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EFFECTS OF CULTIVATIONS ON THE PERSISTENCE AND PHYTOTOXICITY OF ATRAZINE AND PROPYZAMIDE

R.J. Hance., P.D. Smith., T.H. Byast., and E.G. Cotterill
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford, OX5 1PF

Summary Atrazine at 0.2 or 1.0 kg ha^{-1} and propyzamide at 0.5 or 2.5 kg ha^{-1} were applied in 1977 & 1978 to field plots which were either ploughed, tine cultivated, rotavated or left uncultivated. Turnip and barley were sown in each plot immediately after cultivation.

Propyzamide tended to be more persistent in the untilled plots at the higher rate of application but the differences between treatments were small. Atrazine persistence did not vary with cultivation.

There was no relationship between plant response and herbicide persistence. Most phytotoxicity occurred on plots that had been tine cultivated or rotavated. In 1977 crops on ploughed plots were less affected by the herbicide than those on uncultivated areas but in 1978 yields from non-tilled plots were always at least equal to those from ploughed plots and sometimes exceeded them.

Résumé L'atrazine à 0.2 ou 1.0 kg ha^{-1} et le propyzamide à 0.5 ou 2.5 kg ha^{-1} ont été appliqués en 1977 et 1978 à des parcelles soit soumise à des façons culturales (charrue, cultivateur a dents ou cultivateur rotatif) soit laissées incultes. Des navets et de l'orge ont été semées dans chaque parcelle.

Le propyzamide, à la dose plus elevée s'est montré plus persistant dans les parcelles incultes mais les differences entre les traitements n'étaient pas importantes. La rémanence de l'atrazine n'a pas varié avec la façon culturale.

Il n'y avait aucun rapport entre la réponse de la végétation et la remanence de l'herbicide. La phytotoxicité a été plus grande dans les parcelles soumises au cultivateur à dents ou au cultivateur rotatif. En 1977 la végétation des parcelles labourées a été moins influencée par l'herbicide que celle des parcelles incultes mais en 1978 les rendements des parcelles incultes ont été toujours au moins pareils, et parfois superieurs, à ceux des parcelles labourées.

INTRODUCTION

Usually soils containing phytotoxic herbicide residues receive some sort of ultivation treatment in the hope that this will reduce residual effects on the crop. n particular, advice to plough is given by ADAS (Eagle 1976) and is included in some abel recommendations. This can be logically justified on several grounds. erbicides are degraded faster in moist than in dry soil and low concentrations tend o decompose faster than higher levels (Hamaker 1976). Hence incorporation of esidues into the soil should accelerate decomposition by a) reducing the oncentration and b) moving the herbicide from the surface, which may often become ry, to the moister bulk of the soil. In addition, intuitively we expect the ilution effect of mixing the residue through the soil to reduce its phytotoxicity.

However, since the crop is usually sown soon after the cultivation, the time or enhanced degradation to have an effect is small and may be insignificant. Also ilution may not necessarily reduce phytotoxicity because the quantity taken up by he plant is related to the product of herbicide concentration and the fraction of he root system exposed (Walker 1973). Hence the effect of dilution in reducing concentration could be balanced by the exposure of a larger proportion of the roots of the crop.

There is little published evidence on the subject. The trials reported here were designed to give an indication of the relative effects of different methods of cultivation both on the persistence of residues and on their phytotoxicity. Unfortunately no "natural" residues were available so plots were used that had been given recent herbicide applications. Hence the initial distribution was not the same as that of a aged residue. However, experiments with similar compounds on adjacent plots (Hance et al 1976) suggest that residues of atrazine and propyzamide, the compounds used in this work, would normally be confined close to the soil surface.

METHOD AND MATERIALS

Field Plots

These were laid down in 1977 and 1978 in different fields at the Weed Research Organization, but the soils were similar coarse sandy loams. The previous crop was spring barley on the 1977 area and arable silage on the 1978 area. In both years the areas were first prepared with a spring-tine harrow to produce a seed bed. The treatments were then arranged in a split plot randomised block design with plots 5m x 4m. There were four herbicide treatments; atrazine at 0.2 kg ha^{-1} or 1.0 kg ha^{-1} and propyzamide at 0.5 kg ha^{-1} and 2.5 kg ha^{-1}. There were also four post-spray cultivation methods; ploughing to 20-25cm, tine cultivation to 15cm, rotavation to 7.5-10cm and no cultivation (after the initial pre-spray seed bed preparation). Cultivations were carried out immediately after spraying (April 19 in 1977 and April 16 in 1978).

On the same day each plot was sown with barley (cv Julia) and turnip (cv Imperial Green Globe), 3 rows of each in 1977 and 6 rows of each in 1978. Soil samples were taken on two occasions. The ploughed plots were sampled to 30cm, the tined rotavated plots to 20cm and the uncultivated plots to 10cm. No residues were present in check samples taken deeper. Ten cores of 2.5cm diameter were taken from each replicate. Cores from individual replicates were combined, mixed and stored at -15°C while awaiting analysis.

In both years turnips were sprayed with HCH for flea-beetle control. In 1978 the barley was sprayed with "Oxytril P" at a rate of 1.4 l product in 250 l ha^{-1} on May 25th while the turnips were push hoed on May 24 and singled to about a 15 cm spacing on June 5.

Analysis of residues

Both compounds were extracted from the soil with methanol and determined by gas chromatography using an AFID detector for atrazine (McKone, et al 1972) and an electron capture detector for propyzamide (Leistra, et al 1974). Recoveries from fortified samples were 90% for atrazine and 80% for propyzamide with a limit of detection below 0.05 ppm in each case.

Crop assessments

In 1977 crops were not grown to harvest because weed growth was sufficient to affect yields. Since one of the objects of the experiment was to study persistence an additional herbicide was not used to avoid possible side-effects on soil microbial activity. Similarly mechanical weed control was not compatible with the various cultivation treatments. Therefore assessments were made by visual scoring. In 1978 more emphasis was given to crop performance and weed control methods were used as described above so that yields could be taken. The crops were harvested in early August although the barley was not yet ripe. Dry weights of straw and ear together with percentage grain of barley and dry weights of roots and tops of turnips were recorded.

RESULTS

Persistence of residues

Residue levels are given in table 1. Although each plot was not sampled to the same depth, the results have been converted to a common basis of μg g^{-1} in 0-30cm

Table 1

			μg g^{-1} w/w herbicide in 0-30 cm soil layer				
		Time (days)	Plough	Tine	Rotavate	No cultivation	SE
Atrazine							
0.2 kg ha^{-1}	1977	62	0.03	0.04	0.04	0.02	0.01
		129	0.01	0.01	0.01	0.01	0.01
	1978	37	0.09	0.05	0.06	0.04	0.02
		70	0.03	0.01	0.02	0.02	0.01
1 kg ha^{-1}	1977	62	0.15	0.11	0.19	0.13	0.06
		129	0.09	0.03	0.03	0.03	0.02
	1978	37	0.16	0.16	0.18	0.22	0.06
		70	0.04	0.08	0.07	0.06	0.03
Propyzamide							
0.5 kg ha^{-1}	1977	62	0.08	0.06	0.06	0.08	0.02
		129	0.02	0.04	0.02	0.04	0.02
	1978	37	0.10	0.10	0.10	0.08	0.03
		70	0.06	0.04	0.06	0.08	0.02
2.5 kg ha^{-1}	1977	62	0.20	0.28	0.32	0.42	0.10
		129	0.06	0.06	0.10	0.14	0.04
	1978	37	0.42	0.58	0.46	0.64	0.19
		70	0.14	0.18	0.18	0.26	0.08

In both years atrazine residues at both sampling dates were essentially the same for each cultivation. Propyzamide levels in both years in plots treated at 2.5 kg ha^{-1} were a little higher in uncultivated areas than the others but the differences were not great. Residues following applications of 0.5 kg ha^{-1} were similar for all treatments.

Crop growth

Assessment of crop density at one date (June 17) in 1977 is given in Table 2.

Assessments were made at other times and plant size and colour were also scored. However, the other observations all follow the same trends illustrated in Table 2. With turnip both herbicides were least active on the ploughed plots with no differences between the other treatments. With barley ploughing again gave the best crop growth although with atrazine it was a little, if any, better than no cultivation.

Table 2

Crop Density Scores

Herbicide	Rate kg ha^{-1}	Plough	Tine	Rotavate	No cultivation
		Turnip			
Atrazine	0.2	9.0	3.5	5.0	5.5
	1.0	4.0	0.5	0	0.8
Propyzamide	0.5	8.8	9.5	7.5	8.8
	2.5	7.8	4.2	4.5	4.5
		Barley			
Atrazine	0.2	9.0	5.2	5.5	8.8
	1.0	3.8	1.8	1.0	3.0
Propyzamide	0.5	8.8	1.5	0.8	3.2
	2.5	8.0	0	0	0

Control = 10

The 1978 data is give in Table 3.

Turnips in atrazine treated plots gave much better yields in the uncultivated plots than the others at the 1 kg ha^{-1} rate. At the lower rate yields of roots, but not tops were significantly lower in the ploughed plots than those that had been rotavated or not cultivated.

Propyzamide seems to have had no effect on the crop at either dose rate regardless of cultivation, except for an apparent stimulation of root yield in the tine and rotavated areas treated at 2.5 kg ha^{-1}. Barley was not greatly affected by atrazine at the low dose rate but was severely affected by 1 kg ha^{-1} with the least damage on the uncultivated areas.

Propyzamide reduced barley yields at the lower rate with the greatest yields on the uncultivated plots and lowest on the tined and rotavated areas. At the high rate damage was severe with only a little growth on ploughed and uncultivated areas and none at all the others.

Since the barley was not ripe at harvest the figures of % grain give an indication of its maturity. Clearly atrazine at 1 kg ha^{-1} and propyzamide at both rates delayed maturity with a tendency for the effect to be greater after tine cultivation or rotavation than after ploughing or no cultivation.

Table 3

Herbicide	Rate	kg dry matter ha^{-1}			
	kg ha^{-1}	Plough	Tine	Rotavate	No cultivation
			Turnip (roots)		
Atrazine	0.2	3719	4351	5352	5240
	1.0*	620	208	0	3380
Propyzamide	0.5	4038	4031	4250	3931
	2.5	4284	5833	5895	5054
Control		3823	4656	4306	3670
Least significant difference; p=0.05			995		
			Turnip (tops)		
Atrazine	0.2	3843	4326	4377	4298
	1.0*	743	357	0	3444
Propyzamide	0.5	3654	3998	4066	3880
	2.5	4043	4190	4397	4174
Control		3857	3864	3833	3654
Least significant difference; p=0.05			814		
			Barley		
Atrazine	0.2	5973	5036	7563	7842
	1.0*	1086	1086	0	2384
Propyzamide	0.5	1720	685	432	3814
	2.5	76	0	0	66
Control		8634	7122	8374	6846
Least significant difference; p=0.05			1734		
			Barley % grain		
Atrazine	0.2	42.3	35.1	38.8	44.6
	1.0	29.1	23.9	-	20.1
Propyzamide	0.5	30.4	18.4	13.6	31.1
	2.5	11.4	-	-	9.8
Control		42.2	43.0	42.4	45.9
Least significant difference; p=0.05			13.7		

* Treatment excluded from statistical analysis

DISCUSSION

The persistence of the compounds was similar in both years. Rainfall was a little higher in the 1978 experimental period (198 mm compared with 168 mm) but soil temperatures were similar so this result is predictable.

The tendency for residues to be higher in untilled plots was more noticeable with propyzamide but it is of doubtful significance. The insensitivity of atrazine persistence to cultivation is consistent with the results of similar experiments in France (Jan et al, 1977).

Because the "residues" in our plots were applied immediately before cultivation the observations on crop response are best considered as the effect of incorporation techniques on herbicide activity although it is probably valid to extrapolate the results to a "true" residue situation. Shallow incorporation has been shown to increase the activity of many but not all soil applied herbicides (Jordan et al 1968, Wiese & Smith 1970, Walker & Roberts 1975). Similarly, Cochet et al (1977) found that a variety of crops could be grown more safely in soil containing residues of several herbicides following ploughing than shallower cultivations.

Hence the trend to greater toxicity with tine cultivation and rotavation was expected. Although the 1977 crop density assessments suggested an advantage for ploughing in no case in our 1978 experiments were yields from uncultivated plots lower than those from the corresponding ploughed treatments.

Jan et al (1977) made a similar observation with winter wheat in soil containing atrazine. Since, like Cochet et al (1977) they were working with plots containing authentic "residues" the similarity in results is encouraging.

There was no simple relationship between residue levels and phytotoxicity, a reflection of the importance of placement in relation both to site of uptake and the age of the plant when it encounters the herbicide.

These results, together with those of other workers, lead to the conclusion that shallow cultivations are not to be recommended when residues are present. The choice between ploughing and zero tillage is more difficult as the evidence so far produced suggests that the response will vary from year to year and probably also from crop to crop. The distribution of the residue is likely to be important as the nearer to the surface it is concentrated the higher the probability that no-tillage will be better than ploughing. However, in many circumstances some sort of cultivation will be necessary for seed bed preparation, in which case ploughing should have a clear advantage over shallower cultivations.

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ESTABLISHMENT OF CROP DAMAGE LEVELS IN SOILS FOR THE HERBICIDES LENACIL, LINURON AND TRIFLURALIN.

D. J. Caverly

Agricultural Development and Advisory Service, Wye, Ashford, Kent TN25 5EL

Summary On three sites of differing soil types lenacil, linuron and trifluralin were applied at nine rates and incorporated. After 2 or 3 weeks 16 crops were sown and observations made on their growth and symptoms of damage due to the presence of herbicide residues. Soon after the onset of damage symptoms soil samples were taken for residue analysis. The results showed that lenacil was generally more phytotoxic than either linuron or trifluralin. Cereals were particularly sensitive to all three herbicides.

Résumé Lenacil, linuron et trifluralin ont été appliqué à neuf taux et incorporé sur trois emplacements de sol différent. Après deux ou trois semaines, douze récoltes ont été semé et des observations faites au sujet de leurs croissances et symptomes de dégats dû par la présence des résidus d'herbicides. Aussitôt après l'attaque des symptomes, des échantillons de sol ont été pris pour analyser les résidus. Les résultats ont indiqué que lenacil été générallement plus toxique que ou linuron, soit trifluralin. Les céreales ont été particulierèment sensitive aux trois herbicides.

INTRODUCTION

Due to overapplication or unusual weather conditions herbicides can persist to cause problems to subsequent crops. Frequently due to the margin of tolerance the crop to which the chemical has been applied may show no damage. It is therefore important when investigating cases of suspected herbicide damage to crops or advising on subsequent cropping where soil residues exist, to have information available about residue levels above which crops will show damage. The work reported here was not intended to assess the risk of damage in terms of yields but to establish levels in soils that cause crop damage - this was found to occur especially in the early stages of growth. It is well established that plants only slightly damaged by herbicides will recover to grow normally.

METHODS AND MATERIALS

The sites chosen for these experiments were all local, being situated at Brook (site A - Wicken series), Kennington (site B - Barming series) and Wye (Gore series). Results of chemical and physical analyses of soils from these sites are given in Table 1.

Table 1

Chemical and physical properties of soils studied

Site	Texture	pH	% o.m.	mg/kg: P	K	Mg	<2u	<20u	<50u	<100u	<200u	>200u
A	Clay loam	8.0	5.57	24	301	148	51.4	25.9	11.2	2.1	2.3	7.1
B	Fine sandy loam	7.3	3.12	43	178	28	12.7	13.0	13.7	6.3	20.7	29.6
C	Silty loam	8.0	3.23	167	359	106	17.4	50.8	18.2	3.2	4.1	6.3

The areas were ploughed and cultivated during early Spring and fertilizers applied at the rates shown in Table 2.

Table 2

Fertilizer application

Site	kg/ha: K_2O	N	P_2O_5
A	120	90	20
B	200	90	20
C	120	90	0

The area of each site was 34 x 20 m each herbicide occupying 9 x 18 m with individual treatments being 9 x 2 m. The herbicides were applied as aqueous suspensions or solutions in April or early May 1977. The plots were rotovated to ensure thorough incorporation to a depth ideally of 15 cm. They were then allowed to stand for at least 2 weeks before crops were sown.

The potatoes after chitting were hand planted whilst the other crops were sown using a small commercial drill (Planet). The crops, varieties and sowing dates are given in Table 3.

Table 3

Crops studied, dates of sowing

Crop	Variety	Sowing Date: Site A	Site B	Site C
Barley	Ark Royal	24/5	12/5	11/5
Beans (dwarf)	Tendergreen	1/6	1/6	1/6
Beet (red)	Empire Globe	25/5	12/5	13/5
Carrots	Ormskirk Market	25/5	12/5	13/5
Lettuce (cabbage)	Feltham King	25/5	12/5	13/5
Linseed	Noralta	25/5	13/5	13/5
Maize	LG11	25/5	13/5	18/5
Oats	Seanda	24/5	12/5	11/5

Table 3 (Cont..)

Crops studied, dates of sowing

Crop	Variety	Sowing Date: Site A	Site B	Site C
Onions	Bedfordshire Champion	25/5	12/5	13/5
Parsnip	Hollow Crown	24/5	12/5	11/5
Peas	Little Marvel	24/5	12/5	11/5
Potatoes	Pentland Crown	24/5	9/5	11/5
Rape (oil-seed)	Lesira	25/5	13/5	13/5
Rye Grass	S24	24/5	12/5	11/5
Turnip	Green Top White	25/5	12/5	13/5
Wheat	Kolibri	24/5	12/5	11/5

Crop progress was monitored weekly and soon after symptoms of damage began to show soil samples were taken (early July) for residue analysis (Caverly and Denney 1977 and 1978), (Caverly 1978) and (Smith 1972). The analytical results together with the theoretical rates at the time of application are given in Table 4. The samples were taken (0-7.5 cm) diagonally across each plot using a graduated bulb corer; each sample consisting of ten cores.

Table 4

Rates of application and residues obtained by chemical analysis at the time of onset of symptoms of damage

Dates of application: Site A 9/5; Site B 25/4; Site C 25/4.

Treatment	Rate of application mg/kg	Concentration determined mg/kg 8/7								
		Lenacil			Linuron			Trifluralin		
		Site A	Site B	Site C	Site A	Site B	Site C	Site A	Site B	Site C
T0	0.00	<0.02	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T1	0.10	0.05	0.02	0.02	0.10	0.09	0.10	0.03	0.06	0.13
T2	0.20	0.08	0.09	0.05	0.15	0.14	0.13	0.07	0.10	0.20
T3	0.30	0.10	0.16	0.09	0.19	0.16	0.17	0.11	0.16	0.38
T4	0.40	0.18	0.18	0.20	0.22	0.25	0.20	0.22	0.40	0.58
T5	0.60	0.24	0.22	0.26	0.41	0.36	0.37	0.30	0.56	0.98
T6	1.00	0.68	0.30	0.42	0.66	0.48	0.70	0.61	0.13	1.73
T7	2.00	1.00	0.75	1.06	0.85	0.59	0.80	0.92	1.98	3.92
T8	4.00	2.40	1.60	1.50	1.08	0.92	1.06	1.44	4.95	5.45

(4.00 mg/kg ≙ 10 kg/ha)

Conditions at sites B and C made working in to 15 cm very difficult and shallow incorporation resulting from this could account for the higher than expected values given for trifluralin. The lower levels of this herbicide recorded at site A were probably due to a delay of two days in working in trifluralin after its application.

RESULTS

Observations of crop damage and soil residues determined chemically are given in Table 5. Germination and plant growth resulting from treatments below those given were not significantly different to those of 'controls'.

Table 5

Soil residues and symptoms of damage

Crop	Soil residues levels mg/kg			Observations - symptoms and stage of growth
	Site A	Site B	Site C	
Lenacil				
Barley	0.10	≠	≠	Poor germination, stunting and slight chlorosis mainly to leaf tips. Growth Stage: 15 (Zadoks, et al 1974)
Beans	0.24	0.18	0.26	Discrete veinal chlorosis of primary leaves. Growth stage: first true leaf
	1.00	0.30	1.06	Marked veinal chlorosis to primary leaves with stunting. Necrosis to interveinal areas.
Beet	0.68	0.75	1.06	Poor germination and stunting. Growth stage: second pair of true leaves.
	1.00	1.60	1.50	No emergence.
Carrots	0.18	0.16	0.20	Poor germination and stunting. Growth stage: 100 cm.
	1.00	0.30	1.06	Severe stunting.
Lettuce	0.05	0.09	≠	Poor germination and growth with some veinal chlorosis. Growth stage: third pair of true leaves.
Linseed	1.00	0.75	1.06	Poor germination and stunting. Growth stage: approximately 150 cm.
Maize	0.18	-	-	Stunting of plants. Growth stage: 130 cm.
Oats	0.10	≠	≠	Poor germination and stunting. Growth stage: 15.
Onions	≠	0.16	0.20	Poor germination and growth. Plants 130 cm.
Parsnip	0.18	0.16	0.20	Poor germination and growth. First true leaf.
	1.00	0.30	1.06	Very severe stunting.
Peas	≠	0.16	0.09	Marginal necrosis to mature leaves. Plants approximately 220 cm.
Potatoes	0.24	0.18	0.20	Slight veinal chlorosis. Plants approximately 250 cm.
	0.68	0.30	0.42	Marked veinal chlorosis with necrosis in mature leaves.

- signifies not sown.
≠ rabbit/bird damage.

Table 5 (Cont..)

Soil residues and symptoms of damage

Crop	Soil residues levels mg/kg Site A	Site B	Site C	Observations - symptoms and stage of growth
Rape	0.18	0.09	0.05	Poor germination some veinal chlorosis to mature leaves. Third true leaf.
Rye Grass	≠	0.09	0.26	Stunting and poor germination. Plants approximately 80 cm.
Turnip	0.05	0.02	0.05	Poor germination. Third true leaf.
	0.08	0.09	0.09	No emergence.
Wheat	0.08	0.09	≠	Poor germination and growth. Growth stage: 15.

Crop growth stages for linuron and trifluralin were the same as given above.

Linuron

Barley	0.41	0.36	≠	Poor germination, stunting and chlorosis mainly to leaf tips.
Beans	0.41	0.36	0.37	Veinal chlorosis mainly on primary leaves.
	1.08	0.48	1.06	Chlorosis to primary and first true leaves with areas of interveinal necrosis.
Beet	0.41	0.36	0.70	Poor germination and stunting.
Carrots	>1.08	0.59	1.06	Slight effect on germination and growth.
Lettuce	0.22	0.25	0.37	Yellow chlorosis to first leaves with stunting.
Linseed	>1.08	0.92	>1.06	Poor germination with stunting.
Maize	0.41	-	-	Slight stunting.
Oats	0.41	0.25	≠	Poor germination general chlorosis more especially at leaf tips.
Onions	≠	0.48	1.06	Poor germination and stunting.
Parsnips	>1.08	0.59	1.06	Poor germination and stunting.
Peas	>1.08	0.59	1.06	Poor germination with stunting and areas of chlorosis to central parts of some leaves.
Potatoes	0.85	0.36	0.80	Some veinal chlorosis in early leaves no overall effect on growth.
Rape	0.41	0.14	0.17	Slight stunting.
	0.66	0.25	0.37	Poor germination and growth.
Rye Grass	0.41	0.36	0.70	Poor germination, stunting some necrosis to leaf tips.

- signifies not sown.
≠ rabbit/bird damage.

Table 5 (Cont..)

Soil residues and symptoms of damage

Crop	Soil residues levels mg/kg			Observations - symptoms and stage of growth
	Site A	Site B	Site C	
Turnip	0.22	0.16	0.37	Poor germination and growth.
Wheat	0.22	0.25	≠	Poor germination and growth with some chlorosis to leaf tips.
Trifluralin				
Barley	0.11	0.10	0.20	Stunting with thickening of roots. Leaf colour deeper than control.
Beans	0.92	0.56	0.98	Slight stunting.
	1.44	1.13	1.73	Severe stunting with some thickening of roots.
Beet	0.07	0.10	0.13	Slight stunting.
	0.22	0.16	0.20	Poor germination and severe stunting.
Carrots	1.44	1.98	3.92	Slight stunting.
Lettuce	≠	1.13	0.98	Slight stunting.
	≠	1.98	1.73	Severe stunting.
Linseed	>1.44	1.98	1.73	Slight stunting.
	1.44	4.95	5.45	Severe stunting.
Maize	0.07	0.10	0.20	Slight stunting some root restriction although thickening not marked.
Oats	0.11	0.10	≠	(as barley)
Onions	0.61	0.40	0.98	Poor germination and stunting.
Parsnip	>1.44	1.98	3.92	Slight stunting.
Peas	0.92	0.56	0.98	Slight stunting.
Potatoes	0.92	0.56	0.98	Slight stunting.
	1.44	1.13	1.73	Severe stunting.
Rape	0.92	≠	0.98	Slight stunting.
	1.44	≠	1.73	Severe stunting.
Rye Grass	0.07	0.10	0.13	Slight stunting.
	0.22	0.16	0.20	Severe stunting with thickening of roots.
Turnip	0.30	0.40	0.58	Slight stunting.
Wheat	0.22	0.16	0.20	(as barley).

- signifies not sown.
≠ rabbit/bird damage.

In some cases the crop showed very clear differences in growth in adjacent treatments, eg normal growth, slight damage, severe damage and death or no emergence of crop.

Symptoms of Damage

Lenacil and Linuron: Monocotyledonous species were stunted with chlorosis mainly to leaf tips. Dicotyledonous plants showed a veinal chlorosis, more discrete in the case of lenacil followed by interveinal necrosis in cases of severe damage.

Trifluralin: Cereals and ryegrass showed stunting with a deeper than normal colour and some root restriction, the roots being much thickened in cases of severe damage. Stunting and some root restriction was observed for other crops all of which, with the exception of red beet, were much more tolerant to this herbicide.

DISCUSSION

The results given show that certain crops are extremely sensitive to the herbicides studied whilst others, eg linseed show a high degree of tolerance.

It is possible from breakdown study data in soils of these herbicides to calculate from the results given here the level at the time of sowing, and thus establish levels in soils likely to cause symptoms of damage to crops.

Calculation of damage levels for other herbicides especially those related to the compounds studied could be calculated from the figures reported here if their relative activities are known.

Acknowledgements

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EFFECT OF CLIMATIC AND EDAPHIC FACTORS ON THE PERSISTENCE AND MOVEMENT OF ETHOFUMESATE

A. Rahman

Soil and Field Research Organisation, Ruakura Agricultural
Research Centre, Hamilton, New Zealand

Summary Persistence of ethofumesate applied at nine trial sites varying widely in their soil properties and climatic conditions was studied in the glasshouse by bioassay of soil samples collected from 0-5 cm at monthly intervals. The phytotoxic residues lasted considerably longer under cold and dry conditions than under warm and wet conditions. Differences in the soil properties appeared to be important for persistence of ethofumesate mainly within regions of similar rainfall and temperatures. The movement of ethofumesate was similar in a clay loam and a sandy loam soil. The concentration in the top 5 cm of soil was much higher than in the 5-10 cm soil throughout the active residual life of the chemical.

Résumé La rémanence de l'éthofumesate, appliqué à 9 locaux, dont les conditions pédalogiques et climatiques montraient de fortes variations, a été étudiée en serre où des plantes test ont été semées dans des échantillons de sol prélevés à intervalles d'un mois. Dans des conditions de sècheresse froide, les résidus ont maintenu leur activité phytotoxique plus longtemps que par une chaleur humide. Les différences pédologiques semblent avoir exercé une influence plus marquée là où il y avait uniformité de conditions climatiques (température, pluviosité). En effet, on a pu déceler peu de différence dans le mouvement de l'éthofumesate dans le sol, fût-il argilo- ou sablo-limoneux. Pendant toute la période d'activité résiduelle du produit, les concentrations sont restées beaucoup plus élevées dans la couche superficielle du sol (jusqu'à 5 cm de profondeur) qu'entre 5 et 10 cm de profondeur.

INTRODUCTION

Ethofumesate initially developed as a sugarbeet herbicide in Britain, has been extensively tested for control of barley grass (Hordeum spp.) in New Zealand (Hartley et al, 1974; O'Connor et al, 1975). It has also proved valuable for the control of a number of weeds in sugarbeet (Eshel et al, 1976; Schweizer, 1976), some grass seed crops (Hammond et al, 1976; Lee, 1977) and onions (McLean, 1977).

New Zealand pastures in general are comprised of ryegrass (Lolium spp.) and clover (Trifolium spp.), mostly white clover (Trifolium repens). Trials with ethofumesate in this country have shown very promising control of barley grass and good tolerance of ryegrass to this herbicide but clovers have been severely damaged at rates required for barley grass control (Hartley, 1976).

Limited data are available on the regeneration of resident clovers in areas treated with ethofumesate, but no work has been reported in New Zealand on the establishment of clovers sown in the treated soil. This work was initiated to study the persistence and movement of ethofumesate under different soil and climatic conditions in order to determine the period after which it would be 'safe' to establish susceptible crops in the treated soil.

METHODS AND MATERIALS

The persistence study included nine field trials located in different parts of New Zealand. All trials were on established sheep or cattle grazed pastures. Some physical and chemical properties of the soils at different locations are listed in Table 1, determined by methods described elsewhere (Rahman, 1977).

Table 1

Some soil properties of the trial sites

Site No.	Soil texture	Sand (%)	Clay (%)	Organic carbon (%)	pH	C.E.C. (mEq/100 g)
1	Sandy loam	46	19	13.4	5.5	42.6
2	Sandy loam	55	16	9.1	5.8	40.0
3	Silt loam	22	26	4.0	6.0	15.1
4	Silt loam	14	35	3.0	6.0	21.3
5	Sandy loam	49	19	4.3	6.0	25.4
6	Silt loam	31	23	3.7	5.9	16.6
7	Sandy loam	41	18	3.0	5.7	15.3
8	Silt loam	36	20	3.5	5.4	14.5
9	Sandy loam	48	18	3.5	5.9	14.2

Climatic data for the various trial sites are presented in Table 2.

Table 2

Rainfall and temperature records of trial sites

Site No.	Rainfall (mm)				Mean soil temp. (^{o}C)*		
	0 - 3 months	3 - 6 months	6 - 9 months	Yearly Total	June	January	Year
1	716	651	300	2041	8.4	19.1	13.5
2	459	338	312	1358	7.7	18.7	13.2
3	425	351	257	1344	6.8	17.3	11.9
4	319	317	183	1072	6.0	19.3	12.3
5	349	172	309	992	5.5	18.6	12.2
6	221	261	213	821	3.8	16.3	9.6
7	190	174	185	707	3.9	16.4	9.8
8	177	137	212	672	3.0	14.3	8.8
9	100	109	189	495	2.0	15.9	8.7

* At 10 cm depth, recorded at 9 am.

The work on movement of ethofumesate in the soil included two field trials located within 3 km of each other. One was on a Horotiu sandy loam soil (52% sand, 17% clay, 8.8% organic carbon and a pH of 5.7) and the other on a Hamilton clay loam (29% sand, 31% clay, 5.5% organic carbon and a pH of 5.2). The total yearly rainfall was 1282 mm and the average yearly soil temperature at 10 cm depth was 13.0 ^oC (both sites).

Ethofumesate at 1, 2, 4 and 8 kg/ha was applied between late May and mid June 1976 in a spray volume of 350 l/ha. The pasture was mown or grazed to a height of 2 to 4 cm before the treatments were applied. Individual plots were 10 m long and 1.5 to 3 m wide and treatments were arranged in a randomised block design with four replications.

Soil samples for bioassay of herbicide activity were collected at monthly intervals from the date of spraying. Samples were collected from 0-5 cm for the persistence trials and from depths of 0-5 and 5-10 cm for the movement studies. All samples were bioassayed using barley grass (Hordeum murinum) and red clover (Trifolium pratense) as the test species. Details of the procedure have been described previously (Rahman, 1977).

Initially five plant species (Table 3) were tested in the glasshouse to determine the most suitable plant for the bioassay of ethofumesate residues. Damage from ethofumesate was based on dry matter weight reductions of wheat and barley grass. In the case of clovers unless the damage was severe, injured plants produced green weights and dry weights similar to the untreated plants. Clovers were, therefore, assessed on the basis of the typical damage symptoms of ethofumesate viz. the number of trifoliate leaves which failed to open. High concentrations of the chemical also reduced the total plant growth drastically but this was not taken into account.

Table 3

Effect of ethofumesate on bioassay species in the glasshouse

Ethofumesate (ppmw)	% damage Red clover	White clover	H. murinum	H. glaucum	wheat
0	0 a*	0 a	0 a	0 a	0 a
0.1	40 b	45 b	0 a	2 a	7 a
0.2	65 c	75 c	8 a	10 a	3 a
0.4	100 d	100 d	14 ab	23 b	15 ab
0.6			29 b	35 bc	42 c
0.8			64 c	69 d	66 d
1.0			84 d	88 e	85 e

* Duncan's multiple range test ($P<0.05$)

Data in Table 3 show that the two clovers were much more susceptible to ethofumesate than the three monocotyledonous species. Wheat showed similar sensitivity to this chemical as the two barley grasses. Based on above results red clover and H. murinum were selected for bioassay of ethofumesate as due to the more foliage growth of these two species damage symptoms were readily visible in them.

RESULTS

Bioassay results showing the time taken for ethofumesate residues to fall below phytotoxic levels in the top 5 cm of the soil in the nine trial sites are given in Table 4. Residues were considered non phytotoxic when the damage to clover plants or the reduction in the dry matter weight of barley grass was not significantly different from the untreated controls. Barley grass was more tolerant to ethofumesate as residues became non toxic to this species much sooner than clovers. However, data from both species showed similar trends for the residual activity of ethofumesate.

Table 4

Months after application when ethofumesate residues fell below phytotoxic levels

Site No.	Red clover Ethofumesate (kg/ha) 1	2	4	8	Barley grass Ethofumesate (kg/ha) 1	2	4	8
1	3	4	7	9	1	2	4	5
2	3	4	7	9	1	2	4	5
3	4	5	7	9	1	2	4	6
4	4	7	9	10	2	3	5	7
5	4	7	9	11	2	3	5	7
6	6	8	10	13	3	4	6	9
7	7	9	11	13	3	5	7	9
8	7	9	11	16	3	5	7	10
9	7	10	14	21	4	6	9	15

The pattern of dissipation of ethofumesate residues in the top 5 cm of the soil from 2 and 4 kg/ha rates is presented in Tables 5 and 6 respectively. Similar trends were also apparent by the results from 1 and 8 kg/ha rates.

Table 5

Residual activity of ethofumesate from 2 kg/ha rate

Site No.	% damage to clovers* Months after application 1	2	3	4	5	6	7	8	9
1	86	55	25						
2	80	60	25						
3	100	80	58	22					
4	100	91	75	51	30	15			
5	100	88	80	60	28	15			
6	100	100	100	82	65	35	22		
7	100	100	100	85	78	50	28	15	
8	100	100	100	88	81	55	30	15	
9	100	100	100	100	100	78	55	43	20

* Figures in this table are all significantly different from untreated controls (=0), (P<0.05), pooled S.E. ± 5.3. Blank spaces indicate no significant difference recorded.

Table 6

Residual activity of ethofumesate from 4 kg/ha rate

Site No.	% damage to clovers* Months after application 3	4	5	6	7	8	9	10	11	12
1	80	68	50	20						
2	85	70	55	18						
3	93	78	50	25						
4	100	85	65	41	30	20				
5	100	88	60	35	25	15				
6	100	100	100	75	60	32	18			
7	100	100	100	88	75	40	25	14		
8	100	100	100	85	73	52	35	20		
9	100	100	100	100	90	80	65	40	28	15

* See footnote Table 5, pooled S.E. ± 5.8.

The movement of ethofumesate in a clay loam and a sandy loam is demonstrated by the data in Table 7. The concentration of the herbicide was higher in the top 5 cm of soil than in the 5-10 cm layer throughout its period of activity.

Table 7

Movement of ethofumesate in two soil types

Rate (kg/ha)	Soil type	Sampling depth (cm)	% damage to clovers* Months after application 1	2	3	4	5	6
2	clay loam	0-5	88	60	20			
		5-10	25	30	15			
	sandy loam	0-5	90	70	25			
		5-10	28	35	20			
4	clay loam	0-5	100	100	90	64	40	18
		5-10	45	85	80	40	30	
	sandy loam	0-5	100	100	95	70	40	20
		5-10	52	91	73	48	35	15

* See footnote Table 5, pooled S.E. ± 6.7.

Data in Table 7 also show that the movement of ethofumesate was similar in both soil types. Results from 1 and 8 kg/ha treatments showed trends similar to those observed for the 2 and 4 kg/ha rates in both soils. As was the case with persistence studies, data obtained with barley grass supported the trend shown by the clover bioassay.

DISCUSSION

An examination of the climatic and edaphic data for trial sites in Tables 1 and 2 shows a very strong relationship of these factors with the residual activity of ethofumesate reported in Tables 4, 5, and 6. Statistical analyses of the data pooled over all the rates of application revealed that rainfall and soil temperature were the factors most highly related to the herbicide persistence (r=0.88*** and 0.92*** respectively). The relationship with soil properties was not so strong with r values of 0.66** for organic carbon content of the soil, 0.53* for the clay content and a non significant value for the C.E.C.

As rainfall and soil temperature were strongly related to each other (r=0.87***), it is not possible to differentiate between the effects of these two factors. Schweizer (1976) found that the persistence of ethofumesate was closely associated with the soil temperature. For New Zealand climatic conditions it appears of little importance to pinpoint as to which factor has the major influence as the two factors seem to vary together in most locations. Results from this work support the conclusion of van Hoogstraten et al (1974) from experiments in several countries that decomposition of this herbicide is much more rapid in warm moist soils than in cold dry soils. Differences in the organic carbon content of the soil and soil texture appear to be important mainly within regions of similar temperatures and rainfall.

The work of Schweizer (1976) suggests that the rate of degradation was independent of the initial rate of ethofumesate applied. Our results from all the field trials show that the residual activity increased as the initial rate was increased, although not to the same degree. Similar observations have been made by van Hoogstraten et al (1974).

Results on the movement of ethofumesate clearly indicate that once the top 5 cm of soil is 'safe' from the ethofumesate residue point of view, the lower depths should pose no threat of damage to susceptible crops. They also suggest that the data on time required for disappearance of residues in Tables 4, 5, and 6 could be used with confidence as the residual activity in the deeper layers would have disappeared when the top soil was found to contain no phytotoxic residues. These results are in agreement with those of van Hoogstraten et al (1974) and Schweizer (1976) who also reported that ethofumesate is not usually leached below 10 cm in the soil.

As mentioned earlier, the assessment of clover damage was based on the number of trifoliate leaves which failed to open. By taking some dry matter weights it was estimated that the damaged clover plants could produce dry matter similar to the untreated plants when the damage assessments had fallen to between 20 and 35% levels, depending on the trial site. Thus if the damage was not taken into account, an area could be 'safe' to oversow clovers for normal dry matter production one or two months earlier than expected from the data of Tables 4, 5, and 6. Further the data are based on the residual activity in the top 5 cm of soil which has the highest level of residues. If the area was cultivated to an average depth of 15 cm, the soil could be 'safe' for the susceptible species earlier than reported here.

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SIMULATION OF THE PERSISTENCE OF METAMITRON ACTIVITY IN SOIL

A. Walker and W. Bond

National Vegetable Research Station, Wellesbourne, Warwick CV35 9EF

Summary Metamitron was incubated in a sandy loam soil at different temperatures and soil moisture contents. At 9% soil moisture, the half-life varied from 14 days at 30°C to 91 days at 5°C. At 25°C, the half-life increased from 8.5 to 43 days with a reduction in soil moisture content from 11 to 3%. Relationships derived from the laboratory data were used in a model to simulate persistence of the herbicide in the field. The model predicted the patterns of residue decline in uncropped soil, and predicted soil residues at crop harvest in 3 out of 4 experiments with red beet. In the fourth experiment, the observed residues were much larger than those predicted. The tolerance of 6 crops to low doses of metamitron incorporated into the soil was assessed in field tests and the results were used to estimate possible safe periods before these crops can be sown following use of metamitron in the spring.

INTRODUCTION

A model which takes into account the variations in surface soil temperature and moisture content in the field to enable herbicide persistence to be simulated has been described (Walker, 1974). The model combines the effects of soil temperature and soil moisture content on the rates of herbicide loss, determined under controlled conditions, with measurements of rainfall, evaporation and soil temperature which are used to predict the field environment. A potential use of this model is to assess persistence of new herbicides in the field. Once the validity of the model for a particular compound has been established in a limited number of field experiments, it could be used to simulate the possible variations in persistence following application of the herbicide in different years or at different times in the same year. Metamitron has recently been developed for selective weed control in sugar beet, red beet, fodder beets and mangolds. During evaluation of this compound in field trials at the National Vegetable Research Station, measurements were made of its persistence in the soil in both cropped and uncropped plots. The present report summarises these residue data and shows the extent to which the simulation model can be used for predictive purposes with this herbicide.

EXPERIMENTAL METHODS AND RESULTS

Full details of the methods used in both the laboratory and field experiments have been published elsewhere so only brief descriptions are given here.

Laboratory studies

The soil was a sandy loam with 2% organic matter, 18% clay, pH of about 7 and field capacity soil moisture content of 15.8% (w/w). A commercial wettable powder formulation of metamitron (70% a.i.) was incorporated into a freshly collected sample of field soil and subsamples were incubated at different soil moisture and temperature levels. The concentration of herbicide remaining was determined at intervals using a bioassay based on the shoot growth of lettuce (*Lactuca sativa* L. cv. Borough Wonder). Details of the treatments examined and of the bioassay procedure were given by Bond and Roberts (1976) and Walker (1978). It was assumed that degradation followed first-order kinetics and half-lives derived from the results are shown in Table 1.

Table 1

Half-lives (days) for metamitron degradation in soil under controlled conditions

Moisture content (% w/w)	Temperature (^{o}C)				
	5^{a}	10^{b}	20^{b}	25^{a}	30^{b}
2.9			93	43	
5.9			47	24	
9.2	91	53	30	14	14
11.1			21	8.5	

[a] Data from Bond and Roberts (1976); [b] Data from Walker (1978)

These half-lives show that degradation is strongly dependent on both soil temperature and soil moisture content. Under the range of conditions examined they also suggest a simple interaction between temperature and moisture content in determining degradation rates - the relative effects of temperature were similar at the different moisture levels.

The simulation model

In order to use the laboratory data in the computer program for simulation of herbicide persistence in the field, functional relationships are required to describe the effects of soil temperature and soil moisture content on degradation rates. In previous experiments using the model (Walker, 1976a; 1976b; 1976c) moisture effects have been characterised by the empirical equation :

$$H = A\,M^{-B} \qquad \ldots . \quad 1$$

in which H is the half-life at moisture content M, and A and B are constants, and temperature effects have been characterised by the Arrhenius equation. The data with metamitron (Table 1) were fitted to these relationships and the values for the constants A and B at 20°C were 255.3 and 0.998 respectively, and the activation energy for use in the Arrhenius equation was 11.1 kcal/mol (Walker, 1978).

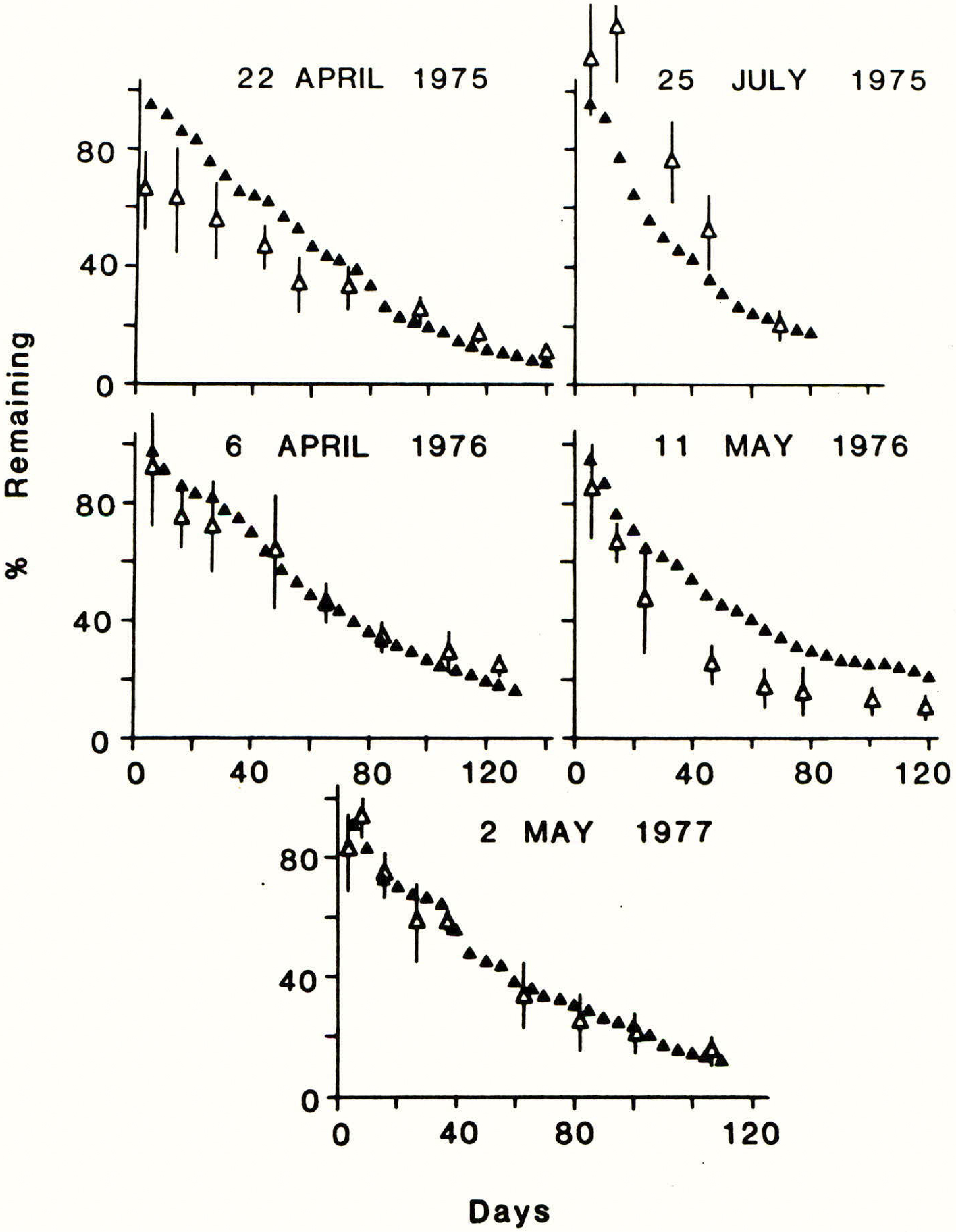
When the simulation program is run, the half-life at 20°C is calculated using the appropriate field soil moisture content in equation 1 and this half-life is substituted in the Arrhenius equation to give the corresponding half-life at the appropriate field soil temperature. Half-lives are derived in this way at short time intervals and the rates of herbicide degradation are calculated. These rates of change are then integrated over the experimental period to simulate or predict the degradation curve.

Measurement and prediction of residues in the field

Separate small field plots (6 x 1.5 m) were sprayed with metamitron at 2.0 kg a.i./ha on 22 April and 25 July 1975, 6 April and 11 May 1976 and 2 May 1977. Immediately after spraying and at intervals during the subsequent 70 to 140 days, replicate plots were sampled and the herbicide content of the soil was determined by the methods described previously (Bond and Roberts, 1976; Walker, 1978). All plots

Fig. 1

Observed (△) and predicted (▲) soil residues of metamitron in uncropped plots
a, Data from Bond & Roberts (1976); b, Data from Walker (1978)

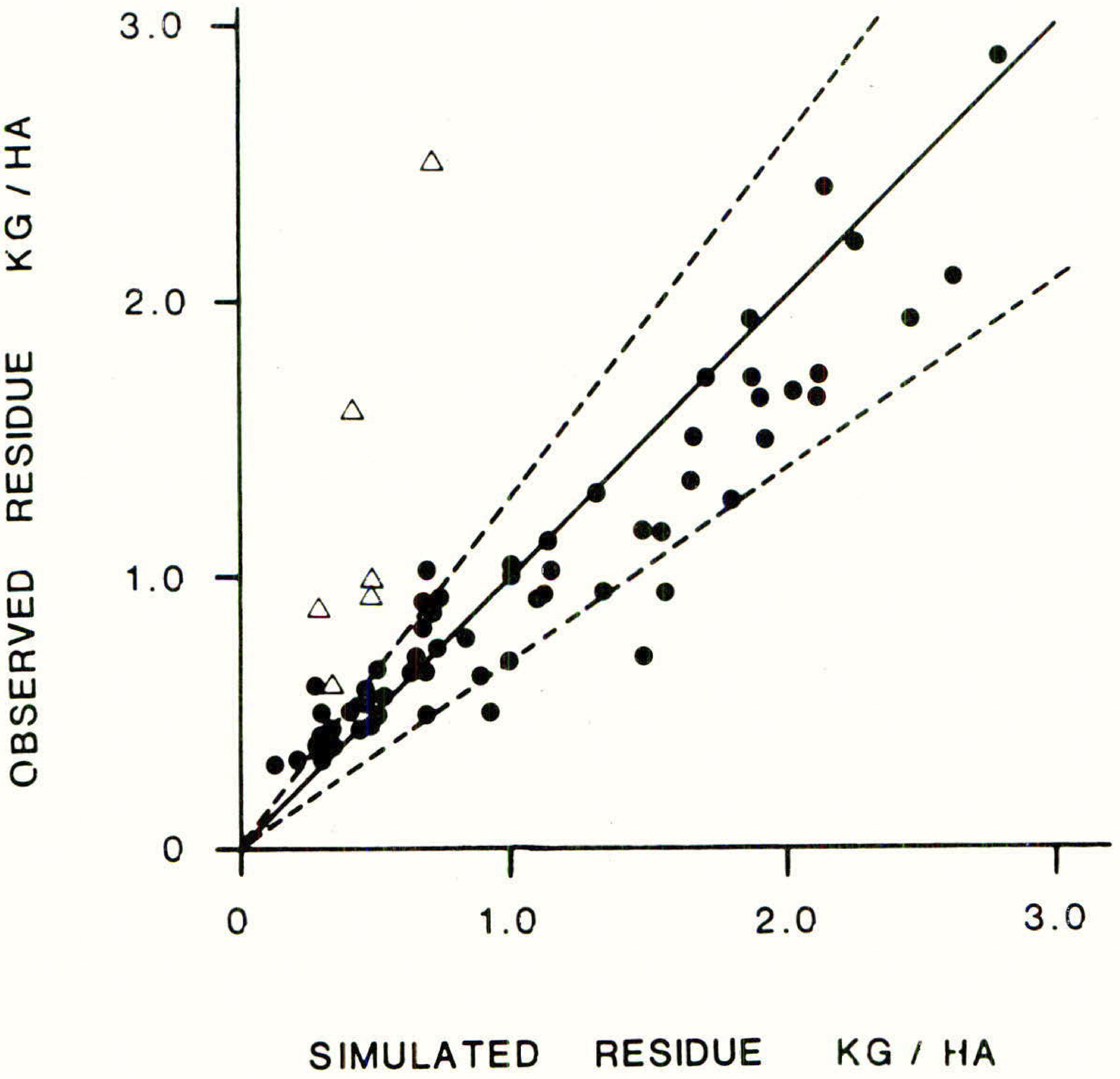


were kept weed free by hand-weeding as necessary. Full weather data of rainfall (mm/day), evaporation (mm/day) and soil temperature at 10 cm (°C) for the periods of the field experiments were used in the computer simulation program (Walker, 1974). The simulated curves for metamitron degradation in the five experiments are compared with the observed soil residues in Figure 1. In general, the agreement between observed and simulated results is good although in one of the experiments (prepared 11 May 1976) the model consistently overestimated the determined values.

Further measurements of soil residues of metamitron were made in plots cropped with red beet. Full details of the experimental design were given by Roberts, Bond and Ricketts (1976). Depending upon the experiment, the herbicide was incorporated pre-drilling, applied pre-emergence to the soil surface, or applied post-emergence when the crop plants had two true leaves. At least two doses were examined in each experiment and the treatments were replicated three or four times. Soil samples were taken at crop harvest and, in some experiments, on occasions during growth of the crop. A summary of the soil residues determined at harvest is shown in Table 2, together with the residues predicted by the model. In three of the four experiments, the model predicted the observed soil residues with reasonable accuracy, but in the fourth experiment, the observed residues were considerably higher than those predicted. All of the data from these experiments with red beet are presented in Fig.2,

Fig. 2

Relationship between observed and predicted soil residues of metamitron in cropped plots. △, Data from experiment 4 Table 2



including the residues determined at intervals between herbicide application and crop harvest. The observed residue is plotted as a function of that predicted by the model and the full line shows the expected relationship. The two dashed lines allow for an error of ± 30%. Most of the observed residues fall within these error limits. The data from experiment 4, Table 2, are indicated by a separate symbol and the results suggest that the large discrepancies between observed and predicted residues in this experiment were unusual.

Soil residues and subsequent crops

Metamitron was applied to separate small field plots (4 x 1.5 m) at 3.0, 2.0, 1.0, 0.5 and 0.25 kg a.i./ha and the herbicide was incorporated to a depth of 7 - 8 cm with a single pass of a rotary power harrow. There were two plots for each rate, the first of which was drilled with a single row of cabbage, lettuce and carrot and the second with dwarf bean, onion and wheat. The treatments were not replicated but

Table 2

Metamitron residues (kg/ha) in soil at crop harvest

Application	Rate (kg/ha)	Observed residue	Predicted residue	Observed residue	Predicted residue
		Experiment 1; Harvest 1/8; Pre-em 24/4; Post-em 21/5		Experiment 3; Harvest 5/9; Pre-em 20/5; Post-em 16/6	
Pre-emergence	1.4	0.34 ± 0.041	0.21	0.32 ± 0.015	0.17
	2.8	0.45 ± 0.095	0.41	0.42 ± 0.029	0.34
	4.2	0.65 ± 0.062	0.62	0.46 ± 0.126	0.51
Post-emergence	2.8	0.67 ± 0.105	1.00	0.29 ± 0.043[a]	0.32
	4.2	1.18 ± 0.335	1.50	0.53 ± 0.116[a]	0.49
		Experiment 2; Harvest 9/8; Pre-em 30/4; Post-em 30/5		Experiment 4; Harvest 8/9; Pre-em 20/5; Post-em 13/6	
Pre-emergence	2.8	0.57 ± 0.120	0.47	0.60 ± 0.117	0.33
	4.2	0.89 ± 0.241	0.71	0.95 ± 0.148	0.49
Incorporated	2.8	0.48 ± 0.061	0.47	0.88 ± 0.132	0.33
	4.2	0.75 ± 0.140	0.71	0.97 ± 0.060	0.49
Post-emergence	2.8	0.92 ± 0.109	0.67	1.60 ± 0.258	0.42
	4.2	1.02 ± 0.250	1.00	2.50 ± 0.536	0.71

[a] Soil samples taken September 26

Table 3

Response of six crops to metamitron incorporated into the soil pre-drilling

Crop	Phytotoxicity score (0 - 10)[a] with rate (kg/ha)				
	3.0	2.0	1.0	0.5	0.25
Cabbage	8.7	6.3	1.7	0	0
Lettuce	10.0	8.7	7.3	3.3	0.3
Carrot	9.3	8.7	4.0	1.0	0
Dwarf bean	6.0	3.5	0	0	0
Onion	10.0	7.7	4.0	1.7	0
Wheat	8.0	6.0	2.7	0.7	0

[a] 0 = No effect; 10 = complete kill; mean of 3 experiments

the experiments were repeated three times during the summer of 1977. When the responses of the plants had stabilised (after about 5 to 8 weeks), the crops were scored according to the degree of phytotoxicity. The results (Table 3) showed marked differences between the crops in their tolerance of metamitron. Dwarf bean was the most tolerant and was not affected by 1.0 kg/ha incorporated into the soil, and lettuce was the most susceptible. The other crops were intermediate with cabbage showing somewhat more tolerance than carrot, onion or wheat.

DISCUSSION

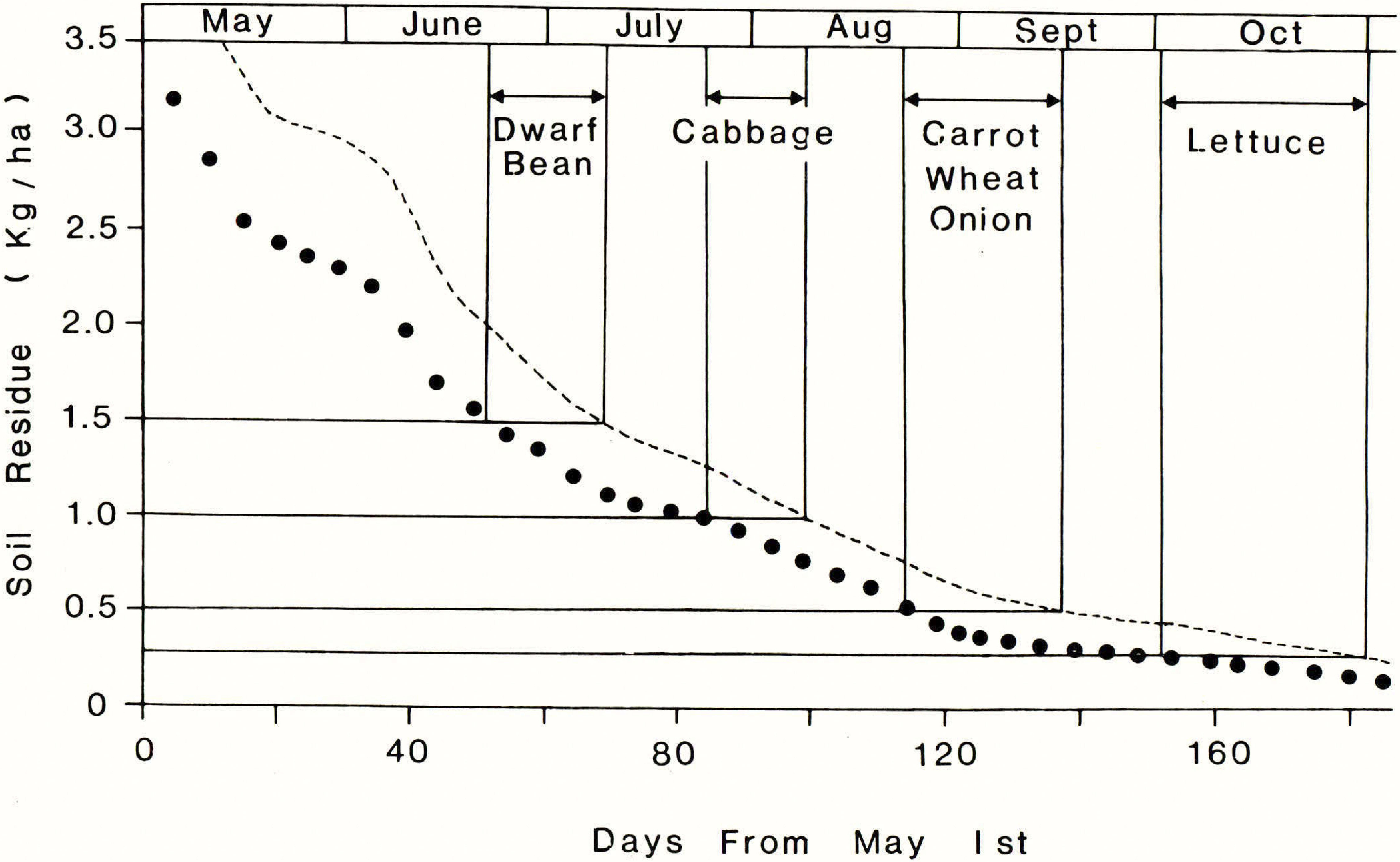
The ability to predict the rate at which a herbicide will disappear from field soil would allow possible residue problems to be foreseen and in the wider context, would help to ensure that use of a particular compound would not be a hazard to the environment. The computer model for simulation of herbicide persistence described by Walker (1974) has been shown to predict the persistence of a number of herbicides in soil in the field once the rates of degradation have been established in the same soil in the laboratory (Walker, 1976a; 1976b; 1976c; 1978) although there is a tendency to underestimate the rate of loss in some circumstances. The present data with metamitron in uncropped plots further demonstrate the ability of the model to predict persistence in the field (Fig.1) although in one of the five experiments, the model consistently underestimated the rate of loss. Since the data are expressed as percentages of the amounts determined at time 0, it is possible that a consistent inaccuracy of this type might result from an error in the initial determinations. From the practical point of view, persistence in cropped plots is of more relevance than that in uncropped plots and the data in Table 2 show the extent to which the model can be used to predict residues in the soil at crop harvest. In three of the four experiments. the predicted residues were in reasonable agreement with those observed, but in the fourth, there were large discrepancies. The reasons for this are not clear because this experiment was prepared at the same time as experiment 3, in which the agreement was good, and the two experiments were adjacent to one another. There were no differences between the experiments in the amounts of irrigation received. The only difference between them was in the timing of the bioassays for the residue measurements. These were conducted much later in the autumn for the samples from experiment 4 and the growing conditions were not so favourable. The growth response of lettuce to a standard series of known concentrations of metamitron in the soil was much reduced and it is possible that errors in the bioassay were, in part, responsible for the poor agreement.

One feature of the measurement of pesticide residues in field soils is the high degree of variation often encountered (Hance et al., 1976). Taylor et al. (1971) suggested that the coefficient of variation could not be reduced practically below about 20%. The data in Table 2 give coefficients of variation which range from 4.7 to about 28.4% with an overall mean of 20.3%, very close to that suggested by Taylor et al. In Fig.2 all of the observed residues in the cropped plots are shown as a function of those predicted by the model and the full line represents the expected relationship. The two dashed lines allow for an error of ± 30%, about the maximum found in these experiments. When the slightly suspect data from experiment 4, Table 1 are ignored, 51 of the remaining 59 residue levels fit within these error limits, suggesting that for practical purposes, the predictive capability of the model for metamitron is acceptable.

Another aspect of herbicide persistence which is important in practice is the significance of soil residues to succeeding crops. The data in Table 3 give an indication of the relative tolerance of six crops to metamitron residues in the soil and with the aid of the simulation model, it is possible to use these results to predict possible safe periods before these crops can be sown following use of metamitron in the spring. This is illustrated in Fig.3. Disappearance of metamitron activity has been simulated using weather data from May to November 1975 and the position of the curve assumes that the recommended rate (3.5 kg a.i./ha) has been

Fig. 3

Predicted times before various crops can be sown following use of metamitron in the spring (●, predicted residue; ---- 1.3 x predicted residue)



applied to the soil on May 1. An error of 30% has again been allowed for in this Figure and the predicted times before the various crops can be sown have been given as ranges. The shortest period is the time taken for the residue to fall to that at which the particular crop will not be affected and the longest is the time for the predicted residue to fall to 30% below this value. The results suggest that at least 10 weeks should elapse before dwarf beans are sown following use of metamitron in early May, at least 15 weeks for cabbage, at least 20 weeks for carrot, onion and wheat, and at least 26 weeks for the highly susceptible lettuce. It must be stressed that all of the data shown in this Figure are highly specific to the soil in which the various experiments were made. It is likely that both the position of the simulated degradation curve and the absolute values for the various crop tolerance levels will be different in other soils. Nevertheless, these results demonstrate how the model can be used to evaluate the practical significance of herbicide persistence. This procedure could be repeated using data from different years showing variations in weather pattern to show the possible effects from varying weather conditions on persistence and on the safety to following crops.

CONCLUSIONS

The computer model for prediction of herbicide persistence (Walker, 1974) can be used to simulate the persistence of metamitron activity in the soil. In cropped plots, most of the observed residues were within 30% of those predicted by the model. The model can be used to forecast safe periods before subsequent crops can be sown following use of metamitron for selective weed control in a beet crop.

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