number of samples	cultivated plots (control)	paraquat and MSMA	atrazine	atrazine and MSMA
1st	1	0.07	0.08	0.05	0.25
	2	0.04	0.11	0.04	0.28
2nd	1	0.04	0.09	0.06	0.24
	2	0.04	0.08	0.05	0.25
3rd	1	0.05	0.11	0.04	0.27
	2	0.04	0.10	0.05	0.28
Mean		0.047	0.095	0.048	0.261

Least statistically significant difference (L.S.D.) (5%) = $\pm$ 0.016
(L.S.D.) (1%) = $\pm$ 0.030

No differences were found between the cultivated control and those treated only with atrazine.

The coefficient of variability (C.V.) was 1.06% which means that the samples from the different plots, treated identically, were extremely uniform in As-content.

DISCUSSION

The results show that the quantity of arsenic in grapes taken from the plots in which no herbicides were used was around 0.047 µg/g of dry matter. The quantity of arsenic in the grapes taken from the plots treated for 3 consecutive years only with triazine (atrazine) was also on the same level (0.048 µg/g). In the plots treated with paraquat, for 3 consecutive years, and the last year also with MSMA, the quantity of As in the grapes doubled reaching 0.096 µg/g. This augmentation is considered to be due only to the added MSMA, as the paraquat is immediately inactivated in contact with the soil.

These results seem to be in contrast to those stated in our previous article (Grimanis et al., 1970), where the applied MSMA had not increased the quantity of As in the grape berries, but on looking more closely at the problem we can give an explanation: the influence of soil and rainfall. In the region of Attica, where no differences were found between plots treated with MSMA and untreated plots, the soil is heavy and the season is completely dry from June (when MSMA was applied) until September (harvesting period). On the contrary in the region of Amalias where the present work was carried out, the soil is light and permeable and in the period from the application of MSMA till harvesting rain fell on 4 occasions, so that the arsenic reached the root level (around 60 cm below soil surface) in a short time and the uptake of As was high.

In the plots treated with atrazine for 3 consecutive years, and in the last year also with MSMA, the uptake of arsenic is quite high, the As in berries reaching 0.26 µg/g of dry matter. This proves that atrazine, which has a residual action in the soil of several months, facilitates the uptake of arsenic by the plant. It can be seen that the dose of arsenic found in the berries is much lower than the maximum tolerable dose of As, which is 4 µg/g of dry matter (Comar, 1955) and therefore the consumer is in no danger from these grapes.

The experiment has not finished, as it remains to find out after how many years of continuous application of MSMA, the uptake of As by the grapes will exceed the tolerable limits. This danger is unlikely to be realised as total control of Sorghum halepense can be achieved in 2-3 years, with two applications per year; furthermore MSMA is very soluble in water, hence the winter rainfall will probably leach the compound below the root system of the vine.

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THE EFFECT OF CHEMICAL AND MECHANICAL WEED CONTROL ON THE GROWTH OF YOUNG CITRUS CV. MARSH GRAPEFRUIT

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Summary Several chemical and mechanical treatments were applied around young budded citrus plants cv. Marsh grapefruit in Trinidad and growth measurements made over a period of 12 months. Treatments which resulted in bare ground, whether by chemical or mechanical means, produced growth increases very highly significantly superior to those where weed covers were maintained throughout the year.

INTRODUCTION

Weed growth is very rapid in a warm, moist climate like Trinidad and if weed control is inadequate, a crop can become completely smothered by weeds in a short space of time. Tree crops in Trinidad are usually planted after a minimum of land preparation followed by an occasional cutlassing immediately around the plants. This method of weed control is insufficient to eliminate competition for nutrients, moisture and sunlight by weeds.

Several herbicide experiments have been carried out in Trinidad on young and mature citrus and in nursery plants (Kasasian, 1964; University of the West Indies, 1969). In nursery plants mixtures of TCA with diuron, simazine, atrazine, atraton and neburon gave very promising results and in bearing citrus, dalapon, 2,4-D, 2,4,5-T, diuron, bromacil and isocil were effective. The more effective of these herbicides have been recommended for use in citrus (Kasasian and Seeyave, 1968).

In the present trial, 4 mechanical and 5 chemical treatments were compared in young citrus plants.

METHOD AND MATERIALS

In September 1967, nursery plants of nucellar Marsh grapefruit budded on sour orange stock were planted at a spacing of 20 ft x 15 ft along the centres of cambered beds 20 ft wide. Girth measurements of the stock two inches below the bud union and of the scion two inches above the union were made at two-monthly intervals for six months before the differential treatments were applied. During this period the whole area was brushcut every month. The treatments were applied on March 22nd 1968.

The plots consisted of four experimental plants along the bed and were separated from the adjacent plots by single guard plants. There were five replicates arranged in a randomized block design.

Hoeing was done manually, brushcutting by means of an Allen autoscythe and chemicals were applied by knapsack sprayers fitted with a "Dorman" no-drift nozzle to

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minimize drift on to the crop. The mechanical treatments were applied over the entire area of the plot; in addition, for the annual brushcutting treatments, it was found necessary to trample the weeds growing in the immediate vicinity of the plants every 3 months to allow some sunlight to reach the crop. The herbicide treatments were repeated as necessary either as overall sprays or as spot treatment.

The main weed species were Paspalum fasciculatum, P. virgatum, P. conjugatum and Pennisetum purpureum among the monocotyledons and Borreria verticillata, Euphorbia hirta, Pueraria phaseoloides and Laportea aestuans among the dicotyledons. The grass species were more abundant.

Girth measurements of stock and scion were made every 2 months for 12 months after treatment. At the end of the trial, on 25th March, 1969, a volume index was obtained for each tree by measuring the height, the maximum diameter of the foliage and the width of foliage at right angles to the latter; the product gives the approximate size of the plant.

RESULTS

Growth Measurements

(a) Girth There were no significant differences in pre-treatment girth increases or in girths at the time of treatment. The mean net increases in girth over the 12 months of the trial and the final girths are shown in Table 1. As there was very little difference between girth of stock and of scion only those of stock are presented here.

Table 1

Mean net increase in girth and final mean girth (mm)

	Treatment	Increase*	Final Girth*
A	Hoeing monthly	89 c	128 bc
B	Brushcut annually	35 a	81 a
C	Brushcut monthly	62 b	107 ab
D	Brushcut three-monthly	48 ab	91 ab
E	Dalapon (broadleaves cut occasionally)	65 b	110 ab
F	2,4-D (brushcut every 3 months)	54 ab	98 ab
G	Dalapon + 2,4-D	65 b	111 ab
H	Diuron + bromacil + brushcut	116 d	165 c
I	Diuron + bromacil overall	120 d	163 c
	S.E.	± 7	± 9

* Values followed by the same letter in the same column are not statistically different at the 1% level by Duncan's Multiple Range Test.

1 = sprayed 10 ft square; unsprayed area brushcut 3-monthly

Girths over the 18 months duration of the experiment for treatments A, B, E and H are presented in graphical form in Figure 1.

(b) Volume of Tree Table 2 shows the average volume index (height x longest diameter x width) at the end of the experiment.

Fig. 1. Stock girths for 4 treatments during the experiment

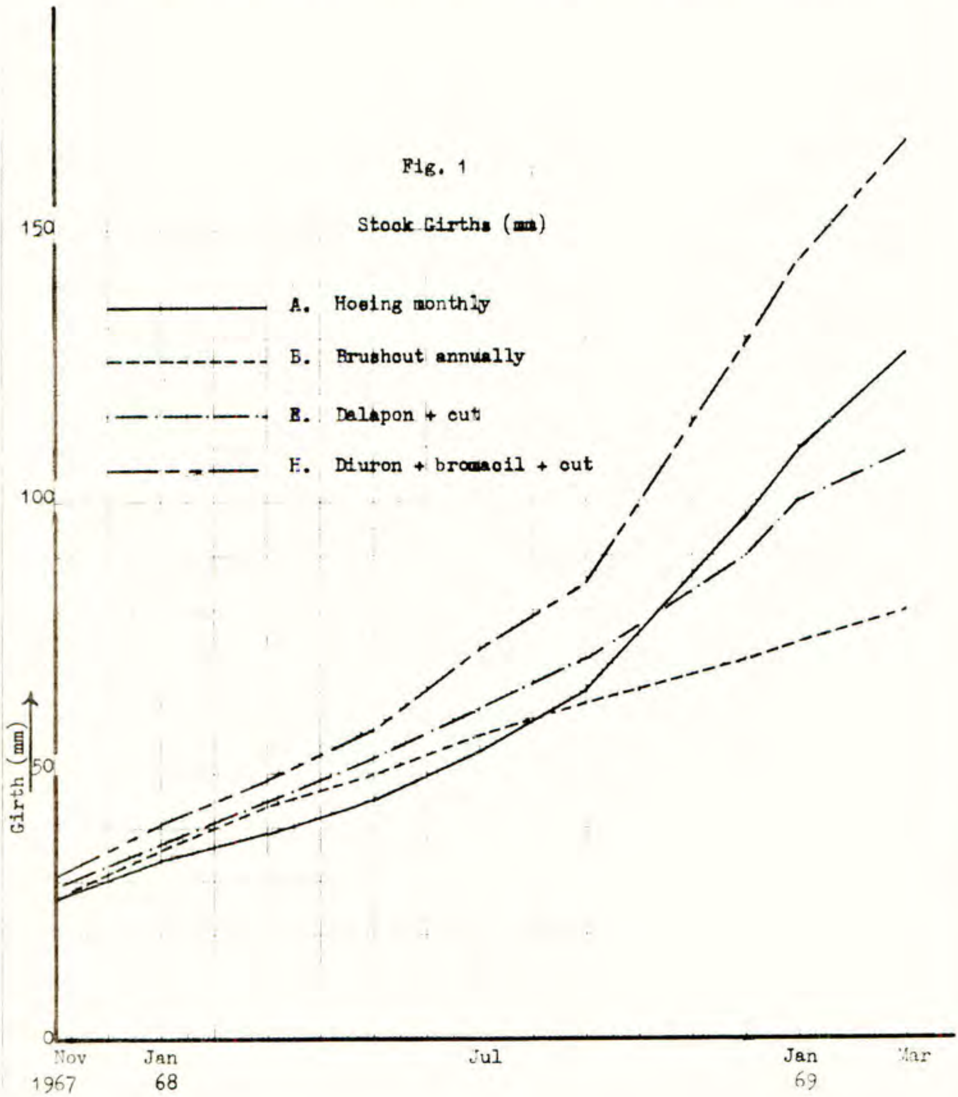

Table 2

Mean Volume index at end of trial (ft^3)

Treatment	Volume Index
A. Hoeing monthly	190 b
B. Brushcut annually	39 a
C. Brushcut monthly	56 a
D. Brushcut three-monthly	40 a
E. Dalapon	69 a
F. 2,4-D	61 a
G. Dalapon + 2,4-D	80 a
H. Diuron + bromacil + brushcut	305 c
I. Diuron + bromacil overall	327 c
S.E.	± 22

* Values followed by the same letter or letters are not statistically different from each other at the 1% level of significance by Duncan's Multiple Range Test.

Weed Control

Table 3 shows the frequency of treatments and the percentage weed cover estimated visually at the end of the Experiment.

Table 3

Number of weed control applications and % weed cover at end

Treatment	Number of applications	% Weed Cover
A. Hoeing monthly	13	17
B. Brushcut annually	1	72
C. Brushcut montly	13	100
D. Brushcut 3-monthly	4	92
E. Dalapon	4	68
F. 2,4-D	2	87
G. Dalapon + 2,4-D	4	60
H. Diuron + bromacil + cut	2	2*
I. Diuron + bromacil overall	2	7

* Refers to sprayed area; 100% weed cover outside

DISCUSSION

The maximum increase in growth was obtained by the treatments resulting in bare ground. Among the latter, chemical weeding was significantly better than mechanical weeding in the case of increase in girth and volume index but not in the case of final girth. The depth of hoeing was restricted to the top inch or so of soil but this superficial treatment may nevertheless have caused enough damage to the feeder root system of the crop to produce less growth than where the soil was not disturbed.

Among the treatments that did not result in complete weed control, dalapon with or without 2,4-D was equivalent to monthly brushcutting in the growth parameters measured and were in general better (but not always significantly so) than the three remaining treatments. Among the former treatments, those containing dalapon resulted in an almost pure stand of broad-leaved species except in two plots where *Paspalum conjugatum*, resistant to dalapon, was abundant. In the monthly cutting treatments on the other hand, the original weed cover, which was predominantly grass species, was maintained. It would seem therefore that the type of weed cover was immaterial and that crop growth was directly related to the degree of total weed control.

In conclusion, the experiment has shown that under the climatic conditions prevailing in Trinidad:- (1) Weed competition is a limiting factor in the growth of newly planted citrus, (2) complete elimination of the weed flora in the immediate vicinity of the crop, especially by herbicide application, leads to maximum growth, and (3) this may be achieved by spraying a mixture of 5 lb/ac diuron + 5 lb/ac bromacil around the tree with an occasional brushcutting of the unsprayed areas. It should be mentioned that this method of weed control, apart from being cheaper than an overall spray or hoeing at monthly intervals, would also reduce soil erosion which is liable to occur on slopes with bare ground.

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RECENT DEVELOPMENTS IN CHEMICAL WEED CONTROL IN BANANAS

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Summary Chlorbromuron was very promising as a highly selective herbicide in bananas. MCPA was effective on vines and was safe on the crop if drift was prevented. The addition of a wetter did not improve the efficiency of paraquat. Mechanical clean weeding gave significantly better yields than other treatments where weeds were merely cut back.

Old banana mats were eradicated by injecting dicamba and replanting of bananas was possible 2 weeks after treatment.

The results of previous herbicide trials in bananas in the West Indies have been reported upon (Kasasian and Seeyave, 1968). The present paper summarizes the results of trials subsequently laid down in St. Lucia.

In a pre-emergence trial, average bunch weight and yield over the first 18 months was not affected by 1.5 lb/ac pyriclor, 3 lb/ac simazine, ametryne and diuron and 3 and 6 lb/ac chlorbromuron, whereas 7.4 lb/ac dalapon plus 2 lb/ac 2,4,5-T produced a marked but not significant reduction in yield. Chlorbromuron gave extremely good weed control and was safe even at 6 lb/ac. Subsequently, 3, 6, 12 and 24 lb/ac chlorbromuron and diuron were compared post-emergence to weeds and bananas in a 3-month old plant crop and in a second ratoon crop. Other treatments included 3.4 lb/ac MSMA, 0.5 lb/ac paraquat, 2 lb/ac MCPA and 2 lb/ac 2,4-D + 2,4,5-T. Chlorbromuron gave excellent control of weeds (mainly <u>Brachiaria mutica</u>) at the lowest rate and no symptoms developed on the plants at the highest rates. Diuron was comparable to the former in effectiveness of weed control but phytotoxic symptoms were apparent on the leaf at rates of 6 lb/ac and higher in the plant crop but was safe even at the highest rate in the ratoon crop. The other treatments also gave good results but where the base of the plant and followers were deliberately sprayed, the following treatments produced a moderate to severe effect on the followers: diuron 6 lb/ac and higher, MCPA and brushkiller. There was only a slight and temporary effect on the followers receiving MSMA spray and none on those receiving chlorbromuron.

Several large scale observation plots using chlorbromuron were laid down in various locations in the Windward Islands and the following remarks summarize the results:

1. Chlorbromuron is safe in bananas as a pre-emergence treatment on light and heavy soils.

2. It is safe where bullheads and sword suckers are used as planting material but where corms are split into pieces, there is a slight retardation in growth, possibly due to absorption of chemical through the cut surface.

3. Its post emergence effect on weeds is considerably enhanced by the addition of 0.25 lb/ac paraquat.

4. It is largely ineffective when the top soil has dried out.

5. As a post-emergence treatment in plant and ratoon crops, 0.5 lb/ac chlorbromuron plus 0.25 lb/ac paraquat controlled weeds for at least twice as long as 0.5 lb/ac paraquat alone.

Broadleaved weeds e.g. Commelina elegans and vines are not controlled adequately by paraquat. In one post-emergence trial, 0.5 and 1 lb/ac MCPA were sprayed on Ipomoea sp. climbing on banana plants. Where directed application was used to prevent the spray from coming into contact with the crop, no phytotoxicity was observed but where the chemical was sprayed directly on the crop and weeds, acute phytotoxicity symptoms appeared, including toppling of the pseudostem. The higher rate gave a complete kill of Ipomoea sp. and Commelina elegans. However, with the present system of poor management and consequent carelessness in spraying, the use of MCPA would be rather limited in banana fields.

The addition of 0.5, 1 and 2 pints per acre of a wetting agent ("Agral 90") did not enhance the activity of 0.125, 0.25 and 0.5 lb/ac paraquat on weeds at either 40 or 80 gallons of spray per acre. The minimum dosage for good control was 0.25 lb/ac paraquat with or without wetter.

In one weed competition trial, monthly clean weeding induced more rapid growth and resulted in earlier cropping than all other treatments, including monthly cutlassing. It would seem therefore that complete elimination of weeds is essential for maximum growth and that the usual practice of chopping weeds or spraying a contact herbicide, even at frequent intervals, is not entirely adequate, (Seeyave and Phillips 1969). The use of a safe and effective pre-emergence herbicide which would give complete weed control for the first 3-4 months of the banana crop would therefore achieve ideal conditions for maximum growth.

ERADICATION OF OLD MATS

Kasasian and Seeyave (1968) found that picloram injected into the pseudostem of banana plants gave a complete kill of the mat but its persistence in the soil prevented its use where bananas had to be replanted almost immediately.

In one trial, 4, 8 and 12 ml of undiluted dicamba (40.6% a.e.) and 2,4-D + 2,4,5-T (24% a.e. of each) were injected into pseudostems or corms. Corm injection gave slightly better kill but was impractical. Brushkiller failed to give a complete kill but the two higher rates of dicamba were highly effective. Growth of corm pieces planted around the dicamba treatments two weeks after application was not affected, which would indicate that dicamba may be useful in the eradication of old mats before planting.

In conclusion, the present recommendations for weed control in bananas in the Windward Islands are:-

(1) Pre-planting: 2 lb a.e./ac 2,4,5-T for brush control and 10 lb/ac dalapon for grass control.

(2) Pre-emergence: 3 lb/ac diuron, linuron, chlorbromuron, atrazine or simazine as an overall spray with the addition of 0.25 lb/ac paraquat if weeds have emerged.

(3) Post-emergence: (a) As (2) above once a year,

(b) paraquat 0.5 lb/ac as required,

(c) paraquat 0.25 lb/ac plus 0.5 - 0.1 lb/ac of above soil acting chemicals 2 or 3 times a year,

(d) 5-10 lb/ac dalapon or 3-4 lb/ac MSMA post-emergence on grasses and

(e) 1-2 lb/ac MCPA or 2,4-D (amine) on vines and broadleaved weeds as a spot treatment with great care being taken to avoid drift.

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A NEW HERBICIDE - 17623 RP: PRELIMINARY STUDIES IN SOME TROPICAL CROPS

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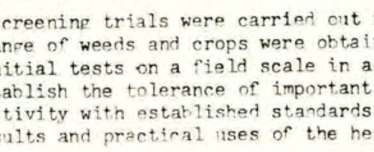
Summary The results are reported of preliminary field experiments with 2-tertiary butyl-4-2'-4'-dichloro-5'-isopropyloxyphenyl-1,3,4-oxadiazolin-5-one (17,623 RP) in groundnuts, cotton, sugar cane and paddy rice (transplanted). Useful levels of herbicidal activity lie between 1 and 3 lb/acre applied pre-emergence, there being some correlation between dose and duration of weed control. At 2-3 lb/acre good levels of control can be maintained for 10 weeks or longer. Considerations of crop selectivity and duration of weed control required, suggest that further work should be based on doses of 1-2 lb/acre in groundnuts, 1-1.5 lb/acre in cotton and 1.5-3.0 lb/acre in sugar cane. In rice, 1-1.5 lb is appropriate when applied before transplanting or 5-10 days after transplanting.

INTRODUCTION

In 1965, a new herbicidal compound, coded 17,623 RP, was prepared in the laboratories of Société des Usines Chimiques Rhône-Poulenc:-



17,623 RP

2-tertiary butyl-4-2'-4'-dichloro-5'-isopropyloxyphenyl-1,3,4-oxadiazolin-5-one.

Field and laboratory screening trials were carried out in 1965/6 and the reactions of a very wide range of weeds and crops were obtained. From 1967, trials were extended to include initial tests on a field scale in a number of tropical and temperate situations to establish the tolerance of important crops to herbicidal doses and to compare its activity with established standards in the various areas. A review of the initial results and practical uses of the herbicide was reported by L. Burgaud et al. (1969).

Initial studies showed the activity and selectivity of pre-emergence treatments to be greater than those applied post-emergence on both broadleaved and grass weeds in most situations and subsequent work was concentrated on pre-emergence use.

The experiments reported here were carried out in countries where the various crops are of importance, in an attempt to establish recommendations for the use of this herbicide in practice.

METHOD AND MATERIALS

All experiments were based on treatments of 17,623 RP applied after sowing or planting of the crop, i.e. pre-emergence of both crop and weeds, except in the case of rice where treatments were applied before or after transplanting.

Liquid formulations were applied with wheeled machines in the logarithmic experiments, but otherwise with knapsack sprayers modified to facilitate accurate application over small plots. Volume rates in the majority of cases were between 20-40 gal/acre. Applications of granular formulations in rice were made with small portable machines of the type commonly used by the small farmer in Japan.

The formulations of 17,623 RP used were a 40% w/v emulsifiable concentrate (Vt 2569) in groundnuts, cotton and sugar cane, and 2, 4 and 7.5% granules in rice.

As the experiments were carried out by several organisations, assessments have been recorded in different ways. The nature of assessments are, however, given in the corresponding tables of results. In all cases treatments were replicated three or more times and the results given are the simple means of replicates. Weed assessments were made on the basis of quadrat counts or visual assessments of per cent ground cover by one or more observers.

RESULTS

Groundnuts The experiments in the Sudan and the U.S.A. (Tables 1 and 2) show high levels of weed control and excellent crop tolerance obtained with 17,623 RP at 1-3 lb/acre applied after sowing. These preliminary field experiments indicate that 1-2 lb/acre of 17,623 RP would provide adequate weed control for at least the first 10 weeks of the crop, enabling it to become well established. The Sudan figures also show that yields comparable with hand-weeded areas are obtained with these treatments. In fact in the Sudan, the experiments of the Agricultural Research Corporation showed 17,623 RP to be the most promising herbicide for use in groundnuts.

Cotton Screening trials in the Sudan (Tables 3 and 4) have indicated that up to 5.5 lb/acre of 17,623 RP is tolerated by cotton without visible signs of phytotoxicity and that a dose of around 1.5 lb/acre provides satisfactory weed control for 13-14 weeks. In the one experiment in which crop weights and seed yields were determined, however, there were slight reductions in crop weight at 5, 9 and 14 weeks after treatment and in seed yield at harvest with 1 lb/acre as compared with the hand-weeded plots. With the higher doses there were greater reductions, but without a marked dose response as between 3 and 5.5 lb/acre.

Several screening trials in the U.S.A. with 17,623 RP at doses from 0.5 to 3.0 lb/acre gave similar results for weed control although crop tolerance was more variable even at low doses. It is suggested that relatively cool conditions and hence slower germination of the cotton may have resulted in the germinating shoots being exposed for a longer time to the herbicide in the soil surface.

Sugar cane Table 5 shows the results obtained by Mongelard and McIntyre (1970) at the Mauritius Sugar Industry Research Institute from two logarithmic screening screening experiments using 17,623 RP pre-emergence. Doses of around 3 lb/acre held weed cover below 20% for 86 and 111 days respectively in the two experiments, and measurements in Experiment 1 showed no harmful effects on cane germination and dewlap height.

Table 1

Groundnuts: Sudan. Weed control and crop tolerance 1968/69

	Assessments	17,623 RP lb/ac 1.0	1.3	1.7	2.2	3.0	Hand-weeded	Non-weeded
Weed control:	Experiment 1. Cumulative weed control. Means of assessments over 6 weeks after treatment. As number of weeds per 5 x $1m^2$ quadrats.		10.5	1.8	0.3		168	
	Experiment 1. Means of all assessments up to harvest. As % of untreated.		0.6	0.1	0.2		10.3	100
	Experiment 2. Weeds at harvest as % of untreated		6	5	3		15	100
	Experiment 3. Weed control at intervals after treatment. As % of hand-weeded. 4 weeks	38				19	100	
	9 weeks	98				41	100	
	14 weeks	91				47	100	
Weed tolerance:	Experiment 2. Crop plants in '000s/ac. at harvest.		55.9	50.1	58.2		58.1	53.5
	Experiment 3. Crop row width as % of hand-weeded at intervals after treatment. 4 weeks	105				88		
	9 weeks	86				117		
	14 weeks	105				97		
	Experiment 1. Yield in lb/ac.		2829	2780	3225		2706	891
	Experiment 2. Yield in lb/ac.		3053	2763	3251		3047	1914
	Experiment 3. Yield as % of untreated	128				181		100

Experiments 1, 2, 3. Treatment immediately after sowing. Variety: Ashford

Table 2

Groundnuts: U.S.A. Weed control and crop yield

Experiments 1 and 2. Pre-emergence application 1968

Assessments	17,623 RP lb/acre 1.0	1.5	2.0	3.0	Untreated control
Expt. 1: % control of broadleaved weeds	85.6	-	97.6	100	0
Expt. 2: % control of broadleaved weeds (After 51 days)	92.0	-	95.0	-	0
Expt. 2: % control of grass weeds (After 51 days)	80.0	-	92.0	-	0
Expt. 1: Crop stand as % of untreated	98.3	-	100	100.6	100
Expt. 2: Crop stand as % of untreated	96.0	98.6	97.3	-	100
Expt. 2: % crop injury (51 days)	0	-	0	-	0
Expt. 1: Yield in lb/acre	-		3023	2726	2777
Expt. 2: Yield in lb/acre		2169	2631	-	2107

Varieties: Expt. 1 - Starr Spanish. Expt. 2 - NC-2.

Table 3

Cotton: Sudan. Experiment 1: Weed control and seed yield 1969

17,623 RP lb/acre	Weed control Period of treatment 5 weeks A*	5 weeks B*	9 weeks A	9 weeks B	14 weeks A	14 weeks B	Mean crop weight as % of clean weeded control 5 wks	9 wks	14 wks	Seed cotton yield as % of clean weeded control	Seed cotton yield as % of non-weeded control
1	14	18	8	22	9	36	97	89	96	94.5	111.6
3	4	20	11	29	10	24	88	90	89	87.2	103.8
5.5	2	11	6	15	4	9	87	90	83	88.0	97.7

* A = % ground cover of weeds

* B = ground cover of weeds in treated plots as % of that in unweeded control

Table 4

Cotton: Sudan. Experiment 2. Crop and weed tolerance (logarithmic) 1969

17,623 RP dose range tested	Crop cotton	Maximum dose tolerated (crop)(lb a.i./acre)			Minimum dose for weed control (lb a.i./acre)		
		4 wks	8 wks	13 wks	4 wks	8 wks	13 wks
0.5 to 6.5 lb/ acre	Early sown	5.0	5.8	5.7	1.45	1.84	1.49
	Late sown	6.5	6.5	-	1.18	1.23	-

Table 5

Sugar cane: Mauritius. Weed control and crop tolerance (logarithmic) 1968/69

Dose range of herbicide in lb/acre	1.25-1.65	1.65-2.15	2.15-3.80	2.85-3.80	3.80-5.00	Untreated control	Days after spraying
% ground cover by weeds							
Expt. 1 17,623 RP	30.0	38.5	23.0	18.0	6.5	100	86
Expt. 2 17,623 RP	26.4	25.7	18.6	18.6	17.9	100	111
Expt. 2 diuron	33.4	26.1	21.6	19.1	16.4	100	111
Dewlap height as % of untreated							
Expt. 1 17,623 RP	97	94	97	103	98	100	86
Cane germination as % of untreated							
Expt. 1 17,623 RP	95	100	108	115	104	100	86

These two experiments were in the Super-humid zone (>100 in. rainfall per year)

Table 6

Sugar cane: Mauritius. Fixed dose experiments 1969

Experiment No. Zone Cane variety	Ground cover of weeds as % of untreated							Days after spraying
	17,623 RP			diuron			TCA + Na chlorate + 2,4-D	
lb/ac	2	3	4	3	4	3	$7\frac{1}{2}+3+1\frac{1}{2}$	
3: Humid M.377/56 (Plant)	-	22.6	16.1	-	-	-	-	120
4: Super-humid M.202/46 (Plant)	-	-	27.7	45.6	33.5	-	-	74
5: Humid M.147/44 (Ratoon)	29	20	9	-	-	12	18	64
6: Super-humid M.93/48 (Ratoon)	25.7	21.6	-	37.8	-	-	-	96

No cane damage was observed with 17,623 RP in any of these experiments.

Subsequent experiments (Table 6) by the M.S.I.R.I. with fixed dose plots in humid (50 - 100 in. rainfall per year) and super-humid (100 - 150 in. rainfall per year) zones confirmed that 17,623 RP at 3 lb/acre was well tolerated by plant (virgin) and ratoon crops and retained weed cover at around 20% of the untreated for periods of 64 to 120 days after treatment. Residual weed cover indicated that the sedges Cyperus rotundus and Kyllinga monocephala, and Bothriospermum tenellum (Boraginaceae) were resistant.

Results of our own experiments in the Caribbean are presented in Table 7. Assessments at 31-35 days after treatment indicated good weed control with 1 lb/acre (79% control) and very good control with 2 and 3 lb/acre (89 and 91% respectively) - equivalent to that obtained with a relatively high rate of atrazine (4.2 lb a.i./acre). At 56-76 days after spraying the 2 and 3 lb/acre rates still gave good control of grass weeds - substantially better than atrazine at 4.2 lb/acre - but control of broadleaved weeds was only moderate (63 and 67% respectively). Weeds which appeared resistant at this stage included Croton lobatus, Cassia multiflora, Ipomoea sp., and Cyperus rotundus. At the later assessments there was some evidence of compensatory spread of broadleaved weeds, and to some extent Cyperus rotundus, in 17,623 RP treated plots where competitive grass weeds had been largely eliminated. This was particularly so in Experiment 4, in which there were virtually only grass weeds in the untreated plots at 67 days, whereas there were substantial populations of Ipomoea sp. and Croton lobatus in the 17,623 RP plots.

In none of these experiments were any visible signs of crop damage recorded, although it is recognised that yield experiments should be undertaken to determine whether 17,623 RP has any effect on cane development or sugar production.

In the Caribbean experiments, rainfall over the three months in which the work was carried out was 30 - 60 inches.

In other experiments not reported here, post-emergence applications of 17,623 RP have caused extensive leaf scorch and local necrosis on sugar cane at rates as low as 1 lb/acre. Post-emergence applications are therefore considered inappropriate, unless directed spraying techniques are used.

Rice. Table 8 presents the results of extensive series of experiments organised by the Nissan Chemical Co. in Japan over 1967, 1968 and 1969 using granular formulations of 17, 623 RP. Essentially, they show that 17,623 RP applied at 0.9 - 1.3 lb/acre before transplanting or at 1.0 - 2.5 lb/acre after transplanting gives excellent weed control and good crop selectivity for periods of 30 days or more after treatment. Pre-transplanting treatments were incorporated in the soil to prevent physical removal during subsequent flooding of the paddy.

Owing to the practice of transplanting, these techniques achieve a situation where the treatment is made pre-weed-emergence but post-crop-emergence. In other areas of the world there is an increasing preference for direct sowing of rice and investigations of appropriate application techniques for 17,623 RP have yet to be considered.

From the results it appears that 0.9 lb/acre is adequate for pre-transplanting treatments and that 1.0 - 1.5 lb/acre is required for treatments applied 5-10 days after transplanting. If treatment is delayed until 11-16 days after transplanting a slightly higher rate may be required to achieve control of emerging or emerged weeds.

Most common rice weeds of Japan are controlled with these rates: only Scirpus hotarii having appeared to be resistant from the information obtained so far.

Table 7

Sugar cane: Caribbean. % weed control based on ground cover assessments 1970

(Figures in 'Untreated' column are actual levels of ground cover recorded)

Treatments and dose lb/acre		Grass weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)	Broad-leaved weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)	All weeds 17,623 RP 1	2	3	atrazine 4.2	untreated (% cover)
Expt. No.	Days after treatment															
1	33	82	94	94	82	16	42	84	95	95	19	57	85	90	88	39
2	33	55	82	72	63	11	77	97	99	99	62	74	95	95	92	75
3	31	94	94	94	94	47	100	100	100	100	1	93	93	93	93	53
4	32	70	96	100	81	42	73	82	100	97	33	70	88	98	89	80
5	34	73	100	91	-	4	85	89	91	-	30	78	82	81	-	37
6	35	97	98	98	-	37	92	99	100	-	17	94	97	97	-	64
7	35	100	100	100	-	13	100	100	100	-	10	90	84	88	-	31
Mean	31-35	81	94	92	80	23	81	95	97	97	24	79	89	91	90	54
1	60	80	77	73	23	34	0	86	76	92	50	25	48	74	59	90
2	76	0	50	55	0	20	18	82	87	89	78	11	65	69	52	100
3	66	45	63	53	44	98	-	-	-	-	-	42	57	47	42	98
4	67	29	55	74	11	99	0	0	0	100	1	2	13	23	10	100
5	63	49	76	78	-	15	42	70	69	-	48	40	64	66	-	67
6	56	87	87	86	-	75	28	54	76	-	17	74	77	82	-	97
7	56	99	100	98	-	57	92	85	95	-	13	83	72	47	-	87
Mean	56-76	55	72	74	19	57	30	63	67	94	35	39	56	58	40	91

No crop injury was recorded in any of these experiments.
Varieties of cane: Expts: 1 Cu 87/51, 2 B.42231, 3,4 B.4362, 5 CP.52/43, 6,7 PR.980

Table 8

Rice: Japan. Weed control and crop tolerance 1967-69

The figures in these tables give the number of experimental sites in which the specified levels of weed control or crop phytotoxicity were obtained.

A. Application 1-2 days before transplanting.
Assessment made about 35 days after treatment (1967-8).

% weed control	17,623 RP lb/ac 0.9 lb	1.3 lb
90 - 100	16	17
80 - 100	2	4
80 - 90	1	2
60 - 80	2	0
40 - 60	1	0

Phytotoxicity	17,623 RP lb/ac 0.9 lb	1.3 lb
None	11	9
Slight	11	11
Noticeable	0	3
Severe	0	0

B. Application 5-10 and 11-16 days after transplanting.
Assessments made 20-30 days after treatment (1968)

% weed control	17,623 RP lb/ac 1.9 lb 5-10 days	11-16 days	2.5 lb 5-10 days	11-16 days
90 - 100	6	4	7	4
80 - 100	1	1	2	2
80 - 90	3	2	2	5
60 - 80	1	4	0	0
40 - 60	0	0	0	0

Phytotoxicity	17,623 RP lb/ac 1.9 lb 5-10 days	11-16 days	2.5 lb 5-10 days	11-16 days
None	9	9	9	9
Slight	2	2	2	2
Noticeable	0	0	0	0
Severe	0	0	0	0

C. Application 5-10 and 11-16 days after transplanting.
Assessments made 20-30 days after treatment (1969)

% weed control	17,623 RP lb/ac 1 lb 5-10 days	11-16 days	1.4 lb 5-10 days	11-16 days
90 - 100	10	6	6	5
80 - 100	1	1	1	1
80 - 90	0	2	0	2
60 - 80	0	0	1	2

Phytotoxicity	17,623 RP lb/ac 1 lb 5-10 days	11-16 days	1.4 lb 5-10 days	11-16 days
None	4	4	3	2
Slight	6	5	4	7
Noticeable	1	0	1	0
Severe	0	1	0	1

A range of rice varieties including temperate and near tropical types, were included in these experiments and no differences in susceptibility were noted. Younger plants appear more susceptible and it is suggested that transplants should have 6-7 leaves and be about 20 cm high at transplanting to minimise reaction to 17,623 RP.

DISCUSSION

Burgaud et al. (1969) reported that 17,623 RP migrates very little in the soil and remains in the top few centimetres. Its pre-emergence herbicidal effect then becomes manifest at germination as shoots penetrate the soil layer containing herbicide. Large-seeded plants exhibit tolerance probably owing to the relatively high ratio of shoot volume to shoot surface in contact with treated soil. A faster rate of penetration through the herbicide layer may also contribute to the apparent tolerance. A connection may also be inferred with the reserves status of the plant as most bulbous, rhizomatous and deep-rooted weeds are resistant to 17,623 RP (with the important exception of the bindweeds, Convolvulus arvensis, and Calystegia sepium). Crops which can be regarded as resistant to pre-emergence applications on the basis of having large seeds or large reserves include sugar cane, groundnuts and cotton.

Many Gramineae are relatively resistant to 17,623 RP applied at doses up to 2 lb/acre post-emergence. Varying degrees of leaf scorch or local necrosis may occur, particularly with liquid formulations but the use of granules minimises this. Thus the use of 17,623 RP granules in rice before or after transplanting provides a situation where the crop is tolerant whilst the weeds will be subject to the pre-emergence effect of the herbicide.

The experiments reported here indicate that sugar cane and groundnuts tolerate 17,623 RP at doses of 3 lb/acre and over. Results from a number of areas show that at 2-3 lb/acre good levels of weed control are maintained for 8-14 weeks, and more in some cases. However, the sugar cane experiments in particular, suggest that after about 6-7 weeks the control of certain broadleaved species tends to deteriorate. In cotton, rates of up to 6.5 lb/acre caused no visible crop phytotoxicity although a yield experiment suggested slight depression with 1 lb/acre of 17,623 RP and more with higher doses. Up to 2.5 lb/acre were tolerated by transplanted rice, but lower doses have caused slight phytotoxic symptoms in some experiments. On the other hand, doses in the range 0.9 - 1.5 lb/acre in rice provided adequate control for periods of 30 days or more after transplanting, sufficient to obviate 2 or 3 hand-weedings.

It is concluded that 17,623 RP is an extremely promising pre-emergence herbicide for use in groundnuts (1-2 lb/acre), sugar cane (1.5 - 3.0 lb/acre), cotton (1.0 - 1.5 lb/acre) and in rice (1.0 - 1.5 lb/acre).

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THE PERFORMANCE OF ALACHLOR ON SOME ANNUAL SUMMER CROPS AND WEEDS IN SOUTH AFRICA

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Summary A series of trials, under a wide variety of conditions in summer crops in South Africa, demonstrated the exceptional reliability of both gran. and e.c. formulations of alachlor (CP 50144) for control of the major annual grasses. Some broadleaves, especially *Amaranthus hybridus* the most important, were effectively controlled, while control of others such as *Tagetes minuta*, *Schkurhia pinnata*, *Cleome monophylla* and *Datura spp.* was often unreliable. The addition of low rates of 2,4-D or atrazine to alachlor resulted in improved broadleaved weed control. The effect on *Cyperus esculentus* has often been acceptable to good, although unreliable in some conditions. Maize and groundnuts have shown excellent tolerance to alachlor, and under normal conditions the addition of low rates of 2,4-D appeared fairly safe to both crops. In one trial alachlor and alachlor + 2,4-D appeared safe to potatoes, while cotton (under adverse conditions) and field beans were damaged initially with good recovery later.

INTRODUCTION

Amongst the weeds encountered in trials and demonstrations in summer crops of the summer rainfall area of South Africa, the following were the most abundant in order of importance: *Eleusine africana*, *Panicum leavifolium* (moist eastern areas), *Amaranthus hybridus*, *Cyperus esculentus* and in some areas *Tagetes minuta* and *Schkurhia pinnata*. The other weeds, *Portulaca oleracea*, *Cleome monophylla*, *Physalis angulata*, *Bidens pilosa* and *Commelina sp.* assume importance in isolated areas. *Datura sp.* is scattered in distribution, but can be particularly important in the drier western and northern summer cropping areas. *Digitaria sanguinalis* is common on heavier soils (fairly high in clay) while *Brachiaria eruciformis* and *Urochloa panicoides* are the dominant grasses on sandy clays high in montmorillonite and/or illite (Margallitic forms). Other weeds, not encountered in trials, which assume some importance are *Xanthium spp.*, *Cosmos bipinnatus*, *Acanthospermum australe*, *Panicum maximum* and *Convolvulus arvensis*.

The value of alachlor alone or in combination with other herbicides was demonstrated on some summer crops, particularly maize and groundnuts, under a wide variety of conditions. Some of these results are presented here.

METHOD AND MATERIALS

All trials and demonstrations were carried out in the Orange Free State, Natal and Eastern areas of the Transvaal (Tvl) highveld on a variety of soil types ranging from sands to sandy clays.

Demonstrations 1968/69

These were unreplicated plots ranging in size from 0.25 to 2 ac. Alachlor e.c. and/or gran. was applied on all sites at planting with tractor and planter mounted sprayers or granular applicators giving a band of 12-14 in. over the crop row.

Weed control was assessed visually into categories outlined in table 2.

Replicated trials

All trials were sprayed on small plots (1/200 to 1/100 ac) in randomised block design with 3 to 4 replicates. All treatments were applied pre-emergence within two days after soil preparation and planting. Details of sites are given in table 1. E.c. and w.p. formulations were sprayed by knapsack sprayer at 25 to 30 $lb/in.^2$ at a volume rate of 20 gal/ac using 3 x 8003 T-jet fan nozzles mounted on a hand lance and boom.

Weed control was assessed by counting weeds in 5 to 20 random placements of quadrates varying in size from 1.5 to 4 ft^2. The area assessed was based on the density of the weed population. For the sake of convenience all counts were converted to an area of 10 ft^2.

Weed assessments listed in the tables, unless specified, were undertaken from 4-8 weeks after planting and spraying, at a time when the crop (3 ft rows) was considered sufficiently competitive not to be affected adversely by further weed germination.

Product formulations were as follows :

Alachlor alone : e.c. - 4.8 lb a.i./imp gal.

Formulated mixtures :

Alachlor + 2,4-D	e.c. -	3.6 lb a.i. + 1.2 lb a.e.
	gran. -	10% a.i. + 3.3% a.e.
		or 5.0% a.e.

2,4-D as the iso-octyl ester.

Tank mixtures :

Alachlor e.c. as above with atrazine 80% w.p. or 2,4-D iso-propyl/butyl esters.

Table 1

Details of trial sites

Site No.	Year	Location	Soil type	Rain 1st week	Rain 1st 3 weeks
1	1967/68	Eastern Tvl.	Sandy clay	Adequate for herbicides	Adequate for herbicides
2	1967/68	Eastern Tvl.	Sandy clay loam	Adequate for herbicides	Adequate for herbicides
3	1968/69	Eastern Tvl.	Sandy clay loam	7.9 mm	34.8 mm
4	1968/69	Orange Free	Sandy loam	0 mm	27.4 mm
5	1969/70	Eastern Tvl.	Sandy loam	14.3 mm	94.8 mm
6	1969/70	Eastern Tvl.	Sandy clay loam	15.0 mm	76.8 mm
7	1969/70	Eastern Tvl.	Sandy clay loam	22.6 mm	86.4 mm
8	1969/70	Eastern Tvl.	Sandy loam	32.5 mm	49.0 mm
9	1969/70	Eastern Tvl.	Sandy loam	15.7 mm	48.2 mm
10	1969/70	Northern Tvl.	Sandy clay loam	82.6 mm	262.9 mm
11	1969/70	Orange Free State	Sand	Adequate for herbicides	Adequate for herbicides
12	1969/70	Orange Free State	Sand	8.0 mm	89.0 mm

Organic matter content less than 2% on all sites.
Sites 3 and 7 were on same farm in different years.

RESULTS

Summarized results of demonstrations and replicated trials on weeds and crops are presented in the following tables.

Table 2

The affect of alachlor on weed species on 16 demonstration sites conducted in groundnuts and maize

WEED SPECIES	Alachlor 1 to 1.2 lb a.i./ac No. of Sites showing			Alachlor 1.8 to 2.2 lb a.i./ac No. of Sites showing		
	Total Sites/ Weed	+Accept. control	Good con- trol	Total Sites Weed	+Accept. control	Good con- trol
Eleusine africana and Panicum laevifolium	13	2	11	16	1	15
Digitaria sanguinalis	3	0	3	4	0	4
Cyperus esculentus	10	4	2	13	3	6
Amaranthus spp.	10	1	8	12	1	10
Tagetes minuta	6	0	0	7	1	0
Commelina sp.	2	0	0	3	0	0
Schkurhia pinnata	4	0	0	4	0	0
Bidens pilosa	5	3	0	5	2	1
Datura sp.	4	1	0	5	2	0
Portulaca oleracea	2	1	1	3	1	2
Physalis angulata	1	0	1	2	0	2

+Acceptable control = commercially acceptable to grower.
No visible crop damage was recorded at any of the above sites.

Table 3

Replicated trials with alachlor formulations and mixtures on Cyperus esculentus and the annual grass Brachiaria eruciformis (weeds/10 ft^2.

Treatments a.i. or a.e./ac		Cyperus esculentus			Brachiaria eruciformis
	Site No. :	1	5	6	1
Untreated		100 a	103 a	124 a	39 a
atrazine	2.0 w.p.	-	75 a	146 a	-
	3.0 w.p.	102 a	-	-	15 a
propachlor	4.0 w.p.	41 b	-	-	1 b
alachlor	2.0 e.c.	43 b	-	28 b	0 b
	2.0 gran.	-	13 b	-	-
alachlor	e.c. 1.5 + 2,4-D 0.5	-	13 b	-	-
	gran. 1.5 + 0.5	-	15 b	-	-
alachlor	e.c. 2.0 + 2,4-D 0.67	-	-	26 b	-
	gran. 2.0 + 0.67	-	11 b	-	-
C.V.% (Based on logarithmic transformation of count)		8.62	17.09	23.89	-

Absence of a common letter indicates significant difference at P = .05 based on the logarithmic transformation. Log (Count + 1) alachlor/2,4-D mixtures were formulated materials.

Table 4

Replicated trials with alachlor formulations and mixtures for control of broadleaved weeds
Weeds/10 ft^2

Treatments, lb a.i./ac	Amaranthus hybridus				Physalis angulata	Cleome monophylla	Schkuhria pinnata
Site No.	2	3	5	7	3	6	4
Untreated	246 a	109 a	145 a	105	27 a	62	22 a
atrazine 2.0 w.p.	52 b	-	0 d	0	-	1	-
MCPA 1.5 e.c.	49 b	5 bc	-	-	4 b	-	-
2.0 e.c.	-	4 c	-	-	4 b	-	-
alachlor 1.5 e.c.	-	12 bc	-	-	5 b	-	24 a
2.0 e.c.	37 b	9 bc	-	-	3 b	30	22 a
alachlor 1.5 gran.	-	18 b	-	-	7 b	-	28 a
2.0 gran.	-	8 bc	28 b	1	8 b	-	22 a
alachlor 1.0 e.c.+atrazine 1.0 w.p.	15 b	-	-	-	-	-	-
1.5 e.c.+atrazine 1.0 w.p.	-	-	0 d	0	-	-	-
alachlor 1.0 e.c.+ 2,4-D 1.0 e.c.	15 b	-	-	-	-	-	-
1.0 e.c.+ 2,4-D 0.5 gran.	-	9 bc	-	-	5 b	-	6 b
alachlor 1.5+2,4-D 0.5 e.c.	-	-	5 d	0	-	-	-
1.5+ 0.5 gran.	-	-	17 bc	0	-	-	-
alachlor 2.0+ 0.67 e.c.	-	-	-	-	-	2	-
2.0+ 0.67 gran.	-	-	7 cd	0	-	-	-
C.V.%(based on log.transf.)	24.24	24.79	30.75	-	36.03	-	16.86

Absence of a common letter indicates significant difference at P = .05 based on the logarithmic transformation. Log (Count + 1).

NOTE: alachlor + atrazine and alachlor 1.0 e.c. + 2,4-D 1.0 e.c. were tank mixtures while all other alachlor + 2,4-D treatments were formulated mixtures.

Table 4 (cont'd)

Replicated trials with alachlor formulations and mixtures for control of broadleaved weeds
Weeds 10 ft^2

Treatments, lb a.i./ac	Tagetes minuta			
Site No.:	2	3	5	7
Untreated	471 a	146 a	87 a	116 a
atrazine 2.0	74 bc	-	0 d	1 d
MCPA 1.5	25 d	20 c	-	-
2.0	-	9 d	-	-
alachlor 1.5 e.c.	-	68 b	-	-
2.0 e.c.	218 ab	77 b	-	-
alachlor 1.5 gran.	-	62 b	-	-
2.0 gran.	-	70 b	77 ab	22 b
alachlor 1.0 e.c.+atrazine 1.0	70 bc	-	-	-
1.5 e.c.+ 1.0	-	-	5 c	1 cd
alachlor 1.0 + 2,4-D 1.0 e.c.	14 d	-	-	-
1.0 + 2,4-D 0.5 gran.	-	16 c	-	-
alachlor 1.5 + 2,4-D 0.5 e.c.	-	-	28 ab	5 cd
1.5 + 0.5 gran.	-	-	20 bc	7 bc
alachlor 2.0 + 0.67 gran.	-	-	17 bc	3 cd
C.V.%(based on log.transf.)	17.06	12.66	37.87	32.47

Absence of a common letter indicates significant difference at P= .05 based on the logarithmic transformation. Log.(Count + 1).

NOTE: alachlor + atrazine and alachlor 1.0 + 2,4-D 1.0 were tank mixtures while all other alachlor + 2,4-D treatments were formulated mixtures. Atrazine was applied as w.p., 2,4-D and MCPA as liquid formulations.

DISCUSSION

Alachlor has proved to be one of the most consistent herbicides for control of annual grasses, the major weed problem in South Africa. Amongst those controlled were Eleusine africana, Panicum laevifolium, Digitaria sanguinalis and Brachiaria eruciformis.

The efficiency of this compound on annual grasses, even under relatively dry conditions was demonstrated in a number of trials in sugar cane in Natal conducted over four years (Richardson, 1970). Amongst the grasses controlled at rates of 2-4 lb a.i./ac were Digitaria adscendens, D.sanguinalis and Eleusine indica.

Control of Cyperus esculentus, a weed of increasing importance, was often acceptable to good in trials and demonstrations (table 2 & 3) however, some variability did occur. Commercial applications of alachlor in maize during the 1969/70 season indicated that deep seed bed preparation, combined with early effective rain after application were important requirements for control of this weed. Activity on Cyperus esculentus was reported in sugar cane trials in Natal (Richardson, 1970) although it was generally considered that alachlor could not be recommended where this weed was dominant.

Table 5

Vigor assessments and crop yields in cultivated conditions+

Treatments lb a.i. or a.e./ac	Maize		Field (dry) beans Michigan pea (Var. Sanilac)	
	Site 5	Site 7	Site 8	
	Yields 200 lb/ac	Yields 200 lb/ac	Health 57 days	Yield 200 lb/ac
atrazine 2.0 w.p.	15.18	13.48	-	-
alachlor 1.5 e.c.	-	-	1.67	5.30
2.0 e.c.	-	-	3.00	5.00
alachlor 2.0 gran.	14.60	11.70	-	-
alachlor 1.5 e.c.+atrazine 1.0 w.p.	15.53	13.61	-	-
alachlor 1.5+2,4-D 0.5 e.c.	16.03	14.19	3.33	4.29
1.5+ 0.5 gran.	16.89	15.11	-	-
alachlor 2.0+2,4-D 0.67 e.c.	-	-	4.00	3.72
2.0+ 0.67 gran.	15.60	13.38	-	-
Cultivated check	14.71	12.10	1.33	5.27
S.E. of means	1.09	0.96	-	0.29
LSD P = .05	N.S.	2.81	-	0.95

Treatments lb a.i. or a.e./ac	Potatoes	Groundnuts	
	Site 9	Site 11	Site 12
	Yield 150 lb/ac	Yield 200 lb/ac	Yield 200 lb/ac
alachlor 1.5 e.c.	96.87	3.69	4.32
2.0 e.c.	94.78	3.64	5.32
alachlor 1.5+2,4-D 0.5 e.c.	95.49	3.88	4.40
alachlor 2.0+2,4-D 0.67 e.c.	91.75	4.00	3.86
Cultivated check	89.20	4.15	3.57
S.E. of means	4.56	-	-
LSD P = .05			

Treatments lb a.i. or a.e./ac	Cotton	
	Site 10	
	Health 15 days	Yield lb/ac
alachlor 1.5 e.c.	2.75	1243
2.0 e.c.	4.00	1321
2.5 e.c.	4.00	1174
Cultivated check	1.25	1227
S.E. of means	-	53
LSD P = .05	-	148

+ In all sites above, excluding those for groundnuts (Sites 11 & 12) weeds were removed by cultivation. On groundnut sites only the check was cultivated. Vigor assessments are only included where damage was evident at some stage and are based on a scale 1 (no damage) - 10 (complete crop kill).

Acceptable to good control of some broadleaved weeds, including Amaranthus hybridus, the most important, Portulaca oleracea and Physalis angulata was obtained (tables 2 & 4). The addition of low rates of 2,4-D and atrazine (table 4) resulted in improved control of other broadleaves. Alachlor/atrazine mixtures proved to be the most effective, however, combinations with 2,4-D at rates as low as 0.5 to 0.67 lb a.e./ac usually gave acceptable control of Cleome monophylla, Schkurhia pinnata and early germinating Tagetes minuta. Commercial applications of alachlor + 2,4-D at the above rates, have confirmed generally acceptable to good control of the above broadleaved weeds, plus Bidens pilosa. Early, shallow-germinating Datura stramonium has also been controlled.

In all trials granular formulations of alachlor have proved as effective as the emulsifiable concentrates.

In trials, demonstrations and commercial applications, pre-emergence sprays of alachlor have proved completely safe to maize and groundnuts at recommended rates. Under abnormally cold conditions recommended rates of 2,4-D (1.5 to 2.5 lb a.e./ac) can cause varying degrees of damage to maize and groundnuts when applied within three days of planting. In two trials under weed-free conditions (table 5) alachlor/2,4-D mixtures at 1.5 + 0.5 and 2.0 + 0.67 lb a.i. or a.e./ac respectively, did cause malformation of a few maize plants (less than 1%) on one site where spring conditions were cold, however, this did not affect yield (table 5). Groundnuts under warm spring conditions have shown good tolerance to the above rates of alachlor/2,4-D.

In one trial potatoes showed good tolerance to alachlor and alachlor/2,4-D, while cotton and beans were damaged initially with good recovery later. In the cotton trial, spring conditions were abnormally cold, and cotton germination was slow. Under adverse conditions, resulting in slow emergence, cotton has been damaged in South-eastern U. S. A. (Monsanto 1969/70), however, under normal warm conditions good selectivity has been obtained.

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RESULTS OBTAINED WITH PRYNACHLOR* IN SOYA BEANS, SORGHUM AND MAIZE

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Summary The report describes the herbicidal efficacy and the selectivity of prynachlor (proposed common name of 2-chloro-N-(1-methyl-2-propynyl)-acetanilide) based on the results of approximately 200 field trials on maize, sorghum and soya beans. The results obtained may be summarised as follows:

The herbicide prynachlor can be applied to weed-free soil in the pre-emergence period, i.e. up to 3 days after sowing maize, sorghum and soya beans. The finer the tilth of the seed-bed, the better the weed control. Adequate moisture for the germination of weeds is a prerequisite for efficient control with prynachlor.

Prynachlor is tolerated well by maize, sorghum and soya bean crops, even at a rate of 8 lb a.i./ac.

Prynachlor controls both annual dicotyledonous and monocotyledonous weeds, but is at its most effective in the eradication of grasses such as Echinochloa, Digitaria and Setaria species.

Prynachlor remains effective for only 6-8 weeks, which precludes the possibility of damage to the next crop in rotation.

INTRODUCTION

Prynachlor is a new herbicide from the acetanilide group, which has been tested in recent years as part of a world-wide trial programme under the code names BAS 2900 H, BAS 2901 H, BAS 2902 H and BAS 2903 H. The results obtained are discussed in the following report.

METHOD AND MATERIALS

Chemical name: 2-chloro-N-(1-methyl-2-propynyl)acetanilide
Proposed common name: Prynachlor
Formula: $ClCH_2$-CO-N-

CH_3-CH-C≡CH

* proposed common name of 2-chloro-N-(1-methyl-2-propynyl)-acetanilide (originally chloretin)

Prynachlor is formulated as an emulsifiable concentrate (500 g/l) bearing the trade mark Butisan. *

Toxicological details of the formulated product:

Rat p.o.	LD 50	ca. 1950 ml/kg
Rabbit p.o.	" "	ca. 750 ml/kg
Mouse i.p.	" "	ca. 320 ml/kg
Rat dermal	" "	ca. 1550 ml/kg

The results for herbicidal efficacy and selectivity were obtained from over 200 field trials using randomised plots replicated 3-4 times. The product was applied pre-emergence: i.e. up to 3 days after sowing. It was not incorporated.

Crop tolerance and herbicidal efficacy were assessed according to a scale ranging from 1 to 10, i.e.

1 = no injury to crop or weeds

10= complete eradication

RESULTS

Prynachlor is a distinctive soil herbicide working chiefly through the weed roots. The germinating weeds absorb the active ingredient and usually die shortly before or shortly after emergence. The product remains active for 6-8 weeks, depending on soil type and rainfall.

The following table shows crop tolerance in maize, sorghum and soya beans.

Table 1

Crop tolerance

	Prynachlor lb/ac			
Crop	3	4	5	8
Maize	1.2 (1.5) n=37	1.1 (2) n=98	1.2 (1.3) n=43	1.1 (0.3) n=31
Sorghum	1.1 (1) n=17	1.2 (1.5) n=24	1.5 (1.2) n=3	1.2 (0.6) n=8
Soya beans	1.3 (1.5) n=24	1.6 (2.6) n=31	1.5 (1.7) n=13	-

( ) = Range = Highest rating minus lowest rating

n = Number of trials

*(R)Butisan = Registred Trade Mark of BASF AG, Ludwigshafen, Germany

The product showed good selectivity in these crops. Even application rates of 5 and 8 lb active ingredient per acre, twice the recommended rate, were tolerated. The soil types varied from loamy sand to clay, with varying organic matter contents.

The type of soil has very little influence on prynachlor's efficacy if the soil is moist enough. The weed control is, however, increased if the tilth of the seed-bed is very fine, and if adequate moisture is present for germination of the weeds, thus enabling prynachlor to take effect.

The herbicidal efficacy is also improved if rapid germination of the weeds follows treatment with the compound.

The efficacy against weeds and grasses is summarised in Table 2. The assessments were made approximately 40 days after treatment.

Table 2

Herbicidal efficacy in %

	Prynachlor lb/ac			
Crop	3	4	5	8
Maize	86 n=44	88 n=104	89 n=49	92 n=32
Sorghum	92 n=17	95 n=25	90 n=3	95 n=9
Soya beans	79 n=25	85 n=32	92 n=13	97 n=2

n = Number of trials

The table shows that an application rate of 4 lb prynachlor per acre destroys 85-95 % of the weeds. The recommended application rates lie between 3 and 4 lb per acre.

The weed spectrum of prynachlor, including results from trials with other crops (peanuts, cotton), takes the following form:

Table 3

Weed spectrum of prynachlor 3 lb/ac

Efficacy >85 %

Weeds	0 80 90 100	n
Stachys arv.		3
Papaver rh.		5
Spergula arv.		3
Anagalis arv.		5
Matricaria spp.		72
Galeopsis tetr.		6
Euphorbia spp.		5
Galium apar.		28
Lamium spp.		37
Myosotis arv.		9
Stellaria med.		134
Centaurea cyan.		3
Capsella b.p.		26
Fumaria offic.		2
Chenopodium spp.		96
Galinsoga parv.		27
Erysimum cheir.		2
Portulaca oler.		11
Richardia scab.		1
Senecio vulg.		21
Urtica spp.		29
Amaranthus spp.		146
Ambrosia artem.		8
Sida spin.		3
Atriplex spp.		19
Mollugo vert.		4
Polygonum spp.		131
Sonchus oler.		14

Efficacy <85 %

Weeds	0 60 70 80	n
Malva parv.		3
Abutilon th.		6
Xanthium spp.		8
Solanum nig.		20
Ipomoea spp.		8
Ranunculus spp.		3
Cassia obt.		1

Grasses	0 80 90 100	n
Paspalum spp.		2
Alopecurus spp.		1
Poa annua		17
Apera s.p.		4
Eleusine ind.		5
Digitaria spp.		19
Setaria vir.		4
Echinochloa c.g.		19
Setaria spp.		12
Setaria faberii		9
Bromus un.		3
Eragrostis lept.		2
Panicum max.		5
Setaria glauca		3
Cynodon dact.		2

n = Number of trials

Prynachlor is especially effective against common grasses such as *Echinochloa crus-galli*, *Digitaria* and *Setaria*, even at a low rate of application.

It is also highly effective against *Amaranthus*, *Euphorbia*, *Galinsoga*, *Galeopsis*, *Lamium*, *Matricaria*, *Portulaca*, *Stellaria* and *Veronica*. Its effect on *Ipomoea*, *Malva*, *Sesbania*, and *Solanum* is limited and it has no effect at all on root-propagated weeds.

DISCUSSION

Prynachlor is effective against both annual broadleaved weeds and annual grasses. The marked selectivity and the broad weed spectrum make prynachlor an effective herbicide for use in maize, sorghum and soya beans, especially where years of broadleaved weed control have favoured the development of grasses. If the predominating weeds are species on which prynachlor has only a limited effect, another herbicide must be added. A mixture of prynachlor with a urea or triazine derivative is particularly suitable. As prynachlor breaks down fairly rapidly in the soil and loses its effectiveness after 6-8 weeks, there is no danger to later crops.

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