Proceedings 1980 British Crop Protection Conference - Weeds

EFFECTS OF SIMULATED RAIN ON BENTAZONE ACTIVITY AGAINST MEADOW FESCUE, TIMOTHY AND WHITE MUSTARD

R. Skuterud[1]
J.C. Caseley

Agricultural Research Council Weed Research Organization
Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary Light rain (0.5 mm) applied at 5 min, 3 and 6 h after spraying bentazone had no effect on herbicide performance although retention studies using fluorescein dye indicated that about half of the spray deposit was removed from the plants. This may be partly explained by redistribution of some of the remaining herbicide to vulnerable sites on the plant, particularly the inner leaf sheath. Application of bentazone in this region of meadow fescue resulted in greater phytotoxicity than application of the same amount of herbicide to the leaf blade. In addition, bentazone reaching the soil also contributed to phytotoxicity in meadow fescue. Herbicide applied to the soil avoiding the foliage had substantial toxic effects especially when followed by rain. A leaching study showed 10 mm of rain in the absence of vegetation moved bentazone 6-7 cm down a soil column of Begbroke sandy loam. Soil activity made a smaller contribution to the toxicity of bentazone to white mustard, and with the 2.5 and 10 mm rain intensities herbicide performance increased as the period between spraying and rain was prolonged. Timothy was highly tolerant to all the treatments tested.

INTRODUCTION

In Norway, bentazone is commonly used as a post-emergence treatment to control broad leaved weeds in leys sown with red clover alone or in a mixture with grasses including meadow fescue (*Festuca pratensis*) and timothy (*Phleum pratense*). While red clover and timothy are highly tolerant to bentazone at 1.2-1.5 kg/ha, meadow fescue shows some susceptibility particularly at higher temperatures (Skuterud, 1979 and 1980).

In Japan, bentazone is used as a pre-emergence herbicide in rice (Mine *et al*., 1974) but it is more commonly applied as a post-emergence treatment which renders it susceptible to removal from the foliage by rain. Reduction of broadleaf weed control by rainfall soon after bentazone application has been reported by several workers including Andersen *et al*. (1974), Doran and Andersen (1975), and Nalewaja *et al*. (1975). Andersen *et al*. (1974) observed that heavy rain, resulting in temporary flooding, led to increased herbicide toxicity to soyabeans. Penner (1975) found that covering wet soil with vermiculite prior to spraying avoided the reduction in soyabean tolerance suggesting that bentazone absorption by roots can occur under these conditions.

The main aim of this work was to investigate the effects of different amounts of simulated rain applied at several time intervals after spraying on bentazone

[1] Division of Herbology, Norwegian Plant Protection Institute, 1432 AAS-NLH, Norway

selectivity in meadow fescue and timothy, and toxicity to a representative broad-leaved plant, white mustard (*Sinapis alba*). Toxicity of the herbicide resulting from both foliage and soil routes of entry are considered.

METHOD AND MATERIALS

Plant material. Twenty seeds of timothy cv. Forus and meadow fescue cv. Løken and 8 seeds of agricultural white mustard were each sown in Begbroke sandy loam contained in 10 cm diameter pots of 0.75 l capacity. The nutrient status of the soil was maintained by incorporation of 3 g of Vitax QS3 slow release fertilizer per kg of soil. Approximately one week after emergence the grasses were thinned to 15 plants and the white mustard to 4 plants per pot. Watering was from above, avoiding the foliage, for the first two weeks and by sub-irrigation thereafter. The plants were kept in a glasshouse at a temperature of $17 \pm 7^{\circ}C$ and a humidity of $60\% \pm 20\%$ RH up to one day before treatment with bentazone when they were moved to a controlled environment room where the day/night temperature and humidity regimes were $16/10^{\circ}C$ and 75/89% RH respectively. A light intensity of 95 W m^{-2} for 14 h per day was provided by cool white fluorescent lamps supplemented with tungsten lamps. The plants remained in the controlled environment rooms for two days after the herbicide and rain treatments and were then returned to the glasshouse.

The grasses were sprayed with herbicide at growth stage 1.2-1.2½ (Zadoks, Chang and Konzak, 1974) and the white mustard when the first true leaves were 1-3 cm in length. The grasses were harvested 14 and the white mustard 10 days after spraying and the fresh weight was recorded. The number of replicates ranged from three to eight as shown under individual tables and the experiments were arranged in a randomised block design.

Herbicide treatments. The sodium salt of bentazone (480 g ai/l) formulated without wetting agent was used throughout these experiments. Herbicide solutions were applied with a laboratory pot sprayer fitted with a single Spraying Systems 8001 'Tee-Jet' nozzle operating at 2.11 bar. The speed of the nozzle carriage and its height above the foliage were adjusted to deliver 200 l/ha.

Deposition of bentazone solution on specific sites on meadow fescue (Table 4) was made using a Burkard automatic syringe. The volume applied approximated to that retained on the plant following application with the sprayer and a concentration of 7.5 g ai/l equivalent to 1.5 kg ai/ha was used. Four 3 µl drops were applied to the following locations:-

a. 'mid leaf' - a 2 cm portion of the second leaf, mid lamina region, adaxial surface,
b. 'inner sheath' - the herbicide was deposited in between the leaf sheath (2nd leaf) and the shoot tissue it encloses, and
c. 'shoot base' - the herbicide was deposited at the shoot base junction with the soil.

In the case of both b and c the location of the herbicide cannot be defined precisely.

The 'soil only' treatments (Table 3) were also made with the Burkard applicator. Forty 4 µl drops were evenly distributed over the soil surface avoiding contact with plant shoots. The total volume applied to each pot was approximately the same as that from the pot sprayer.

In the 'foliage only' treatment (Table 3) the soil was protected with polystyrene beads which were removed after the spray deposit had dried.

Rain treatments. These were made with the WRO rain simulator briefly described by Caseley (1979). The target area of 4.5 m^2 allowed simultaneous rain application to all the plants in each rain treatment. The amounts of 0.5, 2.5 and 10 mm were each applied in a period of 0.5 h and at intervals after spraying bentazone of 5 min, 3 and 6 h.

Spray retention. Plants at the growth stages selected for herbicide treatment were sprayed with bentazone at the 1.5 kg ai/ha dose plus 1 g/l of fluorescein. The spray deposit was allowed to dry for 1.5 h and following the rain treatments the foliage was cut at soil level and carefully transferred to a plastic bag. Twenty ml of 0.005 M NaOH was added and the bag shaken for 30 sec. The solution was then decanted and its content of fluorescein immediately determined using an EIL fluorimeter.

Leaching studies. Longitudinally split 10 cm diameter, 15 cm long, soil columns as described by Nyffeler and Blair (1978) were packed with air dry Begbroke sandy loam, which was moistened both from above and by sub-irrigation and then sprayed at field capacity with bentazone at 1.5 and 3.0 kg ai/ha. Following application of 10 mm of rain the columns were allowed to drain for 24 h before being split and sown along their length at 1 cm intervals with white mustard and meadow fescue. The split columns were then kept in a growth room at 26/16°C and 85/93% RH day and night respectively. The plants were scored 12 days after sowing using a 0-7 scale (Richardson and Dean, 1974).

RESULTS

Table 1

Effect of 2.5 mm of rain applied at three intervals after spraying on bentazone activity against meadow fescue, timothy and white mustard

		Meadow fescue	Timothy	White mustard
Fresh weight		6.2	2.2	18.4
Retention µl/g		474	184	610
Interval from spraying to rain	Bentazone dose[1]	Fresh weight as % of control		
		S.E.	S.E.	S.E.
5 min	a	40±6.3	104±5.1	92±2.6
	b	1±0.4	85±3.2	78±3
3 h	a	23±2.6	98±1.8	19±4.1
	b	3±0.6	91±12.5	9±2.0
6 h	a	27±3.0	104±8.3	30±6.0
	b	3±0.6	81±8.9	4±1.7
No rain	a	44±6.7	108±9.2	3±1.2
	b	9±1.1	84±10.5	1±0.3

[1] Bentazone dose kg/ha a b replicates 8
grasses 1.5 3.0
white mustard 0.04 0.08

glasshouse conditions: mean for 10 days after spraying.

light Wm^{-2}	Temperature °C max	Temperature °C min	Humidity % RH max	Humidity % RH min
272	24	12	74	30

Timothy was unaffected by bentazone at 1.5 kg/ha and only slightly damaged at double this dose (Tables 1 and 3). In contrast meadow fescue sustained severe damage at the lower dose and few plants survived 3.0 kg/ha (Tables 1, 2 and 3).

The phytotoxicity of bentazone was not affected by 0.5 mm of rain although this removed about half of the spray solution from the plants. Almost all the spray solution was removed by 2.5 mm of rain which enhanced bentazone activity when its application was delayed until 3 and 6 h after spraying meadow fescue (Table 1). In a second experiment (Table 2) this amount of rain decreased bentazone activity whereas 10 mm of rain did not affect performance against fescue except when applied 5 min after the herbicide (Table 2).

Table 2

Effect of three amounts of rain applied at three intervals after spraying on bentazone activity against meadow fescue and white mustard

Interval from spraying to rain				no rain		5 min		3 h		6 h	
Bentazone dose[1]		control		a	b	a	b	a	b	a	b
		g fresh wt		% of control							
Rain mm	% spray retention										
				Meadow fescue							
0	100	8.4	S.E.	22 ±3.2	13 ±2.2						
0.5	47		S.E.			23 ±3.3	13 ±1.6	22 ±5.8	7 ±1.5	28 ±3.9	13 ± .9
2.5	2		S.E.			47 ±5.9	20 ±1.9	36 ±3.6	22 ±3.3	44 ±4.6	21 ±3.4
10.0	1		S.E.			45 ±3.7	22 ±4.4	26 ±2.6	15 ±1.7	31 ±3.8	13 ±1.7
				White mustard							
0	100	19.3	S.E.	1 ±0.2	0						
0.5	65		S.E.			3 ±0.9	1 ±0.5	1 ±0.9	0	1 ±0.4	1 0.5
2.5	8		S.E.			89 ±7.2	74 ±4.9	8 ±1.9	1 ±0.7	1 ±0.9	1 ±0.4
10.0	3					102 ±7.3	100 ±8.4	24 ±4.9	7 ±1.9	11 ±3.7	2 ±1.1

[1] bentazone dose kg/ha a b as in Table 1.
Replicates: Retention & fresh wt. meadow fescue 4 and white mustard 5.
Glasshouse conditions mean for 10 days after spraying.

Light W m^{-2}	Temperature °C max	Temperature °C min	% RH max	% RH min
187	22	13	86	46

Applying bentazone to the foliage alone of meadow fescue reduced activity particularly when 10 mm of rain was applied, but this amount of rain increased phytotoxicity when the herbicide was applied only to the soil (Table 3).

Table 3

Effect of different sites of application on the activity of bentazone against meadow fescue, timothy and white mustard with and without rain

	Bentazone location	kg/ha	Fresh wt.(g)	Rain, 10 mm after 3 h -	+	
				% of control		
Meadow fescue	Control	0	4.3			
	Overall	1.5		20	29	
	Foliage only	1.5		40	74	
	Soil only	1.5		77	52	S.E.$\pm$4.4
Timothy	Control	0	2.8			
	Overall	1.5		101	102	
	Foliage only	1.5		99	110	
	Soil only	1.5		95	98	S.E.$\pm$4.0
White mustard	Control	0	24.2			
	Overall	0.04		2	51	
	Foliage only	0.04		5	48	
	Soil only	0.04		94	102	
	Soil only	1.5		95	84	S.E.$\pm$3.7

replicates 6.

Application of the herbicide to the mid lamina region resulted in the desiccation of that portion of the leaf and all tissue distal to it. The same amount of herbicide applied to the inner surface of the leaf sheath resulted in visible damage throughout the aerial portion of the plant. Herbicide application to the junction of the shoot with the soil had least toxic effect but fresh weight was reduced significantly compared to untreated controls (Table 4).

Table 4

Effect of site of application of bentazone on its activity against meadow fescue

Untreated control	Site of application mid-leaf	inner sheath	shoot base
	g fresh wt.		
1.93	1.36	0.79	1.61

replicates 6. S.E. = $\pm$ 0.09

White mustard sustained the most damage in the 'no rain' and 0.5 mm of rain treatments (Tables 1 and 2). Giving 2.5 and 10 mm of rain 5 min after spraying resulted in little and no herbicide activity respectively. Application of herbicide to the foliage alone resulted in as much activity as the foliage plus soil treatment and 10 mm of rain 3 h after spraying reduced phytotoxicity substantially in both cases (Table 3). Treatment of the soil alone had little effect even when the herbicide dose was raised to 1.5 kg/ha and 10 mm of rain was applied.

The leaching study showed that 10 mm of rain in the absence of vegetation moved the bentazone 6-7 cm down the soil column with the highest activity 2 to 4 cm from the soil surface (Table 5).

Table 5

Growth of meadow fescue and white mustard in bentazone treated soil columns after application of 10 mm of rain

	Meadow fescue		White mustard	
Bentazone, kg/ha	1.5	3.0	1.5	3.0
Depth, cm				
1	5.9	4.3	5.2	3.1
2	5.5	3.7	4.7	2.8
3	5.1	3.9	4.5	2.4
4	5.2	3.3	4.8	2.8
5	4.7	4.3	5.9	4.2
6	6.7	5.3	7.0	5.4
7	6.7	6.5	7.0	7.0
8	7.0	7.0	7.0	7.0

0 = dead and 7 = no effect (control)
replicates 3

DISCUSSION

None of the 0.5 mm rain treatments had any effect on bentazone activity although the fluorescein retention results suggest that about half the spray solution was removed from the foliage. The consistency in phytotoxic effects following removal of substantial amounts of spray deposit may be explained in terms of redistribution of the herbicide to regions where deposition results in greater herbicide activity, particularly the inner surface of the leaf sheaths of meadow fescue. This position in wild oats was found to be very sensitive to difenzoquat (Caseley and Coupland, 1980) and meadow fescue response to bentazone is similar (Table 4). The rewetting effect of light rain may also be important and has been shown to increase the activity of difenzoquat against wild oats (Coupland et al., 1978) and bentazone against *Amaranthus retroflexus* (Nalewaja et al., 1975). The results in Table 3 indicate that herbicide reaching the soil may also contribute to phytotoxicity. Soil activity was favoured in these experiments as the soil was kept moist by sub-irrigation, conditions known to enhance phytotoxicity (Penner, 1975).

The increase in toxicity of the soil-only treatment following application of 10.0 mm of rain (Table 3) was probably due to increased contact with the roots following movement of the herbicide down the soil profile as this compound is not strongly absorbed on soil constituents (Abernathy and Wax, 1973). However in sub-irrigated pots and in the presence of vegetation the herbicide may not have moved to the same extent as found in the leaching study (Table 5).

Most of the fluorescein was removed from the foliage by 2.5 and 10.0 mm of rain and, judging from the lack of toxic effects on white mustard subjected to rain 5 min after herbicide treatment, it would appear that at least the low doses of bentazone are also removed by these amounts of water. Prolonging the interval between spraying and rain led to increased bentazone damage particularly in white mustard (Tables 1 and 2). In this species overall herbicide treatment was no more toxic than application to foliage alone and deposition on the soil had little effect. This might be expected at the lowest doses (0.04 and 0.08 kg/ha), but not at the 1.5 kg/ha dose. In contrast meadow fescue suffered more damage from the 'overall' compared with the 'foliage only' treatment, and 'soil only' application resulted in considerable damage (Table 3). Visual examination of excavated plants showed meadow fescue to have more roots in the upper layers of the soil than white mustard. The leaf canopy of the latter tended to deflect some of the rain, and probably herbicide solution, away from the plant stem and part to outside the rim of the pot. In contrast the foliage of meadow fescue had relatively minor effects on the progress of the rain to the soil surface.

The environmental conditions in the glasshouse appear to have affected the results. For example, meadow fescue plants treated with the lower dose of bentazone without rain and kept in a higher light and lower humidity regime (Table 1) developed necrosis rapidly in leaves present at the time of spraying, but new leaves continued to emerge from several plants per pot. The same treatment kept in a lower light and higher humidity regime (Table 2) resulted in much slower development of symptoms, but more damage. The 2.5 mm rain treatment applied 3 and 6 h after spraying improved performance, probably by making herbicide available to the unaffected leaves (Table 1), but appeared to reduce activity when the damage developed more slowly (Table 2).

In contrast to meadow fescue and white mustard, timothy showed considerable tolerance to all the bentazone treatments. Its tolerance may be associated with reduced retention, uptake and transport and/or increased metabolism of the active ingredient as found in tolerant soyabean cvs (Hayes and Wax, 1975).

In both the susceptible species, bentazone was most damaging when applied to the foliage, but herbicide entering the plant via the soil also made a significant contribution to phytotoxicity particularly in meadow fescue. Consequently, 2.5 and 10.0 mm of rain soon after herbicide application reduced bentazone activity against white mustard most and meadow fescue least.

Acknowledgements

R. Skuterud is greatly indebted to the Weed Research Organization for making this investigation possible, to the Norwegian Agricultural Research Council for financial support and to J.C. Caseley for great help in planning the experiments and writing this report.

References

ABERNATHY, J.R. and WAX, L.M. (1973) Bentazone mobility and absorption in twelve Illinois soils. Weed Science, 21, 67-77.

ANDERSEN, R.N., LUESCHEN, W.E., WARNES, D.D. and NELSON, W.W. (1974) Controlling broad-leaf weeds in soyabeans with bentazone in Minnesota. Weed Science, 22, 136-142.

CASELEY, J.C. (1979) Techniques for investigating effects of weather on herbicide performance. Proceedings European Weed Research Society Symposium. The influence of different factors on the development and control of weeds. 105-112.

CASELEY, J.C. and COUPLAND, D. (1980) Effect of simulated rain on retention, distribution, uptake, movement and activity of difenzoquat applied to *Avena fatua*. Annals of Applied Biology, 95 (in press).

COUPLAND, D., TAYLOR, W.A.T., and CASELEY, J.C. (1978) The effect of site of application on the performance of glyphosate on *Agropyron repens* and barban, benzoylprop-ethyl and difenzoquat on *Avena fatua*. Weed Research, 18, 123-128.

DORAN, D.L. and ANDERSEN, R.N. (1975) Effects of simulated rainfall on bentazone activity. Weed Science, 23, 105-109.

HAYES, R.M. and WAX, L.M. (1975) Differential intraspecific responses of soyabean cultivars to bentazone. Weed Science, 23, 516-521.

MINE, A., MATSUMAKA, S., HIND, N. and VEDA, M. (1974) Studies on the herbicidal properties of bentazone under paddy-field conditions. II Absorption and translocation in plants and behaviour in soil. Weed Research, Japan, 18, 5-9.

NALEWAJA, J.D., PUDELKO, J. and ADAMCZEWSKI, K.A. (1975) Influence of climate and additives on bentazone. Weed Science, 23, 504-507.

NYFFELER, A. and BLAIR, A.M. (1978) The influence of burnt straw residues or soil compaction on chlortoluron and isoproturon activity. Proceedings British Crop Protection Conference - Weeds, 113-119.

PENNER, D. (1975) Bentazone selectivity between soyabean and Canada thistle. Weed Research, 15, 259-262.

RICHARDSON, W.G. and DEAN, M.L. (1974) The activity and post-emergence selectivity of some recently developed herbicides: oxidiazon, U-29,722, U-27,658, metflurazone, norflurazon, AC 84,777 and iprymidan. Technical Report No. 32, pp 74. Agricultural Research Council Weed Research Organization.

SKUTERUD, R. (1979) Engveksters toleranse overfor bentazon og bromfenoxim. Informasjonsmote plantevern. Aktuelt fra LOT, NR1, 79-82.

SKUTERUD, R. (1980) Ugrasbekjempelse ved gjenlegg til eng. Informasjonsmote plantevern. Aktuelt fra LOT, NR 2, 89-95.

ZADOKS, S.L., CHANG, T.T. and KONZAK, C.F. (1974) A decimal code for the growth stages of cereals. Weed Research, 14, 415-421.

THE EFFECTS OF COLD AND FROSTY WEATHER CONDITIONS ON THE TOLERANCE OF WINTER CEREALS TO AN HYDROXYBENZONITRILE/MECOPROP ESTER MIXTURE

C.F.A. Kyndt and P.R. Auld

May & Baker Ltd., Ongar Research Station, Ongar, Essex.

Summary Trials were carried out to determine winter cereal tolerance to a bromoxynil, ioxynil and a mecoprop ester mixture applied under varying degrees of cold and frosty weather conditions.

Applications of the herbicide at twice the recommended dose to light to moderate weed infested winter wheat generally resulted in yields similar to those of untreated controls. Significant yield increases were obtained at one site with applications made during the severest winter weather conditions of 1979/80.

The direct effects of the herbicide on the yield of winter barley and the influence of weather conditions were masked by severe weed infestation. Statistically significant yield increases were obtained, even when twice the recommended dose was applied under frosty conditions.

There was no evidence to suggest that the crops were more sensitive when treated during a period of continuous night frosts.

Résumé Des essais ont été realisés pour déterminer la tolérance des céréales d'hiver à un mélange de bromoxynil avec l'ioxynil et un ester de mécoprop appliqué sous différentes conditions de temps froids et gelées.

Des applications de l'herbicide au double de la dose homologuée sur blé d'hiver, avec une infestation légère à moderée de mauvaises herbes, ont produit, en général, les rendements du même ordre que ceux des témoins. Les augmentations significatives de rendement ont été obtenues sur une parcelle où les applications ont été faites pendant les régimes climatériques les plus rigoureux de l'hiver 79-80.

Pour l'orge d'hiver, les effets directs de l'herbicide sur le rendement et l'influence des régimes climatériques ont été masqués par une infestation sévère de mauvaises herbes. Des augmentations de renements, statistiquement significatives, one été obtenues même quand le double de la dose homologuée a été appliquée sous les conditions de gelées.

Il n'y a pas eu d'évidence quant au fait que les cultures étaient plus sensibles quand elles étaient traitées pendant une période continue des gelées de nuit.

INTRODUCTION

The benefits of early removal of weed competition in winter cereals has been reported (Evans, 1974, Wilson et al, 1978, Wilson, 1980). However, autumn/early winter weather conditions limit the number of possible days that herbicides can be applied (Adams, 1978). Caseley (1974) reported that weather conditions before, during and after application can influence herbicide tolerance and that the period immediately around spray time is usually the most critical. Phenoxyalkanoic based herbicides have also been shown to reduce cold hardiness of winter wheat (Freeman, 1979).

This paper summarises winter cereal tolerance data obtained from crops treated with ARD 12/75 at 3.5 and 7.0 l/ha during the winter of 1979/80 under varying degrees of cold/frosty weather conditions.

METHOD AND MATERIALS

Compounds used	:	ARD 12/75 - bromoxynil + ioxynil (as octanoate esters) + mecoprop (as iso-octyl ester) as e.c. containing 52.5% total a.i. Standard rate of use: 3.5 l/ha.
Site details	:	12 small plot replicated trials in commercial crops of winter wheat (2 sites) and winter barley (1 site) in W. Essex. 3 replicates sprayed with Ongar small plot motorised (wheeled) sideboom precision sprayer. 196 l/ha. Plots 3.0 m x 15.0 m.
Metereological readings	:	Max/min. air and min. soil temperatures + rainfall were recorded daily at each site.
Assessments	:	Crop tolerance - plots visually scored by a minimum of 3 assessors for post-spray phytotoxic symptoms using a 0-100% score system, 0 = as per mean of untreated plots with degrees of phytotoxicity assessed in 5% graduations; 100% = complete kill. Observations on ear deformity were made before harvest. Grain yields were taken using Claas "Columbus" combine and expressed at a calculated 85% dry matter. Weed control - Pre-spray species counts using 2 x $\frac{1}{2}$ m^2 quadrats/plot. Plots visually scored for % bulk total weed control prior to harvest.

RESULTS

Each spray date was designed as a separate experiment and the results have been summarised in Table 1 according to spray dates, crop growth stage and temperature at the time of spraying. References should be made to figure 1 for the seasonal weather pattern and figure 2 for 48 hour pre and post-spray weather conditions.

Weed control is beyond the scope of this paper. However, apart from the very advanced Stellaria media which was moderately well controlled (75-80% control of bulk), all other weed species showed a high degree of susceptibility (90-100%) to ARD 12/75 at 3.5 l/ha applied at all growth stages encountered in these trials. There was little or no difference in weed control between the two doses.

Table 1

Yield response of winter cereals to treatment under winter conditions UK, 1979/80

Grain yields in tonnes/ha

Crop	Winter Barley			Winter Wheat				Winter Wheat				
Variety	Maris Otter			Mardler				Maris Huntsman				
Major weed (pop/m^2)	Matricaria matricarioides (200) Stellaria media (32)			Veronica persica (15)				Stellaria media (20)				
ARD 12/75 7.0 l/ha	6.39**	6.13***	6.84***	7.60	5.45	7.63	6.12	7.07	7.03	7.52***	8.26***	7.31
ARD 12/75 3.5 l/ha	6.75***	6.39***	6.95***	7.62	5.87	7.93	7.06	6.83	7.42	7.12**	7.28	7.27
Unsprayed control	5.03	4.51	4.75	6.34	5.20	7.98	7.13	7.00	6.41	6.38	6.52	6.87
S.E. of means ±	0.27	0.14	0.19	0.73	0.59	0.30	0.76	0.53	0.48	0.14	0.28	0.30
Date of application	19/11	16/12	22/1	15/1	12/2	4/3	7/4	13/11	28/11	10/1	26/2	4/4
Crop growth stage (Zdc)	13-14.2	14.23	14.22-23	12-13.21	13.21-22	14.21-22	22-23	11-12.21	13-14.21	14.21-24	15.22-27	22-27
Air temp (°C)	6	5	1	-1	9	10	15	4	9	4	6	13
Soil temp (°C)	7	5	4	0	6	8	10	5	10	2	5	10

* Significantly different from untreated at 5% level
** Significantly different from untreated at 1% level
*** Significantly different from untreated at 0.1% level.

Figure 1: Summary of seasonal weather pattern - winter 1978/80

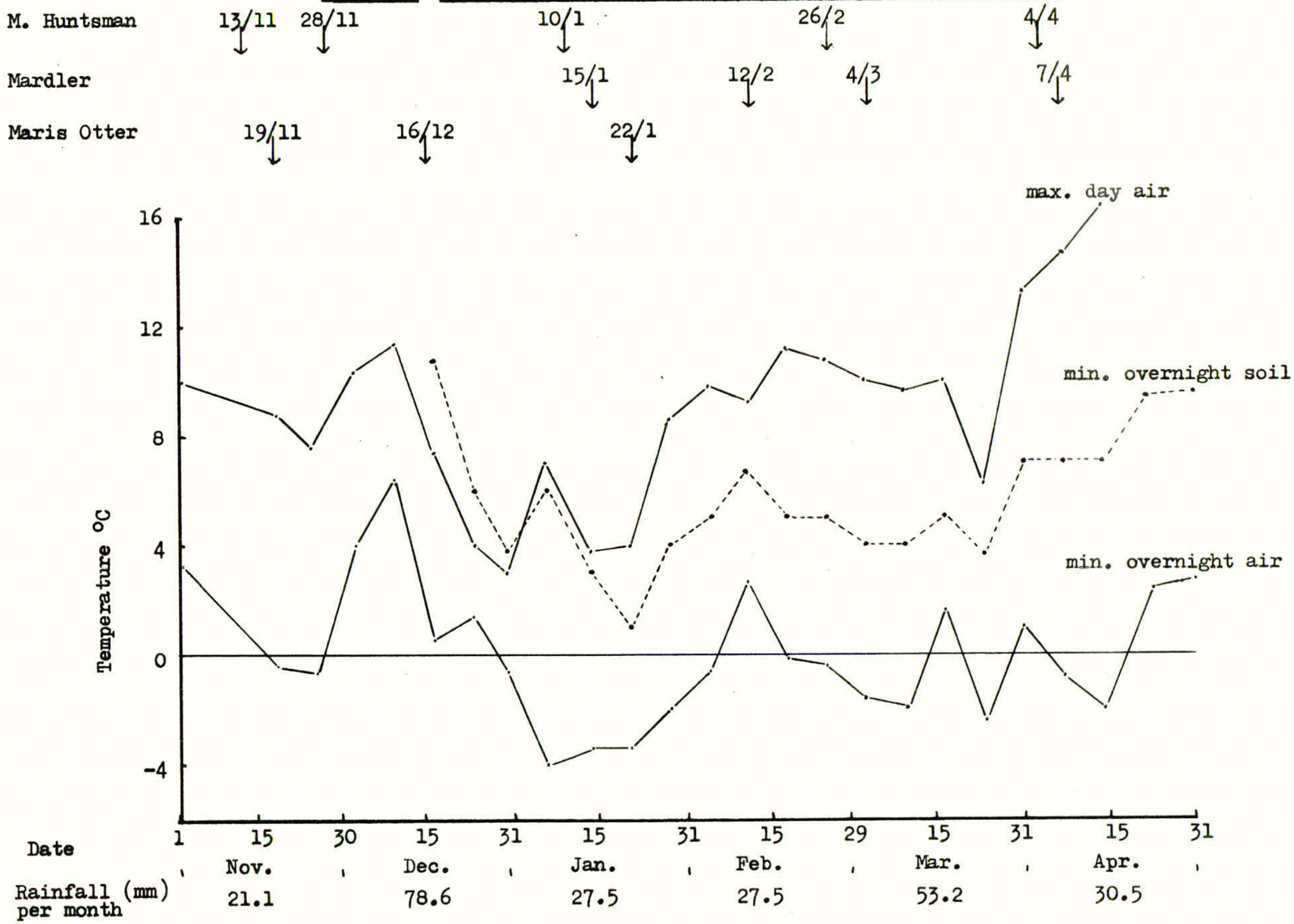
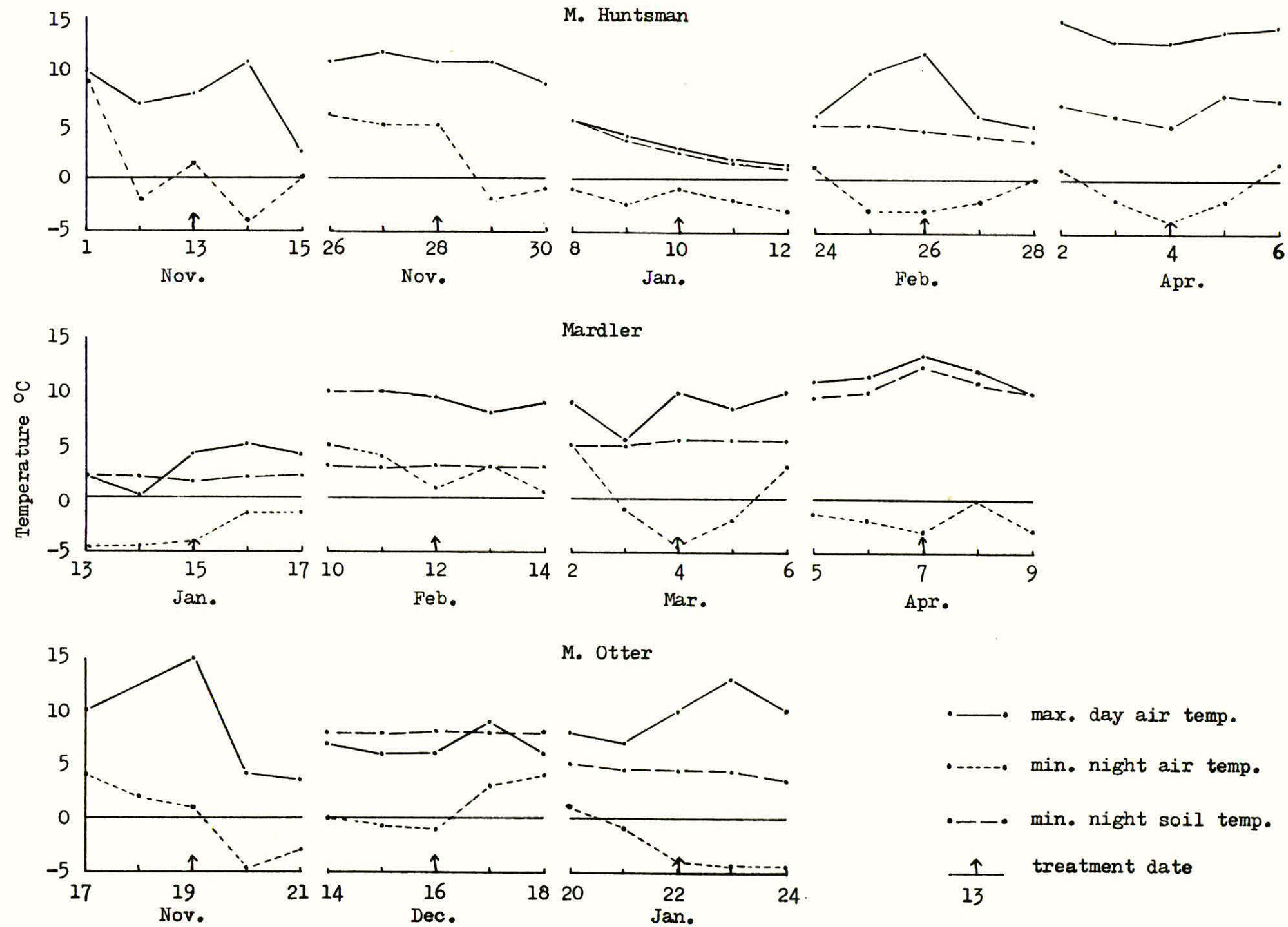


Figure 2: Summary of individual trial weather details 24 hrs pre and post-treatment



ARD 12/75 at 7.0 l/ha was well tolerated at all timings. Only transient phytotoxicity expressed as slight leaf margin scorch (max. 5% level) was evident for up to 14 days post-spray and there were no noticeable symptoms of ear deformities.

Winter barley

The effect of autumn germinating Matricaria matricarioides on the yield potential of Maris Otter is clearly shown between treated and untreated yield levels. Removal of this weed pressure with ARD 12/75 gave significant yield increases ranging from 1.36 to 2.2 tonnes/ha.

ARD 12/75 applied under differing weather patterns was well tolerated by Maris Otter and final yield differences between the two dose rates were insignificant. Applications during periods of mild days and moderate overnight air frosts (19/11 and 22/1) and cold days and light-moderate overnight air frosts (22/1) appeared to have no adverse effects on the resultant yield potential. The 22/1 application which was during the severest weather period of the winter gave the highest yield increase.

Winter wheat

Removal of a low population of Veronica persica from Mardler wheat with ARD 12/75 at all application timings gave no significant yield increase. This would indicate that this level of weed pressure had no adverse effect on the final yield potential of this crop. Applications of ARD 12/75 at 7.0 l/ha, whether during periods of cold days and light-moderate overnight air frosts (15/1) or mild days and light overnight frosts (12/2, 4/3 and 7/4) appeared to be well tolerated by Mardler wheat. Final yields on treated and untreated crops were comparable at all application timings.

Removal of a moderate population of S. media with ARD 12/75 at 3.5 and 7.0 l/ha at all application timings did not consistantly give significant yield increases of Maris Huntsman. Treatments made during the severest weather period (10/1 and 26/2), gave significant dose related yield increases ranging from 0.74 to 1.74 tonnes/ha, whilst those made during less severe weather periods (13/11, 28/11 and 4/4) gave yields similar to those of untreated controls.

DISCUSSION

Trials were conducted within a 7 mile radius of Ongar Research Station. The winter of 1979/80 in this area was comparatively mild. The severest weather conditions were in January when daily maximum air temperatures ranged from 2°C to 4°C and minimum night temperatures ranged from -1 to -4°C. At no time during this period did the soil temperature at 2.5 cm depth fall below 1°C. Average monthly rainfall over the 6 month winter period was 41.6 mm. Cereals and weeds were never completely dormant throughout this period and the extreme weather factors that were most likely to increase winter cereal sensitivity to herbicide treatment i.e. application after lush crop growth followed by sudden sharp frosting, were not generally encountered. Nevertheless under the various weather conditions tested, these trials clearly show that ARD 12/75 at up to 7.0 l/ha was well tolerated by winter cereals.

It is unfortunate that the yield figures of Maris Otter and to a certain extent Maris Huntsman are complicated by the presence of weed competition. However, the results indicate that at all treatment timings the advantages of weed removal generally outweighed any yield reduction which may have occurred due to any effect of the herbicide on the crop. The yield potential of 'weed free' Mardler wheat was unaffected by all application timings of ARD 12/75 indicating that any phytotoxic effect on the crop is of little or no consequence. The absence of any adverse effect of ARD 12/75 on all crops, may be further deduced from the very small difference between yields at the 3.5 and 7.0 l/ha dose rate, despite the fact that weed control was similar at either rate.

Acknowledgements

Thanks are due to Mr. P. Duncan of Writtle Agricultural College and to the staff of May & Baker Ltd. who conducted the field experiments.

References

ADAMS, R.J. (1978) Meteorological aspects of changes in spraying techniques. Proceedings 12th British Weed Control Conference, 2 625-630.

CASELEY, J.C. (1979) Techniques for investigating effect of weather on herbicide performance. Proceedings European Weed Research Society 105-113.

EVANS, S.A. (1974) The timing of post-emergence herbicide spray application for broad-leaved weeds in cereals. Proceedings 12th British Weed Control Conference 3 967-976.

FREEMAN, S.O. & HAMMAN, W.M. (1979) Effect of phenoxy herbicides on cold hardiness of winter wheat. Canadian Journal of Plant Science 59 237-240.

WILSON, B.J. & CUSSANS, G.W. (1978). The effects of herbicides, applied alone and in sequence on the control of wild oats (*Avena fatua*) and broad-leaved weeds, and on yields of winter wheat. Annuals of Applied Biology 89 459-466.

WILSON, B.J. (1980) The effect on yield of mixtures and sequences of herbicides for the control of *Alopecurus myosuroides* and broad-leaved weeds in winter cereals. Weed Research 20 65-70.

NOTES

THE EFFECT OF HERBICIDES ON THE DRY MATTER YIELD AND REGROWTH ELONGATION OF AN ESTABLISHED LOLIUM PERENNE (RYEGRASS) SWARD

A. D. Courtney and R. M. Johnson

Department of Agriculture for Northern Ireland,
Field Botany Research Division,
Newforge Lane, Belfast BT9 5PX

Summary Although when applied at recommended rates the herbicides asulam, mecoprop and dicamba/mecoprop produced no significant effects on annual d.m. yields of perennial ryegrass, even in years when the swards were subject to considerable drought stress, severe depressions of yield occurred at some individual harvests. The effects of the herbicide treatments were reflected in a prolonged reduction in regrowth elongation which appeared to be most pronounced for mecoprop and dicamba/mecoprop, and was still apparent in some instances 12 weeks after spraying. This effect on elongation appeared to involve an interaction with drought stress and the incidence of rainfall.

Résumé Quoique appliquées aux doses recommandées les herbicides asulam, mecoprop et dicamba/mecoprop ont produit aucun effet significant sur des récoltes d.m. de ray-grass Anglais, même pendant des années ou les pelouses ont soumis à une contrainte considérable de sécheresse, des abaissements de récolte se passérent à des moissons individues. Les effets des traitements avec les herbicides ont été réflétés dans une réduction prolongée de l'élongation de la régéneration qui sembla être plus marqué pour mecoprop et dicamba/mecoprop, et qui était encore apparente dans quelques cas douze semaines après le poudroiement d'écume. Cet effet sur l'élongation sembla encapsuler une action réciproque avec la contrainte de la sécheresse et l'incidence de la précipitation.

INTRODUCTION

Soper (1970) reported in detail on the effect of asulam on the grass sward at rates recommended for dock control. The present experiment, conducted as part of a programme aimed at the effective control of broadleaved weeds, particularly broad-leaved dock (Rumex obtusifolius), in established grassland, was intended to evaluate the tolerance of a perennial ryegrass sward to various herbicides which are utilised for dock control and determine the effect, if any, of time of application prior to defoliation.

METHOD AND MATERIALS

TABLE 1

List of treatments

Herbicides	Rate kg a.i./ha	Date of Application Prior to each Harvest	Harvest Dates	1975	1976
asulam	N - 1.12	7, 14 or 21 days	H1 (early)	15/5	19/5
	2 N - 2.24		"		
mecoprop	N - 2.37		H2 (mid-season)	16/7	14/7
	2 N - 4.74				
dicamba/mecoprop	N - 1.58		H3 (late)	16/9	25/8
	2 N - 3.16		"		

One unsprayed control plot was included in each of the 4 blocks.

The experimental area at Greenmount Agricultural College, Co Antrim, was an established perennial ryegrass sward sown in 1973 with a mixture containing equal parts of the cultivars Gremie and Cropper. The treatments are summarised in Table 1. Three herbicides, asulam, mecoprop and dicamba/mecoprop were applied at normal and twice normal rates 7, 14 or 21 days prior to three dates of conservation cuts - early, midseason and late. Each plot received only a single application of herbicide and all treatments were fully randomised in 4 blocks, including an unsprayed control plot. 300 kg N/ha together with 35,000 ℓ/ha of pig slurry were applied each year.

The herbicides were applied with an Oxford Precision Sprayer with "OO" fan jets operating at a pressure of 2.0 bar and delivering 225 ℓ/ha of spray. Herbage yield clips were taken with a motor scythe and d.m. yields determined. In an attempt to detect the persistence of treatments effects, growth heights based on ten observations per plot were taken in the first season only (1975) at weekly intervals, and are presented as percentages of the height of the unsprayed control herbage.

RESULTS

Dry Matter Yields

The dry matter yield data were analysed, without transformation, to compare herbicide treatments with each other, and as a group with the unsprayed control treatment.

A highly significant difference was found between the unsprayed control and herbicide treatments as a group in both years for the second harvest ($P<0.001$ (1975) $P<0.01$ (1976) but not for any of the other harvests or for the annual yields. In 1975, spraying before harvest 1 and in 1976 before harvest 2 was the most damaging to annual yields. In both years (Table 2) however, the yields at the second cut were most depressed; in 1975, reflecting a carry-over effect from spraying prior to harvest 1, and in 1976, exhibiting the immediate effects of spraying in advance of that harvest. In 1975, the interaction of herbicide and harvest at which the crop was sprayed was significant at harvest 2. The application of both mecoprop and dicamba/mecoprop prior to 15 May was more damaging to regrowth yields at harvest 2 than the application of asulam. This can be seen from the data presented in Table 2.

Although large effects were apparent at individual harvests, particularly harvest 2, annual yields were affected to a much lesser degree. In 1975 the most

Table 2

The effect of rate and date of herbicide application on perennial ryegrass production

Year: 1975

DM Yield % Unsprayed Control

	Rate	Sprayed Prior to	Har 1 15/5	Har 2 16/7	Har 3 16/9	Annual Total
asulam	N		98.3	90.1	99.1	99.9
	2N	Har 1	97.6	79.0	107.9	97.6
	N			80.3	104.5	96.8
	2N	Har 2		81.8	99.5	99.9
	N				98.0	105.5
	2N	Har 3			94.9	102.1
mecoprop	N		97.7	72.5	99.1	93.7
	2N	Har 1	95.0	52.3	104.8	86.7
	N			89.4	101.3	99.6
	2N	Har 2		92.6	102.5	102.3
	N				111.7	107.7
	2N	Har 3			94.0	102.5
dicamba/ mecoprop	N		98.7	74.6	100.9	95.6
	2N	Har 1	100.1	69.1	103.0	94.6
	N			95.3	92.9	101.7
	2N	Har 2		90.4	110.1	104.3
	N				103.9	105.8
	2N	Har 3			100.5	105.1
CONTROL YIELDS t/ha			(5.67)	(3.75)	(2.22)	(11.16)
			Sig. SE ±	Sig. SE ±	Sig. SE ±	Sig. SE ±
Difference between tmts			NS 4.3%	NS 6.4%	NS 6.3%	NS 3.5%
Difference tmts. v. control			NS 3.2%	*** 4.8%	NS 8.9%	NS 4.9%

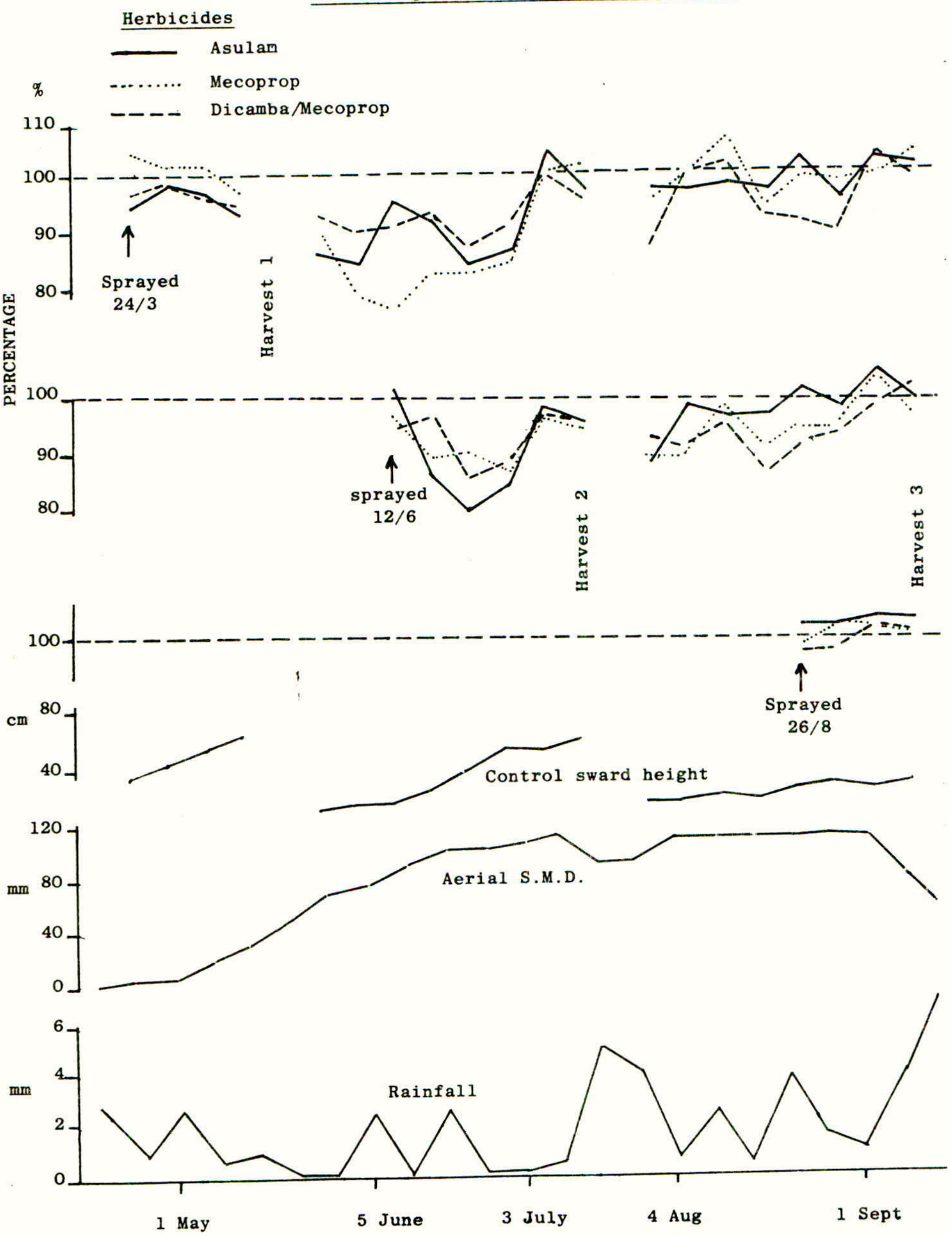
Year: 1976

	Rate	Sprayed Prior to	Har 1 19/5	Har 2 14/7	Har 3 25/8	Annual Total
asulam	N		101.4	101.0	126.0	105.6
	2N	Har 1	102.9	94.0	144.7	103.7
	N			97.0	148.0	94.4
	2N	Har 2		79.2	132.0	92.6
	N				117.3	103.0
	2N	Har 3			110.0	104.9
mecoprop	N		104.0	90.7	150.0	103.0
	2N	Har 1	75.1	93.2	131.3	98.8
	N			83.9	81.3	99.8
	2N	Har 2		86.5	130.0	99.1
	N				135.3	102.4
	2N	Har 3			146.7	100.4
dicamba/ mecoprop	N		102.1	91.0	146.7	102.0
	2N	Har 1	99.9	93.6	126.0	101.5
	N			89.0	120.7	96.5
	2N	Har 2		92.3	76.0	98.4
	N				119.3	114.6
	2N	Har 3			118.0	105.0
CONTROL YIELDS t/ha			(5.88)	(4.22)	(0.15)	(9.87)
			Sig. SE ±	Sig. SE ±	Sig. SE ±	Sig. SE ±
Difference between tmts			NS 5.7%	NS 7.7%	NS 2.3%	NS 4.5%
Difference tmts v control			NS 4.2%	** 5.9%	NS 3.3%	NS 6.5%

FIG 1

Effect of herbicides on sward regrowth

Sward height % control unsprayed height



detrimental treatment, the double rate of mecoprop before harvest 1, depressed the annual total by 13.3%. At the recommended rates, the greater depression was less than 7%, again from mecoprop applied in advance of harvest 1. In 1976 the greatest depression recorded was some 7% with asulam applied prior to havest 2. Conversely it is of interest to note that certain treatments, particularly those made prior to harvest 3 produced an increase in yield of about the same order.

In relation to timing of application i.e. 7, 14 or 21 days before defoliation, in terms of annual total yields, spraying 14 days in advance of defoliation in 1975 was more damaging for all the herbicides than either the shorter or longer intervals. In 1976 there were no significant effects. In both years spraying 7 days before defoliation appeared to be the least damaging.

Sward height assessments

The weekly record of plant height, relative to the unsprayed control, is illustrated in Fig. 1. These data are for the recommended herbicide rates, applied 21 days in advance of defoliation. There was a slight reduction in sward height relative to the control in the period prior to the harvest defoliation. The heights of the plots treated with all three herbicides lagged behind the unsprayed swards up to the 10th July, 12 weeks from the date of spraying. In the regrowth after harvest 2, for the mecoprop and dicamba/mecoprop treatments, there was a period between 15 August and 8 September when sward heights again lagged behind those of the control. All the herbicides applied in advance of harvest 2 depressed elongation. With asulam, elongation was depressed for about 4 weeks, but there was little effect after the harvest. Both mecoprop and the dicamba/mecoprop, however, continued to show height reductions relative to the control until 8 September - some 12 weeks after herbicide application. As with the d.m. yield data, spraying prior to harvest 3 had no obvious detrimental effect on regrowth.

Apart from illustrating the extended periods of up to 12 weeks for which the herbicide treatments depressed sward heights, another interesting observation is that the sprayed areas could, on occasion, having recovered to a similar height as the unsprayed sward, subsequently lag behind again. This effect occurred either after the defoliation or, as for example in the period between 15 August and 5 September with the dicamba/mecoprop treatments applied in advance of both harvest 1 and harvest 2, due to some other stress factor. The effect may relate to the incidence of rainfall and the level of the soil moisture deficit. There was a severe drought throughout May and June, relieved by rain in early July and a further drought period during August with rain sufficient to relieve the soil moisture deficit in early September.

DISCUSSION

There have been few data published concerning the effects of herbicides on weed free pastures. Soper (1970) has, however, given a detailed account of the effects of phytoxicity of asulam in a range of swards. He concluded that greater sward damage is likely to occur when the cut herbage is sprayed within one week after defoliation, and that this can be reduced, but not eliminated, by allowing a recovery period of at least 3 weeks. In the present study, in each year, it was the treatment applied 7 days before defoliation (equivalent in Soper's data, in certain instances, to 3 weeks after the previous defoliation) which gave the least effect on the sward. However, with mecoprop and dicamba/mecoprop (Anon, 1975) this can lead to reduced control of Rumex spp. and may therefore be impractical. Although none of the herbicides produced significant effects on annual yields, in spite of severe drought conditions, both mecoprop and dicamba/mecoprop could be as or more damaging than asulam in the short term.

The effects of the herbicides on regrowth elongation suggest that in combination with other stress factors, herbicide treatments can have a prolonged effect on regrowth rates.

Maas (1968) reported that both mecoprop and dicamba/mecoprop can induce abnormal root development in winter wheat and rye. More recently Tottman and Davies (1978) reported that mecoprop but not dicamba could induce abnormal root development in wheat and suggested some possible influence of this on drought tolerance in the field. The effect in the sward may therefore be on root growth and function or alternatively on the more general physiology of moisture uptake and cell elongation in the leaf lamina.

Acknowledgements

I should like to acknowledge the assistance given by the principal and staff at Greenmount Agricultural College during the conduct of this trial.

References

ANON, (1975) Annual Report on Research and Technical Work of the Department of Agriculture for N. Ireland. 91-92

MAAS, G. (1968) Über Shaden an den Ankerwurzeln (Kronwurzeln) des Getreides nach herbingidbehandlung. Zeitschrift für Pflanzen-Krankheiten, Pflanzenpathologie ind Pflanzenschutz 75, 139-144

SOPER, D. (1970) The tolerance of pasture grasses to Asulam. Proceedings 10th British Weed Control Conference 2 465-475

TOTTMAN, D.R. and DAVIES, E. Li. P. (1978) The effect of herbicides on the root systems of wheat plants. Annals of Applied Biology 90, 93-99

Proceedings 1980 British Crop Protection Conference - Weeds

CONTROL OF FIELD HORSETAIL USING A SOIL FUMIGANT CONTAINING 1,3-DICHLOROPROPENE

D. Coupland[1]

D.V. Peabody

Northwestern Washington Research and Extension Unit, Mt. Vernon,

WA 98273, U.S.A.

Summary A field trial was designed to investigate the influence of soil depth and timing of application on the performance of the soil fumigant 1,3-dichloropropene against field horsetail (*Equisetum arvense* L.) Fumigated plots were weed-free for up to two months after application. When the plots were assessed approximately one year after treatment, it was found that application at a depth of 43 cm was significantly better than that made at 15 cm, and treatments applied in September were better than those made in July of the previous year.

INTRODUCTION

Soil fumigants are generally used to control soil-borne pests and diseases. 1,3-dichloropropene is widely used as a nematocide (Seinhorst, 1973), and it also has fungicidal properties (Baines *et al*., 1977). However, there have been a few reports of additional benefits in controlling both annual and perennial weeds with this compound (Fischer *et al*., 1974; Turner *et al*., 1974). Field horsetail (*Equisetum arvense* L.) is a troublesome weed in many parts of Northern Europe, Canada and North America. Its extensive rhizome system which can penetrate deeply into the soil is perhaps the main factor contributing to the success of this plant as a weed. Thus, cultivation treatments and foliage-applied, translocated herbicides may reach only a fraction of the underground parts. Soil-applied herbicides may be more effective, especially if they are volatile and can reach the majority of the rhizome tissues (Coupland and Peabody, unpublished). Because of their extreme volatility, soil fumigants may be even more effective than the more conventional soil-applied herbicides. The purpose of the work reported here was to evaluate the performance of 1,3-dichloropropene against field horsetail.

METHOD AND MATERIALS

The experimental site, near Mt. Vernon, was one that had remained fallow for a year and had previously been used for ornamental bulb cultivation. It had a natural and very dense stand of horsetail; 100% ground cover before treatment. Soil type was a silt loam with 3 to 4% organic matter and a pH of 6.5. Plot size was 7.6 m x 15.2 m and treatments were arranged in a randomized block design with four replicates.

The fumigant "DD", manufactured by the Shell Chemical Co., was used. The main active ingredient of this product is 1,3-dichloropropene; other constituents include:

[1] Present address: ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford, U.K.

1,2-dichloropropane, 2,3-dichloropropene, 3,3-dichloropropene and related C3 chlorinated hydrocarbons. A week before fumigant application, the ground was rotary cultivated to a depth of 15 cm to destroy and bury all horsetail shoot material. The fumigant was applied at two depths, 15 cm and 43 cm. Application volume was 463 l/ha, the flow being regulated by Spraying Systems 4916 orifice plates. Shank injectors spaced 30 cm apart were used for the shallow application; for the deeper one, chisel shanks spaced 120 cm apart were used. Two applications with this latter equipment gave a final row spacing of 60 cm. With both types of application, a rotary harrow was used to cover up the rows and partially compact the ground to prevent excessive vapour loss. Control plots were treated in exactly the same way as the fumigated plots except that no chemical was applied.

Fumigation was carried out on two dates: July 24 1979 and September 17 1979. Conditions at the time of application were similar on both dates, the weather being warm (15°C), humid (95% rh) with a slight breeze. Soil temperatures at 10 cm were 17°C (July) and 14°C (September).

The plots treated in July were harvested approximately three months after application to assess "short-term" effects. All plots were harvested in June of the following year to assess "long-term" effects. At harvest, shoot samples were taken using 30 cm x 30 cm quadrats thrown at random ten times per plot. Shoots were cut just above soil level and their dry weights subsequently determined. Soil cores were taken to obtain samples of rhizome material. A 40 cm x 5 cm (diameter) soil corer was used, five cores being taken at random per plot. All rhizome and tuber tissues were then separated from the soil, carefully washed, blotted dry, weighed, then fragmented into single-node and single tuber pieces. All pieces were counted, then planted in sand contained in trays. These were kept moist in the glasshouse for approximately three weeks after which all sprouted nodes and tubers were counted. Percent regrowth was calculated as: (number regrown ÷ number planted) x 100.

All results were statistically analyzed and mean values are compared using LSD values.

RESULTS

Three month assessment

There were no significant differences between the shallow or deep fumigation treatments and both of these were significantly lower than the control plots for both shoot and rhizome data (Table 1).

Table 1

Effect of 1,3-dichloropropene on horsetail three months after treatment

Treatment	Shoot regrowth dry wt.(g)	Rhizome and tuber fresh wt. (g)	Rhizome and tuber viability (%)
Control (shallow)	33.4	14.5	53.1
Control (deep)	30.8	15.0	66.5
Fumigant (shallow)	2.2	5.9	24.7
Fumigant (deep)	1.1	4.5	20.2
LSD (5%)	5.5	1.7	15.1

Values are means of 40 sample quadrats or 20 soil cores.

Treated plots were observed to be weed-free for almost two months after application. At harvest, the control plots were completely overgrown with horsetail. The shallow treatment plots had isolated but relatively large, healthy-looking horsetail shoots and a sparse covering of other weed species. The deep treatment plots had a much denser covering of other weeds and a more uniform cover of horsetail shoots although these appeared stunted in comparison to those of the shallow treatment plots. The weed flora was the same for both plots and included: Sonchus spp. (L.), Solanum nigrum (L.), Lamium amplexicaule (L.), Spergula arvensis (L.), Matricaria matricarioides (Less.) Porter, Poa annua (L.), Capsella bursa-pastoris (L.) Medic., Chenopodium album (L.), Rumex spp., and Senecio vulgaris (L.).

Twelve month assessment (Table 2).

An overall analysis of variance showed that the fumigated plots were significantly lower than the control plots for both shoot and rhizome data. In general, the September treatment was more effective than that made in July, and the deep application was more effective than the shallow one. Thus the treatment applied in September at 43 cm was the most effective, reducing shoot regrowth by over 99%, rhizome and tuber fresh weight by 82%, and reducing the viability of these tissues by 89%.

Table 2

Effect of 1,3-dichloropropene on horsetail approximately twelve months after treatment

Appl^{n} Date	Treatment	Shoot regrowth dry wt. (g)[1]		Rhizome and tuber fresh wt. (g)[1]		Rhizome and tuber viability (%)[2]	
July	Control (shallow)	74.4	(2.83)	11.4	(2.04)	58.3	(50.0)
	Control (deep)	74.8	(2.84)	12.1	(2.08)	52.4	(46.39)
	Fumigant (shallow)	25.6	(2.35)	6.9	(1.80)	42.2	(40.29)
	Fumigant (deep)	15.6	(1.99)	5.6	(1.71)	42.4	(40.45)
Sept	Control (shallow)	63.9	(2.79)	12.3	(2.08)	53.7	(47.17)
	Control (deep)	50.0	(2.67)	10.8	(2.02)	64.4	(53.50)
	Fumigant (shallow)	13.4	(1.96)	5.5	(1.72)	39.5	(38.71)
	Fumigant (deep)	0.27	(0.11)	1.9	(1.16)	6.6	(10.86)
	LSD (5%)		(0.26)		(0.18)		(6.33)

Values are means of 40 sample quadrats or 20 soil cores. [1,2] figures in parenthesis are transformed values for comparing means: [1] logarithmic, [2] arc sin transformation.

At harvest, the control plots were completely overgrown with horsetail. Although there was much less shoot material obtained from the July-treated plots, there was still considerable ground cover due to horsetail (80-90%), whereas with the September-treated plots the amount of cover was appreciably less varying from 40-50% (43 cm application) to 70-80% (15 cm application).

DISCUSSION

The results reported suggest that the soil fumigant "DD", containing 1,3-dichloropropene as the main active ingredient, is an effective treatment for the control of field horsetail. Short-term effects were very impressive. The fumigated plots were completely weed-free for almost two months after application and when the plots were assessed one month later the treated plots showed, on average, a 94% reduction in the amount of shoot regrowth, a 65% reduction in the rhizome and tuber content of the soil, and a 63% reduction in the viability of these tissues. These effects can be attributed to the initial phytotoxic effects on the rhizome tissues and any residual fumigant remaining in the soil preventing further rhizome and shoot development.

An overall analysis of the data from the second harvest showed that the September treatments were significantly more effective than those made in July. There could be several reasons for this. First, because of the sensitivity of horsetail to frost, there was less time for recovery between application and the onset of winter for the September treatments. Second, the weather following application was different for the two times of application. Although the amount and frequency of rain showers were similar for both application times, soil temperatures were much cooler following the September application. With lower temperatures it might be expected that less vapour would be lost to the atmosphere, less bio- and chemical degradation would take place and the solubility of the fumigant in the soil water would increase (Munnecke and Van Gundy, 1979). Perhaps these are some of the reasons leading to the increase in efficacy of "DD" fumigant in cold soils reported by Altman and Fitzgerald (1960). Lastly, because both treatments were harvested at the same time, the July-treated plots had approximately two months more growth than the September application.

In general, the fumigant gave a better performance when applied at 43 cm than at 15 cm. There may be several reasons for this. First, because of the difference in row spacing, the amount of fumigant injected per row was different for each depth of application. Although the quantity applied per hectare was the same, there may have been an initial localised concentration effect resulting in a better performance from the deep application. Second, the 15 cm application was made at approximately the same depth to which the original horsetail shoot material was buried. It is known that the sorption of fumigants is mainly dependant upon the organic matter in the soil (Goring, 1967), so the reduced efficacy at this depth may have been due to this. Also, the presence of this plant residue could have stimulated the growth of soil bacteria and fungi with subsequent effects of increased biodegradation of the fumigant (Munnecke and Van Gundy, 1979). Lastly, an observation of the soil profile to a depth of one metre below soil level revealed that apart from a few developing rhizomes occurring within the top 5 cm, the majority of rhizomes were growing from deep within the soil. Thus with the chosen experimental site more rhizome material could be treated by the deeper application.

Although this is a relatively high cost treatment, the effects on weed control were impressive and the additional benefits of soil pathogen control may make this cost worthwhile, especially in high value cash crops.

Acknowledgements

We wish to thank Larry Johnson for practical assistance and the Shell Chemical Company for donating the fumigant.

References

ALTMAN, J. and FITZGERALD, B.J. (1960) Late fall application of fumigants for the control of sugar beet nematodes, certain soil fungi, and weeds. Plant Disease Reporter, 44, 868-871.

BAINES, R.C., KLOTZ, L.J. and DEWOLFE, T.A. (1977) Some biocidal properties of 1,3-D and its degradation product. Phytopathology, 67, 36-40.

FISCHER, B.B., LANGE, A.H., MAY, D.M. and JOHNSON, D.E. (1974) Fumigation studies. In: "Toward more effective bindweed control". Progress Report Co-op. and Extension Service, University of California, Fresno, California, U.S.A., 19-30.

GORING, C.A.I. (1967) Physical aspects of soil in relation to the action of soil fungicides. Annual Review of Phytopathology, 5, 285-318.

MUNNECKE, D.E. and VAN GUNDY, S.D. (1979) Movement of fumigants in soil, dosage responses, and differential effects. Annual Review of Phytopathology, 17, 405-429.

SEINHORST, J.W. (1973) Dosage of nematicidal fumigants and mortality of nematodes. Netherland Journal of Plant Pathology, 79, 180-188.

TURNER, G.O., GREATHEAD, A.S. and WELCH, N.C. (1974) Control of annual weed seeds with soil fumigants containing 1,3-dichloropropenes. Down to Earth, 29, 25-28.

NOTES

Proceedings 1980 British Crop Protection Conference - Weeds

THE PREDICTION OF COUCH INFESTATIONS - A MODELLING APPROACH

D.J.McMahon and A.M.Mortimer

Department of Botany,University of Liverpool,P.O.Box 147,
Liverpool L69 3BX.

Summary Some demographic data for populations of Agropyron repens (L.) Beauv. are presented. A mathematical model for simulating population growth is described. The use of the model for predicting the size and growth of couch populations under various management regimes is demonstrated.

INTRODUCTION

The importance of couchgrass, Agropyron repens (L.) Beauv. as a weed of arable land is well known. A review by Hakansson (1975) considered it to be the major perennial weed problem in Northern Europe. The difficulty this species presents for weed control lies in its potentially vast reserves of dormant rhizome buds. Systemic herbicides such as glyphosate provide a very effective means of control but usually not total eradication. There is therefore a need to be able to predict growth rates of couch populations in various environments so that the effect of control measures may be evaluated.

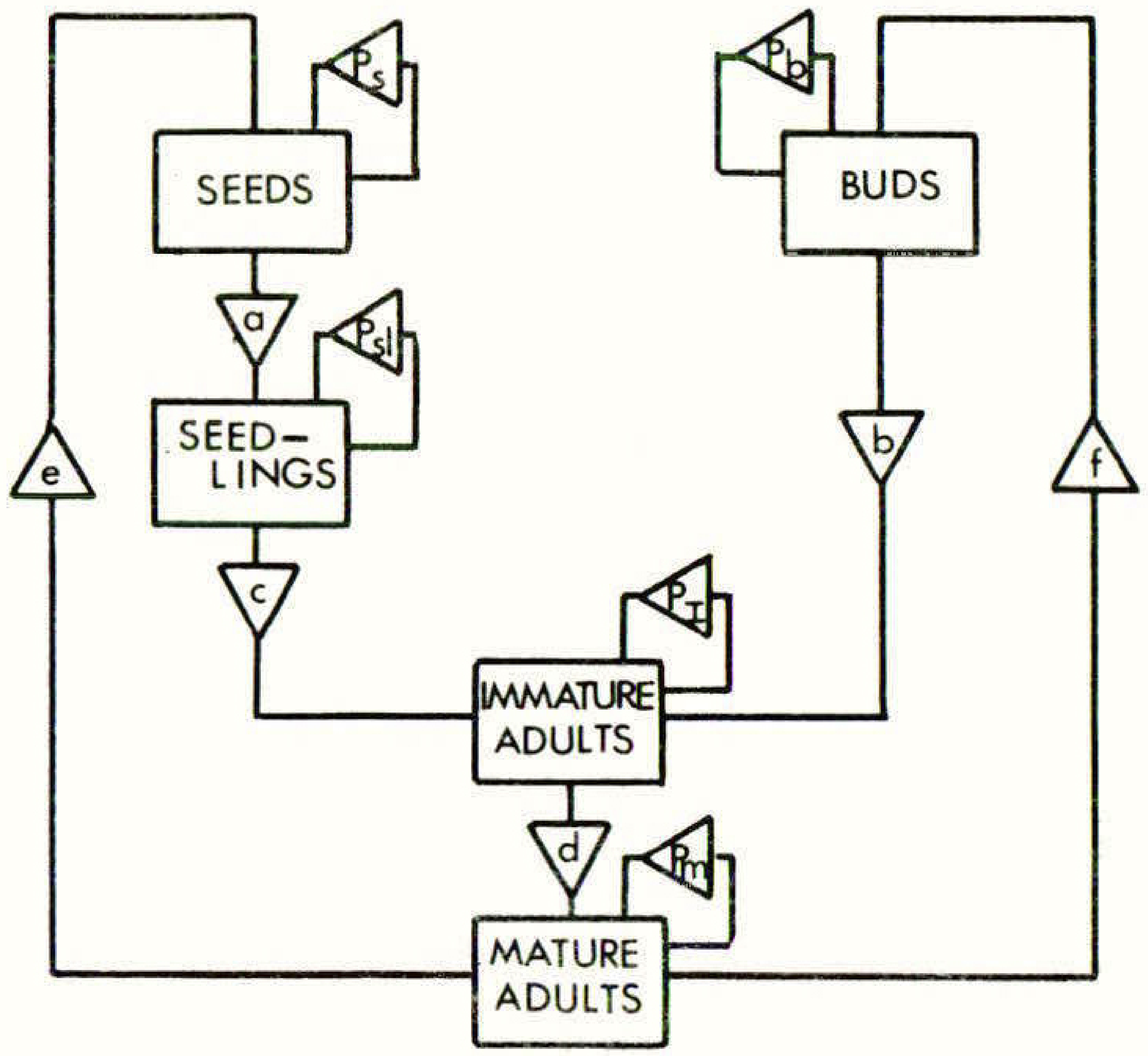
We have previously described a mathematical model for predicting the sizes of weed populations (Mortimer et al.,1978) and suggested its use as a means of evaluating weed control procedures. The model relies on the acquisition of detailed demographic data in the field for the particular weed species under study. Such data are very incomplete for Agropyron repens (Sagar and Mortimer, 1976) although there have been many studies on aspects of its biology and ecology (for example Courtney, 1977; Williams, 1973). This paper describes the development of the model for couch populations and some field studies performed on couch in order to obtain the relevant demographic data for its application.

THE MODEL

The construction of the model for Agropyron repens follows the approach taken in Mortimer et al., 1978. The diagrammatic life table presented in Figure 1 distinguishes five'age-states' (Rabotnov, 1969) within the life cycle and illustrates the fluxes or transitions in unit time that may occur. An adult plant is defined as a tillering shoot system arising from a seed or bud. The adult aerial plant fraction is subdivided into 'immature' and 'mature' categories on the basis of reproductive state; 'mature' adults only, contribute in this model to seed and bud banks by flowering and by rhizome growth. It is envisaged that within a single time period it is possible that individuals (seeds, buds,seedlings or adults) may persist in an age-state. Hence there is a probability of this occurrence attached to each category in the population. As described by Mortimer et al. (1978) this lifetable can be translated into a matrix model consisting of a transition matrix which when multiplied by a column vector of the number of individuals in each state at one time period,gives the numbers present at the next time period (Figure 2). The value of this approach is that it allows firstly a means by which the rate of infestation or population growth may be calculated and secondly provides a device by which the effects of differing control practices may be examined.

It is important to understand the behaviour and growth of a weed population unrestricted by interspecific competition or weed control practices, since this provides the template against which the magnitude of control procedures may be measured. It is essential therefore that, in the collection of the necessary data for the application of the model, the demography of both 'pure' stands of couch as well as 'managed' ones be considered.

Fig. 1. Diagrammatic life table for *Agropyron repens*.



Demographic events taking place in any one time period:

Proportions	P_s	-	SEEDS SURVIVING.
	P_{sl}	-	SEEDLINGS SURVIVING.
	P_I	-	IMMATURE ADULTS SURVIVING.
	P_m	-	MATURE ADULTS SURVIVING.
	P_B	-	BUDS SURVIVING.
	a	-	SEEDS GERMINATING.
	b	-	BUDS GERMINATING.
	c	-	SEEDLINGS SURVIVING TO BECOME IMMATURE ADULTS.
	d	-	IMMATURE ADULTS SURVIVING TO BECOME MATURE ADULTS.
Fecundities	e	-	NUMBER OF SEEDS PRODUCED BY MATURE ADULTS.
	f	-	NUMBER OF BUDS PRODUCED BY MATURE ADULTS.

Fig. 2. A matrix model of the life table of *Agropyron repens*

TRANSITION MATRIX — COLUMN VECTORS OF AGE STATES

$$\begin{bmatrix} P_s & 0 & 0 & e & 0 \\ a & P_{SL} & 0 & 0 & 0 \\ 0 & c & P_I & 0 & b \\ 0 & 0 & d & P_m & 0 \\ 0 & 0 & 0 & f & P_b \end{bmatrix} \times \begin{bmatrix} S_t \\ SL_t \\ I_t \\ M_t \\ B_t \end{bmatrix} = \begin{bmatrix} S_{t+1} \\ SL_{t+1} \\ I_{t+1} \\ M_{t+1} \\ B_{t+1} \end{bmatrix}$$

S_t and S_{t+1} - the number of seeds at times t and t+1 respectively

SL_t " SL_{t+1} - " " " seedlings at times t and t+1 respectively

I_t " I_{t+1} - " " " immature adults at times t and t+1 respectively

M_t " M_{t+1} - " " " mature adults at times t and t+1 respectively

B_t " B_{t+1} - " " " buds at times t and t+1 respectively

METHODS

The long term monitoring of pure stands of couch was carried out on four colonizing populations established at the University Botanic Gardens, Ness, in October 1977. The central 1 m^2 area of pairs of plots (2m.x2m.) were either planted with 50 single node rhizome fragments (subsequently referred to as "rhizome plots") or with 500 seeds ("seed plots"). The above ground unit of the population chosen for study was the aerial shoot system. Monitoring of births and deaths of aerial shoots together with tiller and seed counts was performed at regular intervals (usually every two weeks) over a period of 34 months. Recognition of individual shoots in the first year was by mapping and subsequently by numbered plastic tags placed around the shoot. Seedlings were recognised by adjacent placement of coloured mapping pins. The bud fecundities of adult plants were measured by excavation of the plots at the termination of the experiment.

Monitoring of populations started from seed and single node rhizome fragment was performed similarly in field plots sown with winter wheat (var. Maris Huntsman) in October 1978. The survivorship of buried seed populations was examined over one year by following the monthly changes in viability of seed buried in nylon mesh bags at a range of depths from 0-10cm. The mortality of dormant buds on rhizomes was measured by monthly viability tests on bud populations of known age.

RESULTS AND DISCUSSION

Figure 3 shows the pattern of births of aerial shoots on a monthly basis in the pure stands established from rhizomes and seeds. Data are presented for the internal, initially colonised, $1m^2$ area of the plot and the external area latterly colonised 0.5m belt. Apart from the initial germination in the seed plots, seedlings are not included as there were very few and none progressed beyond the seedling stage. In all plots a similar temporal birth pattern was observed, namely peaks in the spring and autumn each year with troughs in mid-summer at the time of flowering (June-July) and in mid-winter. Numbers of births were generally higher in the rhizome plots than in the seed plots and colonization of the external area was earlier in the rhizome plots. This indicates a lag in the seed plots due to these effectively starting later and from an earlier age state (seedlings in April 1978) compared with the rhizome plots ('immatures' in December 1977). This is confirmed by the observation that flowering did not occur in the seed plots until 1979 whereas in the rhizome plots flowering occurred in 1978.

The pattern of mortality of adult shoots (Fig.4) clearly demonstrates that death was slight in the early phase of colonisation but increased with time, this being presumably an effect of increasing density.

Figure 5 shows the cumulative births and deaths/m^2 for all plots. This shows clearly the colonizing situation with births far exceeding deaths. There is tentative evidence in the third year (1980), in the seed plots, that regulation may be occurring to stabilize the size of the population. The absence of seedlings establishing to become adults within the plots suggests that whereas seed may be an important source for colonization of bare areas (as in the start of the seed plots), within an established stand, their role is not as important. The absence of any noticeable mortality in the external areas of the seed plots suggests that little significant regulation may be occurring and that the birth of additional adults will continue to occur in autumn 1980 in these areas.

Figure 6 illustrates the decline in the size of the viable buried seed population over one year. The results are subject to field variation but two conspicuous features emerged. The decrease in numbers from February through to April is due to germination and hence removal from the seed bank. After twelve months about 10% of the sown seed crop was near the soil surface. Slightly higher values were found at greater depths, probably due to enforcement of seed

Fig. 3. The pattern of births of aerial shoot systems of Agropyron repens. (——) internal area, (- - -) external area; R - rhizome plots, S - seed plots.

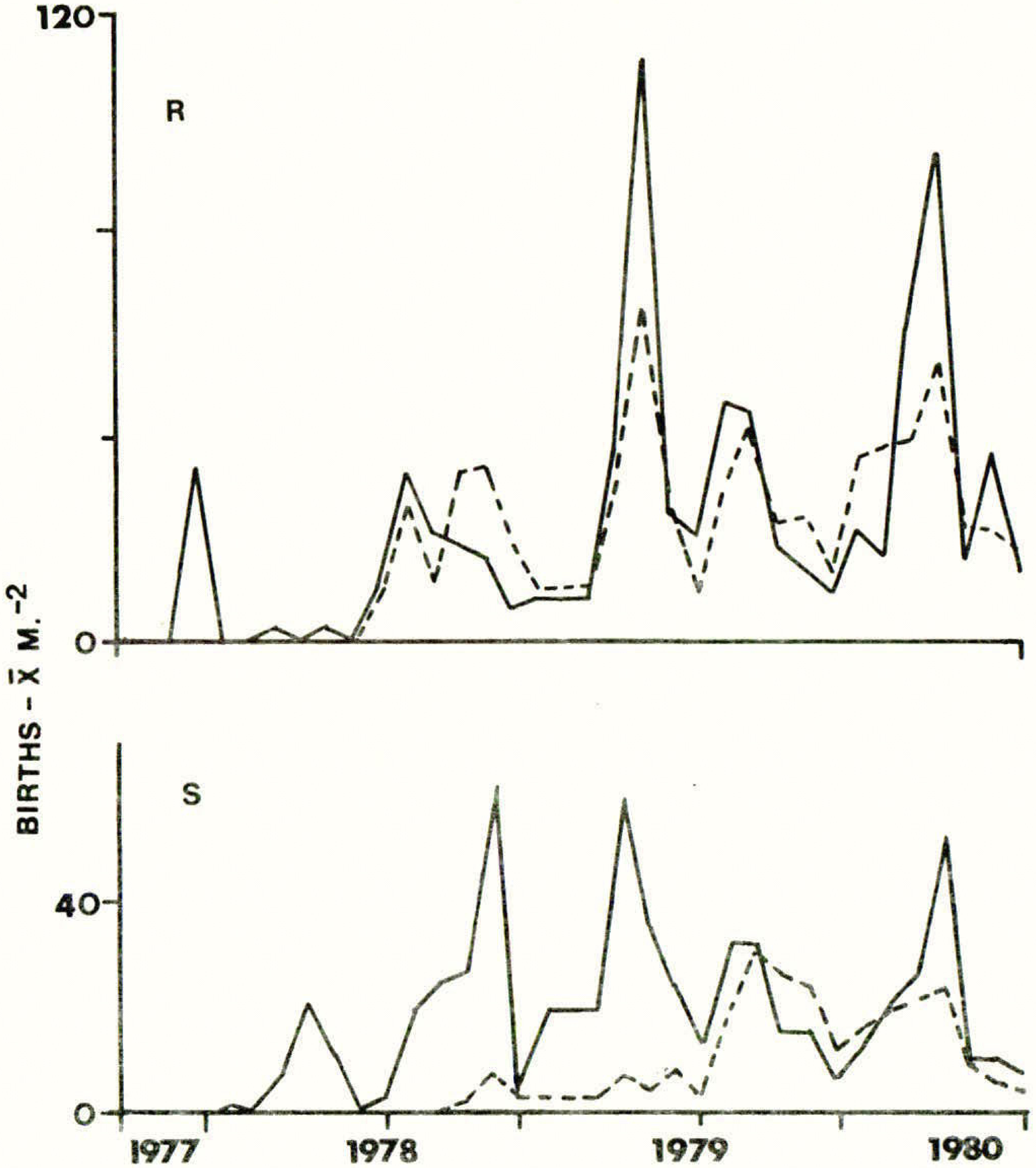


Fig. 4. The pattern of mortality of aerial shoot systems of Agropyron repens. Symbols as Fig. 3.

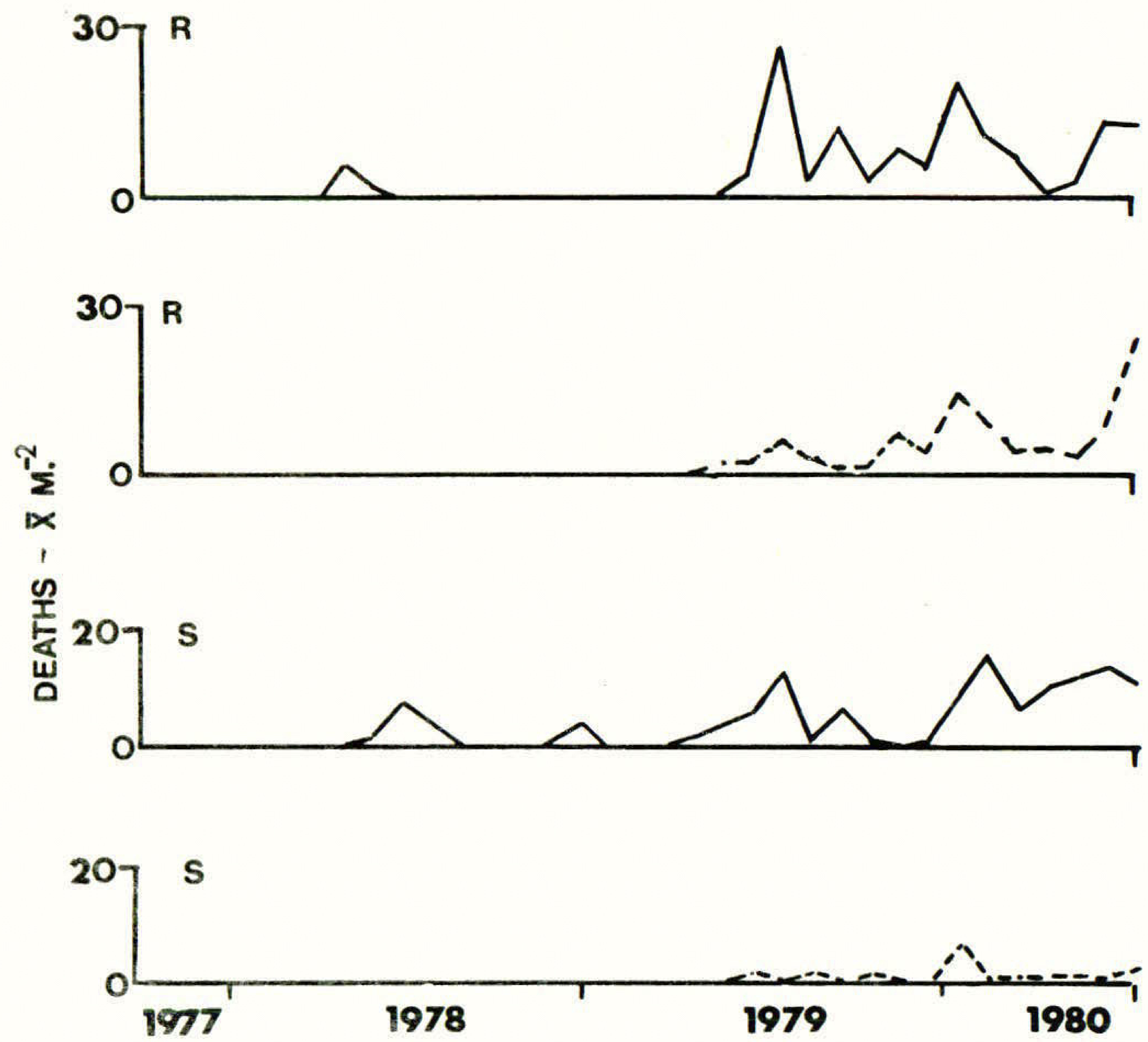


Fig. 5. Cumulative births and deaths in an aerial shoot population of Agropyron repens. Symbols as Fig. 3. Lines marked A are actual population sizes.

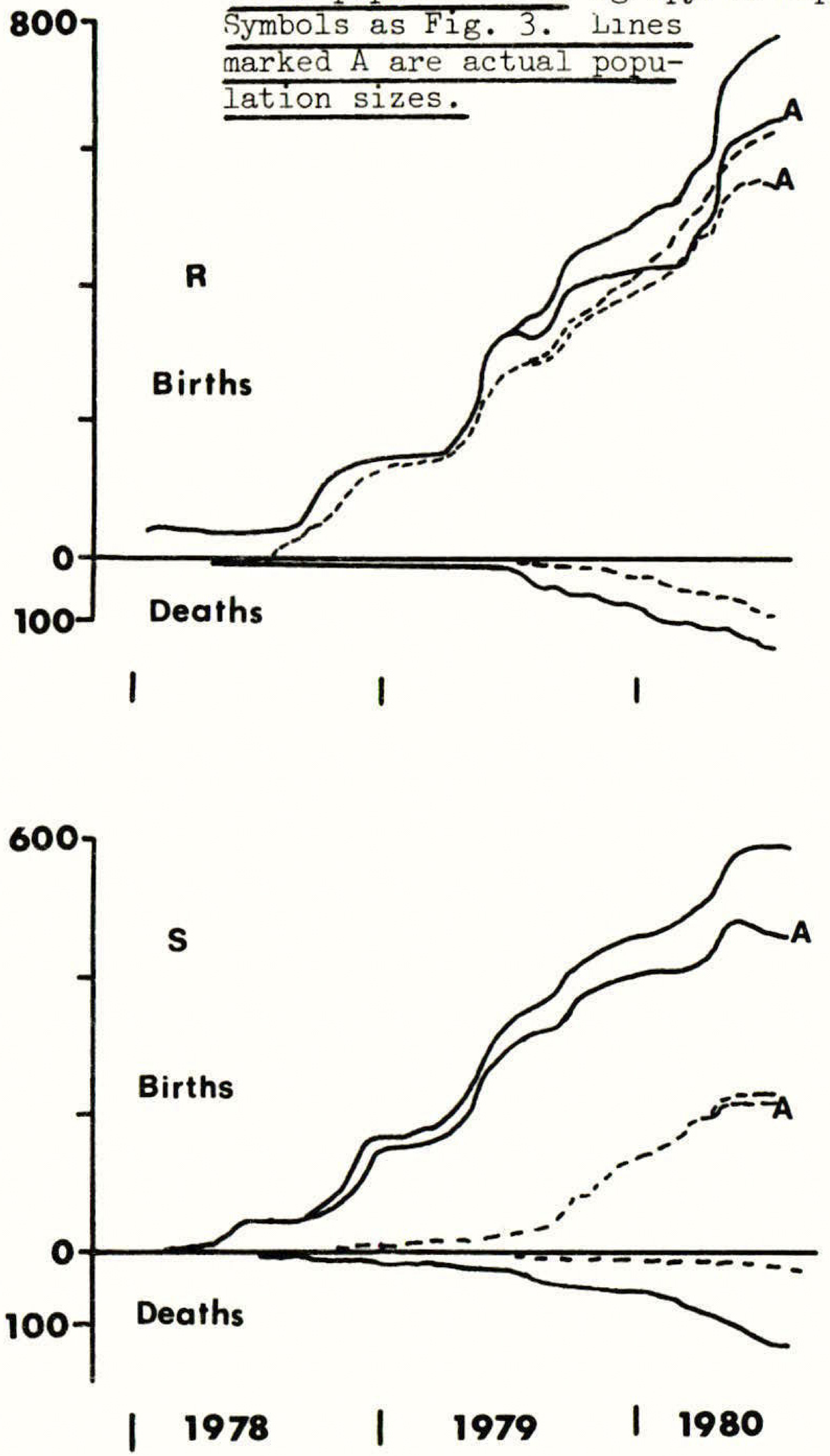


Fig. 6. Changes in the size of the buried seed bank of Agropyron repens.

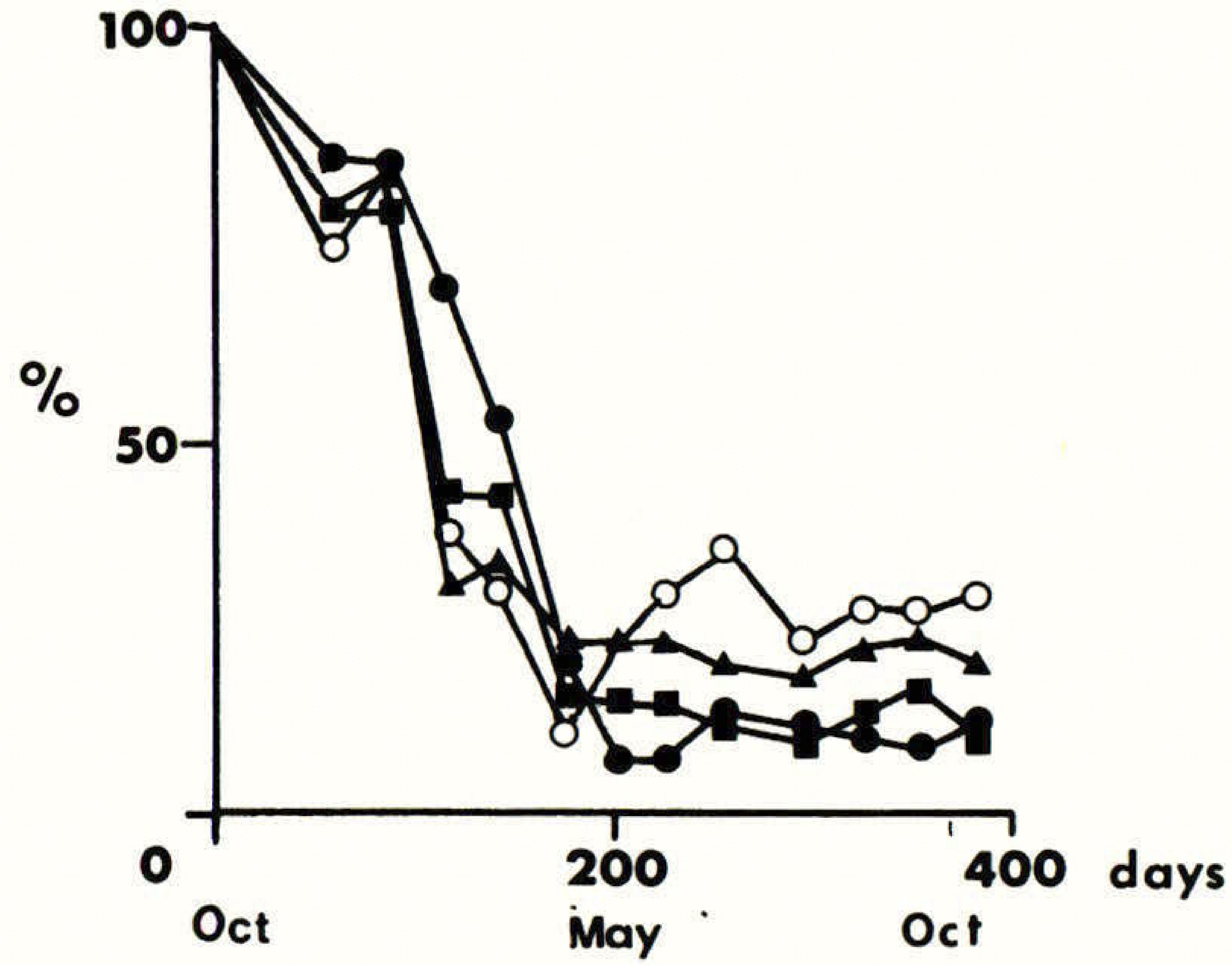


Fig. 7. Transition matrices and initial age distribution for the simulation of an infestation of Agropyron repens.

TRANSITION MATRICES

FEBRUARY - MARCH (FM)

0.59	0	0	0	0
0	0.33	0	0	0
0	0	0	0	0.004
0	0	0.97	0.98	0
0	0	0	10	0.99

APRIL - MAY (AM)

0.2	0	0	0	0
0.08	0.6	0	0	0
0	0	0	0	0.015
0	0	0.97	0.99	0
0	0	0	75	0.99

JUNE - JULY (JJ)

0.9	0	0	13.74	0
0.05	0.66	0	0	0
0	0	0	0	0.004
0	0	0.9	0.98	0
0	0	0	225	0.99

AUGUST - SEPTEMBER (AS)

0.9	0	0	0	0
0	0.59	0	0	0
0	0	0	0	0.004
0	0	0.89	0.99	0
0	0	0	100	0.99

OCTOBER - NOVEMBER (ON)

0.9	0	0	0	0
0.01	0.46	0	0	0
0	0	0	0	0.02
0	0	0.97	0.99	0
0	0	0	50	0.99

DECEMBER - JANUARY (DJ)

0.85	0	0	0	0
0	0.5	0	0	0
0	0	0	0	0.004
0	0	0.9	0.97	0
0	0	0	0	0.99

INITIAL AGE DISTRIBUTION

Seeds	0
Seedlings	0
Immature adults	38
Mature adults	0
Buds	0

INITIAL AGE DISTRIBUTION CORRESPONDS TO NUMBERS PRESENT IN FIELD PLOTS AT THE END OF JANUARY 1978.

Fig. 8. A comparison of simulation and field results.

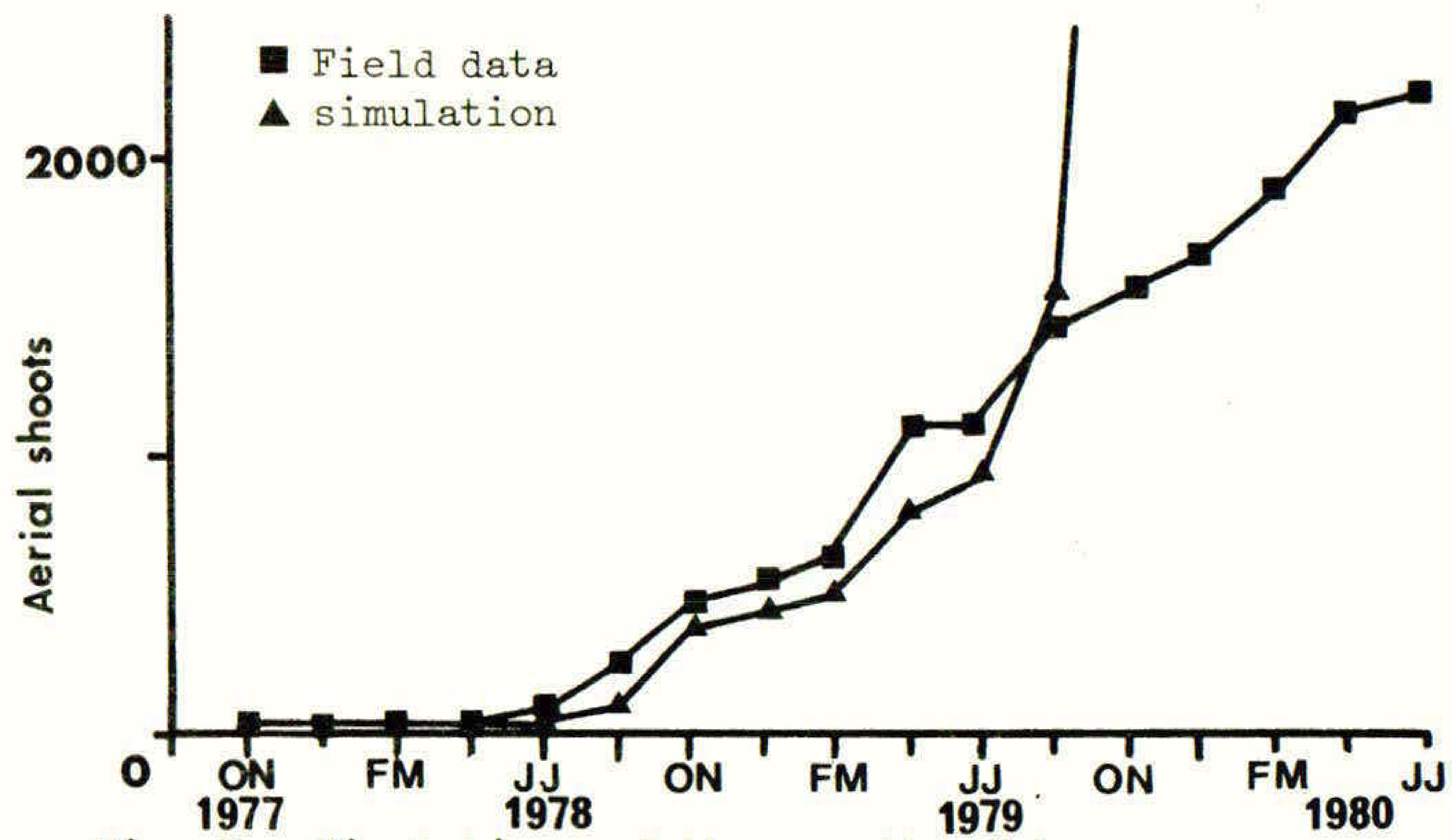
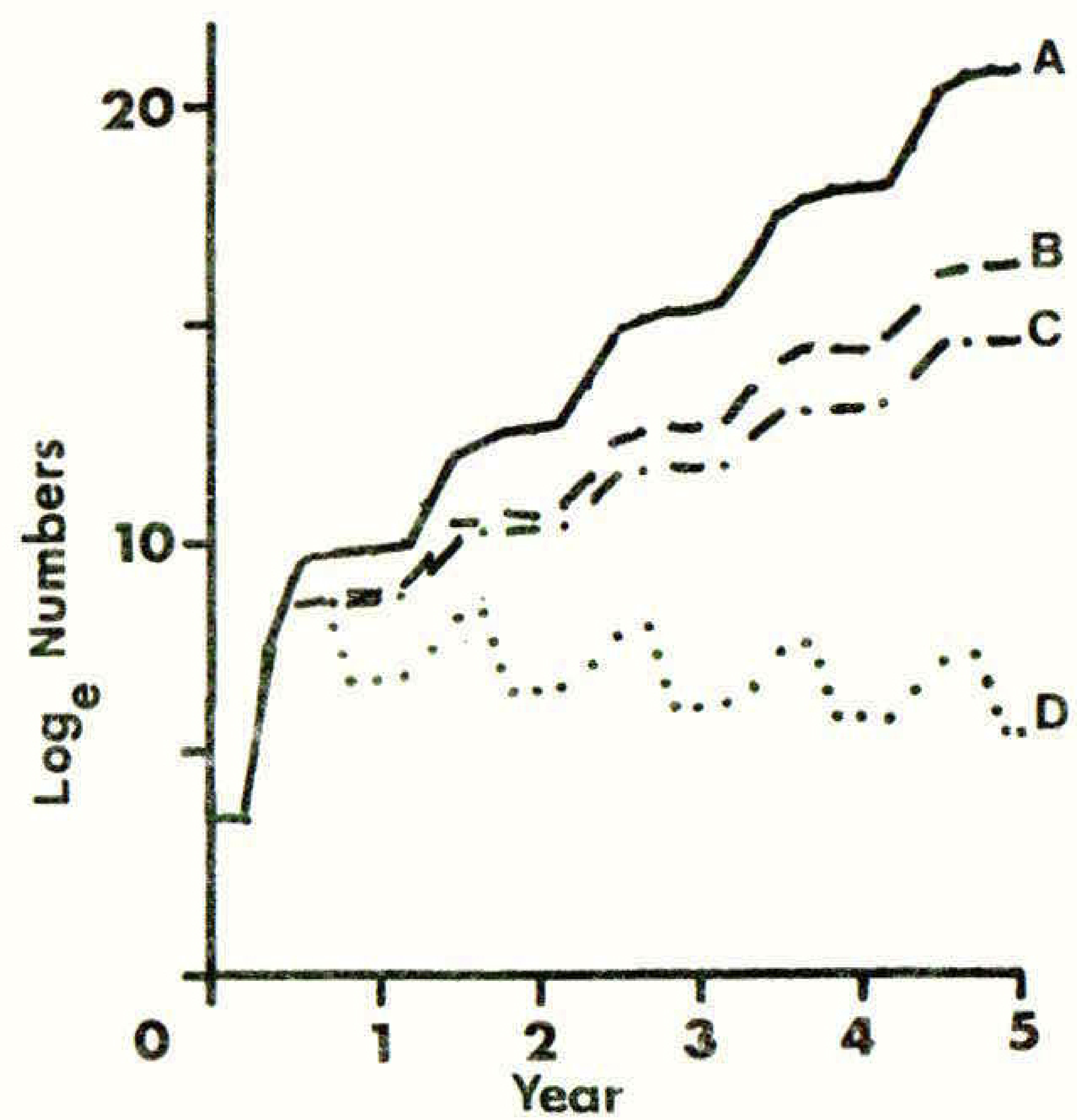


Fig. 9. Simulations of the growth of Agropyron repens populations.



A A.repens alone.

B A.repens in winter wheat.

C A.repens in winter wheat, Case A.

D A.repens in winter wheat, Case B.

See text for details.

dormancy. No significant change in viability of dormant buds was observed over a period of 20 months.

Use of the Model

With data from regular and frequent monitoring it is possible to choose the time interval over which the transition matrices will operate. We have chosen here a time period of two months and transition matrices for each two monthly period of the year have been constructed (Figure 7). The realism and precision of the model can be tested by comparing the results of a simulation with the data actually obtained in the field. This has been done for the rhizome plots in Figure 8. The simulation corresponds fairly precisely to events in the field until September 1979 when the model predicts a sudden vast increase in numbers which did not occur in the field. This discrepancy arises because the model does not take into account the effects of increasing couch density and consequent changes in adult survivorship and bud and seed fecundity. To improve realism, elements of the transition matrices themselves need to be made a function of the density of the population. This simulation does, however, allow the calculation of the rate of growth of the population in terms of the finite rate of increase (λ) in an unrestricted environment. This is the factor by which numbers change from year to year once the population structure has reached a stable age-state distribution. The value of λ here is 15.95.

To illustrate the effect of a crop on the rate of growth of a couch population, alterations to elements in the transition matrices based on data from the study in winter wheat have been made. The changes concern measured reductions in bud and seed production, seedling and adult survival. The resulting simulation (Fig.9) indicates that the rate of growth of the infestation ($\lambda = 6.69$) has been substantially reduced by the presence of the crop. To demonstrate the use of the model in simulating the effectiveness of control practices two scenarios are included in Fig.9. The first, Case A, envisages a weed management programme in which control of the couch population in winter wheat is applied, possibly by the use of a non-systemic herbicide, post harvest and prior to winter sowing; and which results in very low seedling survival, a ten fold reduction in the survival of mature adults, total mortality of immature adults and a halving of adult bud fecundity. The simulation predicts that whilst this programme lowers the rate of infestation ($\lambda = 4.37$) it clearly does not contain the infestation. In Case B, Fig. 9, a similar control regime is considered except that a systemic herbicide is used which reduces bud survival a hundred fold in addition to the reductions listed above. In this instance, effective control of the weed population is achieved ($\lambda = 0.73$) and a decline in the infestation is predicted.

In conclusion, if the demographic consequences of control measures are known it is possible to apply these to the model described and therefore predict the effect on population growth rate. If information on crop losses in relation to infestation level is available then the model provides a means of predicting the economic consequences of a control procedure. Hence there is the possibility of using the model to design cost effective programmes of control. This is discussed further by Mortimer et al. (1980).

References

COURTNEY, A.D. (1977). Some studies on the growth and development of rhizomatous grasses. Ph.D.Thesis, Queens University, Belfast. 310 pp.

HAKANSSON, S. (1975). Perennial grass weeds in Europe. Proc. Europ. Weed Res. Soc. Symp., Paris 1975, 71-83.

MORTIMER, A.M., McMAHON, D.J., MANLOVE, R.J. and PUTWAIN, P.D. (1980). The prediction of weed infestations and cost of differing control strategies. Proc. 15th Brit. Weed Control Conf.

MORTIMER, A.M., PUTWAIN, P.D. and McMAHON, D.J. (1978). A theoretical approach to the prediction of weed population sizes. Proc. 14th Brit. Weed Control Conf., 467-474.

RABOTNOV, T.A. (1969). On coenopopulations of perennial herbaceous plants in natural coenoses. Vegetatio, 19, 87-95.

SAGAR, G.R. and MORTIMER, A. M. (1976). An approach to the study of the population dynamics of plants with special reference to weeds. Appl. Biol., 1, 1-43.

WILLIAMS, E.D. (1973). A comparison of the growth and competition with wheat of seedlings and plants from rhizomes of *Agropyron repens* L. Beauv. and *Agrostis gigantea* Roth. Weed Research, 13, 422-429.

CROP RESPONSES TO LOW DOSES OF HERBICIDES IN THE SOIL

Allan Walker and Pauline A. Brown

National Vegetable Research Station, Wellesbourne, Warwick, CV35 9EF

Summary The herbicides simazine, atrazine, metribuzin, metamitron, trifluralin, propyzamide and linuron were incorporated into the surface 7 - 10 cm soil at several doses lower than those recommended commercially. Cabbage, lettuce, carrot, red beet, onion, dwarf bean and wheat were sown in the treated plots and their responses measured by visual assessment of phytotoxicity or by recording fresh weights. Responses of the different crops varied considerably between herbicides. With wheat for example, the minimum concentration which gave a reduction in plant vigour varied from 0.71 µg/g in 0 - 10 cm with metamitron to 0.07 µg/g with metribuzin. With lettuce, phytotoxicity was apparent at concentrations of 0.04, 0.08, 0.11, 0.23, 0.42 and >0.71 µg/g with metribuzin, atrazine, simazine, linuron, metamitron, trifluralin and propyzamide respectively. The results were used to estimate possible safe periods before the different crops can be sown following spring application of the herbicide.

INTRODUCTION

Evaluation of the activity of herbicides in the field concentrates on crops which show tolerance of particular compounds and there is relatively little information available on the sensitivity of susceptible crops to low doses in the soil. This information is essential to interpretation of the practical significance of residues in the soil since the obvious way to minimise their effects is to avoid sowing highly sensitive crops. In recent years, some attempts have been made to measure crop responses to defined soil concentrations of herbicides to permit better interpretation of residue analyses. For example, Caverly (1978) incorporated lenacil, linuron and trifluralin into soil at various rates at three field locations and sowed 16 crops in the treated plots. When symptoms of phytotoxicity developed, the soil was sampled (0 - 7.5 cm) and residual concentrations were measured. Tables were presented to show the minimum soil concentrations which produced symptoms of phytotoxicity in the various crops. Similar results for more limited herbicide-crop combinations have been reported by Miller et al. (1975), Schweizer (1975), Walker and Bond (1978) and Eagle (1978). The present paper summarises results from experiments made at Wellesbourne to measure the responses of different crops to low doses of seven soil-applied herbicides.

METHOD AND MATERIALS

The soil was sandy loam with pH 7.0 containing approximately 2% organic matter and 18% clay. The herbicides used were commercial formulations of simazine, atrazine, metribuzin, metamitron, trifluralin, propyzamide and linuron, and the crops examined were cabbage (cv. Winningstadt), lettuce (cv. Borough Wonder), carrot (cv. Chantenay), red beet (cv. Detroit), onion (cv. Rijnsburger Wijbo), dwarf French bean (cv. Processor) and wheat (cv. Cappelle Desprez).

Experiments in 1977

With the exceptions of metribuzin and metamitron, the herbicides were applied to separate small field plots (4 x 1.5 m) at 0.8, 0.6, 0.4, 0.2 and 0.1 kg a.i. in 1100 l/ha. Metribuzin was applied at 0.4, 0.3, 0.2, 0.1 and 0.05 kg/ha and metamitron at 3.0, 2.0, 1.0, 0.5 and 0.25 kg/ha. The herbicides were incorporated with a single pass of a rotary power harrow at a working depth of approximately 10 cm. There were two plots for each rate, the first of which was drilled with single rows of cabbage, lettuce, carrot and onion, and the second with red beet, wheat and dwarf beans. There were six untreated control plots for each group of crops. The treatments were not replicated but the experiment was carried out three times (preparation dates: 6 May, 1 June and 5 July). When the responses of the crops had stabilised (after about 5 to 8 weeks), the crops were scored according to the degree of phytotoxicity, and fresh weights were measured by harvesting the central 2 m of each crop row in each plot. Immediately after preparation of the experiment on 1 June, the plots treated with simazine, atrazine and propyzamide were sampled by taking 20 cores (2.5 cm diam. to a depth of 10 cm) at random positions between the crop rows. The cores from each plot were bulked separately and thoroughly mixed by sieving. The herbicide concentrations in the soil were measured by GLC as described in detail previously (Walker, 1978).

Experiments in 1978 and 1979

The herbicides were applied to field plots (25 x 1.5 m) in 200 l/ha using a Chesterford mini-log sprayer calibrated to halve the dose at successive 5-m intervals along the plot. This gave a logarithmically decreasing dose range from 1.0 to 0.0625 times the initial application rate over a distance of 20 m. The final 5 m of each plot served as an untreated control. With the exceptions of metribuzin (0.5 kg/ha) and metamitron (3.5 kg/ha), the initial dose for all the herbicides was 1.0 kg/ha. The herbicides were incorporated and the crops sown as in 1977. When crop responses had stabilised they were assessed by measuring fresh weights in successive 1-m lengths of crop row. The experiment was carried out twice in 1978 (preparation dates: 10 May and 7 June) and twice in 1979 (preparation dates: 9 May and 6 June). After preparation of the experiment on 10 May 1978, the plots sprayed with atrazine were sampled at intervals of 2 m beginning 0.5 m from the start of the plot by taking 20 cores (2.5 cm diam. to a depth of 10 cm), 10 from each plot, in a straight line at right angles to the direction of spraying. Atrazine concentrations in the soil were measured as described previously (Walker, 1978).

RESULTS AND DISCUSSION

Recovery of applied dose

The recovery of simazine, atrazine and propyzamide from soil from the various treatments in one of the experiments in 1977 is shown in Table 1. This varied from 83 to 137% of the theoretical quantity and the overall mean recovery was 102 ± 12.2%. The average soil concentration for each rate of application is also shown in Table 1, and in all instances, this was close to that expected.

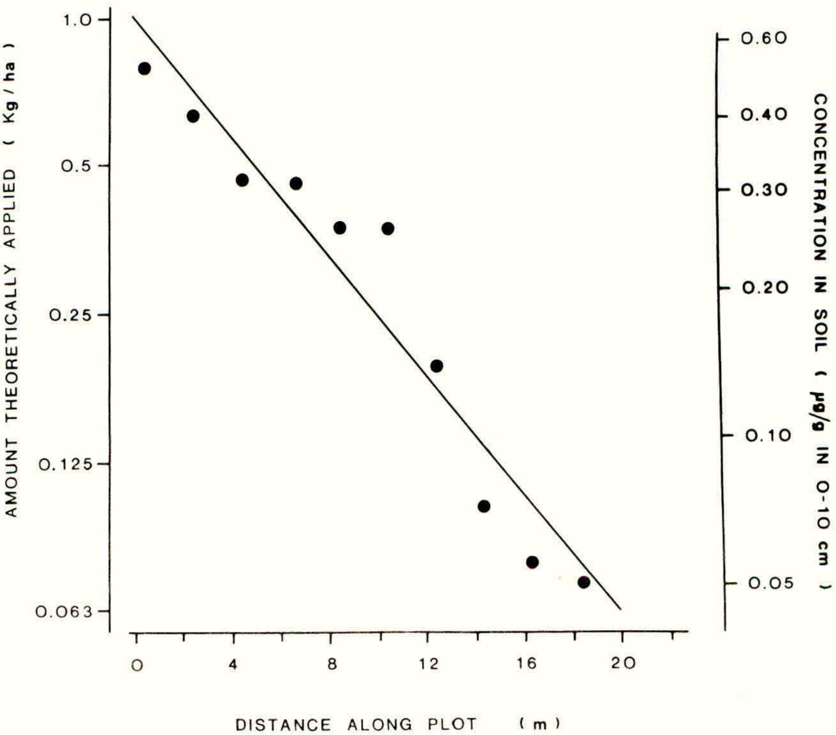
Table 1

Recovery of applied herbicide (% of theoretical amount) and average concentration in the soil (µg/g dry soil in 0-10 cm)

Amount applied Kg/ha	µg/g[a]	Recovery of applied dose Simazine		Atrazine		Propyzamide		Observed average soil concentration
0.80	0.57	96	95	102	96	100	90	0.55 ± 0.025
0.60	0.43	88	91	93	93	101	106	0.41 ± 0.029
0.40	0.29	101	103	96	99	106	114	0.30 ± 0.019
0.20	0.14	108	109	94	96	120	114	0.15 ± 0.014
0.10	0.07	124	137	89	83	100	123	0.08 ± 0.015

a. Calculated from amount applied, sampling depth, and observed bulk density (1.4 g cm^{-3}).

Fig. 1. Measured concentrations of atrazine in the soil following application with the logarithmic sprayer



Recovery data for one of the log-dose experiments with atrazine in 1978 are shown in Figure 1. The straight line in this Figure shows the expected relationship between dose and distance, and the observed soil concentrations were in good agreement with those expected.

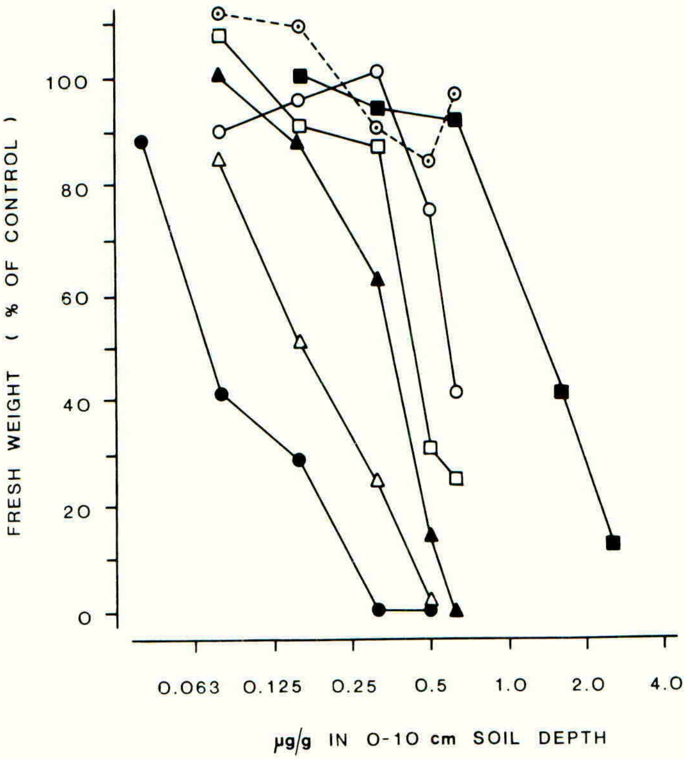
Throughout the rest of this report, all doses will be referred to as µg/g dry soil in 0 - 10 cm.

Evaluation of crop responses

Some examples of the dose-response curves obtained in the different experiments are shown in Figures 2, 3 and 4. The data in Figure 2 are from the experiment prepared on 1 June 1977 and show the fresh weights of cabbage (percentages of the untreated controls) as a function of herbicide concentration in the soil. Trifluralin had little effect at any of the concentrations examined, but the other 6 compounds all reduced fresh weight by more than 50% at one or more of the doses. Metribuzin was the most active, and gave an ED50 of about 0.06 µg/g, and metramitron the least (ED50 about 1.2 µg/g). The other herbicides were intermediate with the activity of atrazine > simazine > linuron > propyzamide.

The data in Figure 3 are from the experiments with metamitron in 1977 and show the mean phytotoxicity scores from the 3 experiments with each of the crops as a function of the soil concentration of herbicide. Metamitron had no effect on the

Fig. 2. Response of cabbage to different concentrations of herbicide in the soil. ▲ , simazine; △ , atrazine; ● , metribuzin; ■ , metamitron; ⊙ , trifluralin; ○ propyzamide; □ , linuron



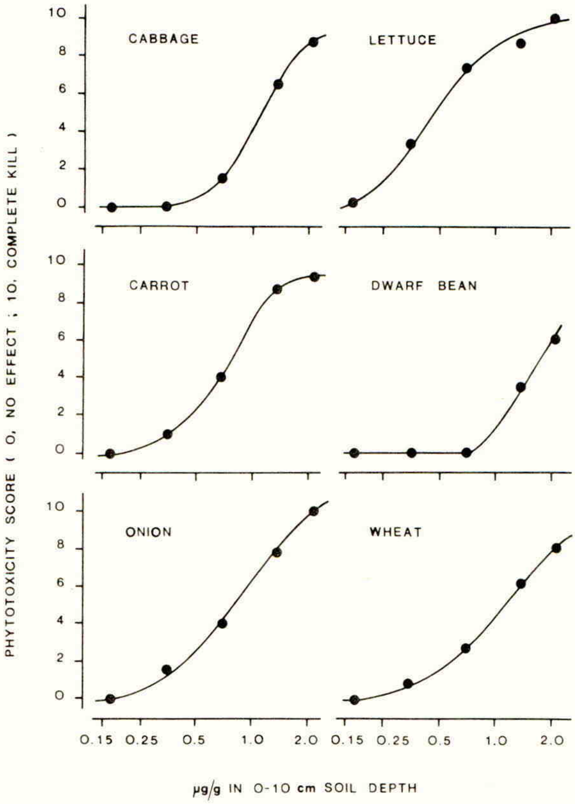
growth of red beet and the results for this crop are not presented. Lettuce was the most sensitive crop and had a mean phytotoxicity rating of 5.0 at 0.5 μg/g soil. Dwarf bean was the least sensitive, and required a soil concentration of about 2.0 μg/g to give a similar phytotoxicity score. The other crops were intermediate in sensitivity and required between 0.8 and 1.2 μg/g to give a phytotoxicity rating of 5.0.

Results from one of the log-dose experiments are shown in Figure 4. These are from the experiment prepared on 10 May 1978 and show the responses of the seven crops to metribuzin. To even out some of the variability in the results, the fresh weights (percentages of the untreated controls) are expressed as running means of three successive measurements. Dwarf bean and carrot were the least sensitive, with ED50's between 0.25 and 0.30 μg/g; lettuce was the most sensitive (ED50, 0.07 μg/g); the other crops were intermediate in susceptibility between these extremes.

Summary of responses

A summary of the crop responses to the seven herbicides, averaged across all the experiments is shown in Table 2. The concentrations shown are those which gave a reduction in crop fresh weight of 20% from the untreated controls. The average

Fig. 3. Response of six crops to metamitron incorporated into the soil pre-drilling (mean of three experiments)



coefficient of variation in control fresh weights was about 10%, and a reduction of 20% therefore represents the least significant difference at P = 0.05.

Although the results in Table 2 will be specific to the sandy loam soil in which the experiments were made, they are in reasonable agreement with the limited data which have been published previously. For example, Caverly (1978) reported that the minimum soil concentrations of linuron which were phytotoxic to lettuce, wheat, onion, carrot, dwarf bean and beet were 0.28, 0.24, 0.77, 0.91, 0.38 and 0.49 µg/g soil respectively, which compare with 0.23, 0.43, 0.41, > 0.71, 0.50 and 0.54 µg/g found in the present experiments. In a similar study, Eagle (1978) reported that the minimum soil residues which could damage cereals on mineral soils were 0.10, 0.10, 0.08, 0.10, 0.20 and 0.20 µg/g for atrazine, simazine, metribuzin, propyzamide, linuron and trifluralin respectively, which compare with the values of 0.12, 0.18, 0.07, 0.09, 0.43 and 0.23 µg/g reported for the same herbicides and wheat in Table 2.

Interpretation of the possible significance to following crops

A mathematical model for prediction of herbicide peristence (Walker, 1974; Walker and Barnes, 1980) has been shown to predict satisfactorily the persistence of most of the herbicides used in the present experiments (Walker, 1978), although with

Fig. 4. Response of seven crops to metribuzin incorporated into the soil pre-drilling

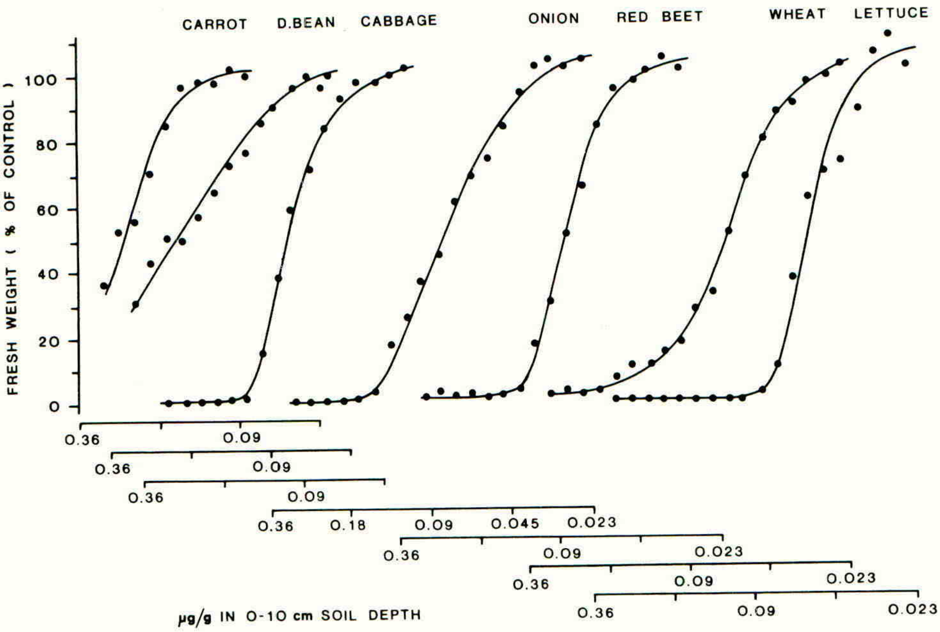


Table 2

Herbicide concentrations in the soil (µg/g in 0-10 cm) giving a 20% reduction in crop fresh weight (mean of seven experiments)[a]

Herbicide	Cabbage	Lettuce	Carrot	Red beet	Onion	Dwarf bean	Wheat
Simazine	0.18 ± 0.024[b]	0.11 ± 0.024	0.17 ± 0.030	0.19 ± 0.086	0.16 ± 0.067	0.23 ± 0.047	0.18 ± 0.083
Atrazine	0.17 ± 0.066	0.08 ± 0.018	0.12 ± 0.051	0.14 ± 0.068	0.12 ± 0.045	0.18 ± 0.096	0.12 ± 0.054
Metribuzin	0.06 ± 0.016	0.04 ± 0.009	0.11 ± 0.049	0.07 ± 0.031	0.05 ± 0.019	0.13 ± 0.066	0.07 ± 0.042
Metamitron	0.89 ± 0.212	0.23 ± 0.103	0.50 ± 0.114	>2.85	0.43 ± 0.121	1.07 ± 0.306	0.71 ± 0.132
Trifluralin	>0.71	0.42 ± 0.063	>0.71	0.19 ± 0.059	0.19 ± 0.065	>0.71	0.23 ± 0.083
Propyzamide	0.46 ± 0.075	>0.71	0.32 ± 0.133	0.21 ± 0.040	0.31 ± 0.035	0.54 ± 0.100	0.09 ± 0.036
Linuron	0.31 ± 0.043	0.23 ± 0.057	>0.71	0.54 ± 0.116	0.41 ± 0.076	0.50 ± 0.120	0.43 ± 0.048

a. Not all values are a mean of seven; in some experiments poor crop growth or bird damage made assessment of phytotoxicity impossible.

b. Errors are standard deviations and therefore represent the error associated with individual determinations.

some compounds (eg. metribuzin, trifluralin), there was a tendency to overestimate soil residues. The model was used to predict the persistence of the seven herbicides in the Wellesbourne soil using appropriate constants derived previously (Walker, 1978) and weather data from May 1 1978. The predicted degradation curves, in conjunction with the soil concentrations shown in Table 2 were used to estimate the time intervals between application and when the various crops could be safely sown in this soil. The results are shown in Table 3.

Table 3

Predicted time (weeks) following application in May before the various crops can be safely sown

Herbicide	Cabbage	Lettuce	Carrot	Red beet	Onion	Dwarf bean	Wheat
Simazine (0.8 kg/ha)	15	22	16	15	17	13	15
Atrazine (1.1 kg/ha)	16	24	20	18	20	16	20
Metribuzin (0.5 kg/ha)	30	51	18	26	45	16	26
Metamitron (3.5 kg/ha)	8	16	13	0	14	8	10
Trifluralin (1.1 kg/ha)	0	22	0	66	66	0	59
Propyzamide (1.1 kg/ha)	9	0	13	18	14	6	44
Linuron (0.8 kg/ha)	15	22	0	2	9	4	8

It must be stressed that the time periods specified in Table 3 cannot be taken as general predictions of safe intervals; they will be specific for the particular location for which they were derived. The rate of degradation, and the activity of the herbicide will vary in other soils, therefore modifying the safe periods. Nevertheless, the results for most of the herbicides are in general agreement with current label recommendations. For example, with propyzamide, the label specifies that beans can be sown 5 weeks after application in spring, that brassicas and onions can be sown after 10 weeks, carrots and beet after 20 weeks, and cereals after 40 weeks. These periods are similar to those shown in Table 3. The label for linuron recommends that no succeeding crop should be sown within 2 months of application in spring or summer, and that lettuce should not be sown until the following year. Again, the present results agree with these recommendations. There are some examples where the safe periods shown in Table 3 do not agree entirely with label recommendations. With simazine and atrazine, for example, the label suggests that no following crop should be sown within 7 months of application, whereas the present results suggest that on this soil, periods much shorter than this may be safe with some crops. With trifluralin, the results in Table 3 suggest that an interval of more than 12 months should elapse before beet, onion or wheat can be sown. The label, however, specifies that these crops can be sown safely after only 5 months. The model which was used to predict the soil residues from which the safe intervals in Table 3 were derived allows only for degradation of the herbicide. A significant proportion of the trifluralin applied in the field is probably lost through volatilisation and the herbicide will therefore disappear more rapidly than the model predicts; this could account, in part, for the apparent discrepancy.

The data in Table 3 will be valid only when the herbicide residue is located within the top 0 - 10 cm soil. Deep cultivation, such as ploughing, may allow crops to be sown at intervals shorter than those suggested by the present work (Eagle, 1978).

Further data similar to those in Table 2 are required for other soils, crops and herbicides since only when such information is available will it be possible to interpret soil residue analyses to forecast reliably the possible safety of rotational crops.

References

CAVERLY, D.J. (1978) Establishment of crop damage levels in soils for the herbicides lenacil, linuron and trifluralin, Proceedings 1978 British Crop Protection Conference - Weeds, 549-555.

EAGLE, D.J. (1978) Interpretation of soil analyses for herbicide residues, Proceedings 1978 British Crop Protection Conference - Weeds, 535-539

MILLER, J.H., KEELY, P.E., CARTER, C.H. & THULLEN, R.J. (1975) Soil persistence of trifluralin, benefin and nitralin. Weed Science, 23, 211-214.

SCHWEIZER, E.E. (1975) Crop response to residues of ethofumesate, Weed Science, 23, 409-413.

WALKER, A. (1974) A simulation model for prediction of herbicide persistence, Journal of Environmental Quality, 3, 396-401.

WALKER, A. (1978) Simulation of the persistence of eight soil-applied herbicides, Weed Research, 18, 305-313.

WALKER, A. & BOND, W. (1978) Simulation of the persistence of metamitron activity in soil, Proceedings 1978 British Crop Protection Conference - Weeds, 565-572.

WALKER, A. & BARNES, A. (1980) Simulation of herbicide persistence in soil: A revised computer model, Pesticide Science, 11, In Press.

Proceedings 1980 British Crop Protection Conference - Weeds

COMPUTER SIMULATION OF HERBICIDE LEACHING IN A STRUCTURED SOIL

P. Nicholls and T.M. Addiscott

Rothamsted Experimental Station, Harpenden Herts., AL5 2JQ

Summary The winter leaching of fluometuron applied to a well structured soil was measured. The distribution pattern after three months was compared with those simulated by two different computer models: Leistra's, which is representative of models based on the physical laws describing water and chemical movement in soil, and Addiscott's adapted from one describing nitrate movement and using the concept of mobile and immobile water categories. Both correctly predicted the general pattern of movement but were quantitatively inaccurate at soil depths below 10cm, possibly because neither took sufficient account of non-equilibrium processes within the well developed aggregate structure of the soil.

INTRODUCTION

The movement and degradation of pesticides during spring and summer has been reasonably successfully simulated in relatively unstructured soil by Leistra et al. (1980). The movement and degradation of $Na^{36}Cl$, fluometuron and simazine were measured on well structured soil by Graham-Bryce et al. (1979) during spring and summer 1978. However the evaporation of water during the summer period and the concomitant upward movement of water through the soil led to negligible movement of the herbicides, making the influence of the soil structure on movement difficult to discern.

Our experiment was in a soil of a type where prediction would be expected to be difficult and in winter when most leaching takes place. Fluometuron was incorporated into the surface of the soil in November 1979 and its distribution was measured three months later after seasonal weather conditions produced significant movement of herbicides and little evaporation of soil water.

METHOD AND MATERIALS

1. Field Measurements Leaching was studied on a fallow plot at Compton Beauchamp, Oxfordshire on a clay loam soil of the Denchworth series. Plastic tubes (40cm long, 15cm internal diameter) were driven vertically into the soil so that the rims were level with the soil surface. Fluometuron (0.201g equivalent to $10kg.ha^{-1}$) was incorporated into the top 2.5cm in each pipe on 21.11.79. Rainfall was measured daily at the site. Two tubes were removed for analysis 93 days after the chemical was applied, and the soil in each was divided into 15 layers each 2.5cm deep. Duplicate (20g) subsamples were taken from each layer. The fluometuron remaining was extracted into acetone and analysed by HPLC on a reversed phase O.D.S. column.

2. Computer Models
   A. The Leistra Model. A version of the model similar to that described by Leistra et al. (1980), typical of models based on the physical laws describing water and chemical movement and loss in soil was used. It uses the hydraulic conductivity form of the Darcy equation describing water flow in

soil. For simulation, the top 80cm of the soil was divided horizontally into 21 layers of increasing thickness with depth. The thickness of the top layer was set at 0.2cm. Time was divided into intervals of 0.001 day. At each 0.001 day interval the current soil and weather conditions were used to calculate the rates of herbicide and water exchange and herbicide degradation. The new water content and herbicide concentration for each layer were calculated from these rates and the process repeated for the next time step. Herbicide degradation was calculated, using the equations of Walker (1976), from data obtained from measurements of degradation in laboratory soil incubations.
The model requires: (i) Soil Data; Bulk density, initial volumetric water content, soil moisture characteristic, hydraulic conductivity function, dispersion distance and diffusion impedance factor. (ii) Chemical Data; Initial amount applied, adsorption coefficient, aqueous diffusion coefficient and degradation rate constants. (iii) Weather Data; Daily: rainfall, evaporation and 10cm bare soil temperature.

B. The Addiscott Model. The model was originally developed to describe the movements of nitrate and chloride ions in a structured soil (Addiscott, 1977) but was adapted to treat the movement of a compound that is reversibly adsorbed by the soil and subject to degradation. It divides the soil into layers, 2.5cm thick in this instance, and partitions the soil solution in each layer into mobile and retained phases. The division between the phases was set at 2 bars, and fluometuron was assumed not to enter the most inaccessible 10 percent of the total soil water. The form of the model used assumed that the profile remained at field capacity throughout the period (in winter). Rainfall displaces the mobile phase only, and during movement, the solute was assumed to equilibrate with the proportion of the soil surface in contact with the mobile phase. After movement, the model assumes that equilibration of concentration occurs between the mobile and retained phases and between soil and solution. For any rainfall input, the model is concerned only with the amount of solute movement and not with the rate at which it occurs. It therefore takes less than one thousandth as much computer time as the Leistra model and needs only the following smaller amount of input data. (i) Soil data; Moisture content at field capacity and at 2 bars. (ii) Chemical data; Initial amount applied, adsorption coefficient and first order degradation rate constants. (iii) Weather data; Daily rainfall and evaporation from bare soil.

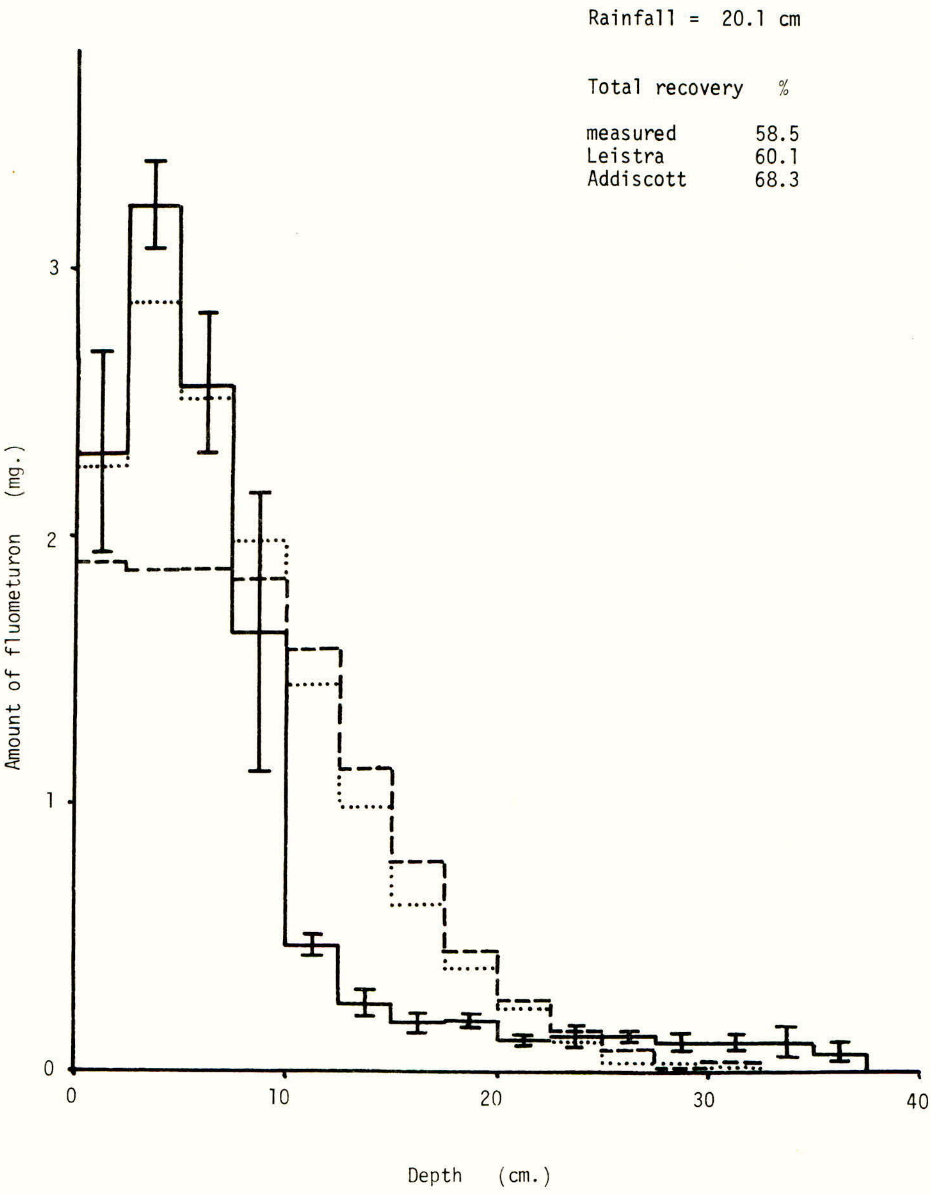
RESULTS

Fig. 1 shows that both models correctly predicted that the maximum amounts of herbicide remained in the top 7.5cm, indicating that the laboratory measured adsorption coefficient used in both models reasonably estimated herbicide movement. Both models overestimated the amount in the layers between 10 and 22.5cm possibly because neither took sufficient account of non-equilibrium processes resulting from the well developed aggregate structure of the soil which retained chemical in the surface layers. Both models assumed instantaneous adsorption equilibrium. Possibly for the same reasons neither model accurately predicted the small but significant amounts of fluometuron which reached soil layers below 25cm. The regressions of observed on predicted data for each model were for Leistra, slope = 1.13, S.E. 0.202, intercept = -121.3, $r = 0.84$ and for Addiscott, slope = 0.99, S.E. 0.096, intercept = -120.3, $r = 0.94$.

CONCLUSIONS

Both models gave a useful estimate of the pattern of fluometuron movement in a

Fig. 1. Distribution of fluometuron after 93 days,
——— measured, bars represent variation of duplicate pipes,
– – – Leistra simulation, ... Addiscott simulation



soil of a type where prediction would be expected to be difficult, and in winter when most leaching takes place. Both models are sufficiently flexible to be adapted, in the future, to account for some of the physical processes which may have caused deviations from the measured data. Such models may be of most immediate use in evaluating the likely environmental performance of new pesticides before extensive field trials can be completed. They may be especially valuable where knowledge of the properties of the herbicide required as inputs to the models is limited. They might also be used in place of some of the current registration requirements of certain countries. Addiscott's model is especially suitable for this because it requires very simple soil property data.

Acknowledgements

We gratefully acknowledge the influence of Dr. I.J. Graham-Bryce in initiating this project, Dr. R.H. Bromilow for his collaboration in the field experiment and Dr. M. Leistra for use of his computer programme.

References

ADDISCOTT, T.M. (1977) A simple computer model for leaching in structured soils, Journal of Soil Science, 28, 554-563

GRAHAM-BRYCE, I.J., NICHOLLS, P.H., HANCE, R.J., HILL, D. (1979) Behaviour of pesticides in soil; leaching in the field, Rothamsted Experimental Station Report for 1979, 118-119

LEISTRA, M., BROMILOW, R.H., BOESTEN, J.J.T.I. (1980) Measured and simulated behaviour of oxamyl in fallow soils, Pesticide Science, in press

WALKER, A. (1976) Simulation of herbicide persistence in soil. II. Simazine and linuron in long term experiments, Pesticide Science, 7, 50-58

Proceedings 1980 British Crop Protection Conference - Weeds

A CRITICAL STUDY OF THE PERFORMANCE OF VLV/CDA HERBICIDE APPLICATORS

P. Fuller Lewis, N.K. Sylvester and R. Scarlett

Pan Britannica Industries Limited, Britannica House, Waltham Cross, Herts EN8 7DY

Summary Flow rates, droplet size spectra (v.m.d. and n.m.d.), swath widths and patterns were obtained for two representative models of VLV/CDA herbicide applicators when spraying water + wetter, glyphosate diluted in water and atrazine diluted in water. Outputs from various jets and the effect of handle angle were measured. It was found that the type of formulation and the flow rate had a greater influence on droplet size than variations of over 200 rev/min in atomiser speed. A cup type atomiser of type fitted to the Micron Herbi produced a narrow droplet spectrum with water + wetter, v.m.d:n.m.d. = 1.4 to 1.8 according to flow whereas for dilute atrazine and glyphosate the low profile twin disc type fitted to the Turbair Forester gave the best results, v.m.d:n.m.d. = 1.2 to 1.7. Depending on the flow rate and type of atomiser, swath width varied from 1.1 to 1.7 m and from 2 to 4 distinct droplet size groups were produced.

As a result of this study, a new VLV/CDA sprayer, the Turbair Weeder, has been developed.

INTRODUCTION

Simple hand-held battery operated spinning disc VLV/CDA herbicide applicators have been available for a number of years. These sprayers are usually used to apply herbicides in a band at about 10 - 20 l/ha. Bals (1975), Johnstone (1977), Matthews (1977), Combellack (1978) and others have described this type of sprayer but most published data relating to swath width, liquid flow rate and droplet spectra have been quoted for water + wetter and not actual herbicide formulations. Now that some 25 herbicides ranging from solutions in oil to water dispersed flowables are available for use through this type of equipment, it was considered desirable to study the interaction of formulations with factors such as atomiser configuration, air bleed system, jet design and location of chemical container. The performance in the laboratory of two types of sprayer specifically recommended for herbicide application was studied.

These sprayers, the Turbair Forester (1) and the Micron Herbi (2), are simple hand-held battery powered, spinning disc units with a chemical container which feeds herbicide (by gravity) on to an atomiser disc which revolves at a speed to produce droplets of approximately 150 - 250 μm diameter to restrict drift. Both sprayers have been designed for use with similar types of herbicide, but the liquid feed system and atomiser design have been developed along different lines to achieve similar performance. It was considered that a critical study of design factors

(1) Turbair Ltd., Waltham Cross, Herts.

(2) Micron Sprayers Ltd., Bromyard, Herefordshire.

would provide data for developing a new unit with improved performance. Flow rates, droplet size spectra, swath width, swath pattern and the ability of the sprayers to apply a wide range of herbicide formulations were parameters considered. At an early stage key components of the Turbair Forester were redesigned and the data reported relates to subsequent tests.

METHOD AND MATERIALS

Materials

Model A - A sprayer with a chemical container feeding a low profile 2-disc atomiser via a short length of tube and a metal metering jet (similar to the Turbair Forester).

Model B - A sprayer with a remote chemical container feeding a simple dish type atomiser via a long length of tube and a plastic jet (Micron Herbi).

Atomiser "A" was driven by a non-governed small 6 volt electric motor whilst atomiser "B" was driven by a constant speed governed 12 volt motor.

Liquids used for flow rate were water + 1% wetter, glyphosate diluted with water (2 parts : 3 parts water by volume), atrazine diluted with water (2 parts : 3 parts water by volume) and atrazine undiluted.

Methods

Flow rates

These were determined with the atomiser spinning and by collecting and measuring the liquid output from the atomiser during a measured time interval.

Droplet size spectra

These were measured using a Malvern particle and droplet sizer (manufactured by Malvern Instruments, Spring Lane, Malvern, Worcestershire, England). The discs were positioned 3 cm away from the measuring beam so that all the output passed through the beam. The standard Rosin-Rammler distribution was assumed.

Swath width and pattern

Determinations were made using atrazine diluted with water. Each sprayer was held over a large sheet of black PVC film for about 8 seconds with the atomisers positioned 0.5 m above the film. After drying a semi-permanent circular trace was obtained which was measured and photographed.

RESULTS

Table 1

Effect of formulation on flow rate (ml/s)

Formulation	Temp. °C	Model A Jet size, diameter (mm) 1.0	1.2	2.0	Model B Jet size, diameter (mm) 0.7	0.8	1.7
Water + 1% wetter	19	1.4	2.2	5.3	1.4	1.7	5.4
Glyphosate diluted with water	17	1.0	1.7	4.4	1.2	1.7	5.1
Atrazine diluted with water	17	1.0	1.5	4.1	1.0	1.5	4.8
Atrazine undiluted	19	0.1	0.2	0.5	0.2	0.3	0.7

Note

Handle angle relative to ground was 18° for Model A and 40° for Model B and corresponded to the operator's normal position.

Fig. 1

Effect of sprayer handle angle on flow rate

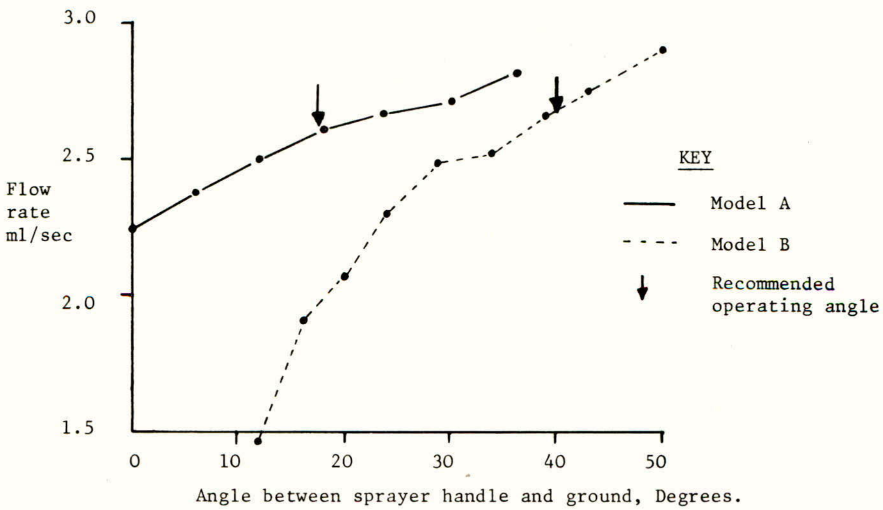


Table 2

Effect of formulation on droplet size (μm)

Formulation		Model A 2050 rev/min Jet size, diameter (mm) 1.0	1.2	2.0	Model A 1850 rev/min 1.0	1.2	2.0	Model B 2000 rev/min Jet size, diam (mm) 0.7	0.8	1.7
Water + 1% wetter	VMD	233	304	374	323	441	495	285	297	414
	NMD	68	57	137	71	113	215	158	172	296
	Ratio	3.43	5.33	2.73	4.55	3.90	2.30	1.80	1.73	1.40
Glyphosate diluted with water	VMD	177	172	200	221	205	272	299	223	198
	NMD	117	124	116	166	173	80	150	112	131
	Ratio	1.51	1.39	1.72	1.33	1.18	3.40	1.99	1.99	1.51
Atrazine diluted with water	VMD	129	142	176	160	175	189	206	201	228
	NMD	97	114	142	129	139	159	103	137	141
	Ratio	1.33	1.25	1.24	1.24	1.26	1.19	2.00	1.47	1.62

Table 3

Effect of flow rate on swath width and spray pattern

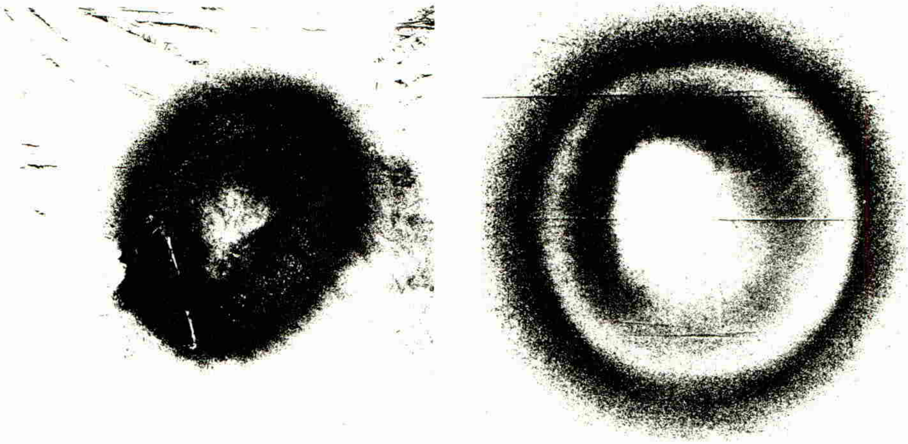
	Model A Flow rate of atrazine in water (ml/s) 1.0	1.5	4.1	Model B 1.0	1.5	4.8
Effective swath width (m)	1.1	1.1	1.3	1.3	1.3	1.7
Total swath width to outer limit of spray pattern (m)	1.4	1.4	2.0	1.7	1.7	2.3
Droplet pattern from static spray head	Round	Round	Oval	Round	Oval	Oval
No. of distinct droplet size groups in spray pattern	2	2	2	4	3	3

Fig. 2

Photographs of static spray patterns

Model A

Model B



Atrazine diluted in water, 12 ml

DISCUSSION

The measurements taken did not reveal a direct relationship between jet diameter and chemical flow rate for all formulations and jet sizes. This is due to the fact that flow appears to be controlled by both jet size and the restrictive effect of the air bleed which allows air into the chemical container as liquid flows out. Very small differences in jet size (< 0.1 mm) can markedly influence flow rate, and in view of the wide variation in herbicide formulations used for these sprayers it is considered that a metal jet, accurately drilled with good consistency between samples is superior to a moulded plastic type. A further advantage of the metal jet is that it can be drilled to produce a wide range of sizes and this enables the operator to walk at a set practised speed with the jet controlling the dose rate. Consistency of jet size is very important if variations in flow rate are to be kept to within 10%.

It was surprising that changes in flow rate and formulation had a greater influence on the droplet spectra than either the atomiser design or small changes in rotational speed. The performance of the cup type of atomiser was excellent with water + wetter, but not nearly so good with either glyphosate or atrazine (Table 2). This emphasises the importance of using actual rather than an arbitrary reference (such as water + wetter) when measuring atomiser performance.

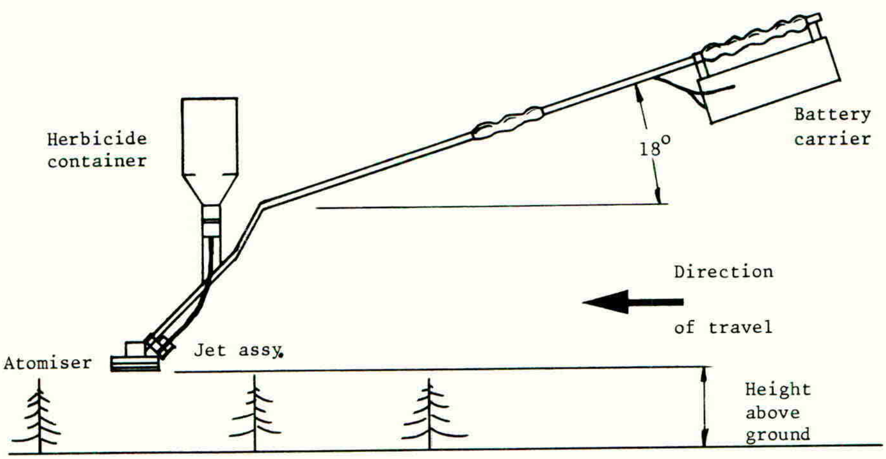
The width of the swath can be significantly influenced by both atomiser design and formulation (Table 3). Since the effective swath width and distribution of droplets within it, are key factors in determining dosage rates, measurements must be made with actual formulations. This means close co-operation between sprayer and chemical manufacturers so that users can be supplied with precise information concerning dilution, flow rate and swath width for each chemical and each model of sprayer.

For the market for which this type of sprayer is recommended it was clear from the operators comments that simplicity and ease of use are primary considerations. This creates a design problem as the sprayer has to apply accurate doses of fairly concentrated solutions/suspensions of herbicides many of which were originally formulated for application at a greater volume in a more dilute form. Dose rate is controlled by three factors - dilution, walking speed and flow rate (jet size). It is difficult for an operator to learn to walk at one constant speed, therefore to alter dose rate by small changes in walking speed is not practical. The difference in viscosity and therefore flow rate between a solution such as glyphosate in water and a flowable such as atrazine is so great that an appropriate dose cannot be achieved by dilution alone. Furthermore chemical manufacturers usually like to standardise dilutions so this leaves change of jet size as the most convenient and practical method of achieving the correct dosage. A second very important consideration which appears to have been overlooked by other workers in this field is the effect of variations in swath width where a 20% wider swath results in a 17% decrease in dose providing the flow is constant. Design of atomiser should minimise variation in swath width when using different formulations and the width should be accurately determined when recommending flow rate and jet size to achieve the desired dosage.

After consideration of the data obtained in this study it was concluded that a VLV/CDA hand-applicator must be a compromise between often conflicting desirable features and performance parameters. Some of the components such as jet assembly, air bleed, chemical container attachment and position evaluated on Sprayer Model A have been incorporated into a new model, the Turbair Weeder, which will be available late 1980. This unit can be regarded as a 'chemical hoe' and should meet some of the needs for a simple VLV/CDA applicator in both advanced and developing countries.

Fig. 3

Turbair Weeder



Acknowledgements

The authors wish to thank the Overseas Spraying Machinery Centre, Imperial College Field Station, Silwood Park, for providing the Droplet size data.

References

BALS, E.J. (1975) Development of a CDA herbicide handsprayer, PANS, 21(3) 345-349.

COMBELLACK, J.H. et al (1978) Spot spraying with hand-held CDA equipment in Australia; a progress report on suitability of equipment and herbicides, British Crop Protection Council Monograph No.22 (1978), 199-211

JOHNSTONE, D.R. et al (1977) Performance characteristics of a hand-carried battery-operated herbicide sprayer, PANS, 23(3), 286-292.

MATTHEWS, G.A. (1977) CDA - controlled droplet application, PANS, 23, 387-394.

A LOW-VOLUME HERBICIDE APPLICATOR FOR TROPICAL SMALL-HOLDER FARMERS

R.P. Garnett

Overseas Spraying Machinery Centre, Imperial College, Silwood Park,

Sunninghill, Berks SL5 7PY

Summary A wheelbarrow sprayer has been developed to overcome some of the problems of herbicide application by peasant farmers. Two metering pumps and a spinning cup are driven directly off the ground-wheel, so a constant spray volume and droplet size are applied irrespective of the operator's walking speed. Biological results have been comparable to those using a knapsack sprayer. The potential uses of the sprayer are discussed.

INTRODUCTION

The role of small-holder farmers in agricultural development has been given much attention during the past few years. Attempts to raise food production by increasing the area cultivated by a farmer have been limited by the size of the area which he can weed adequately. Hand-hoeing, the most common method of weeding in the tropics, can be the major labour in-put to cropping (Table 1).

Table 1

COUNTRY	CROP	WEEDING HOURS	% TOTAL LABOUR	AUTHOR
Gambia	groundnut	260	63	Anon, 1979
Nigeria	cassava	112	56	Fawole
	maize	120	36	"
	maize-cowpea	280	54	Wijewardene
	upland rice	500	54	IITA
Senegal	groundnut	376	50	Ruthenberg
Tanzania	cotton	430	29	"
	maize-sorghum	250	27	"

Time is a major consideration to the farmer as well as crop yield and profit. If weeding takes too long it will not be completed at the optimum time and leaves insufficient time for other activities. It may be necessary to hire labour, if it is available. Reducing weeding time could increase the yield and quality of farm produce, while decreasing the major expense of labour.

Although a large amount of work has been done on herbicides in the tropics, very little is used by small farmers. This position is similar to that 15 years ago

(Steele, 1965) and the only example of large scale herbicide use by farmers is probably of granules in paddy rice in the Philippines (Reesham Fuver, 1975). No application equipment is required, the chemical being distributed automatically by the water. Similarly simple methods of application are vital if herbicides are to be used by small farmers (Parker, 1976) and present sprayers are often unsuitable. Both the sprayers and their usage are complex, and correct use would require more extension activity than most areas obtain at the present. The cost of the sprayer is also a problem, though it may be small relative to the total cost of chemical which could be sprayed during its lifetime.

Tractor mounted sprayers are not suitable for most small farms, but the Geest "Groom System" (Anon, 1980) is a major step towards mechanization. Alternatives are knapsacks and hand-carried, battery operated spinning disc sprayers. Knapsacks are heavy when filled with large volumes of water which may have to be carried a long distance to the field. Hand-held spinning discs are cheaper and require low volumes of water, but the motors driving the disc can be unreliable, the disc can be easily damaged, and torch batteries have a short shelf-life in humid conditions. Accurate dosing is almost impossible with either type, and while the swath width may be varied when using a knapsack, with a spinning disc it is fixed because above a minimum height the drops are falling vertically. The operator is liable to considerable contamination while using a knapsack sprayer, as he holds the lance in front of him (Tunstall & Matthews, 1965), but this is reduced when using a spinning disc sprayer since the disc may be held at the side of the operator or behind him.

To try to overcome these problems, a ground-actuated sprayer using a 'Micromax' spinning cup, has been developed. The 'Micromax' was chosen for its greater versatility of usage compared to a 'Herbi' disc (Heijne, 1978).

SPRAYER MECHANISM

A "wheelbarrow" design (Fig. 1) was adopted, so that spray application could be directly related to walking speed. Two peristaltic pumps, driven off the ground-wheel, deliver the spray liquid to the spinning cup giving an application volume of 20 l/ha. The feed system involves no constrictions which could be blocked by materials in the liquid.

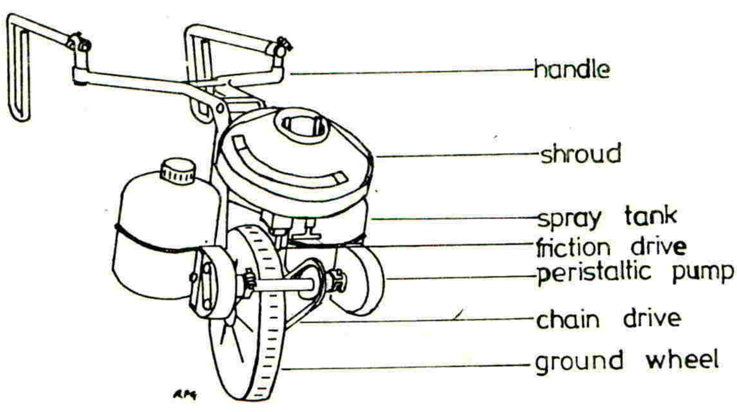


fig1 WHEELBARROW SPRAYER (not showing tubes)

A relatively uniform droplet size can be maintained over a range of walking speeds if the disc speed also increases with flow rate, so the cup is driven by friction directly off the ground wheel. Any liquid running in the cup when the ground wheel stops is spun off by incorporating a free-wheel mechanism into the drive shaft.

The swath width is controlled by a shroud mounted around the cup, with two variable shutters. Spray collected by the shroud drains back to the spray tanks. The shroud also protects the cup from damage.

PHYSICAL CHARACTERISTICS

All work has assumed an average walking speed of 1 m/s.

a) Flow rate

The flow rate increases linearly over the speeds investigated, but the range of flow rates can be changed by using a different diameter of tubing in the peristaltic pumps. Variation in flow rate with temperature is minimal over the temperature range likely to be encountered, and there are negligable differences in flow amongst a range of formulations diluted with water.

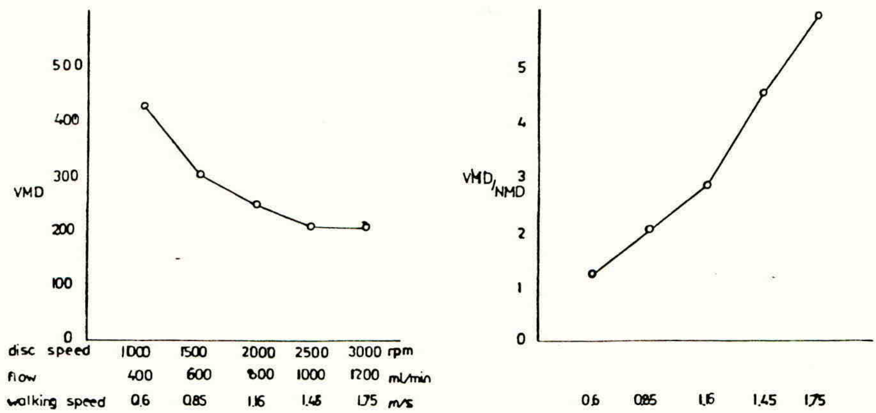
b) 'Micromax' speed

The speed of the cup increases in proportion to the walking speed, giving 2000 rpm at 1 m/s.

c) Droplet size

Spray leaving the shroud has been analysed through a Malvern Instruments Particle Sizer*. A v.m.d. of 270 µm is produced from a cup spinning at 2000 rev/min with a flow rate of 750 ml/min. The v.m.d./n.m.d. ratio is 1.6. These are the parameters for the spray when walking at 1 m/s, but the droplet size is similar over the walking speed range above 0.5 m/s (Fig. 2).

Fig. 2. Droplet characteristics over a range of walking speeds.



* Malvern Instruments, Malvern, England

d) Spray distribution

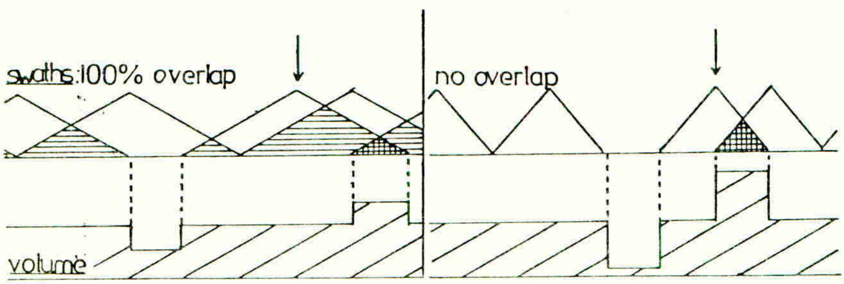
Many patternator tests have shown a variation across the swath ($\frac{\text{max-min}}{\text{max}}$ %) of 10-25% over a range of walking speeds and flow rates, for a swath up to 1.5 m. Above this width, the swath has the 'horned' pattern characteristics of spinning discs and hollow cone nozzles. Two pumps set 90^{o} out of phase produce a variation of 5-20% in the ground spray distribution along the swath; the pulsing of a single pump produces up to 50% variation.

METHOD OF USE

The sprayer is more easily pulled than pushed and the operator does not have to walk through the spray. Although it is then more difficult to check that the machine is spraying, experience in Botswana has shown that untrained operators find it easier to use than a knapsack or a spinning disc sprayer.

When the cup is held horizontal, optimum spray distribution across the field is obtained with a 100% overlap of swaths, so that any swath movement, due to the wind or the operator, gives neither zero or double dose (Fig. 3). Alternatively, the cup can be angled at 40^{o}, directing the spray under the momentum gained from droplet formation. Swaths up to 1 m wide can be sprayed in this way and it is particularly useful for inter-row spraying since the spray is less susceptible to air movement and has greater foliage penetration.

Fig. 3. 100% swath overlap minimizes operator errors.



The sprayer handles need not be adjusted for different operators since hand height of the operator varies much less than their total height. A slight difference in shroud angle will not effect spray characteristics.

There have been no unsurmountable problems in field use, although in wet clay soils the ground-wheel rapidly becomes clogged. The friction drive works well except under such conditions. Enclosing the peristaltic pumps prevents thorns or grit puncturing the tubing; each tube having a life of several hundred hours. Even if punctures occur, there is very little leakage since the system is not under a back-pressure.

BIOLOGICAL EFFICACY

Successful trials have been conducted in the laboratory and in the field, in England and Botswana, using a range of types of herbicide and including comparisons with a knapsack sprayer fitted with a 'Polyjet' nozzle, and a 'Herbi' sprayer.

Greenhouse grown radishes and oats were sprayed with very low herbicide doses to pick out differences between sprayers (Fig. 4). Pre-emergence applications of atrazine and pendimethalin showed no significant differences between sprayers. The wheelbarrow gave a significantly better kill of radishes and oats with all doses of paraquat than either the knapsack or a fan nozzle in a spray cabinet. Only the wheelbarrow produced a good response with glyphosate on radish, whereas all sprayers gave similar results with 2,4D.

Table 2. % Kill using 3 pre-emergence herbicides applied at recommended discs.

	Atrazine + Alachlor		2,4D		Gardomil + Dual	
	Eleusine	Tribulus	Eleusine	Tribulus	Eleusine	Tribulus
Wheelbarrow	100	100	100	100	100	81
Herbi	100	100	100	100	100	25
CP3	100	62	98	81	99	0

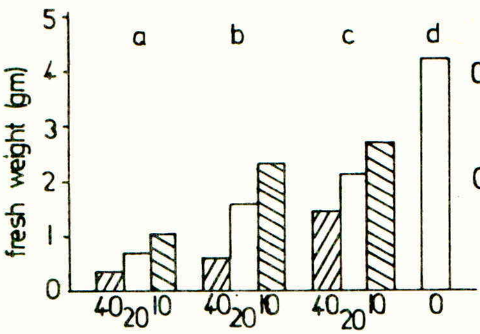
Field trials have given similar results with soil applied chemicals (Table 2). These cannot be sprayed successfully at reduced dosages, and no difference between sprayers has been observed. Similarly there is little difference between sprayers for foliage applied herbicides - even when reduced doses have been used. However, there is some evidence that slightly reduced doses can be used with the wheelbarrow compared to a knapsack sprayer. Walking speed has not affected pre- or post-emergence activity with the wheelbarrow sprayer (Table 3).

Table 3. Weed numbers after metolachlor at three different walking speeds.

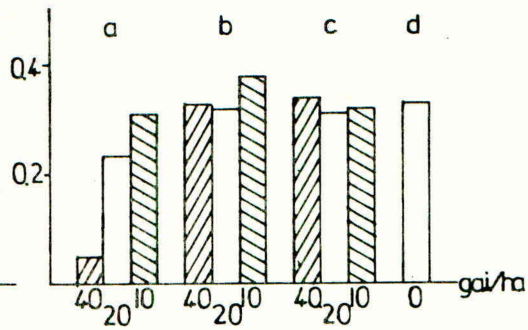
Walking speed (m/s)	Metolachlor			Alachlor	Control
	0.5	1.0	2.0	1.0	Untreated
P. oleraceae	843	848	944	1094	1497
T. terrestris	191	192	167	213	194
C. bontei	69	45	32	51	175
Ipomoea sp.	40	48	44	39	45
E. africana	3	16	2	1	52

Fig. 4. Low dose applications of herbicides to greenhouse grown plants.

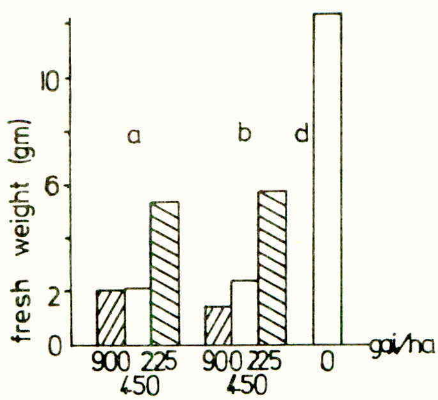
a) paraquat on radish



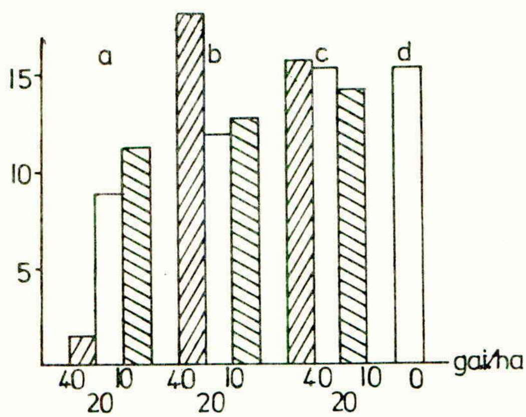
b) paraquat on oats



c) 2,4-D ester on radish



d) glyphosate on radish



There is no evidence that the pulsing of the spray due to the pumps has any effect on its biological activity. Weeds were harvested from 10 cm^2 quadrats in transects along the swath and each sample was weighed. The results were analysed for the presence of a pattern due to pulsing using two-term local variance analysis (Hill, 1976).

POTENTIAL APPLICATIONS

The wheelbarrow sprayer is suitable for most small farms, throughout the world. Its simplicity makes it particularly suitable for developing countries, and, with the exception of the spinning cup and shroud, the sprayer could be built locally.

Herbicides may be technically safe if applied accurately, at the correct dose, at the right time and on a tolerant crop. Compared to a knapsack sprayer, the wheelbarrow sprayer increases the chance of accurate spraying at the correct dose by relating walking speed to flow rate, and may allow better timing since time is not spent collecting water. Pre-packaged herbicides ready to spray in small bottles would minimize the risk of incorrect concentrations being sprayed, and colour-coding of bottles for specific crops could reduce the possibility of spraying susceptible crops (Matthews, 1980). Swath width control allows inter- or intra-row spraying, which is impossible with a "Herbi" and may be inaccurate with a knapsack.

Many small farmers combine weeding with crop-thinning, taking 200 hours/ha even on a completely weed-free sorghum-millet field in Nigeria (Ogborn, 1978). If weed control by herbicides was incomplete hoeing out a few remaining weeds would take little extra time. Under such circumstances, the herbicide dose could be reduced by 10-50%, reducing expenditure and minimizing the risk of crop damage and operator contamination.

Farm systems can be moulded around new potential for weed control. No-till techniques being developed for tropical farmers which require herbicide spraying to produce a mulch through which the crop grows without weed competition (Wijewardene, 1979). A low-volume sprayer, such as the wheelbarrow, with a high work-rate would be more suitable than a knapsack sprayer.

The recent increase in tractor use, both farmer and contractor owned, has given rise to larger areas being cultivated. However, the women who weed the crops cannot hope to cover the whole area adequately. Developments such as the wheelbarrow sprayer and the "Groom" system should reduce the present gap in levels of technology between cultivation and weed control, and contribute to improved land use.

Acknowledgements

The work was carried out under an Overseas Development Administration research grant R3337. I am grateful to Dr. G.A. Matthews of Imperial College and Messrs C. Parker and W. Taylor of the Weed Research Organisation for their help and advice, and to Micron Sprayers for their assistance with the construction of two prototype sprayers. Thanks are also due to the Botswana Ministry of Agriculture and the staff of the Evaluation of Farm Systems and Implements Project for allowing me to work at Content Research Farm, Gaborone, and for their help with accommodation and field trials.

References

ANON (1979). Cultivating your land. *West African Farming, Nov. 1979*, 33-35.

ANON (1980). Geest make and market the "Groom" system. *Farm Equipment International*, 1, iv-vi.

FAWOLE, L.O. (1980). Mechanization needs and problems of small farms in Nigeria. *Farm Equipment International*, 1, 13-16.

HEIJNE, C.G. (1978). A study of the effects of disc speed and flow rate on the Micron "Battleship". *Proceedings BCPC Conference - Weeds*, Vol. 2, 673-679.

HILL, M.O. (1976). The intensity of spatial pattern in plant communities. *J. Ecol.*, 61, 225-232.

IITA (1977). Annual Report. *Institute of Agricultural Research, Zaria, Nigeria.* p. 83.

MATTHEWS, G.A. (1980). Sprayers in Nigeria - limitations and potential. *West African Farming, Jan. 1980*, 36-37.

OGBORN, J.A. (1978). Samaru experiment report AP268(77). *Institute of Agricultural Research, Zaria, Nigeria.*

PARKER, C. (1976). Weed research requirements in developing countries. *Proceedings BCPC Conference - Weeds*, Vol. 3, 801-808.

REESHAM FUVER, (1975). Assessment of herbicide use in rice production in the Philipines. *Philipine Weed Sci. Soc. Bulletin*, 2, 26-32.

RUTHENBERG, H. (1971). Farming systems in the tropics. *Clarendon Press, Oxford*, 71, 156.

STEELE, B. (1965). The economics of chemical weed killers in the tropics. *PANS (c)*, 11, 1-5.

TUNSTALL, J.P. & MATTHEWS, G.A. (1965). Contamination hazards in using knapsack sprayers. *Emp. Cott. Gr. Rev.*, 42, 193-196.

WIJEWARDENE, R. (1979). Systems and energy in tropical small-holder farming. *Proceedings Appropriate Tillage Workshop, Zaria*, 73-86.

Proceedings 1980 British Crop Protection Conference - Weeds

SLOT-SEEDING - DEVELOPMENT TO COMMERCIAL INTRODUCTION

R.V. Edwards

Monsanto Ltd., Agricultural Division, Thames Tower, Burleys Way , Leicester

Summary Slot-seeding is a one-pass technique for sowing seeds into swards, so that grasses, clover and fodder brassicae can be established at low cost with minimum interruption to field management. The development of the machine is briefly described together with the final two years trials prior to the commercial introduction of the G.B. Slot-seeder.

Emphasis is placed on the need to select sites for slot-seeding carefully. These must be reasonably fertile with good grazing management. Swards should not have a thick organic mat nor include those where *Holcus*, *Nardus* or *Festuca* spp. are in dominance. Where slugs (*Agriolimax* spp.) or frit fly (*Oscinella frit*) occur, appropriate protective measures should be taken.

Résumé Le 'Semis en Fente' est une technique permettant en une seule operation d'effectuer des semis en parcelles enherbees, de facon que les graminees, le trefle et les choux fourragers puissent etre cultives a faible cout en retardant au minimum la culture du champ.

Le developpement de la machine eso brievement decrit, ainsi que le resugtats apres deux annees d'essais avant l'introfuction commerciale du G.B. Slot-seeder.

L'accent est mis sur la necessite de choisir soigneusement les sites destiney au semis 'en fente'. Ceux-ci doivent etre raisonnablement fertiles et permettre une bonne technique d'utilisation. Ces sites ne devraient pas etre couverts d'un tapis de matiere organique epais ni comprendre ceux ou *Holcus*, *Nardus* ou *Festuca* spp. dominent.

Aux endroits ou des attaques de limaces (*Agriolimax* spp.) ou de mouches (*Oscinella*) se produisent, des mesures appropriees devraient etre prises.

INTRODUCTION

Slot-seeding is a method of sowing seed into swards, so that grasses, clover and fodder brassicae can be established at low cost, with minimum interruption to grazing management. The technique is particularly relevant to grassland farmers who are unable or unwilling to carry-out the complete reseeding of old pastures or leys. The technique was devised at the Weed Research Organisation (Haggar, 1977). The operation involves removal of surface organic matter by cutting out a slot in the old turf, followed by the sowing of seed and crop protectants into the slot.

The drill also sprays an 8 cm band of glyphosate over the slot area. This destroys herbage on the slot shoulders, allowing the seedlings to establish with -out undue competition (Squires, 1976).

In 1977, seven prototype slot-seeders were constructed. These were based on the Gibbs Mark II kale direct drill with the addition of two independently sprung discs, to enable a slot to be opened out and a pump, reservoir and spray boom to allow the application of a band spray. This work (Squires, 1977) showed that forage crops gave a rapid and even establishment. Excellent crops resulted from trials where overall spraying was carried out. Where only an 8 cm band spray was applied, brassica seedlings were smothered by competition from the surrounding sward. Clover established well in the few trials where it was sown alone. The work was confirmed by Squires et al (1979).

Grass establishment varied. There was better establishment where soil was friable or moist at the time of drilling and where sites were reasonably well drained. Pests, diseases and possibly allelopathy were blamed in some cases of establishment failure. Mechanical problems were implicated at other sites.

In 1978, a redesigned and strengthened slot-seeder was produced. This was used to establish the trials described in this paper.

The majority of the 1978 and 1979 work concerned grass establishment and colonisation. Clovers and brassicae grew well where sown.

METHOD AND MATERIALS

Trials were established using the 1978 pre-production model of the G.B. Slot-seeder (Gibbs, 1979). In all the trials, glyphosate was used at 1.08 kg a.e/ha on an 8 cm band producing an overall rate of 0.29 kg a.e/ha. In the majority of trials, methiocarb or metaldehyde slug pellets were sown with the seed.

Seed mixtures used varied, but were based on perennial ryegrass with white clover with or without Italian ryegrass. Seed rates were between 10 and 20 kg/ha, but other work (Squires and Haggar, 1978) has shown the optimum seed rate of Italian ryegrass to be 16 kg/ha, perennial ryegrass 12 - 15 kg/ha and white clover 2 kg/ha.

Fertiliser applications were confined to those made during routine spreading of nitrogen, phosphate and potash on the fields in question. The rates of nitrogen fertiliser are summarised in Tables 1 and 2.

Assessment of establishment was made on the following basis - commercially acceptable : 25 - 50 evenly distributed ryegrass seedlings per metre row, outstanding : 40 - 50 seedlings with outstanding vigour, poor : less than 25 seedlings per metre row with sporadic distribution.

Assessment of colonisation was carried out in the year following initial establishment - commercially acceptable : ryegrass plants tillering well, outstanding : plants tillering and beginning to expand into the band sprayed area, poor : plants failing to increase in tiller number.

RESULTS

Sward management:

The most even stands of grass were achieved where the swards were closely defoliated prior to drilling, approximately 6 cm regrowth appeared ideal. Longer grass surrounded the emerged seedlings with large quantities of decaying foliage, caused drill blockages and uneven seeding and resulted in uneven band spray width.

Table 1

Trial site details - 1978 drillings

Annual nitrogen fertiliser usage (kg/ha)

Grazing Animals.	0-63	64-125	126-188	189-250	251-313	314-375	Total
				Successful establishment			
Sheep	2	2					4
Beef		2					2
Dairy Cows		1		2	1	3	7
Sheep/Dairy			3	2			5
Sheep/Beef	1		1				2
Beef/Dairy		1					1
Dairy/Sheep/Beef		1					1
Total :	3	7	4	4	1	3	22
				Poor establishment			
Sheep	4	3(1f)	2(1w)				9 (2)
Beef		2(1w)		1(1d)			3 (1)
Dairy Cows		3		2(1f,1w)	1(1d)		6 (3)
Sheep/Dairy			1				1
Sheep/Beef		3(1f)		1(1d)			4 (2)
Beef/Dairy						2(1d,1f)	2 (2)
Dairy/Sheep/Beef	1						1
Total :	5	11(3)	3(1)	4(4)	1(1d)	2(2)	26 (11)

( ) Number of sites failed due to : (f) a severe attack of frit fly, (w) very wet soil at drilling, (d) drought.

Summary of establishment -
Poor - 26 (11) ; Commercially acceptable - 17 ; Outstanding - 5

Table 2

Trial site details - 1979 drillings

Annual nitrogen fertiliser usage (kg/ha)

Grazing Animals.	0-63	64-125	126-188	189-250	251-313	314-375	Total
				Successful establishment			
Sheep		4	1		1		6
Beef	1						1
Dairy Cows				2	1	1	4
Sheep/Dairy			1				1
Sheep/Beef	1	3		2		1	7
Beef/Dairy						2	2
Dairy/Sheep/Beef							0
Total :	2	7	2	4	2	4	21
				Poor establishment			
Sheep	1(1m)						1 (1)
Beef							0
Dairy Cows				2(2f)			2 (2)
Sheep/Dairy		2	2				4
Sheep/Beef		1	1				2
Beef/Dairy							0
Dairy/Sheep/Beef							0
Total :	1(1)	3	3	2(2)	0	0	9 (3)

( ) Number of sites failed due to : (m) drillings into *Nardus/Molinia*, (f) a severe attack of frit fly.

Summary of establishment -
Poor - 9 (3) ; Commercially acceptable - 15 ; Outstanding - 7

Sward management post-drilling was at least as important. Where the sward was allowed to get too long, smothering of the emerged seedlings occurred. Thus regular grazing is necessary, while avoiding over-grazing. Where clover is sown, W.R.O.data (Squires and Haggar, 1978) suggests that a two to three week rest between grazing is necessary to allow clover reserves to build up.

Sward composition:

Only two trials were carried out on swards considered unsuitable for the use of the slot-seeder. The first was drilled into a 6 cm thick *Festuca rubra* mat. The density of *Festuca* regrowth and mat thickness, resulted in a slow growth of seedlings. The sward recolonised the destroyed band of herbage, resulting in excessive competition. In another trial, seed was drilled into a *Nardus/Molinia* sward. In this case the tussocky nature of the vegetation proved impossible for adequate drill operation, without extensive site preparation. Other work has shown (Squires et al 1979) that seedlings do not grow well in swards with very thick mats or those containing a high proportion of *Holcus lanatus* or *Deschampsia caespitosa*.

All other swards were found suitable for emergence and early growth of seedlings. However, where the sward was thin and much less matted, a very quick establishment occurred.

Level of soil fertility and type of grazing animal:

Levels of soil nitrogen, phosphate and potash must be sufficient for seedling growth and establishment (M.A.F.F. 1978).

In Table 1 it can be seen that more trials established successfully at a higher level of nitrogen. Those establishment failures which did occur at these high nitrogen levels, could be attributed to extreme drought or frit fly attack.

In 1979 (Table 2) seedling establishment did not suffer from drought. The incidence of severe frit fly attack was also lower. Again, above 189 kg/ha of nitrogen was required to ensure 100% establishment success. The establishment at lower levels of nitrogen showed an improvement over 1978, mainly due to better grazing management both before and after drilling.

TABLE 3

Trial site details - 1979 grass colonisation

	Annual nitrogen fertiliser usage (kg/ha)						
Grazing Animals	0-63	64-125	126-188	189-250	251-313	314-375	Total
				Successful colonisation			
Sheep		1					1
Beef		2					2
Dairy Cows		1		1	1	3	6
Sheep/Dairy				1			1
Sheep/Beef		1	1				2
Beef/Dairy							0
Dairy/Sheep/Beef							0
Total :		5	1	2	1	3	12
				Poor colonisation			
Sheep	2	1					3
Beef							0
Dairy Cows				1			1
Sheep/Dairy			3	1			4
Sheep/Beef	1						1
Beef/Dairy							0
Dairy/Sheep/Beef		1					1
Total :	3	2	3	2	0	0	10

Summary of colonisation:-
Poor - 10; Commercially acceptable - 8; Outstanding - 4

Those trials which established successfully in 1978 were monitored in 1979. Of these, 45% failed due to over or under grazing, or lack of adequate nutrition. Where first-class grazing management was practiced, colonisation of the band sprayed area progressed well. There was also complete success where 250 kg/ha of nitrogen was used annually. This fits in with experiments carried out by Mudd (1971) who found that perennial ryegrass increased from 16 to 50% of the sward, following annual applications of 250 kg/ha of nitrogen over 5 years.

Hopkins and Green (1978) concluded that as long as other mineral nutrients are in adequate supply, and defoliation is matched to grass growth, increased nitrogen supply will maintain or increase the proportion of perennial ryegrass in the sward.

In these trials (Tables 1,2 and 3) type of grazing animal did not have a direct influence on establishment or colonisation provided that grazing was matched to rate of growth or sward and introduced species.

Severe pest attack:

Use of the slot-seeding technique results in seedlings growing in the centre of a living sward with an associated complex of pests and diseases.

In seven trials, frit fly was identified as being the cause of establishment failure. In other trials reported by Lemon and Greig (in press), bendiocarb seed dressing and chlorpyriphos spray have been used successfully to combat frit fly and other soil inhabiting pests. In high risk areas or in years where heavy attacks are forecast, protective measures will be essential.

In several trials, slugs caused considerable damage to young seedlings. The use of metaldehyde or methiocarb pellets was found to be essential when there was any possibility of attack.

DISCUSSION

As with any new technique, successful usage depends on level of understanding and expertise. Many of the sites drilled in 1978 were hindered in their establishment by lack of understanding of the fundamental requirements of the technique. The most common problem was the inability to defoliate the field adequately prior to drilling, particularly on dairy farms. The second major problem was that the trial sites was often on the worst field on the farm, that is poorest in fertility, grazing management and drainage.

In the 1979 trials, the adoption of improved management resulted in an increase in grass establishment.

In 1978 and 79, the major factor inhibiting grass establishment were low levels of NPK and in some instances low soil pH.

Where stocking rate and fertiliser input was increased or already high, the introduced species thrived. In many instances, fields received less than 189 kg/ha of nitrogen. Where these lower levels of nitrogen were used, sites have only been successful where at least one of the following criteria apply:-

- High inherent soil fertility
- First-class grazing management
- Sudden improvement in nutrient supply and/or grazing practices
- Thin or poached sward with no organic mat

In the trials reported here, these factors applied in half of the sites receiving less than 189 kg/ha nitrogen. The fact that these criteria applied to such a high proportion of trials, was due to the progressive nature of many of the farmers using the drill.

The drill itself performed well with few break-downs. There were still many cases where the ribbon of turf was not removed from the slots, this usually occurred when the soil was too wet or too dry. In commercial usage, this would be less of a problem as soil conditions could be monitored more closely and drilling times chosen accordingly.

The G.B. Slot-seeder is now being made commercially as an 8 row drill. The first of these entered service in 1979/80.

CONCLUSIONS

Slot-seeding is particularly suited to the following situations:-

a) In permanent pastures where farmers wish to introduce improved species, but retain consolidation or where there are physical constraints to ploughing (eg water meadows) or direct drilling (eg uplands).

b) The intensively stocked all-grass farm where the farmer does not wish to take swards out of production.

The technique is successful in:-

a) Introducing perennial ryegrass into worn-out leys or low grade permanent pasture with little organic mat.

b) Establishing red and white clover in all grass swards.

c) Introducing Italian ryegrass into permanent pasture to improve early spring or mid-summer growth.

d) Renovating swards where poached, overgrazed or damaged.

e) Direct drilling forage crops such as kale or turnips in conjunction with an overall application of glyphosate.

The major constraint is that farm and field locations and soils chosen for slot-seeding must be those where soil nutrition is adequate and where there is an intention and potential for first-class management. Introducing new species can only improve output if other aspects of management are not limiting.

Acknowledgements

Appreciation is expressed to the many farmers and personnel from A.D.A.S., W.R.O. and Monsanto for their advice and help in providing and establishing trial sites. I would also like to thank the Miln Marsters Group Limited, Nickerson Seed Specialists Limited and The National Seed Development Organisation Limited for supplying seed for these trials and to J. Gibbs Limited for designing, modifying and maintaining the slot-seeders used.

References

GIBBS, (1979) The G.B. Slot-seeder Specifications, operation and maintenance data. J. Gibbs Ltd., Bedfont, Middlesex

HAGGAR, R.J. (1977) Herbicides and low cost grassland establishment, with special reference to clean seedbeds and one-pass seeding. Proceedings of the International Conference in Energy Conservation in Crop Production (in press)

HOPKINS, A. and GREEN, J. O. (1978) The effect of soil fertility and drainage on sward changes. British Grassland Society Occasional Symposium No. 10, 115-129

LEMON, R.W., and GREIG, R.J. The use of bendicarb in ryegrass establishment. Pesticide Science (in press)

M.A.F.F. (1978) Sowing and establishing grassland swards GFG 54 2-3

MUDD, C.H. (1971) Yields of natural and artificial grassland under 5 levels of fertiliser treatment. Proceeding of the 4th General Meeting of the European Grassland Federation, Lausanne, 1971, 69-72

SQUIRES, N.R.W. (1976) The use of band applications of three herbicides in the establishment of direct drilled grasses and legumes by the WRO one-pass sowing technique. Proceeding 1976 British Crop Protection Conference - Weeds, 2, 591-596

SQUIRES, N.R.W. (1977) Agricultural Research Council - Weed Research Organization personal communication.

SQUIRES, N. R. W. and HAGGAR, R.J. (1978) A guide to slot-seeding, WRO Technical Leaflet No. 12.

SQUIRES, N.R.W., HAGGAR, R.J. and ELLIOTT, J.G. (1979) A one-pass seeder for introducing grasses, legumes and fodder crops into swards. Journal of Agricultural Engineering Research, 24, 199-208

NOTES

THE EFFECT OF CONTROL OF VOLUNTEER CEREALS, GRASS AND BROADLEAVED WEEDS ON THE YIELD OF SHORT TERM LEYS

J.L. Scott and J. Johnson

Agricultural Development and Advisory Service, Coley Park, Reading

Summary Various herbicides were applied to an autumn sown ley for the control of volunteer wheat, *Poa annua* and *Stellaria media*. Although the herbicides gave reasonable control of their target weeds there was no significant increase in dry matter yield in the first harvest year. However ethofumesate, TCA and ethofumesate + TCA tank mix increased the proportion of ryegrass in the first cut. The second and third cuts contained virtually 100% ryegrass on all treatments.

INTRODUCTION

Poa annua and *Stellaria media* are the most commonly occurring weeds in short term leys (Griffiths et al 1978). In addition problems can occur with volunteer cereals, particularly where leys have been established by minimal cultivation techniques.

A range of chemicals exists to control broadleaved weeds in establishing leys. The use of mecoprop for chickweed control in non-legume leys is established practice. Recent work in herbage seed (ADAS unpublished) has shown that volunteer cereals can be controlled by the use of TCA. It is only recently that chemicals have been developed, particularly ethofumesate, to control grass weeds, cereals and chickweed.

This paper described the effect in terms of yield and quality of the removal of these weeds from an intensively managed short term ley used for conservation as silage.

METHOD AND MATERIALS

A seeds mixture of RvP Italian and Augusta hybrid ryegrass was drilled at 34 kg/ha on 21 September 1979 following minimal cultivations. The previous crop was winter wheat. The sward became infested with *Poa annua*, volunteer wheat and broadleaved weeds. A range of herbicides, to control some or all of the weeds, was applied on 13 November 1979, with the exception of mecoprop which was applied on 28 November. All herbicides were applied with a modified Oxford Precision Sprayer in 225 l/ha water. The plots were randomised and replicated three times and plot size was 2.0 m x 7.0 m.

In 1980 three silage cuts were taken and yields assessed. Also, at each cut a representative sample of herbage was taken from each plot and separated into component species.

RESULTS

Plant counts were made on 13 November 1979 to assess the initial weed population (Table 1).

Table 1

Initial weed population prior to application of herbicides

Weed species	Mean plant numbers/m^2
Poa annua	165.8
Volunteer wheat	21.5
Stellaria media	46.3
Aphanes arvensis	81.1
Veronica spp.	3.7

Botanical analysis in March showed the control to contain 11% ground cover of volunteer wheat, 5% Poa annua, 16% broadleaved weeds and 20% bare ground (Table 2). Ethofumesate, TCA and ethofumesate + TCA tank mix significantly increased the percentage of ryegrass compared to the control. However on 3 June, after the first cut on 19 May, there was no wheat and only very small amounts of Poa annua and broadleaved weeds in the regrowth but bare ground increased.

In terms of dry matter yield there was no significant difference between any treatments at any of the three cuts, nor in total yield over the three cuts. Similarly there was no significant difference in the digestibility of the herbage (Table 3).

Table 4 shows the composition of the herbage at the first cut. All the herbicide treatments except mecoprop increased the ryegrass content by 7-9.5% and reduced the amount of wheat, Poa annua and broadleaved weeds. Mecoprop controlled the broadleaved weeds but there was a slight increase in the amount of wheat at the expense of ryegrass. At both the second and third cuts each treatment contained virtually 100% ryegrass.

DISCUSSION

The high autumn population of Poa annua is in agreement with Oswald and Haggar (1976) who found peak numbers of this weed in September. By the following spring the ground cover occupied by Poa annua was only one half that occupied by volunteer wheat, although broadleaved weeds particularly Stellaria media and Aphanes arvensis exceeded Poa and wheat. The control area in the spring had a ground cover of 48% sown species, 20% bare ground and 32% weeds. In the context of a short term ley, with fairly erect species, and much bare ground, is it worth controlling the weeds described in order to create more bare ground? The answer would be affirmative if (i) weed control were effective, and (ii) yield was increased and (iii) the cost of the herbicide could be reasonably set against the life of the ley.

In all cases the herbicides had the desired effects. Ethofumesate controlled Stellaria media and Poa annua, but there was a suggestion of tolerance by volunteer wheat. The lower rate was not as effective on the wheat as the higher rate. TCA was as effective as ethofumesate in controlling wheat, but had no apparent effect on Stellaria media and Poa annua. Mecoprop controlled only the Stellaria media. The tank mix of TCA and ethofumesate completely controlled volunteer wheat, but the TCA/mecoprop treatment had no effect on Poa annua. None of the treatments had much effect on Aphanes arvensis.

Differences in terms of yield and quality were not large. At the first cut the low and high rates of ethofumesate gave the highest yields, with the tank mix of ethofumesate and TCA the lowest, probably due to sward damage. Quality difference in terms of the percentage of digestible organic matter and crude protein in the dry matter were small at all cuts. As would be expected, at first cut yields of sown species were highest where weeds had been controlled, but there were no differences subsequently.

The field was cut for silage. In a grazing situation it has been suggested (Griffiths 1978) that animals have selected ethofumesate treated swards even though there were no apparent differences in quality.

There was no Alopecurus myosuroides present and responses to ethofumesate have largely been obtained in the presence of such weeds. Weed levels were lower than those observed by Haggar (1978) who recorded massive reduction in tillering of ryegrass due to competition from Poa annua. It is possible that the dry spring of 1980 did not give the treatments sufficient opportunity to express their potential.

There was a wide range of cost of herbicides in this trial. Mecoprop and TCA cost approximately £6/ha whereas ethofumesate cost ten times as much. We believe that the level and type of weeds quoted in this trial were typical of many reseeded situations. The role of herbicides to improve yield and sward composition needs more careful definition particularly regarding the level at which weeds reduce yield and the implications of husbandry practices on their control.

Acknowledgements

Thanks are due to all ADAS staff who helped to carry out this trial and to Mr B Doble, who kindly provided the site, for his cooperation throughout.

References

GRIFFITHS, W., HAMMOND, C.H. and EDWARDS, C.J. (1978) Weed control in new leys and established pastures with ethofumesate. Proceedings 1978 British Crop Protection Conference - Weeds 1, 309-316.

HAGGAR, R.J. and PASSMAN, A. (1978) Some consequences of controlling Poa annua in newly sown ryegrass leys. Proceedings 1978 British Crop Protection Conference - Weeds 1, 301-308.

OSWALD, A.K. and HAGGAR, R.J. (1976) The seasonal occurrence of Poa spp. seedlings in young ryegrass-white clover swards. Journal of the British Grassland Society 31, 44.

Table 2

Botanical composition (%) in early spring and after the first cut

A. Botanical composition as % ground cover on 21 March 1980

Treatment	Rate of chemical kg a.i./ha	% ground cover: Ryegrass	Volunteer wheat	*Poa annua*	*Stellaria media*** and *Veronica* spp.	*Aphanes arvensis*	Bare ground
Control		47.9	10.7	5.3	13.3	2.8	20.0
Ethofumesate	1.0	55.2	4.7	0.7	0.1	4.3	35.0
Ethofumesate	2.0	59.3	1.1	0.2	1.8	3.7	33.9
Ethofumesate + TCA*	0.84 + 3.23	55.1	0.0	1.8	2.0	4.8	36.3
TCA + mecoprop	4.75 + 2.35	52.4	1.6	9.8	0.0	3.2	33.0
Mecoprop	2.35	48.9	7.6	9.8	0.9	2.8	30.0
TCA	4.75	55.8	1.7	5.4	10.1	2.6	24.4

* = tank mix ** = mainly *Stellaria media*

B. Botanical composition as % ground cover on 3 June 1980

Treatment	Rate of chemical kg a.i./ha	% ground cover: Ryegrass	*Poa annua*	Broadleaved weeds **	Bare ground
Control		55.8	0.2	0.0	44.0
Ethofumesate	1.0	61.7	0.0	0.2	38.1
Ethofumesate	2.0	60.4	0.0	0.2	39.4
Ethofumesate + TCA *	0.84 + 3.23	54.6	0.0	0.7	44.7
TCA + mecoprop	4.75 + 2.35	55.9	0.0	0.3	43.8
Mecoprop	2.35	57.5	0.8	0.0	41.7
TCA	4.75	58.4	0.1	0.1	41.4

* = tank mix ** = mainly *Aphanes arvensis*

Table 3

Total dry matter yields and digestibility

Treatment	Rate of chemical kg a.i./ha	Dry matter yield (t/ha) 19 May	26 June	28 July	Total dry matter yield t/ha	as % of control
Control		6.58 (65.1)	3.87 (62.7)	3.99 (62.0)	14.44 (63.6)	100
Ethofumesate	1.0	6.91 (65.0)	3.47 (63.3)	3.59 (62.2)	13.97 (63.9)	97
Ethofumesate	2.0	6.89 (64.3)	3.72 (64.3)	3.68 (61.4)	14.29 (63.6)	99
Ethofumesate + TCA *	0.84 + 3.23	6.25 (65.9)	3.37 (63.6)	3.78 (62.3)	13.40 (64.3)	93
TCA + mecoprop	4.75 + 2.35	6.47 (64.8)	3.67 (64.5)	3.60 (61.6)	13.74 (63.9)	95
Mecoprop	2.35	6.54 (64.3)	3.60 (64.3)	3.56 (62.8)	13.70 (63.9)	95
TCA	4.75	6.63 (63.8)	3.73 (64.3)	3.97 (60.7)	14.33 (63.1)	99
SE mean		±0.25	±0.17	±0.15	±0.30	

* = tank mix

( ) = digestible organic matter % in the dry matter

Table 4

Separation of first cut into components on a dry matter basis and dry matter yields

Treatment	Rate of chemical kg a.i./ha	% of dry matter yield at first cut				Dry matter yield at first cut	
		Ryegrass	Wheat	*Poa annua*	Broadleaved weed	Total as % of control	Ryegrass as % of control
Control		87.3	10.3	1.1	1.3	100	100
Ethofumesate	1.0	95.7	4.0	0.1	0.2	105	115
Ethofumesate	2.0	96.9	3.0	0.0	0.1	105	116
Ethofumesate + TCA *	0.84 + 3.23	96.8	2.9	0.3	0.0	95	105
TCA + mecoprop	4.75 + 2.35	94.3	4.5	1.2	0.0	98	106
Mecoprop	2.35	83.5	15.1	1.4	0.0	99	95
TCA	4.75	96.0	2.2	0.8	1.0	101	111
SE mean		±1.2	±1.2	±0.2	±0.2		

* = tank mix