TABLE II (Continued)

Winter versus spring spraying

	Winter			Spring		
Site	2 lb	1 lb	0.5 lb	2 lb	1 lb	0.5 lb
T.20 Light loam	100	95	54	99	98	85
T.22 Heavy clay	100	99	95	90	79	31

Broad-leaved annual weeds were frequent and included some 25 to 30 species. With the exception of cleavers (Calium aparine) good control of annuals was obtained. The influence of soil type and of time of spraying is shown in Table III. Spring applications of 1 lb and 0.5 lb gave excellent control, but except on chalk marl soils, winter applications of 1 lb and 0.5 lb were not so effective.

Table III. PERCENTAGE REDUCTION OF ANNUAL BROAD-LEAVED WEEDS (except Cleavers)

Winter spraying only

(i) Heavy soils

Site	2 lb	1 lb	0.5 lb
T.21	79	61	46
T.22	97	97	66
T.23	99	83	29
T.26	98	72	70
T.30	100	99	88
Mean	95	82	60

(ii) Chalk marls

Site	2 lb	1 lb	0.5 lb
T.29	99	96	81
T.35	97	95	93
Mean	98	96	87

TABLE III (continued)

(iii) Light loam, light sand and chalk

Site	2 lb	1 lb	0.5 lb
T.20	100	62	46
T.25	100	91	40
T.31	89	68	0
Mean	96	74	29

Winter versus spring spraying

	Winter			Spring		
Site	2 lb	1 lb	0.5 lb	2 lb	1 lb	0.5 lb
T.20	100	62	46	99	100	98
T.21	79	61	46	97	90	73
T.22	97	97	66	100	97	82
T.25	100	91	40	99	90	80
Mean	94	78	49	99	94	83

Crop

Visible depression of bean plants was noted at several sites though none of these were on heavy clay. The greatest depression was on the light sandy soil (T.25). Here both the 1 lb and 2 lb/ac doses of simazine applied in the winter and 2 lb applied in the spring caused reduction in plant height. Similar effects were noted on the chalk and chalk marl sites (T.29, T.31, and T.35). At the light loam site (T.20) plants on sprayed plots were taller because of the suppression of blackgrass. The 1 lb per ac spring treatment increased height of beans by 27 per cent and even the 2 lb winter application gave an increase of 13 per cent. Any direct stunting effect of the simazine on beans was therefore obscured. It is possible that even at the heavy soil sites, weed competition in the controls masked any depressing trend of the chemical.

Chlorosis and necrosis of bean leaves were not found until rapid growth of bean plants began in the spring. It was associated with the highest winter treatment only and occurred on the light sand, loam and chalky soils. None was observed at any other site. At the light sand and chalk sites a small proportion of dead plants were later found but most recovered. On the light loam site initial thinning of the beans was followed by strong tillering of the remaining plants.

Counts of pods at harvest indicated that thinning combined with removal of weed competition resulted in increased numbers of pods per stem. This was well demonstrated at the light loam site as shown in Table IV.

TABLE IV. NUMBER OF BEAN PODS PER STEM EXPRESSED AS PERCENTAGE OF UNTREATED CONTROLS

(Mean of 40 stems)

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
246.3	214.5	216.2	196.1	179.3	175.4
Sig. diff. at P 0.05 = 43 P 0.01 = 59					

The 2 lb/ac winter treatment had significantly higher pod numbers than the 1 lb and 0.5 lb spring treatments. The untreated control plots had significantly fewer pods per stem than any treated plots. This phenomenon has been noted and commented on by Hodgson and Blackman (1955) in studies of winter bean plant densities, and is probably associated with competition for light.

Although harvest yields were taken from all five trials comparing winter and spring applications, time did not permit for more than four random replicates being harvested at any one site. In addition, yields were taken from three of the ten (twice replicated) trials where winter applications only were made.

At two of the heavy clay sites (T.22 and T.34) comparing winter and spring applications, a significant yield difference was obtained between treatments. At these sites where weed density was low the 2 lb/ac winter dose of simazine yielded significantly less than any other treatment. At a third site (T.21) the trend was the same but the reduction was not significant. These results are shown in Table V.

TABLE V. GREENWEIGHT AS PERCENTAGE OF CONTROL

(Mean of 4 replicates)

Heavy boulder clay. Low weed density.

Site	Winter sprayed			Spring sprayed			Sig. diff.	
	Simazine dose lb/ac			Simazine dose lb/ac				
	2	1	0.5	2	1	0.5	P 0.05	P 0.01
T.22	77.0	95.6	110.1	96.6	100.3	99.2	10.4	14.2
T.34	67.6	86.7	94.6	95.5	91.8	101.7	18.0	24.6
T.21	82.3	92.4	90.8	85.7	91.5	91.6	21.2	29.9

At the light loam site there was a very dense infestation of blackgrass, averaging 285 per sq yd. Germination occurred mainly if not entirely during November-December. Other weed species included wild oats, but were not of great importance at this site. As all chemical treatments gave some control of blackgrass it is not surprising that this is reflected in the yield figures shown in Table VI.

TABLE VI. GREENWEIGHT YIELD AS PERCENTAGE OF CONTROL (EXPT. T.20)

Light loam and high weed density

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
219.7	225.9	191.7	205.3	217.4	198.3
Sig. diff. at P 0.05 = 36.8 P 0.01 = 50.4					

In this experiment all treated plots produced yields significantly higher than the untreated controls. There was no significant difference between chemical treatments.

The light sand site where there was a fairly high density of broad-leaved annuals but virtually no grasses gave a very different result.

TABLE VII. YIELD OF DRY BEANS AS PERCENTAGE OF CONTROL
(Expt. T.25)

Very light gravelly sand - Moderately dense broad-leaved weeds.

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
59.9	95.5	90.9	79.2	103.4	96.2
Sig. diff. at P 0.05 = 12.8 P 0.05 = 17.3					

Both winter and spring applications at 2 lb/ac gave significant yield depressions, the effect of the winter spray being particularly severe.

Dense infestations of wild oats occurred at three heavy clay sites where twice replicated winter sprayings were made. The yield figures for these sites are given in Table VIII.

TABLE VIII. GREENWEIGHT YIELD OF BEAN PLANTS AS PERCENTAGE OF CONTROL

(Expts. T.24, T.27 and T.29)

Heavy clay and chalk marl soils - Heavy wild oat density.

Winter sprayed only.

Expt	Dose			Sig. diff. P 0.05
	2 lb	1 lb	0.5 lb	
T.27	136.1	145.5	136.1	63.5
T.29	194.3	203.6	202.0	75.0
T.24	137.7	120.6	105.9	3.7

The trend towards reduction in yield with winter applications of 2 lb/ac simazine observed in the trials on heavy clay with low weed density is completely absent in these trials. Instead a trend towards increasing green weight yield may be observed which follows the pattern of increasing wild oat control.

Soil Surface Texture

On the heavy soils, aggregates varied in size from 9 in. diameter to fairly fine tilth with few clods. No differences in weed control could be detected which could be attributed to the varying soil surface conditions. In all cases, aggregates were wet or moist throughout. Erosion of the clods during the winter did not give rise to patches of soil in which weeds could grow and develop normally. On the lighter soils, aggregates up to 12 in. in diameter were present on one site (T.20). The surface of this field was extremely rough and cloddy yet weed control was excellent. On the other light soil (T.25) there were no clods of any kind and the surface was rolled level.

DISCUSSION

With the exception of wild oats, volunteer barley and wheat (and black-grass on heavy soils), annual weed species were more effectively killed by the spring spraying than by the winter spraying. The annual broad-leaved weeds germinated mainly in the very early part of the year just prior to the spring applications or just after. The advantage of spring spraying in this respect was more evident at the lower dose levels than at the higher. It was also more marked on light soils than on heavy soils. On chalky soils, winter spraying was very effective even at the lowest level of simazine. However, in this case no comparison could be made with spring spraying.

A possible explanation of this is to be found in the additional rainfall received by the winter applied simazine. Rainfall between winter and spring spraying lay between 5.82 in. for the longest period and 3.81 in. for the shortest period. This was more than sufficient rain to mobilise the highest dose of simazine, which may have been partially leached to a lower level leaving insufficient herbicide in the zone of weed-seed germination and early root development. Additionally, in the case of clay soils, the influence of adsorption cannot be ruled out. The fact that the differences were greatest at the lowest doses adds support to these arguments.

In the case of the spring spraying, there would have been insufficient rainfall to leach simazine, even at the low dose, and diffusion would have been slow. In consequence even the lowest doses would provide sufficient simazine at the site of root development in the critical early stages.

Wild oats, volunteer wheat and barley were controlled better by the winter than by the spring applications. This could be ascribed to the greater depth from which these species germinate and in addition, to earlier germination.

Perennial species were present at all sites but at only one site (T.26) were they an important section of the weed flora. Included were field bindweed (Convolvulus arvensis), creeping thistle (Cirsium arvense) and horsetail (Equisetum arvensis). None of these species was controlled nor indeed visibly affected by any dose of simazine used in these experiments.

Cleavers (galium aparine) were only slightly stunted by the highest dose of simazine as a general rule, but some individuals were killed and others were unaffected. The different reaction of individual cleaver plants may depend on their depth of germination.

Damage and death of beans occurred only at the highest doses and were consistently greater in the winter sprayed plots than in those sprayed in the spring. Damage and death were also more frequent in the light soils. These results are consistent with the arguments put forward in the case of annual weed control. At its maximum, damage resulted in death of individual bean plants, these being often close to apparently healthy plants. It is unlikely that this was due to uneven leaching of simazine, for under the soil moisture conditions prevailing leaching is likely on theoretical grounds to be even (Hartley 1960). It is more likely that death and survival of individuals is associated with depth of planting. This phenomenon has been reported by Roberts 1958) and Elliott (1958b).

Damage not resulting in death of beans sometimes caused stunting of the plants. It appeared, however, that at least in some cases this resulted in increased tillering, the additional tillers being usually healthy. In one case the number of pods per tiller was increased significantly. It is clear that damage to individual beans and especially damage giving rise to tillering may not cause a reduction in yield of winter beans. This view is supported by the findings of Hodgson and Blackman in their work on bean plant density.

Where aggressive weeds were dense and numerous, any effect upon the weight of beans harvested green was counter-balanced by the increase in weight due to weed control. The species with the greatest depressing effect on bean yield in these experiments was blackgrass. This weed was most economically controlled by the application of 0.5 lb simazine applied in the early spring on light loam or in early winter on heavy clay. The reasons for the failure of 0.5 lb simazine to give good control of blackgrass on heavy clay when applied in the spring are not obvious. It does not appear to be due to differences in stage of development, for both at the light loam site and at the heavy clay site blackgrass plants were 2-3in high with 3-4 leaves.

At the rates of chemical used in these experiments, no differences in the behaviour of susceptible weed species were observed comparing coarse and fine soil surfaces of the same type. The condition of both large clods and fine crumbs are similar in that both were wet or moist and in most cases the soils approached field capacity.

It seems likely that the simazine suspension on reaching the soil surface in the spray droplets was readily mobilised throughout the soil surface layer, for the effect on germinating seedlings of susceptible species was both rapid and even. As the season progressed some erosion of the clods occurred, but judged by subsequent reactions of seedlings germinating on and around large aggregates no fenestration occurred in the distribution of the simazine in the soil surface layers. This gives support to the arguments of Hartley that even leaching would occur under such circumstances. The practicability of applying sprays to field crops in early winter is not high because of the excessively wet conditions often prevailing, especially on heavy soils. However, it would not be impracticable to apply the spray immediately after or at the time of drilling the crop.

REFERENCES

ELLIOTT, J. G. (1958a) Herbicide tests on field beans. 4th British Weed Control Conference. 126-131.

ELLIOTT, J. G. (1958b) personal communication.

GREGORY, P. (1959) The use of simazine as a selective herbicide in field beans. Unpublished report.

HARTLEY, G. S. (1960) Physio-chemical aspects of the availability of herbicides in soils. Herbicides and the Soil. Symposium of British Weed Control Council.

HODGSON, G. L. and BLACKMAN, G. E. (1956) An analysis of the influence of plant density on the growth of Vicia faba. J. Expt. Bot. 7. 147-165.

ROBERTS, H. A. (1958) Discussion following Elliott J. G. (1958a). 4th British Weed Control Conf. p. 130; and 1959 private communication.

NAAS/ARC TRIALS WITH SIMAZINE ON FIELD BEANS

E. R. Bullen, and R. G. Hughes,

National Agricultural Advisory Service

Summary. Results are presented of ten trials on weed control in beans using simazine applied pre-emergence at doses usually from ½ lb to 2 lb per acre. Applications of ½ lb simazine gave the highest crop yields at some centres. Higher doses gave improved weed control but this was not necessarily reflected in yields. A tendency to reduced yields was noted at the highest dose at most centres. No adverse effects were observed in the 1960 wheat crops following simazine treatment to the 1959 bean crops.

INTRODUCTION

The discovery of the triazine herbicides was announced at this conference four years ago (Gysin H. & Knusli E. 1956) and at the last conference the results of three trials on beans (*Vicia faba*) incorporating simazine were presented (Elliott 1958). This work was followed up by the N.A.A.S. and the present paper reviews 10 trials carried out on a range of soil types in 1959 and 1960 on both winter and spring beans. Experiments in 1959 using simazine on beans at Rothamsted and Woburn have been reported elsewhere by Moffatt & Hill (1959).

METHODS AND MATERIALS

Details of the sites used and treatments are summarised in Table I.

At all centres a wettable powder (50 per cent w/w) formulation of simazine was used, sprayed at a volume rate of 20 gal/ac. The normal dose range used was ½, 1, and 2 lb/ac simazine, applied pre-emergence. At centre 7 the doses were modified to ¾, 1½ and 3 lb/ac; at centre 9 to ½, ¾ and 1 lb/ac. In addition, centre 2 included the normal doses, applied by spraying on the plough furrow before drilling, and centres 4, 5, 6, 8, 10 and 11 tested the 1 lb dose applied in two instalments of ½ lb each. At centre 3, other pre-emergence herbicides were included; simazine was the most effective and the results from other materials are not presented here.

The spraying was carried out by Oxford Precision Sprayer (Centre 1, 3, 4, 10 and 11) or by Landrover mounted sprayer (all other centres).

Most of the bean crops used for these trials were not of any named variety. However, at centres 6, 7, and 10 the varieties were Gartons S.Q., Hedingham, and Minor respectively.

A randomised block layout was used with three (centres 1, 2, 3, 11) or four replicates (all other centres). Results were assessed by scoring for weed control during the season, by weed counts (Centres 1, 2, 3, 4, 5, 7, 10, 11) and by observations of the stubble after harvest. In addition bean counts were made at centres 1, 2, 3, 9, 10, and yields were taken from centres 1, 2, 5, 6, 7 and 9. Observations were made on the crops following the 1959 trials and grain yields were obtained from the wheat following at centre 2.

TABLE I.

Trial year	1959	1959	1959	1960	1960
Trial No.	1	2	3	4	5
Site	Bicester, Oxon	Cambridge, Cambs	Histon, Cambs	Rearsby, Leics	Cambridge, Cambs
Soil Type	Medium clay loam (Gt oolite)	Clay loam (Gault)	Clay loam (Gault)	Heavy loam (Boulder Clay)	Clay loam (Gault)
Type of bean	Spring	Winter	Winter	Spring	Winter
Sowing date	26.2.59	20.10.58	17.11.58	22.3.60	15.11.59
Spraying date	23.3.59	17.10.58 21.10.58	21.11.58	24.3.60 13.4.60	17.11.59 24.11.59

LOCATION OF SITES

1960 6 Covington, Hunts	1960 7 Wareside, Herts	1960 8 Otley, Suffolk	1960 9 Bicester, Oxon	1960 10 Blewbury, Berks	1960 11 Long-benton
Heavy loam (Boulder Clay)	Heavy loam (Boulder Clay)	Heavy loam (Boulder Clay)	Medium Clay loam (Gt oolite)	Lower chalk	Boulder clay over coal measure
Winter 10.11.59	Spring 10.3.60	Spring 6.4.60	Spring 23.3.60	Spring 23.3.60	Spring 21.4.60
12.11.59 24.11.59	11.3.60 23.3.60	6.4.60 14.4.60	23.3.60	1.4.60 11.4.60	26.4.60 10.5.60

RESULTS

Weed Control

Table II summarises the effect of simazine on the numbers of weeds at the centres where critical counts could be taken. Similarly Table III summarises the score results from the centres where this method of assessment was adopted.

The chief monocotyledonous weeds were Alopecurus myosuroides and Avena fatua. The former was substantially reduced by 1 lb simazine at all centres and further reduced by 2 lb. At centre 2, where volunteer ryegrass was also present, 2 lb was needed to give maximum grass weed control. Avena fatua was reduced at 2 centres especially by the 1 and 2 lb rates, but at best the control was only 75 per cent. With Polygonum aviculare results were rather variable. At centre 1, 1 lb gave an effective control, but at centre 10, 2 lb only reduced the population by 57 per cent. Polygonum convolvulus was not easily killed at centres 4, 7 or 8, but at centre 10 the divided application gave a useful reduction. With Sonchus oleraceus also, results were inconsistent; at centre 7 it was susceptible but not at centre 10. Sinapis arvensis and Stellaria media were generally much more susceptible, except at centre 8 where conditions after spraying were extremely dry and Sinapis arvensis was not effectively controlled. Stellaria was not well controlled at centre 11. Veronica spp also proved susceptible, but at least 1 lb/ac was needed to reduce the very dense stand (almost all V. hederifolia) at centre 5. Chenopodium album was fairly readily controlled by 1 lb except under dry conditions (centre 8) but Cleavers (Galium aparine) appeared fairly resistant and even 2 lb did not markedly reduce numbers at centres 2 & 5; however the vigour of the surviving plants was markedly reduced. At centre 8, where other annual weeds were not effectively controlled, the population of Anagallis arvensis was reduced at all doses.

Perennial weeds were noted at very few sites and in most cases were not sufficiently numerous to be counted. No centre gave any indication that simazine effectively controlled any of the perennials encountered.

TABLE II. EFFECT OF SIMAZINE ON ANNUAL WEEDS
(Population as plants/sq yd)

Weed	Centre	Date of Assessment	Simazine lb/ac							
			0	½	¾	1	1½	2	3	½+½
Alopecurus myosuroides	(1	5.5.59	74	20		2.4		0		
	(2	18.3.59[x]	26	(18		6.5		6.0		
	(			(20+		13+		11+		
	(3	26.2.59	14	2.6		0.9		0.1		
	(5	4.4.60	301	64		5.3		2.0		6.0
Anagallis arvensis	8	1.6.60	240	107		96		36		46
Avena fatua ≠	10	30.5.60	8.7	7.0		2.2		2.2		2.2
Chenopodium album	(1	5.5.60	4.8	3.6		0.6		0		
	(7	27.5.60	9.6		1.6		3.8		0.3	1.0[x]
	(8	1.6.60	23	26		22		24		23
	(11	26.5.60	42	41		16		19		27
Galium aparine	(2	18.3.59	0.2	(0.5		0.4		0.4		
	(			(0.4+		0.1+		0.1+		
	(5	22.5.60	22	17		12		14		11
	(7	27.5.60	3.2		1.6		1.0		0.3	0[x]
Polygonum aviculare	(1	5.5.59	2.1	1.2		0		0		
	(4	13.5.60	20	7.4		4.7		3.3		6.7
	(7	27.5.60	9.3		1.0		1.0		0.3	0[x]
	(10	30.5.60	26	26		20		11		24
Polygonum convolvulus	(4	13.5.60	84	93		53		46		84
	(7	27.5.60	107		50		33		24	27
	(8	1.6.60	57	70		47		59		52
	(10	30.5.60	3.8	3.2		2.0		3.2		0.2
Polygonum lapathifolium	11	26.5.60	35	5.5		15		5.5		6.5
Polygonum persicaria	11	26.5.60	6	4.5		2.5		1.5		3.5
Sinapis arvensis	(7	27.5.60	23		0.6		0.3		0	0.3[x]
	(8	1.6.60	25	35		7.9		16		25
Senecio vulgaris	11	26.5.60	7.5	2.5		1.5		0.5		1.5
Sonchus oleraceus	(7	27.5.60	5.1		0		0		0	0.3[x]
	(10	30.5.60	8.9	7.7		2.9		7.0		2.5
Stellaria media	(1	5.5.59	42	4.2		0		0		
	(4	13.5.60	6.0	4.0		2.7		0		2.7
	(10	30.5.60	36	12		5.2		2.5		3.3
Veronica spp.	(1	5.5.59	20	4.2		0.6		0		-
	(2	18.2.60	4	(3.5		4		1.2		-
	(			(4+		3+		3+		-
	(5	5.4.60	404	253		21		1.4		34
	(7	27.5.60	6.8		0.6		0		0	0[x]

+Herbicide applied pre-drilling. [x]rate ¾ + ¾ at this centre.

*Counts include some self sown ryegrass.

≠*Avena fatua* visibly reduced at centre 6 but counts not made.

Table III summarises data on scores. In most cases scoring was carried out on the basis of general weediness but at centres 1 and 5 monocotyledonous weeds were scored separately from dicotyledons.

TABLE III. EFFECT OF SIMAZINE ON ANNUAL WEEDS

Weed density in spring (10 maximum weed in trial)

Centre	1				2	5	
Date of assessment	5.5.59		3.6.59		9.2.59	16.2.60	
	monocots	dicots	monocots	dicots		monocots	dicots*
Simazine lb/ac							
0	10	10	10	10	9.5	10.0	10.0
½	3.0	2.0	2.0	1.0	(4.3 (8.3*	1.9	3.6
1	1.8	0.3	0.4	0.3	(6.3 (4.3[x]	0.3	2.2
2	0.7	0.1	0.2	0.0	(2.7 (2.3[x]	0.2	0.5
½ + ½	-	-	-	-	-	0.3	3.9

Weed cover in late summer (10 = complete ground cover)

Centre	1	4		11
Date of assessment	18.8.59	20.7.60	27.9.60	Sept. 60
Simazine lb/ac				
0	7.9	5.4	8.5	5.8
½	1.0	1.1	1.8	5.3
1	1.0	1.4	0.8	5.6
2	0.2	1.5	0.2	2.7
½ + ½	-	1.0	0.6	3.5

[x] = applied pre-drilling

* almost entirely *Veronica hederifolia*

Effect on bean crop

Plan counts were made at centres 1, 2, 3, 9, 10.

At centre 1, simazine reduced vigour and also gave progressive and significant reductions in flowering stems when applied at doses exceeding ½ lb/ac. Elsewhere flowering stem numbers were not recorded and there was no consistent trend to the (non-significant) fluctuations in the stand of young plants. The counts are summarised in Table IV.

Apart from the differences noted at centre 1, there was little information on vigour; most centres observed no differences but where weed growth was severe on the control plots (e.g. centre 5) the treated plots became progressively superior in vigour as the season advanced.

TABLE IV. EFFECT OF SIMAZINE ON PLANT POPULATION (1000/ac)

Centre	1	2		3	9	10
Date of Assessment	(5.59)	(12.58)		(3.59)	(5.60)	(5.60)
		pre drilling	pre emergence			
Simazine lbs/ac						
0	160	139		116	195	162
½	168	141	137	102	207	149
¾					181	
1	193	139	125	120	184	168
2	160	156	153	122		162
½ + ½						170

The visual damage to the beans at centre 1 was classified into 'mild' (partial leaf margin scorch) and 'severe' (severe scorch on older leaves, some yellowing of new growth and a reduction of internodes). The results of this assessment are given in Table V.

TABLE V. CENTRE I. POPULATION OF SPRING BEAN PLANTS PER ACRE; NUMBER OF DAMAGED BEANS AND NUMBER OF FLOWERING STEMS

Date of Assessment	5.5.59				1.6.59
Simazine lb/ac	Bean plants per acre	Unaffected plants/acre	Plants showing mild damage/acre	Plants showing more severe damage/acre	Flowering stems/acre
0	160	160	0	0	277
½	168	163	5	0	277
1	194	150	34	10	203
2	160	48	70	42	155

Grain yield

The grain yields which were obtained from six centres are summarised in Table VI. In comparing treatments, it should be noted that the control plots did not receive identical treatment in all trials. The controls were not cleaned at centres 1, 2, 7, 9, 10 but were hoed at centre 5. At centre 6, where weeds were relatively few, all plots were hoed in April as it was thought desirable to obtain some measure of the effect of simazine on a clean crop. In fact the treated plots were visually cleaner than the control plots at harvest, and the herbicide appeared to have had more effect than was anticipated when the land was hoed.

½ lb simazine appears to have increased grain yields consistently except at centre 6 where all the plots were hoed. On average, this increase amounted to nearly 2 cwt/ac grain. Except at centre 6, where the response was not significant, increasing the quantity of herbicide to 1 lb gave no further increase in yield, despite a generally better weed control, and at centre 9 significantly reduced yields were obtained. Here, 1 lb gave almost 2 cwt/ac less beans than ½ lb.

2 lb simazine gave the maximum yield at centre 2, and the response was significant, but 2 lb gave a lower yield than 1 lb at centre 1, and 3 lb gave a lower yield than 1½ at centre 7. There was little difference between 1 lb and 2 lb at centres 5 and 6.

TABLE VI. GRAIN YIELDS CWT/AC (85 per cent D.M.)

Centre	1	2		5	6	7	9
Simazine lb/ac		Pre-sowing	Pre-emergence				
0	24.5	21.2		20.5	41.5	29.5	21.1
½	27.7	22.8	22.8	24.1	41.1		22.5
¾						32.9	21.4
1	27.2	22.5	21.8	23.9	42.5		19.5
(½ + ½)				25.2	41.1		
1½						34.8	
(¾ + ¾)						34.8	
2	23.3	26.1	24.6	23.3	42.4		
3						31.3	
S.E. treatment mean	± 2.04	±0.90		± 0.84	± 0.74	± 0.93	± 0.48
S.E. control mean	± 1.45	±0.64		± 0.84	± 0.74	± 0.93	± 0.48

At centre 10 samples of 80 stems per plot were taken at random and the number and the weight of pods determined. The results, summarised in Table VII, showed appreciable yield increases.

TABLE VII. BEAN POD COUNTS AND DRY MATTER YIELD. CENTRE 10

Simazine lb/ac	Mean no. of pods/stem	Dry matter: pods + grain 80 stems
0	4.9	23.1
½	5.7	29.3
1	6.2	33.2
½ + ½	6.7	35.4
		± 4.76

Effect on subsequent crops

Visual observations were made on the wheat crops in 1960 which followed the 1959 centres. No symptoms of damage were noted. At centre 2 the wheat was harvested in plots corresponding to the simazine treatments; there was no indication of yield reduction after any application of simazine and on average the plots receiving no simazine gave slightly lower yields than the wheat grown on plots sprayed with simazine for the previous crop.

DISCUSSION

At current prices, the cost per lb of simazine is approximately 75/-. It is difficult to give precise figures for the benefits from spraying a bean crop. Apart from the tangible response which may be obtained in yield, a cleaner crop will be easier to combine, particularly in poor harvesting conditions. From the trial results presented in this paper it would seem that an extra 2 cwt of grain is a likely response, and if valued at 30/- per cwt one can justify applying say $\frac{3}{4}$ lb of simazine. This rate will give a fair control of the more susceptible weeds, e.g. Alopecurus and Stellaria.

Yield responses to heavier dressings than this were only obtained under very weedy conditions (centre 2). It would seem likely that there may be some danger of crop damage where doses exceeding $\frac{1}{2}$ lb were applied. It is not possible to specify the conditions where damage is likely from this trial series. However, there were indications that on soil with a high silt or clay fraction damage was less than on lighter soils.

Some weeds, such as wild oat and cleavers, are not reliably controlled by simazine and under very dry conditions e.g. centre 8 the control of relatively susceptible weeds may prove uncertain. For this reason it would seem possible that a combination of low doses of simazine, say $\frac{1}{2}$ lb per acre, with cultivation techniques (e.g. hoeing) might well be more effective than reliance on simazine alone although this would preclude the use of narrow row spacings. The interaction between the use of simazine and subsequent cultivations was not studied in these trials, but since it has been shown on a small scale that severe crop damage followed harrowing-in simazine two days after spraying (R. G. Hughes unpublished data) there would appear to be need for more work on these lines.

In the 1959 trials wheat was taken in 1960 and there was no visual evidence of any damage to the wheat from simazine residues. In fact at the centre where yields were obtained, the grain yield after simazine treatments tended to be higher than the grain yield after the control, presumably due to fewer grass weeds being present in the wheat crop. If it could be shown that succeeding crops derived any consistent benefit from the use of simazine on the beans the economic advantages in the use of this material would be more attractive.

Acknowledgements

Acknowledgement is made to the farmers concerned for the facilities so readily provided for these trials; and to colleagues in the East Midland, South Eastern and Eastern regions who collaborated in the field work.

REFERENCES

ELLIOTT J. G. (1958) Herbicide Trials in Field Beans. Proc. 4th Brit. Weed Control Conf. p.126-131.

GYSIN H. and KNUSLI E. (1956) Chemistry of herbicidal properties of triazine derivatives. Proc. 3rd Brit. Weed Control Conf. p.615-623.

MOFFATT J. R. and HILL M. J. (1959) Report Rothamsted Expt. Station p.177-180.

FURTHER EXPERIMENTAL EVIDENCE ON THE FATE OF SIMAZINE IN THE SOIL

O. R. Dewey

Chesterford Park Research Station, Fison's Pest Control Ltd.

Summary. The paper presents experimental evidence adding some information to the following aspects of the fate of simazine in soil: absorption by plants, adsorption onto soil particles, leaching, evaporation, photochemical degradation, and breakdown by soil micro-organisms.

INTRODUCTION

The major uptake of simazine by plants is by absorption through the roots. As for all other root-absorbed herbicides, the fate of simazine applied to the soil is important in its influence on the weed control obtained, future cropping on agricultural land, and for persistence of weed control on industrial sites. The low solubility of simazine in water (5 p p m) and in lipids which restricts the major entry into the plant to that via the soil, also has a profound influence on its behaviour in the soil.

A number of papers have appeared, especially in the U.S.A., regarding persistence or disappearance of simazine agricultural land. The diversity of results obtained show how greatly the fate of the chemical can depend on a number of inter-related factors which are difficult to separate, and this makes forecasting of exact amounts of remaining simazine unreliable, except in extreme cases.

The simazine applied to soil may have any of the following fates:-

1) absorbed by plants
2) adsorbed into soil particles
3) leached into sub-soil or drainage water
4) evaporation
5) photochemical degradation
6) broken down by soil micro-organisms

Factors which have an overriding influence on any of the above six fates include (a) the crops sown or weeds present, (b) soil type, (c) the precipitation/evaporation ratio, and (d) temperature. Under normal soil water conditions hydrolysis of simazine is unlikely to be a factor leading to significant losses. Each of the above six possible fates of simazine will now be discussed, and recent experimental studies on them described. All rates of simazine quoted are for total active ingredient per acre.

RESULTS

Simazine absorbed by plants

The roots of plants absorb simazine but the degree of injury obtained depends on the ability of the plant to decompose or tolerate it. Simazine can be metabolised by Saccharum officinarum (sugar cane), Cynodon dactylon, Sorghum halipense as well as by Zea mays (maize), Gast and Grob (1960). The speed of decomposition of simazine is slower in the more sensitive plants that have been examined.

When using bioassay techniques of growing sensitive plants to test for simazine residues, the percentage kill due to any one dose can be varied considerably by changes in illumination and relative humidity. Increased transpiration resulting from a low relative humidity would be expected to cause an increased intake of soil water containing simazine and lead to increased kill; however, Burnside (1959) reports decreased toxicity to maize under these conditions.

Interesting results were obtained from an experiment where two logarithmic plots were sprayed on a clean heavy clay soil using peak doses of 20 lb simazine in May 1958. Excellent weed control was obtained on both plots in 1958, down to 1½ lb. In 1959 one plot (A), remained weed free down to 7 lb while the other became severely infested with Cirsium arvense especially at the high rates. The two plots were within 50 yards of each other; no differences in soil composition could be found. When sampled sixteen months later, the two plots gave totally different residue data as shown in Table I.

The summer of 1958 was wet, with sixteen inches of rain between May and September; 1959 was dry with five inches of rain in the same period. In September 1959, four cores of soil twelve inches deep were removed, sliced into six sections and bioassayed for residue within two inch layers. The figures given are arrived at from extrapolation of bioassay standards.

TABLE I. TABLE OF SIMAZINE RESIDUES IN OUNCES, SIXTEEN MONTHS AFTER TREATMENT

Treatments	20 lb		10 lb	
Depth of soil in inches	Plot A	Plot B	Plot A	Plot B
0-2	4	1	1	½
2-4	4	½	1	0
4-6	4	0	1	0
6-8	2	0	1	0
8-10	1	0	½	0
10-12	1	0	0	0
Total oz/ac	16	1½	4½	½

At 5 lb no residue was found on either plot at any depth.

The question of whether the Cirsium invasion in Plot (B) was a cause of this difference in simazine residue or a result of it, could not be settled;

but it appeared from the logarithmic plot, that once the simazine level had fallen below a 3 oz/ac equivalent, the rapid growth of Cirsium quickly disposed of the remainder except for that held in the surface layer of the soil.

Simazine adsorbed onto soil particles

In practical tests Gast (reported in Gysin and Knusli, 1959) showed that soil type has a marked effect on the toxicity of simazine to plants. When a soil of high humus content was used two to five times as much chemical may be necessary to produce the same toxicity found in a sandy soil. Heavy clay soils also need more chemical for an equivalent plant response.

Aelbers and Homburg (1959) have confirmed this in their plant response curves. They needed 5.5 times as much simazine in a soil containing 30 per cent each of humus and clay as compared with a sandy soil. The 60 per cent clay soil needed 1.3 times as much as sandy soil.

Similar results found by the author are given in Table II.

TABLE II. MINIMUM DOSE OF SIMAZINE
NEEDED TO KILL OATS IN 21 DAYS

Soil type	per cent clay	per cent humus	oz/ac simazine
acid sand	0	10	3
clay soil	50	5	5
fen soil	5	60	16

The effect that pH variation may have on the adsorption of simazine by soil, or absorption by plants has not been resolved. Burnside (1959) reports that raising the pH from 5.4 to 7.2 caused increased toxicity to maize.

Leaching from soil

It has been calculated that one inch of rainfall over an acre could dissolve 1 lb of simazine spread uniformly over the surface. Under normal spray conditions chemicals are not spread molecularly uniformly even on a plane surface. The leaching of very soluble chemicals from soil is inefficient and rain does not penetrate uniformly. This illustrates that only under conditions of high rainfall where there is little chemical adsorption onto soil particles, is any leaching of simazine likely to occur. In general the bulk of simazine recovered by various experimenters has shown how the chemical remains at or near the soil surface.

Roadhouse and Birk (1959), reported this effect in a Canadian loam soil using chemical analysis. After fourteen weeks the total amount present on plots that had received 6-20 lb was 34.9 per cent of that applied, and of this 78 per cent was in the top inch. A year later 10 per cent remained and 70 per cent of it was in the first inch. This illustrates well how simazine stays in the top layer of soil and is not leached under temperate conditions.

Under dry loam soil conditions in Canada in 1958, Switzer and Rauser (1960) found some activity persisting from 2 lb/ac until the following spring. The following year irrigation was used and another plot lost all activity from 2 lb/ac in eight weeks. This difference in soil moisture could have a marked effect on activity of soil micro-organisms and it is quite possible that they are more likely to have caused the difference than leaching.

On an English heavy clay soil, treated with 10 lb in the wet summer of 1958, small amounts of simazine did penetrate the soil to a depth of twelve inches, but the majority of the chemical recovered was in the top two inches. The location of simazine as a percentage of the total recovered four months later is given in Table III.

TABLE III. LOCATION OF SIMAZINE AS PERCENTAGE OF TOTAL RECOVERED

Lb/ac Simazine applied	10	2.5
Total lb/ac recovered	5.1	0.28
Depth of soil sample (in.)	per cent	per cent
0-2	70	25
2-4	18	25
4-6	5	18
6-8	4	14
8-10	2	14
10-12	1	4

The following year a crop of potatoes showed no toxic symptoms from simazine.

From an experiment in 1959 where 1 and 2 lb of simazine had been sprayed in April on barley, soil samples were bioassayed four months later. The soil was a chalky fen skirt. No residue was found from the 1 lb plots. Of the 7 per cent recovered from the 2 lb plot, 68 per cent was in the top two inches, 23 per cent in the two to four inch layer, and 9 per cent between four and six inches.

Where simazine has been used as a selective weedkiller at 2 lb in six bean experiments in 1959 on various soils, no trace of residue was seen in cereal crops in 1960.

The reason for the importance of precipitation/evaporation ratio is that any rate of leaching may be greatly influenced by water evaporation from the soil between periods of rain. As Hartley (1960) has pointed out, the evaporation of water from surface soil will cause the surface soil layers to be less well extracted of chemical than deeper ones. This effect is much more pronounced on herbicides of low solubility such as simazine than readily soluble ones, and as the chemical will crystallise out in the surface crumbs, the delay of chemical movement during the next period of rain may be considerable. Hartley has also further considered the aspects of the water status of the surface soil at time of herbicide application. Simazine is normally sprayed onto a dry soil which results in much of the chemical being absorbed by capillary action into the dry lumps, thus much of the herbicide is in a region where it is least accessible to leaching by rain.

Evaporation and Photochemical degradation

The possibility of disappearance of simazine from soil due to ultra-violet light was mentioned by Aelbers and Homburg (1959). No published experimental work on the subject of evaporation from soil or photochemical degradation has been found.

In an experiment which did not attempt to separate the two factors, soil sprayed with simazine in 20 gal/ ac water was exposed dry under a 700 watt Phillip's mercury vapour lamp at twenty inches distance for fourteen days. The air temperature was about 140°F in spite of a fan below circulating air round the pans containing the soil. After exposure, the soil was mixed in the pan, and serially diluted with fresh soil for biological assay, using oats and peas. Similar sprayed pans of soil were kept in the same room, but were covered and did not receive the same light or heat.

Where 32 lb of simazine had been applied, the toxicity after fourteen days was equivalent to that produced by 4 lb on soil not exposed to these conditions; similarly, 8 lb was reduced to approximately 2 lb, but not more than half disappeared at the 2 lb rate.

Break-down by soil micro-organisms

Guillemat (1960) has proved the existence of species of fungi capable of breaking down simazine in the soil and using its nitrogen for their metabolism. The fungal species involved include *Fusarium oxysporum*, *F.avenaceum*, *Penicillium cyclopium*, *P.lanosocoeruleum*, *Cylindrocarpon radicicola* and a *Stachybotrys* species. The fungi did not use the carbon of simazine but degradation was favoured by high carbon availability in the soil. Simazine does not affect the balance of fungi or bacteria in the soil (Guillemat 1960, Pochon 1960). *Bacterium globifrome* and its allies are also capable of degrading simazine (Reid 1960).

The study of the disappearance of simazine in the soil is made more difficult by soil particle adsorption of the chemical. Rates below 1 oz/ac have little effect on the most sensitive test plants in organic soils, but such soils are useful for breakdown work because of their rich micro-organism content. For one experiment, large samples of fen soil were mixed with a range of simazine concentrations and stored in their polythene bags under conditions listed below. One sample was steam sterilised before mixing to kill the micro-organisms. The amount of simazine remaining after two months was determined by bioassay. Assuming that no breakdown occurred at 4°C, and using this as a standard, the percent loss of activity found is given in Table IV.

TABLE IV. PER CENT LOSS OF SIMAZINE IN FEN SOILS

Storage temperature	Pre-treatment	Bag condition	Water Status	oz/ac simazine applied		
				16	4	1
4°C	nil	closed	moist	0	0	0
20°C	steam sterilised	closed	moist	0	0	50
20°C	steam sterilised	open	fluctuating	25	75	100
20°C	nil	closed	moist	61	87	100
20°C	nil	open	fluctuating	44	87	100
20°C	nil	open	dry	38	75	100

Where the bags containing steam sterilised soil were kept closed, no loss of simazine was found except at 1 oz. The open sterilised bags had the moisture level kept up by the periodic addition of distilled water, fresh micro-organism invasion occurred with the resulting loss of simazine. The greatest loss was found in bags kept closed as if under these conditions the micro-organisms made most use of the simazine available to them.

DISCUSSION

This brief summary of information on the behaviour of simazine in the soil, together with the further experiments reported, illustrates that the possible influence of numerous factors must be known before any disappearance of simazine can be ascribed to any one cause.

The absorption and breakdown by resistant plants plays a large part where they are found, and if simazine alone is repeatedly used it can lead to healthy monocultures of a particular weed. If further treatment is not given the appearance of a resistant pioneering species appears to lead to a faster rate of colonisation by susceptible species, than these latter species would do on their own, presumably due to simazine removed by the pioneer species.

The effects of soil particle adsorption, leaching, evaporation, photochemical and micro-organism degradation cannot be sorted out in the field. Laboratory experiments tend to be unreliable as they may introduce artefacts such as abnormal packing density of soil in columns, rain applied as a single head of water and either a limitation or excessive supply of air.

Work so far indicates that with rates of 6-20 lb (non-selective uses), only a small percentage (10 per cent or less) of the applied chemical can be found below the top two inches unless cultivations have taken place. At the normal selective rates of up to 2 lb no residues affecting the next years crop were found under experimental conditions encountered.

Acknowledgements

The author wishes to thank Dr. R. K. Pfeiffer and Dr. G. S. Hartley for various suggestions and advice. Also to thank the Directors of Fisons Pest Control Limited for permission to publish this paper.

REFERENCES

AELBERS, E. and HOMBURG, K. (1959). De inactivering en penetratie van simazin in de grond. 11th Int. Symp. Fytofarmacie en Fytiatrie, Gent, 893-898.

BURNSIDE, O. C. (1959). The influence of environmental factors on the phytotoxicity and dissipation of simazine. Ph.D. thesis, Univ. Minnesota. From Diss. Abs. 20, 3914.

GAST, A. and GROB, H. (1960). Triazines in modern weed control. Brit. Agric. Chems. and Chemical Weed Control, 2, 4-6, in Pest Technology, 2, (8).

GUILLEMAT, J. (1960). Interactions entre la simazine et la mycoflore du sol. C.R. Acad. Sci. Paris, 250, (7), 1343-4.

GYSIN, H. and KNUSLI, E. (1959). Chemistry and herbicidal properties of triazine derivatives, Geigy, (Basle).

HARTLEY, G. S. (1960). Physio-chemical aspects of the availability of herbicides in soils. Herbicides and the Soil, Symposium of British Weed Control Council.

POCHON, J. TARDIEUX, P. and CHARPENTIER, M. (1960). Recherches sur les interactions entre les aminotriazines herbicides et la microflore bacterienne tellurique. C.R. Acad. Sci. Paris, 250, (8), 1555-6.

REID, J. J. (1960). Bacterial decomposition of herbicides. Proc. 14th N.East Weed Control Conf. U.S.A., 19-30.

ROADHOUSE, F.E.B. and BIRK, L. A. (1959). Penetration and persistence in soil of simazine. Res. Rep. E.Sect. Nat. Weed Comm., Canada, 18 or 142.

SWITZER, C. M. and RAUSER, W. E. (1960). Effectiveness and persistence of certain herbicides in soil. Proc. 14th N.East Weed Control Conf. U.S.A., 329-335.

Presentation by Mr. E. R. Bullen of preceeding three papers

Compared with the sugar beet and potato crops, which we have just heard about, the bean crop is something of a poor relation. The present acreage is only one-third of that grown during the war and about one-seventh of that grown by our ancestors in the 1860s. Nevertheless the crop has a special place in the arable farming of heavy land and is well adapted to mechanised handling with the equipment found on the intensive cereal farm.

Snippets of information about new chemicals turn up in widely scattered places. Like pieces of a jigsaw, each individual report may not amount to much. Miss Dewey has found pieces for her jigsaw from five countries situated in two continents. Clearly one very important means of removing simazine is extraction by plant roots; particularly important are those resistant species which possess the power of breaking down the herbicide after absorption. Simazine may also be adsorbed by soil, particularly on the humus and clay fractions. Leaching does not seem to be important in temperate climates, since the bulk of applied simazine appears to be retained in the superficial layers of the soil. Microbiological breakdown, particularly in highly organic soils, clearly takes place in some circumstances either evaporation or photochemical breakdown is possible.

This rather complex picture makes life difficult for the field adviser. The residue of relatively insoluble simazine applications might cause, and will certainly be blamed for, trouble in subsequent crops. There is an obvious need for more detailed information. It is to be hoped that Miss Dewey will continue to collect pieces for her jigsaw and make still clearer the relative importance of the factors she has listed under different climatic and soil conditions.

Turning to the field trials with simazine, nineteen were carried out on autumn-sown beans. All these trials included pre-emergence treatments; five compared pre-emergence with spring applications in early March and one compared pre-emergence with application before drilling. The main grass weeds encountered were the wild oat (Avena fatua) and blackgrass (Alopecurus myosuroides); wild oat proved a tough nut as it usually does. 2 lb/ac were needed for a consistent control on heavy land although lower doses were effective on chalky or loamy soils. Blackgrass was more susceptible, perhaps because it germinates nearer the surface, and on heavy land ½ lb was effective at almost all sites. Pre-emergence application would seem the most effective way of dealing with grass weeds; pre-drilling applications has obvious practical advantages but was clearly less effective in the trial where it was included. Spring application was better than pre-emergence for blackgrass on light land in one trial but not at the centres on heavy land. Among broad-leaved weeds a useful control was achieved with most species, except cleavers, by either seedbed or spring treatment. There was no evidence of any control of perennial weeds; apparently these are resistant to simazine applied in this way.

The seven trials on spring beans were sprayed before emergence, in late March or April. Conditions were not comparable with the spring application to the winter beans as the herbicide was applied to a cultivated and more or less dried out tilth in most cases. At two of the seven centres the weed control achieved was rather poor. Grass weeds occurred rarely in the spring trials; one centre, which was sown particularly early although the land was not ploughed until unusually late, had a good deal of blackgrass which was well controlled.

The main weeds present were broad-leaved but the results on individual species were not wholly consistent between centres. In some trials doses as high as 2 or even 3 lb did not adequately control weeds which were effectively reduced at other centres by lower doses. One is forced to a tentative conclusion that the results must be dependant upon soil moisture (affected both by cultivation, precipitation and soil type) in relation to the time of germination of the weeds and the time of application of the chemical. This is a complex and rather difficult matter to sort out from the records which are available.

Both autumn and spring sown crops were damaged by simazine at a few centres. Lighter land, or shallower drilling, increased this risk.

With both winter and spring beans consistent yield increases were obtained by the lower doses of simazine. From these trials ½ lb would generally appear to be about the optimum. 1 lb gave similar yields, except at one centre, despite the weed control being rather better. While higher rates occasionally gave better yields, quite marked yield reductions were noted at some centres - particularly those not on the heaviest land - and from these results one cannot with any confidence recommend other than a modest dose.

Perhaps the factor of paramount importance is that of economics. Simazine is a good deal more expensive in relation to the profits from beans than are most other herbicides now in use. One wonders what expenditure may be justified for the sake of having a clean bean crop if the crop itself does not respond to more than low doses of simazine. If subsequent crops in the rotation derived some benefit from cleaning the beans with simazine the economics would, of course, be completely altered.

REACTION OF PEA VARIETIES TO COMMONLY-USED HERBICIDES

J. D. REYNOLDS

Pea Growing Research Organisation, Yaxley, Peterborough

Summary. Results are presented of two experiments undertaken in 1958 and 1960, to compare the effects of 8 herbicide treatments at higher rates than normal on 14 popular vining and threshing pea varieties. TCA, applied pre-sowing, induced greatest loss of "bloom" in Big Ben, Lincoln, Pauli and Zelka, and most retarded the growth of Big Ben, Lincoln and Perfected Freezer. MCPB, applied post-emergence, caused most stem distortion in Gregory's Surprise and Thomas Laxton, and to a lesser extent in Dark Skin Perfection, Perfected Freezer and Witham Wonder (tall strain). Gregory's Surprise, Perfected Freezer, Thomas Laxton and Witham Wonder were stunted. Gregory's Surprise and Thomas Laxton sustained most scorch damage from dinoseb- amine and -ammonium, applied post-emergence, and their straw length was also reduced. When dinoseb- ammonium was applied after TCA, the extent of leaf loss due to scorching was increased, on average, by 10 per cent on all varieties. Propham applied pre-sowing, and chlorpropham/fenuron and chlorpropham/diuron mixtures as pre-emergence treatments, had no apparent deleterious effects on any variety. In terms of yield, measured only in the 1960 experiment, adverse effects were caused by TCA to Perfected Freezer and Thomas Laxton, by MCPB to Kelvedon Wonder, Meteor and Perfected Freezer, and by dinoseb- amine and -ammonium to Gregory's Surprise and Thomas Laxton; dinoseb- amine also had a similar effect on Kelvedon Wonder. None of the herbicide treatments affected rate of maturation (measured by a tenderometer) of any variety.

INTRODUCTION

That differences exist in the degree of susceptibility of pea varieties to some of the herbicides used in the crop has been recognised for some time, but there has been a dearth of critical data, particularly as regards effect on yield (the most important factor to be considered) in respect of the many varieties now grown for vining and threshing. Results of early studies in this country with dinoseb led Roberts and Woodford (1951) to classify picking varieties as most susceptible to this herbicide, vining and threshing varieties as intermediate, and field peas as least susceptible. More recently Roberts (1959) presented data which showed differences in reaction to the ammonium salt of dinoseb, in terms of yield, of a number of picking varieties; he also confirmed the greater selectivity of the amine salt to which all varieties tested were tolerant when it was used at the recommended rate. Some results on the differential effect of MCPB on different varieties has also been reported by Hirst et al (1957), Reynolds et al (1957) and Carpenter et al (1957); the latter have also alluded to effect on ripening. Procter and Armsby (1960) presented evidence which suggested that Zelka - a marrowfat variety grown for harvesting dry - is particularly susceptible to damage by TCA, while Butler (1960) has shown that certain other varieties can sustain damage by this herbicide. So far as is known no critical data has been published on the reaction of pea varieties to pre-emergence applications of carbamate/urea mixtures, fairly widely used in the crop during the past three seasons.

In the present contribution, the comparative effect of each of these commonly-used herbicides on widely-grown varieties is described, in an attempt to give guidance to growers and spraying contractors regarding adjustments in rates of application and varieties unsafe to treat with certain herbicides. Factors influencing the effect of these herbicides on the crop in general are not discussed.

METHODS AND MATERIALS

Experiments were laid down in 1957, 1958 and 1960 but for various reasons useful information was obtained only from single sites in 1958 and 1960. Each experiment consisted of long narrow plots of a number of varieties, chosen on the basis of their popularity for vining (canning and quick freezing) and threshing, sown in randomised blocks with three-fold replication. The herbicide treatments were applied randomly, at right angles across the variety plots to give 297 (1958) and 210 (1960) sub-plots per experiment, each sub-plot occupying 54 and 40 sq ft respectively.

Each herbicide was used at the standard time of application, and at a dose equal to $1\frac{1}{3}$ - $1\frac{1}{2}$ times the recommended dose, according to prevailing conditions, in an attempt to accentuate possible differences in reaction between varieties. Applications were made with an Oxford Precision Sprayer, using Allman "O" jets ("OOO" jets for MCPB).

Since all varieties were sown on the same day at each site, they were inevitably at different stages of development when the post-emergence applications were made. However, it was considered that this shortcoming was better than making a series of applications, probably under varying weather conditions.

Control plots were included in both experiments. In 1958 they were left untreated, but in 1960 they were kept free of weeds, from early May onwards, by careful hand-hoeing supplemented by handweeding within the pea rows.

Treatments compared and site details were as follows:-

Herbicides tested

Treatment no.	Chemical	Formulation per cent	Formulation Type	Time of application	Dose in lb.* and volume per acre 1958	Dose in lb.* and volume per acre 1960
1	TCA	94	Na salt	Pre-sowing	9.4lb/40 gal	9.4lb/40 gal
2	TCA followed by dinoseb-ammonium	94 17	Na salt soln.	" " Post-emerge.	9.4lb/40 gal 2.4lb/50 gal	- -
3	Propham	50	wet. powder	Pre-sowing	4.5lb/40 gal	-
4	Chlorpropham/ fenuron	20) +5)	misc conc.	Pre-emerge.	3.0 lb)45 +0.75lb)gal	-
5	Chlorpropham/ diuron	20) +4)	misc conc.	" "	-	1.3lb) 40 +0.27lb) gal
6	dinoseb-ammonium	17	soln.	Post-emerge.	2.4lb/50 gal	1.7lb/100 gal
7	dinoseb-amine	18.5	soln.	" "	-	3.4lb/100 gal
8	MCPB	40	Na salt soln.	" "	3.0lb/20 gal	2.7lb/20 gal
9	Control		-	-	Untreated	Clean-weeded
10	"		-	-	"	" "
11	"		-	-	"	-

Varieties tested

Used for vining green

Dark Skin Perfection
Gregory's Surprise
Kelvedon Wonder
Lincoln
Meteor†
Onward (1958 only)
Perfected Freezer (1960 only)
Thomas Laxton
Victory Freezer (1958 only)
Witham Wonder (tall strain)

Used for harvesting dry

Big Ben (1960 only)
Pauli† (" ")
Rondo† (1958 only)
Zelka (" ")

* Active ingredient/acid equivalent
† Round seeded. All other varieties wrinkle-seeded.

Site details

Year	1958	1960
Site	Nordelph, Norfolk	Yaxley, Hunts.
Soil type	Silty clay	Sandy clay loam
Dates. Pre-sowing applics	4 March	21 March
Sowing	6 " *	5-6 April
Pre-emerge applics	31 "	8 "
Pea emergence	10 April (approx.)	20 " (approx.)
Post-emerge applics	20 May	17 May≠
Clean weeding	-	4-12 and 12-26 May
Weather conditions at times of applic. Pre-emerge	Not recorded	Warm and sunny
Post-emerge	Air temp. 55-60°F.	17 May - Air temp. 65°F. 23 " - " " 67°F. 24 " - Very windy
Ave. size of peas at times of applic Pre-emerge	Radicles up to 1¼ in. plumules "moving"	Seeds swelling
Post-emerge	5" high	3-9 in. high, with 4-5 expanded leaves ≠

* Gregory's Surprise, Lincoln and Witham Wonder re-sown on 28 April due to thin plant establishment on first sowing. Since data obtained is not strictly comparable with the other varieties, reference to these three varieties is omitted from this report.

≠ Except dinoseb-ammonium, applied on 23 May. An application on 17 May had no effect so the plots were re-sprayed six days later.

≠

Variety	Height (in.)	No. of expanded leaves
Big Ben	5	5
Dark Skin Perfection	6	5
Gregory's Surprise	7	5
Kelvedon Wonder	6	5
Lincoln	4	5
Meteor	5	4
Pauli	3	4
Perfected Freezer	6	5
Thomas Laxton	9	5
Witham Wonder (tall)	5	5

RESULTS

In 1958 observations were confined to visual scorings, presented in Table I. In 1960 assessments comprised visual scorings (Table II) and straw lengths (Table III), tenderometer readings (Table IV) and yields on the date of harvesting of each variety (Tables IV and VI).

All plots of each vining variety were harvested as closely as possible to the date they reached, on average, the "practical canning stage", corresponding to a tenderometer reading of 120; in practice the mean reading per variety ranged from 104 to 113, with one exception.ɸ The other varieties were harvested dry.

Although differences recorded in the scorings had largely disappeared by the time of harvest, in many cases effects were reflected in the straw length and yield data.

TABLE I. SCORING FOR EFFECTS ON VARIETIES 1958
(assessed 23 May)

Treatment	Basis of assessment	Varieties							
		Dark Skin Perfection	Kelvedon Wonder	Meteor	Onward	Rondo	Thomas Laxton	Victory Freezer	Zelka
TCA	Loss of bloom, stunting and scorching (10 = no effect; 0 = complete kill)	7.3	8.3	7.7	7.7	7.3	6.3	8.0	2.7
TCA followed by dinoseb-ammonium	Per cent loss of leaf by scorching	48	52	40	50	38	55	48	55
Propham	-	No effect on any variety							
Dinoseb-ammonium	Per cent loss of leaf by scorching	42	42	33	40	30	47	37	35
Chlorpropham/fenuron		No effect on any variety							
MCPB	Stem contortion (10 = no effect: 0 = complete kill)	6.3	5.7	8.7	8.3	9.3	7.0	7.3	9.3

ɸ Meteor, a variety which ripens very quickly, harvested at an average tenderometer reading of 178.

TABLE II. MEAN SCORINGS : 1960 EXPERIMENT

Treatment	Date of assessment	Basis of Assessment	Varieties: Big Ben	Dark Skin Perfection	Gregory's Surprise	Kelvedon Wonder	Lincoln	Meteor	Paull	Perfected Freezer	Thomas Laxton	Witham Wonder (tall)
TCA	17 May	Loss of bloom (10 = no effect; 0 = considerable effect)	0.4	2.6	6.7	5.6	0.4	3.3	0.0	3.3	3.0	3.0
	27 May	Loss of bloom (10 = no effect; 0 = considerable effect)	3.3	6.7*	6.0	4.7**	2.7**†	6.7**	2.7	5.3**	6.0**	5.3**
Chlorpropham/ diuron	-	-	No effect on any variety									
MCPB	23 May	Stem contortion (10 = no effect; 0 = severe effect)	8.0≠	3.3≠	0.7≠≠	4.7≠	5.3≠≠	4.0≠≠	6.0≠	3.3≠≠	2.0≠≠≠	3.3≠≠
Dinoseb-ammonium	27 May	Leaf loss by scorching (10 = no effect; 0 = severe effect - over 40 per cent of leaf surface)	7.5	6.3	2.9	6.3	7.1	7.1	7.5	5.8	2.5	6.7
Dinoseb-amine	23 May	Leaf loss by scorching (10 = no effect; 0 = severe effect - over 40 per cent loss of leaf surface)	5.4	2.9ɓ	0.8ɓɓ	3.3ɓ	3.8	3.3ɓ	4.6ɓ	3.8	0.8ɓ	2.9ɓɓ

* Also slight scorch of lower leaves
** " moderate " " " "
*** " severe " " " "
† " slight bunching (rosette effect)
†† " severe " "
≠ " slight marginal scorch
≠≠ " moderate " "
≠≠≠ " severe " "

ɓ " occasional plants dying off
ɓɓ " a number of plants dying off

TABLE III. MEAN STRAW LENGTH DIFFERENCES (IN INCHES) ON DATES OF HARVESTING, IN RELATION TO CLEAN-WEEDING : 1960 EXPERIMENT

Based on 10 plants, chosen at Random, per treatment per variety

Variety	Date of harvesting	Clean-weeded (means of 20 plants)	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine
Big Ben	2 August	24.5	-4.7	-0.4	-0.9	-3.7	-2.8
Dark Skin Perfection	7 July	28.0	-2.8	-1.1	-1.0	-2.9	-2.2
Gregory's Surprise	29 June	44.9	+5.1	-2.8	-3.7	-3.6	-4.3
Kelvedon Wonder	30 "	15.7	-1.4	-1.5	-1.8	-2.0	-1.0
Lincoln	11 July	19.3	-4.2	0.0	-0.4	-2.7	0.1
Meteor	29 June	17.9	-2.6	+1.0	-0.7	-1.0	-2.1
Pauli	2 August	18.6	-2.6	-1.1	-2.6	-2.3	-1.1
Perfected Freezer	8 July	29.6	-6.9	-0.9	-3.9	-2.0	-2.1
Thomas Laxton	1 "	42.5	+0.8	+0.8	-6.2	-5.9	-7.8
Witham Wonder (tall)	7 "	25.8	-0.6	+1.3	-3.4	-1.8	-3.7
Mean	-	26.7	-2.0	-0.5	-2.5	-2.8	-2.7

TABLE IV. MEAN TENDEROMETER READINGS : 1960 EXPERIMENT

Each value normally represents the mean of 2 or 3 tests (4 or 6 tests in the case of the clean-weeded treatment)

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine	Clean-weeded	Mean (± 3.2)
Dark Skin Perfection	110	106	106	104	105	104	106
Gregory's Surprise	115	112	113	111	118	110	113
Kelvedon Wonder	123	117	123	119	122	122	121
Lincoln	109	105	104	98	102	107	105
Meteor	172	188	173	179	172	180	178
Perfected Freezer	113	101	101	104	101	103	104
Thomas Laxton	108	111	111	113	113	112	111
Witham Wonder (tall)	119	114	111	109	107	114	112
Mean (±1.6)	121	119	118	117	117	(±1.1) 119	119

Herbicide S.E. per plot ± 2.7 (12 d.f.)
Variety S.E. per plot ± 5.5 (14 d.f.)
Herbicide x Variety S.E. per plot ± 5.0 (84 d.f.)

	Body of table	Clean-weeded
S.E. for use in horizontal comparisons (12 d.f.)	±3.1	±3.0
" " " " interaction " (84 d.f.)	±2.9	±2.2

TABLE V. MEAN YIELDS OF PEAS IN CWT/AC 1960 EXPERIMENT

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine	Clean-weeded	Mean
							(± 1.9)
Big Ben	35.1	37.6	36.2	42.5	35.9	36.4	37.2
Dark Skin Perfection	39.1	50.7	35.5	42.0	37.1	40.2	40.7
Gregory's Surprise	15.7	21.5	15.3	13.8	11.3	16.7	15.9
Kelvedon Wonder	27.1	36.7	25.8	36.2	19.9	31.9	29.9
Lincoln	46.9	60.3	49.3	53.9	45.7	57.0	52.9
Meteor	33.4	46.2	31.1	37.0	33.1	39.8	37.2
Pauli	37.5	39.8	37.8	39.5	35.8	40.1	38.6
Perfected Freezer	21.8	34.4	25.2	33.8	30.2	33.0	30.2
Thomas Laxton	26.3	29.4	31.7	29.9	25.2	34.0	30.1
Witham Wonder (tall)	35.0	45.0	34.8	35.8	28.3	34.4	35.4
						(± 0.8)	
Mean (± 1.2)	31.8	40.2	32.3	36.4	30.3	36.3	34.8

Herbicide S.E. per plot ± 2.1 or 5.9 per cent of general mean (12 d.f.)
Variety S.E. per plot ± 3.3 or 9.5 " " " " " (18 d.f.)
Herbicide x Variety S.E. per plot ± 2.1 or 6.1 per cent of general mean (108d.f.)

	Body of table	Clean-weeded
S.E. for use in horizontal comparisons (12 d.f.)	± 1.7	± 1.5
" " " " interaction " (108 d.f.)	± 1.2	± 0.9

(78178)

TABLE V (continued)

Significant differences in cwt/ac	P = 0.05	P = 0.01
Between herbicide treatments for one variety	5.1	7.2
Between clean-weeded and herbicide treatments for one variety	4.8	6.8
Between means of herbicide treatments	3.7	5.1
Between clean-weeded mean and means of herbicide treatments	3.2	4.5

TABLE VI. MEAN YIELDS AS PERCENTAGES OF CLEAN-WEEDED MEAN FOR EACH VARIETY 1960 EXPERIMENT

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine
Big Ben	96	103	99	117	99
Dark Skin Perfection	97	126	88	104	92
Gregory's Surprise	94	129	92	83	68
Kelvedon Wonder	85	115	81	113	62
Lincoln	82	106	86	95	80
Meteor	84	116	78	93	83
Pauli	94	99	94	98	89
Perfected Freezer	66	104	76	102	92
Thomas Laxton	77	86	93	88	74
Witham Wonder (tall)	102	131	101	104	82
Mean	88	112	89	100	82

DISCUSSION

Propham, chlorpropham/fenuron and chlorpropham/diuron. - Neither propham applied pre-sowing nor the two carbamate/urea mixtures had any adverse effect on the varieties tested in these experiments and it would appear that varietal differences are slight or non-existent. None of the treatments delayed pea emergence.

TCA - When TCA was used as a pre-sowing treatment, the marrowfat varieties, Big Ben and Zelka, sustained the greatest visual damage; this accords with the results of other work (Proctor and Armsby, 1960; Proctor, 1960). Pauli, a blue variety grown for harvesting dry, was also markedly affected, but it is of note that yields of this variety and Big Ben (Zelka yields were not measured) were not significantly depressed. Of the vining varieties, Perfected Freezer was most affected visually, and its yield was significantly reduced. Kelvedon Wonder, Lincoln and Thomas Laxton appeared rather less tolerant than the remaining varieties.

MCPB - The marrowfat and blue varieties were least susceptible to this post-emergence herbicide. Dark Skin Perfection, Kelvedon Wonder, Meteor and Perfected Freezer were rather sensitive in that yields of these varieties were reduced. The greatest degree of stem contortion was caused to Gregory's Surprise and Thomas Laxton but yield reductions were not significant. Witham Wonder also sustained injury in the form of stunting, but yield was not affected.

Contrary to popular belief, differences in maturity rating between MCPB-treated and clean-weeded plots, as measured by tenderometer on the dates of harvesting, were not significant for any variety. This supports the findings of Carpenter et al (1957).

Dinoseb - Most scorch damage resulted to Gregory's Surprise and Thomas Laxton. Dark Skin Perfection and Witham Wonder were also affected to a greater extent than the remaining varieties. The marrowfat and blue varieties - Big Ben, Pauli, Rondo and Zelka - were least susceptible to scorching, and Meteor and Lincoln were also quite tolerant. Both salts retarded growth, reflected in a straw length reduction, on average, of nearly 3 in. The effect of scorching resulted in decreased yields in the case of Gregory's Surprise and Thomas Laxton; the yield of Kelvedon Wonder was also reduced.

In general, it would seem that varieties may be placed in two broad groups: the shorter, stronger-strawed and firmer (less lax) leaf types which are generally tolerant, and those of weak appearance which tend to be rather susceptible (Proctor, 1958).

Normally, less scorch damage should be caused by the amine compared with the ammonium salt since the former is more selective (Roberts, 1959). In the 1960 experiments, however, where both were compared, applications were made on separate dates and the different weather conditions obtaining probably accounted for the more drastic effect of the amine salt.

TCA followed by dinoseb - There appeared to be no interaction effect between TCA and dinoseb. The effect of dinoseb on TCA-treated plots compared with