PRELIMINARY STUDIES ON WEED GERMINATION AND HERBICIDE EFFICACY UNDER SEMI-CONTROLLED CONDITIONS

By P. E. T. TURNER

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe 4300

Abstract

One of the main causes of poor weed control on sugarcane farms is the occurrence of weed germination in periods during which demands on the farm's resources are at a maximum and during which wet conditions may prevent timely herbicide application or other weed control operations. It would therefore facilitate weed control if weed germination could be predicted from meteorological data and a knowledge of weed germination patterns. For this reason two experiments were conducted in pots under semi-controlled conditions: the first to study the germination patterns of 4 grass weeds in 5 different topsoil horizons under two different irrigation regimes; and the second to investigate the effects of alachlor on 5 weed species under differing moisture conditions. The results indicated that weed germination patterns varied with soil type and moisture conditions. Survival of weeds was lowest in soils with low water-holding capacities under rainfed conditions. In spite of slower weed germination in heavier soils a greater number of weeds survived in the experiment. The efficacy of alachlor depended on rates of application which appeared to be more important than the timing of water application.

Introduction

Weed control in sugarcane generally entails using an integrated programme involving herbicides, hand labour, and in some instances mechanical cultivation. Programmes are designed to fit in with seasonal requirements; ie in winter, when few grass weeds occur, growth of broadleaf weeds is slow and herbicides are less effective, hand labour is more cost-effective; while in spring and summer under moist conditions growth of grasses, broadleaf weeds and watergrass is vigorous, and herbicides are more effective. In practice, all fields harvested during the early part of the harvesting season will require some weed control measures in spring when conditions become suitable for weed growth, as it is unlikely that the crop will have formed an adequate leaf canopy by then. This places a demand on labour at a time when both planting and fertilizing operations are being carried out.

The use of herbicides in spring and summer has been suggested by Lonsdale,[3] Rau,[4] and Wise[6] as a means of alleviating this problem. Each of these authors emphasised the need for programme planning and careful timing of herbicide applications to achieve acceptable weed control throughout the season. In practice, in spite of a wide choice of herbicides, weed competition still occurs often in sugarcane fields. Although programme planning helps considerably in making contingency plans, the most difficult aspect of weed control is probably deciding when to begin herbicide treatments in spring and when to change from short term treatments to long term residual treatments (which rely on adequate moisture conditions). For this reason it would be useful to define the relationships between the environment and weed germination patterns, as well as the conditions under which herbicides act most favourably.

In particular it would be useful to be able to predict weed germination in various soils using meteorological data, and to predict the performance of a particular herbicide under specific meteorological conditions. A great deal of work has been carried out under controlled conditions to relate various environmental factors to herbicide efficacy. However Gerber *et al.*[1] indicated that laboratory experiments have tended to be focused on single factors, and conclusions can be misleading when applied to field conditions. It was for this reason that the two experiments reported here were conducted under conditions closely resembling those occurring in the field, so that particular factors could be examined without eliminating the effects of other environmental factors.

Relationships between soil characteristics and herbicide performance have been studied extensively, but less work has been conducted on the effects of soil type on weed germination. The objectives of the two experiments reported here were to observe grass weed germination patterns in different topsoils during September, October and November in relation to soil moisture and temperature, and to examine the effects of moisture regimes on the efficacy of alachlor, a commonly used pre-emergence grass-killer.

Table 1

Results of analyses of 5 topsoil horizons

Soil	Topsoil				ppm									
	Form	Series	Horizon	N cat*	pH	P	K	S	Ca	Mg	Na	Zn	Al	Fe
1	Hutton	Clansthal	Orthic	2	8,70	80	35	83	1 800	34	21	1,3	0	12
2	Fernwood	Fernwood	Orthic	1	4,80	28	65	27	112	28	0	1,0	5	113
3	Kroonstad	Kroonstad	Orthic	1	4,85	24	87	39	280	86	0	1,5	8	224
4	Arcadia	Rydalvale	Vertic	3	5,45	30	319	47	1 565	220	0	4,0	0	66
5	Milkwood	Milkwood	Melanic	2	8,35	35	175	162	1 800	184	41	2,1	0	30

* N Cat = nitrogen mineralising category
1 = very low
2 = low
3 = medium

Methods

Experiment I

Five different types of topsoil (Tables 1 & 2) were collected from various sites near Mount Edgecombe and placed in trays (approximately 300 × 300 × 100 mm in dimension). On 29 August and 24 September 1985, 4 weed species were planted in 2 trays of each soil type. The weed species and seed numbers used were:

Panicum maximum : 150 seeds tray^{-1}
Digitaria sanguinalis : 150 seeds tray^{-1}
Eleusine indica : 200 seeds tray^{-1}
Sorghum bicolor subsp. *verticilliflorum* : 150 seeds tray^{-1}

Table 2

Physical characteristics of 5 topsoil horizons

Soil no	Topsoil horizon	Clay (%)	Silt (%)	Sand (%)			OM%*	CEC** (meq l^{-1})
				Fine	Medium	Coarse		
1	Orthic	8	4	60	28	0	0,90	2,50
2	Orthic	6	4	61	29	0	1,00	3,00
3	Orthic	10	11	59	18	2	1,90	5,20
4	Vertic	36	19	29	11	5	5,10	12,70
5	Melanic	42	27	14	5	12	4,30	13,60

* OM% = organic matter percent
** CEC = cation exchange capacity

After planting, the seeds were covered with 10 mm of sieved soil from the same sources. Half the number of trays of each soil type were then watered with a watering can, 900 ml water tray^{-1} being applied. The same amount of water was then applied to these trays every 4 days, while the remaining trays received rainfall only. Rainfall was recorded at a nearby meteorological site. Germinated weeds were counted regularly.

Experiment II

Fumigated soil of the Shortlands series with a clay content of 55%, organic matter content of 2,1%, and a pH of 6,3 was placed in trays (approximately 300 × 300 × 100 mm in dimension). A measured volume of seeds of 5 weed species was placed on the soil surface of each tray. Weed species were:

Digitaria sanguinalis
Panicum maximum
Portulaca oleracea
Sorghum bicolor subsp. *verticilliflorum*
Rottboellia exaltata

Seeds were then covered with about 10 mm of soil and the trays were either left dry or given 900 ml water per tray applied with a watering can.

The trays were then sprayed with various rates of alachlor from a gas-operated knapsack sprayer and placed under plastic rain-shelters. Details and conditions recorded at the time of application were:

Date	: 22.5.85
Weather	: clear and warm
Air temperature °C	: 8 am 18,1
	2 pm 28,0
Relative humidity %	: 8 am 56
	2 pm 31
Nozzle	: 8004-E fan jet
Pressure	: 200 kPa
Output	: 765 l ha^{-1}
Method	: applied directly over the trays with two passes in opposite directions.

The experiment was conducted in two sections and the treatments for each section were:

Trial A

Treatment	Chemicals	Water
(a)	Untreated control	10 mm water applied just before spraying in half of the trays and the remainder sprayed dry. All trays watered 12 days after spraying and every 3 to 4 days thereafter with 10 mm per application
(b)	alachlor at 0,18 kg ai ha^{-1}	
(c)	alachlor at 0,90 kg ai ha^{-1}	
(d)	alachlor at 1,80 kg ai ha^{-1}	

Trial B

Treatment	Chemicals	Water
(a)	Untreated control	10 mm water applied just before spraying in half of the trays and the remainder sprayed dry. The first watering after spraying was varied, ie 1 week, 2 weeks, 3 weeks and 4 weeks. All trays were watered every 3 to 4 days after the first watering
(b)	alachlor at 0,18 kg ai ha^{-1}	
(c)	alachlor at 0,90 kg ai ha^{-1}	
(d)	alachlor at 1,80 kg ai ha^{-1}	

Numbers of germinated weeds were recorded regularly.

Results and discussion

Experiment I

Water: a marked difference in germination occurred between irrigated and rainfed trays at both planting dates and in each soil type. The first germination in rainfed trays occurred on average about 3 weeks after that in the irrigated trays and about 5 days after rainfall of more than 30 mm. With all soil types, weeds died in the rainfed trays as the soil became dry while growth continued in the irrigated trays. Subsequent rainfall stimulated further germination in rainfed trays at the later planting (September) but had little effect on trays planted earlier (August). In rainfed trays containing melanic topsoil weed growth was less affected by dry conditions than in trays with the other soil types. Johnston[2] has reported on the different moisture retention characteristics of different types of soil and this factor probably explains the phenomena observed. Throughout the experiment irrigated trays of all soil types had greater numbers of germinated weeds than the rainfed trays.

Weed species: soil type and water regime affected the 5 weed species similarly. Under irrigated conditions all weed species germinated better than under rainfed conditions. In sandy top soils under rainfed conditions they all tended to die.

Planting time: the difference in germination between irrigated and rainfed trays was most marked in the second planting. This may have been because the more favourable soil temperatures that occurred at the time of the later planting resulted in weeds germinating immediately in the irrigated trays. The pattern of germination also varied between

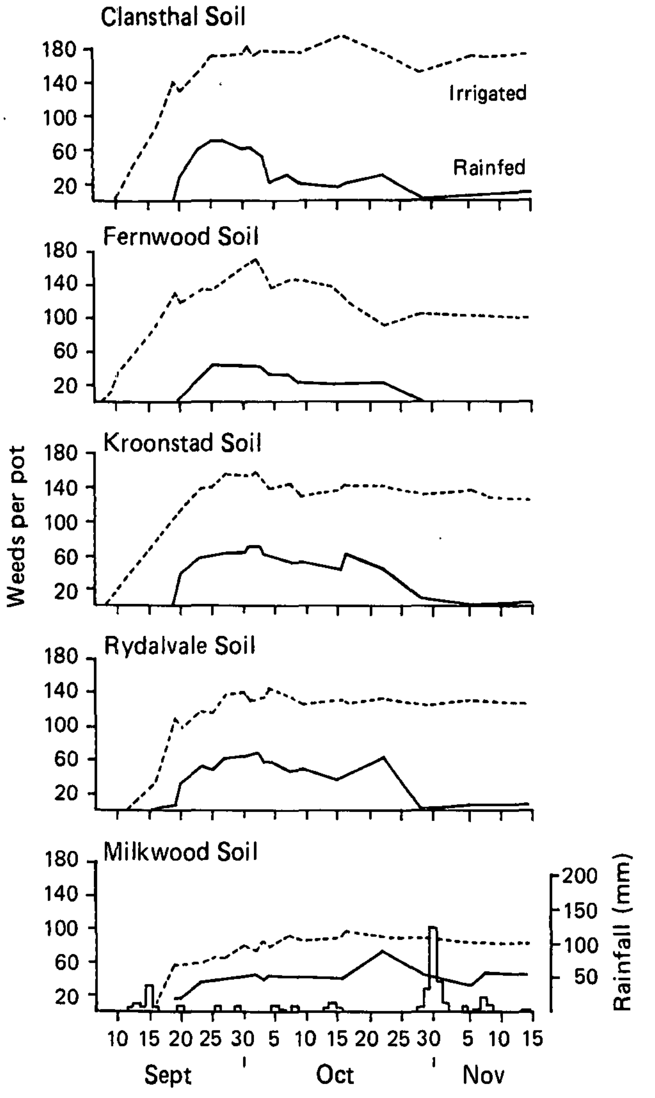

FIGURE 1 Mean germination counts of all weed species on the respective soils, rainfed and irrigated: 1st planting 29/8/85.

planting dates, particularly in trays subjected to rainfed conditions, where a dry spell occurring shortly after the earlier planting tended to desiccate and kill a number of plants. This did not occur with the later planting, and moisture conditions were favourable until the termination of the experiment.

Soil type: in the first planting, under rainfed conditions, early germination of weeds was most vigorous in the Clansthal, Kroonstad and, to a lesser extent, the Rydalvale soils. Most weeds growing in the Clansthal soil died, while a greater number of those in the Kroonstad and Rydalvale soils survived until a longer dry spell occurred when nearly all of the weeds died. Germination was comparatively slow in the Fernwood and Milkwood soils, but the subsequent pattern of germination and survival was markedly different on the two soils, with a steady decline in numbers in the Fernwood soil and a fairly steady but slow increase in numbers in the Milkwood soil.

Under irrigation the number of plants was higher throughout the experiment in the Clansthal, Fernwood, Kroonstad and Rydalvale soils than in the Milkwood soil. However, numbers in the Fernwood soil decreased markedly during October and this may have been due to the very low clay content and consequent poor water-holding capacity of this

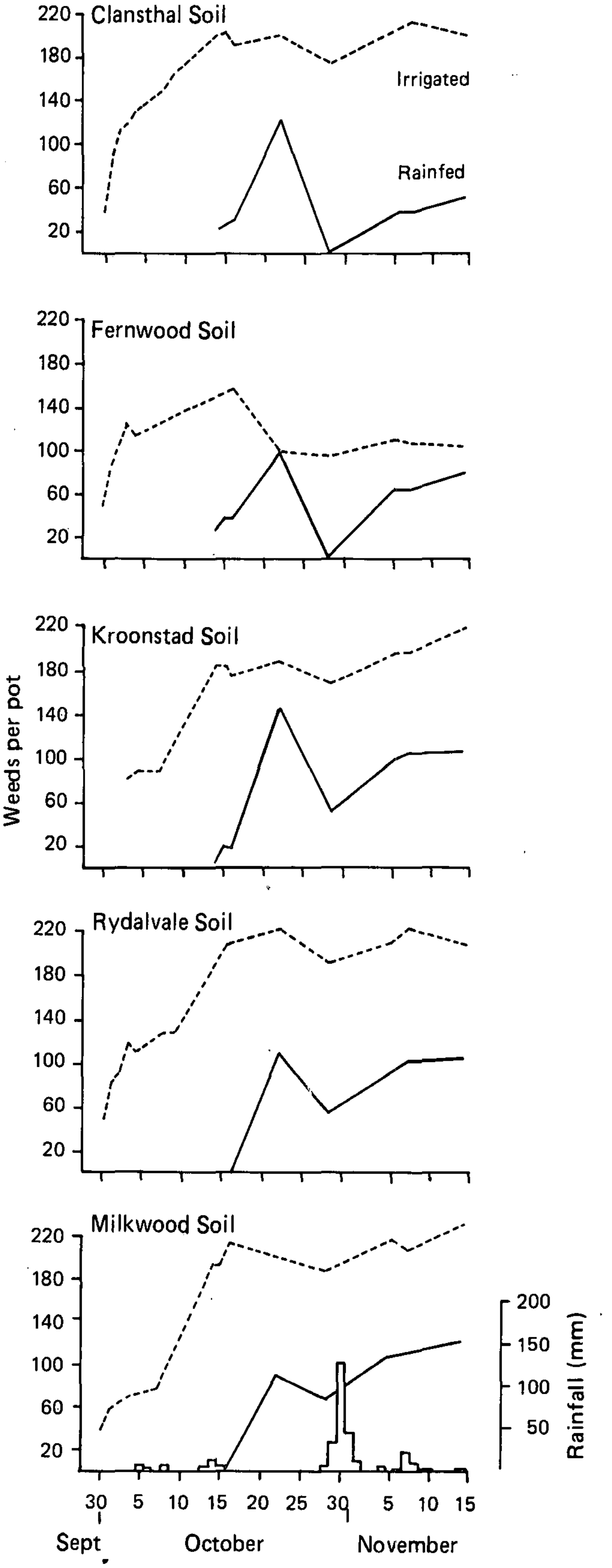

FIGURE 2 Mean germination counts of all weed species on the respective soils, rainfed and irrigated: 2nd planting 24/9/85.

soil. As temperatures rose, the soil could not retain sufficient water to meet the evaporative demand.

Results from the second planting were generally similar to those from the first, except that there was a marked recovery in weed numbers in rainfed trays of the second planting after substantial rain fell at the end of October. Weed growth in the irrigated Milkwood soil was comparable with that in other soils. This contrasted with the poorer germination in the Milkwood soil planted a month earlier.

The Fernwood soil showed the poorest weed growth which may have been due to nematode and nutritional problems as well as to poor physical properties.

Soil temperature: Figure 3 shows soil temperatures at intervals throughout the experiment. The times at which measurements were taken varied slightly, so no critical comparisons can be made between soil types. However, the patterns of temperature variation were similar for all the soil types and differences between soil types were less than the day to day variations.

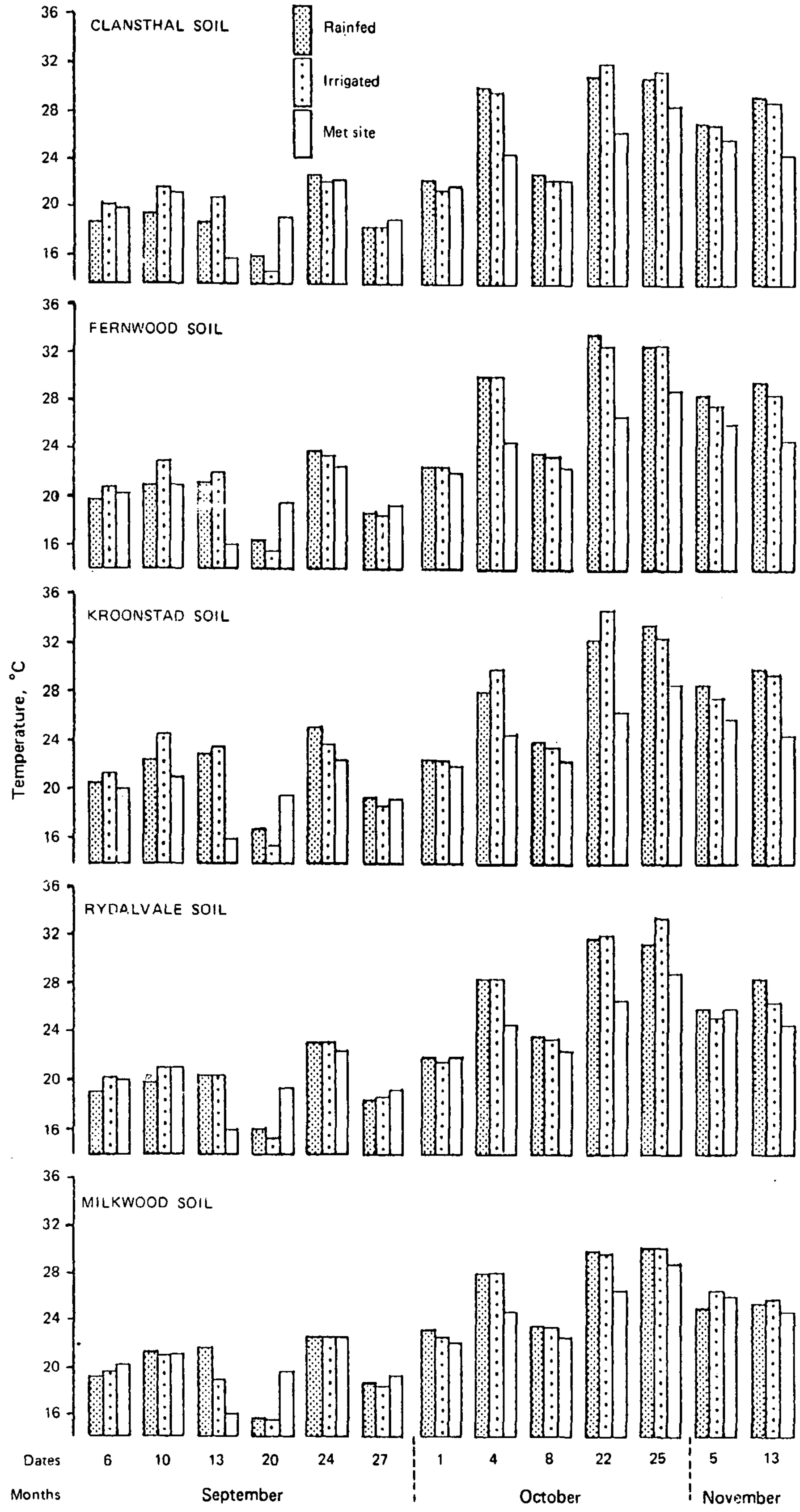

FIGURE 3 Soil temperature (°C) at 5 cm depth at 08.00 in rainfed and irrigated soils.

Visual observations at the end of the experiment: at the end of the experiment the earlier planted rainfed trays of all soil types had virtually no weed growth with the exception of some new germination of *Digitaria sanguinalis* mainly in the Milkwood soil. The irrigated trays planted first had high weed populations but growth was poor to fair in Clansthal and Fernwood soils, better in Kroonstad and Milkwood soils, and very good in Rydalvale soil. Growth in the rainfed trays planted later was superior to that in the trays planted earlier. Again the weeds in the Kroonstad, Milkwood and particularly Rydalvale soils showed the most vigorous growth. The weeds in the irrigated trays planted later generally showed far better growth and higher plant numbers than those of the earlier planting. Growth in the Rydalvale soil was again better than that in other soils.

Discussion: the importance of moisture for weed germination is clearly illustrated by these results and it is also apparent that soil type may markedly affect the pattern of weed germination and growth under both rainfed and irrigated conditions. These results suggest that weed survival and growth are more affected by rainfall pattern in soils with very low clay contents and low water-holding capacities than in soils with higher clay contents. Soil temperature appears to be secondary in its influence on germination although a sudden drop in temperature in September was associated with a slight increase in plant deaths in the Fernwood, Clansthal and Rydalvale soils.

Experiment II

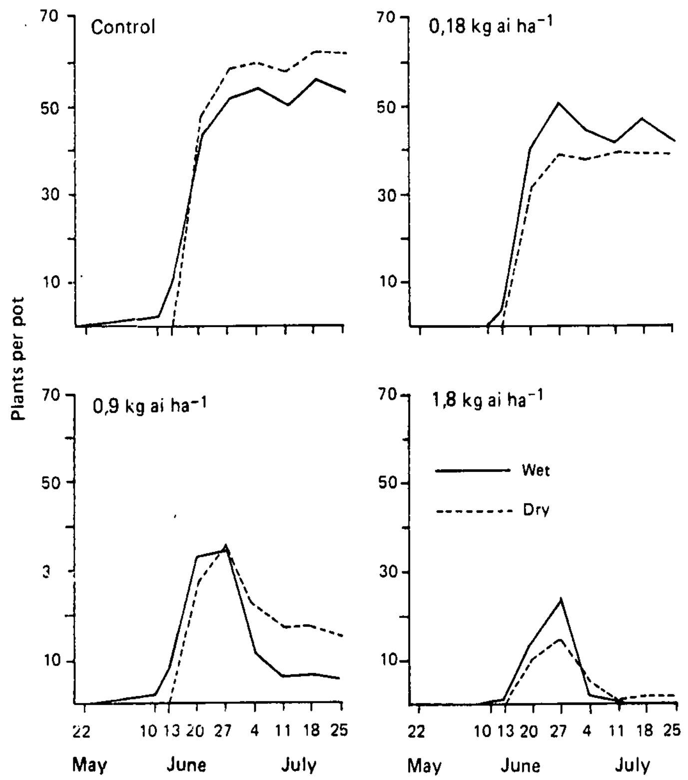

FIGURE 4 Weed germination after application of 3 rates of alachlor to wet or dry soil.

Moisture levels at time of spraying: regular watering was begun 12 days after spraying alachlor treatments onto wet or dry trays and weed germination began about 7 days later. Germination was only slightly delayed in trays which were not watered after planting, whether treated with alachlor or untreated. Generally however, the presence or absence of moisture at spraying had little effect on weed germination patterns in treated and untreated trays (Figure 4).

Alachlor rates: only the rate of 1,8 kg ai ha^{-1} provided adequate control of all weed species (Figure 5). The registered rate for this chemical ranges from 1,92 to 2,3 kg ai ha^{-1}. Similar patterns of weed germination occurred in all the treatments. Germination of all weed species began about 7 days after the first application of water following herbicide treatment. Numbers of germinated weeds increased rapidly, reaching a maximum about 36 days after the application of alachlor. Then a rapid decline occurred, particularly where higher rates were applied. These results suggest that the weeds died after their roots absorbed the chemical.

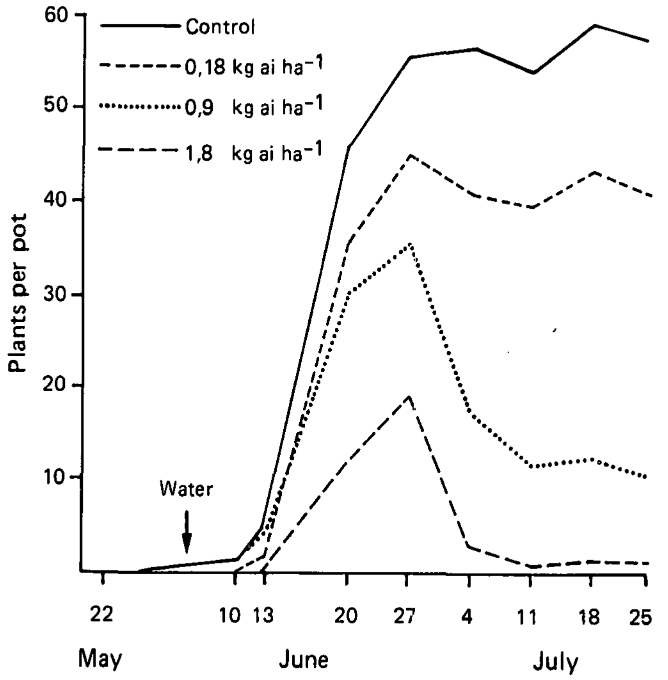

FIGURE 5: Weed germination patterns after treatment with 3 rates of alachlor.

Where higher rates of alachlor were applied the maximum number of germinated weeds recorded was much smaller than that recorded at lower rates. This suggests that most of the weeds were killed before emerging from the soil.

Alachlor appears to be highly effective in controlling *Panicum maximum* (Figure 6). The decline in weed numbers suggests that root absorption may take place after the emergence of some plants.

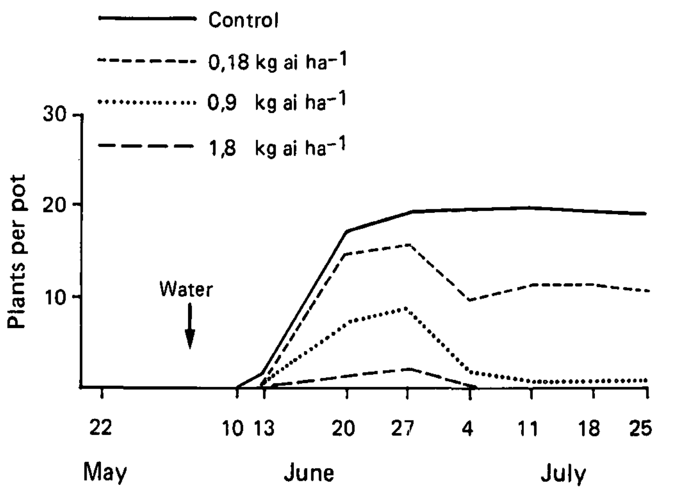

FIGURE 6 Germination patterns of *Panicum maximum* after treatment with 3 rates of alachlor.

Water regimes: although more weeds germinated when water was applied soon after spraying than when it was delayed, trays treated with 1,8 kg alachlor ha^{-1} showed better final weed control in the trays watered earlier. This difference was small in comparison with the differences between alachlor rates but it is nevertheless important for commercial practice. The weed control achieved by 1,8 kg alachlor ha^{-1} when water was first applied 1, 2, 3 and 4 weeks after the treatment of trays containing wet soil was 100; 97,5; 88,5 and 94% mortality, respectively, and these are important differences in commercial terms. It seems that water applied soon after herbicide application helps to give good weed control but that a surprisingly high degree of herbicide activity can be obtained when the application of water is delayed for a month after herbicide application.

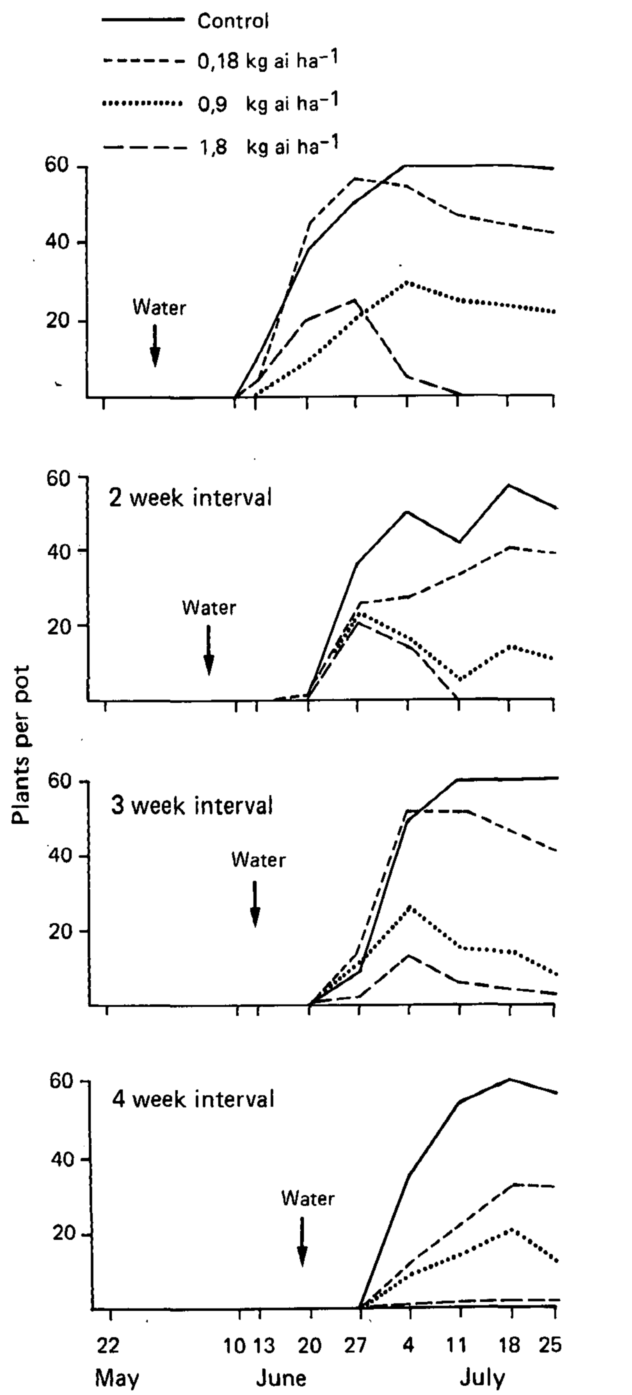

FIGURE 7 Weed germination patterns after treatment with 3 rates of alachlor under various watering regimes. (Results of wet and dry pots at spraying combined).

When all the rates at which alachlor was applied are considered weed control was practically the same, irrespective of the interval between spraying and first watering. Weed control differed little between trays in which the soil was wet or dry at the time of spraying, although treatment was slightly more effective when the soil was wet at the time of spraying than when it was dry.

Discussion: weed germination did not begin in untreated trays until 7 days after the first application of water. This suggests that trays which were wet at the time of spraying had insufficient moisture to stimulate germination. It is likely that there would have been a greater difference in the activity of alachlor between trays containing wet and dry soil if more water had been applied prior to spraying.

The observed pattern of weed germination and subsequent death of weeds was unusual in comparison with commercial applications of alachlor in the field, although similar results have been reported by Richardson and Parker.[5] The favourable moisture conditions in parts of this experiment could explain the ability of weeds to absorb alachlor through the roots in quantities sufficient to kill them after emergence.

The surprisingly good control achieved by alachlor when water was withheld after application may possibly be attributed to the fact that water applied at planting had been insufficient to stimulate weed germination. However, it does indicate that relatively little breakdown of the chemical occurred in the dry soil. Also, once watering began, moisture conditions were very favourable for herbicide action. Gerber *et al.*[1] have suggested that the activity of soil-applied herbicides is related to the exposure time and concentration of chemical in the soil solution. Hence it is clearly linked to the moisture characteristics of the soil and the frequency and quantities of moisture applied. This may explain the high degree of herbicide activity observed in these experiments.

Conclusions

The results of these experiments suggest that weed germination is closely linked to soil type and in particular to its moisture retention characteristics. Soil temperature did not vary significantly between soil types but appeared to have some effect on germination, and a closer examination of germination patterns in the field and soil temperatures from meteorological sites could be useful for predicting weed germination.

The performance of alachlor was dependent more on application rate than on either moisture level at the time of spraying, or the time between spraying and the application of water. This has important implications for commercial use of alachlor when the soil is dry, but confirmation of these results in the field is required.

Acknowledgements

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