3.45 p.m. Summary of review paper (contd)

(a) Agriculture - J. G. Elliott and P. J. Boyle

(b) Horticulture - Dr. D. W. Robinson

(c) Forestry - G. D. Holmes
Presented by J. G. Elliott

Preprints of this paper will be distributed before the symposium

4.20 p.m. DISCUSSIONS OPENED BY:

C. V. Dadd - National Agricultural Advisory Service
J. C. Green - Farmer, H. A. Worth (Fleet) Ltd., Fleet, Spalding, Lincs.
Dr. D. W. Robinson - Horticultural Centre, Loughgall, Northern Ireland.

SYMPOSIUM arranged by
British Weed Control Council,
and held at the Royal Commonwealth Society,
18 Northumberland Avenue, London, W.C.2.

Research Report

PRELIMINARY ASSESSMENTS OF TRIAZINES FOR WEED CONTROL IN POTATOES FROM POT EXPERIMENTS.

G. F. Milford and R. K. Pfeiffer,

Chesterford Park Research Station, Nr. Saffron Walden, Essex.

Summary The results of the experiments have indicated that of the 11 chemicals tested simazine, atrazine, trietazine, G 34361 and prometone exhibited the greater degree of selectivity. Whilst the level of selectivity for the chemical was of a comparable magnitude, trietazine and G 34361 proved less toxic in varying degrees to both crop and weed species. Under the conditions of the experiment it was shown that elimination of weed competition by treatment with simazine and trietazine resulted in increased yields despite yield reductions shown by equivalent rates under weed free conditions.

It is stressed that the results from these experiments are merely qualitative in nature, serving as a preliminary assessment of selectivity upon which to base more definite field experiments.

INTRODUCTION

The desirability of a residual weed control measure in potatoes was noted in papers presented at the last British Weed Control Conference (Robertson 1960, Wood et al, 960) which reported field trials with certain herbicides including triazines. Adequate field testing of a large group of allied compounds such as the triazines would be a cumbersome and lengthy process unless the number of compounds was restricted to those most promising. Pot experimentation provides a useful method for initial screening of a large number of compounds to provide information upon which to base selection for field trials.

METHOD

The chemicals were bulked with sand and mixed in a soil-mixing machine with 4.6 kg of compost, sufficient to fill a 7-inch diameter whalehide pot to a depth of 8 in. The weight of chemical required for each rate was calculated from the surface area of the soil in the pot.

Potatoes (var. Majestic,) cut into ½ oz pieces each bearing a single eye were sprouted until the shoot was a quarter of an inch in length. These were planted, eight pieces per pot, 1½ in. below the soil surface. Standard volumes of seed of Sinapsis arvensis, Stellaria media and Chenopodium album were sown according to treatment. The pots were initially watered with 700 ml. of water and covered with plastic until shoot emergence, after which they were watered as required, care being taken to prevent leaching of chemical.

Weed control was recorded as the decrease in fresh weight of the aerial parts of the plants, whilst crop damage was assessed on three parameters, tuber fresh weight per pot, fresh weight of shoots per pot and a visual score for yellowing or necrosis of leaves.

RESULTS

In the first experiment performed, the selectivity between crop and weed species of eleven triazines at rates from 0.11 - 9.0 lb/ac was examined. A summary of the results is given in Table 1.

a) Crop damage assessment

Dosage-response curves obtained from the three parameters of crop damage recorded for Simazine are given in Figure 1.

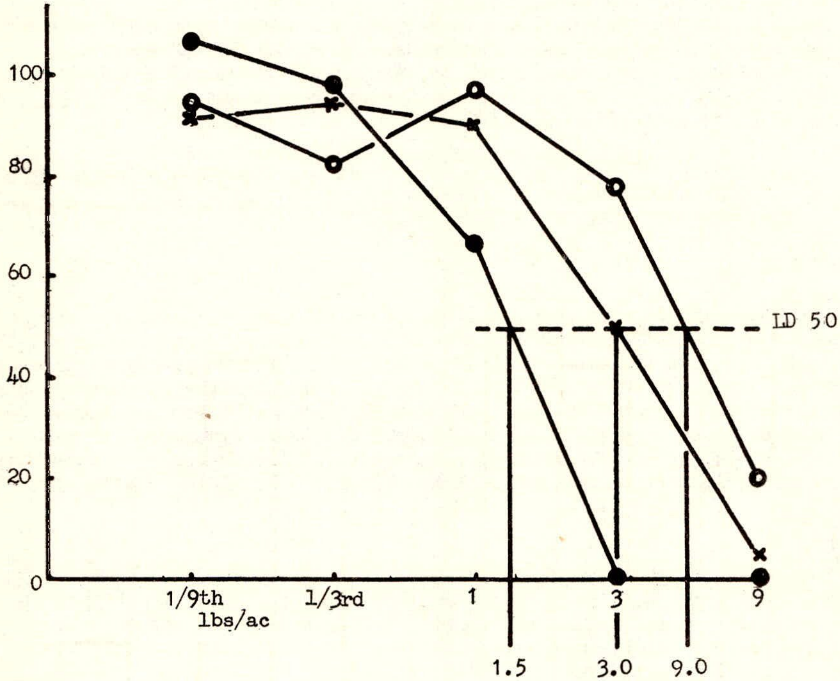


Figure 1. The effect of Simazine on fresh weight of tops (O), fresh weight of tubers (●) and foliar yellowing (X) of potatoes. Weight values given as percentage of untreated. Yellowing score given as 100 minus score value.

The trends indicated by this graph are representative of those obtained from the 11 chemicals tested. A comparison of LD 50 doses indicates that top growth measurements, i.e. fresh weight of shoots (LD 50 dose 6.0 lb/ac) and yellowing score value (LD 50 dose 3.0 lb/ac) reflected the extent of crop damage far less than more determinate yield data such as tuber fresh weight which showed an LD 50 dose of 1.5 lb/ac. Thus the effect of chemicals on tuber growth was disproportionately greater than would be expected from top growth alone. Consequently further considerations of crop damage were based solely upon tuber fresh weight data. The authors are aware of the dangers of extrapolating pot experimental results to field problems, nevertheless they are convinced that valid assessments of crop damage in field trials on potatoes can only be obtained from yield data rather than visual scores.

b) The selectivity of certain triazines in potatoes.

Considering selectivity as the ratio of crop safety to weed control, an index of selectivity is given by the expression:-

$$\text{Selectivity Index} = \frac{\text{Maximum rate tolerated by the crop}}{\text{Minimum rate for adequate weed control}}$$

The selectivity indices of the 11 chemicals tested, together with the minimum rates for adequate weed control, are given in Figure 2.

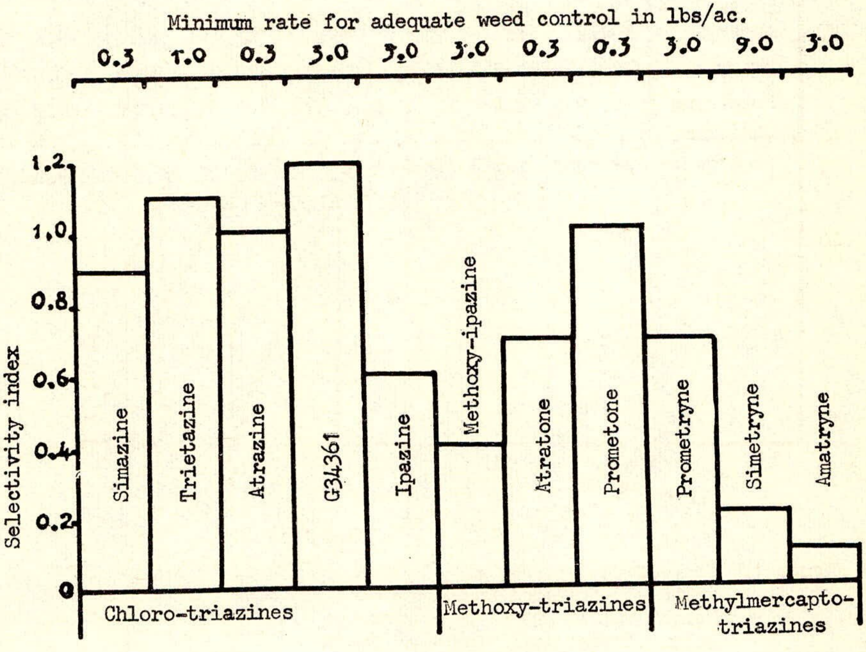


Figure 2. Selectivity indices of the triazines tested .(See text).

TABLE 1. SUMMARY OF CROP DAMAGE AND WEED CONTROL

POTATOES								
lb/ac	Shoot growth fresh wt 1. 0.11	0.33	1.0	3.0	9.0	Tuber fresh wt 1. 0.11	0.33	1.0
Simazine	95.4	83.1	97.5	80.7	20.8	107.2	98.2	64.4
Trietazine	100.0	90.0	108.4	110.0	122.3	116.4	106.4	100.9
Atrazine	113.0	86.2	134.6	78.1	48.5	110.0	101.8	35.5
Ipazine	111.5	91.5	115.5	110.0	129.1	91.8	108.2	104.5
G 34361	94.5	100.0	89.9	103.0	107.6	100.9	118.1	116.3
Atratone	103.0	68.4	103.0	26.2	33.8	122.7	80.9	25.5
Prometone	101.5	81.5	107.6	33.0	28.4	95.5	96.3	13.6
Methoxy-ipazine	97.6	105.3	102.3	109.1	56.1	109.0	124.5	103.6
Simetryne	102.2	81.4	96.8	99.1	48.4	117.3	96.4	117.3
Ametryne	108.4	85.3	112.2	124.5	42.3	93.6	100.9	86.4
Prometryne	89.2	91.4	106.0	110.7	107.6	108.2	108.2	114.5

+ Results are means for 3 species, Chenopium album, Sinapsis arvensis and Stellaria media.

ASSESSMENTS FOR 11 TRIAZINES

							WEEDS				
		Foliar yellowing					per cent Weed Control+				
3.0	9.0	0.11	0.33	1.0	3.0	9.0	0.11	0.33	1.0	3.0	9.0
0.0	0.0	8	5	10	50	95	43.2	92.2	100.0	100.0	100.0
72.7	4.5	5	5	0	3	25	26.4	19.8	100.0	100.0	100.0
0.5	0.5	15	5	5	70	90	63.1	98.2	100.0	100.0	100.0
90.0	12.7	5	3	13	8	15	9.9	11.4	74.6	100.0	100.0
116.3	33.6	0	3	13	5	50	7.0	25.3	65.2	93.9	100.0
0.0	0.0	8	3	40	100	100	52.1	98.5	100.0	100.0	100.0
0.0	0.0	5	3	25	90	100	69.9	90.0	100.0	100.0	100.0
43.6	0.0	8	5	0	10	85	22.0	29.9	89.1	100.0	100.0
75.5	1.8	5	5	3	3	90	22.2	35.5	60.2	82.4	96.6
72.7	0.0	5	5	8	5	90	21.9	36.3	67.2	96.3	100.0
90.0	33.6	3	3	3	0	50	28.5	33.0	77.5	96.3	100.0

1. Results presented as percentage of control values. All results are means of two replicates.

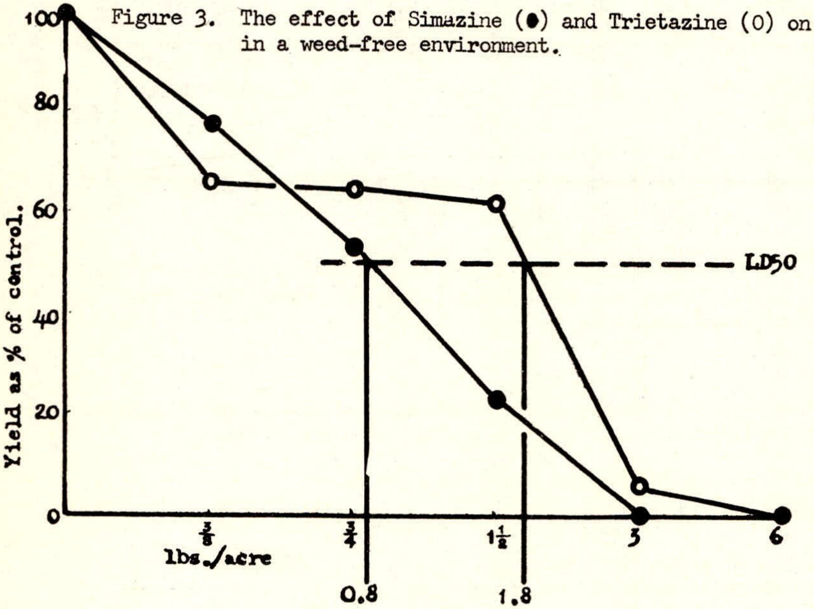
These show that there were no great differences in selectivity between simazine, atrazine, trietazine and G 34361, although as the weed control doses show, trietazine and G 34361 respectively were one-third and one-ninth as toxic as simazine and atrazine to both crop and weed species. Ipazine proved more toxic to potatoes than to weed species. Prometone and prometryne respectively were the most selective of the members of the methoxy- and methyl-mercapto-triazines tested, although prometryne was only one-ninth as toxic as prometone and simazine. It will be noted that the selectivity indices obtained were comparatively low.

In a second experiment, an investigation was made of the effect of simazine and trietazine at doses from 0.38 to 12 lb/ac upon the yields of potatoes grown in weed-infested and weed-free environments.

a) Crop damage

Dose-response curves of the effect of the two chemicals upon the yield of potatoes grown under weed-free conditions are given in Figure 3.

Figure 3. The effect of Simazine (●) and Trietazine (O) on potato yield in a weed-free environment.



From these curves it is clear that even at the lowest dose, 0.38 lb/ac, there was an appreciable yield reduction by both chemicals. At higher doses simazine was approximately twice as toxic to the crop as trietazine as demonstrated by the respective LD 50 doses of 0.8 lb/ac and 1.8 lb/ac.

b) The relation of weed control to crop yield

Under the conditions of this experiment, weed competition alone reduced the yield of potatoes by 72 per cent, as shown by the control value in Figure 4.

b) The relation of weed control to crop yield

Under the conditions of this experiment, weed competition alone reduced the yield of potatoes by 72 per cent, as shown by the control value in Figure 4.

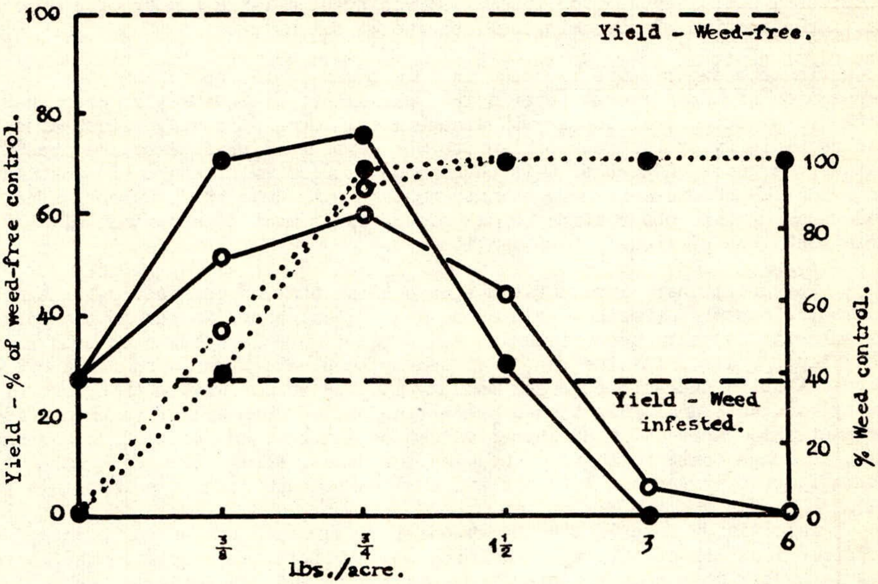


Figure 4. The effect of Simazine (●) and Trietazine (O) on crop yield, (solid lines) and weed control, (dotted lines) in a weed infested environment.

Therefore, upon treatment of weed-infested potatoes with triazines, two major factors would appear to be operating upon the yield:-

(i) Effects of weed competition

(ii) Effects of crop damage by herbicidal treatment.

The relationship of these two factors is presented in Figure 4. At 0.75 lb/ac, a dose which eliminated weed competition, the yield of potatoes was increased from 28 per cent of the weed-free controls to 75 per cent and 60 per cent respectively for simazine and trietazine. Thus at this dose there was still a reduction in yield compared to weed-free controls due to the toxicity of the chemicals. This effect increased with concentration.

Selectivity indices calculated from the results of this experiment were comparable for both chemicals, although being less than 0.5. There are grounds for believing that premature harvesting of the first experiment, before the effect of the chemicals upon tuber growth became pronounced, was partly responsible for the differing magnitude of the selectivity indices.

DISCUSSION

The large number of compounds within the triazine group and the inherent variation encountered under field conditions make adequate field testing both cumbersome and complex. Pot experimentation under controlled conditions provides a useful method for initial screening of a large number of compounds and investigation of physiological aspects of selectivity.

In both experiments reported in this paper it was noted that the depression of tuber growth by triazines was disproportionately greater than would be expected from top growth assessments. Such a finding illustrates the sensitivity of the potato plant to the herbicidal treatments and accordingly raises the question whether this phenoxenon is a general feature of treatments in which the chemical is brought into contact with developing tubers. The relevance of this observation to methods of assessment of experimental treatments has previously been mentioned.

The preliminary investigations have shown that of the chloro-triazines tested, simazine, atrazine, trietazine and G 34361 showed a comparable level of selectivity, although trietazine and G 34361 were less toxic to both crop and weed species. Ipazine was considerably less selective. Prometone was more selective than atratone and methoxy-ipazine whilst within the range of methyl-mercanto analogues tested prometryne proved more selective than simetryne or ametryne. More detailed investigation of simazine and trietazine has shown that although toxic to the crop even at low doses, elimination of weed competition by treatment with the two chemicals could result in increased yields.

Selectivity under field conditions is determined by two components, physiological selectivity at cell level and physical selectivity. The latter is regulated by factors determining the location of the herbicide in the soil. Physiological selectivity is theoretically finite; being dependent upon the response of the species involved to the chemical and independent of environmental factors. Pot experimentation is a suitable method for determination of physiological selectivity. It is emphasised that under field conditions the physical component of selectivity plays an important role in determining the final level of selectivity, and is of considerable importance in relation to the triazines where much of the selectivity depends upon their location within the soil.

Thus the results obtained serve only to indicate those chemicals worthy of further investigation in field trials, without providing information on how physical factors will affect their performance under field conditions. In view of the complexity of the problem and the dangers of extrapolating greenhouse results to field problems, the authors are wary of drawing definite conclusions from these experiments and feel that contributions from other workers using similar methods and confirmation from extensive field trials are essential to provide a suitable weed control measure for potatoes.

Acknowledgment

The authors are grateful to Dr. K. Holly of the Weed Research Organisation, Oxford, for advice on the conduction of pot experiments with potatoes.

REFERENCES

ROBERTSON, I.M. (1960) The use of herbicidal sprays on the potato crop. Proc 5th Brit Weed Control Conf 55-7.

WOOD, C.A. SUTHERLAND, J.P., STEPHENS, R.J. (1960) The use of herbicidal sprays on the potato crop. Proc 5th Brit Weed Control Conf, 59-64.

Research Report

THE RESPONSE OF THE POTATO TO A RANGE OF SOIL ACTING HERBICIDES.

K. Holly

Agricultural Research Council Weed Research Organisation
Begbroke Hill, Kidlington, Oxford.

Summary. The resistance of Majestic potato to 23 herbicides incorporated into the soil was determined in a greenhouse pot experimental. Compounds to which the potato appeared to have some tolerance included trietazine, a group of methylthiotriazines, linuron, diphenamid, and N-(1',2',4'-triazole)-2,4-dichlorophenoxyacetamide. King Edward was more susceptible than Majestic to simazine and monuron, indicating that varietal differences in susceptibility may be important in this crop.

INTRODUCTION

There is widespread interest in the possibility of using herbicides selectively in potatoes. Many soil-acting herbicides have been reported as being used successfully in this c rop, though notalways with reliability. Sometimes the safety of the crop could be ascribed to depth protection, which cannot be relied upon in the diversity of circumstances in which this crop is grown. Therefore it is important to determine whether the potato has an inherent tolerance of the herbicide when present throughout its growing medium. Accordingly, the pot experiment described in this report was intended to ascertain which of 23 potential herbicides appeared likely to be safe for widespread use in potatoes and to be worthy of detailed study under field conditions. In this way the experiment formed a part of the larger programme on weed control in potato conducted by the Weed Research Organisation

MATERIALS & METHODS

Tubers once-grown from Scottish 'seed' were sprouted on a greenhouse bench in January. Cores of 1 in. diameter with a sprout centrally placed were removed with a cork borer. The resulting cylinders were cut at the bottom to leave 20g of tuber attached to the sprout, and placed on trays in a moist atmosphere to suberise for 4 days.

Pots, of 6.25 in. diameter, 5.75 in. depth, in fourfold replication and containing the equivalent of c.1800 g. of dry loam soil with added fertiliser, were sprayed with the various herbicides in water at 44 gal/ac, using a laboratory machine designed for spraying pots. The soil in each pot was thoroughly mixed on the following day by pouring 4 times through a funnel, thus incorporating the herbicide through the full soil depth. At this time the suberised potato cores were graded into four groups according to stage of sprout development and each replicate planted with one size. One core was planted per pot with the sprout 1 - 1.5 in. deep. Prior to planting, water was added to bring the soil to c.18% moisture content. The pots were arranged in randomised blocks on benches in a heated greenhouse. The sprouts broke surface in virtually all pots by the eleventh day after planting. From then onwards supplementary fluorescent lighting was used to increase the level of lighting on dull days and to extend the photo-period to 14.5 - 16 hours. Care was taken to avoid overwatering and thus any risk of leaching out of herbicide.

Visual observations of effects were made at intervals up to 7 weeks after planting. Shoots were then cut off at ground level, weighed fresh, dried at 83°C, and reweighed. The underground system was washed out, scored on an arbitrary 0 - 10 scale for amount of root growth, total number of stolons and of tubers, where visible, recorded, and the tubers dried for determination of their dry weight.

RESULTS

The main experiment was conducted on the variety Majestic which produced, in general, a large amount of vigorous and healthy growth, and at the conclusion of the experiment the controls had produced 1.5 g. dry weight of tuber per plant. There were, however, a number of plants obviously affected by virus and these were discarded. This reduced the statistical accuracy of the experiment but nevertheless clear differences, both qualitative and quantitative were recorded in the effects of the various herbicides. The data obtained are summarised in Table 1. A wide spread of doses were used because this was a preliminary experiment and little was known about the response of potato to these herbicides when present throughout the rooting medium.

The largest single group of herbicides included was the triazine (herbicides 1 - 11). All of them produced typical triazine symptoms of leaflet chlorosis followed by necrosis working in from the margins and ultimately abscission of the severely affected leaves, particularly at the highest dose. In many instances there was chlorosis at the lowest dose. The only treatments which remained reasonably healthy in appearance were the 0.5 lb/ac doses of propazine, simetryne and 4-isopropylamino-6-methylamino-2;methylthio-1,3,5-triazine, together with the 0.5 and 2.0 lb/ac doses of trietazine. The shoot weights show little or no effect from the low doses of all triazines except simazine and atratone, and from the middle doses of trietazine and all the methylthio triazines (8 - 11) except simetryne. Where shoot weight was reduced root growth was also affected. Likewise the number of stolons was reduced by the same treatments but were present in normal numbers where there had been little effect on the shoot. However almost all triazine treatments seem, at the very least, to have delayed tuber production by these stolons, with the result that the weight of young tubers was reduced substantially. A notable exception was the 0.5 lb/ac dose of simetryne where the tuber weight was increased significantly. The only treatment not to produce a significant effect on tuber weight was 0.5 lb/ac of trietazine. Considering all effects trietazine seemed to be the safest triazines when comparison is made at equivalent doses, followed by the methylthio triazines as a group. Within this group simetryne had the least inhibitory effect at the lowest dose but most effect at the middle dose, with little to choose between the other three members of the group.

The urea herbicides (12-16) produced symptoms generally similar to the triazines but with diuron and linuron chlorosis was more markedly veinal in distribution. Symptoms were much less intense with the lower and middle doses of linuron than with other urea treatments. This is reflected in the effects on shoot, root and tuber growth which indicate linuron to have caused least damage to potato, followed by CMU, and with fenuron as the most dangerous urea. The addition of BiPC to CMU, as in a herbicide mixture proposed commercially for other crops, led to a severe inhibition of shoot growth with masking of the urea type symptoms and the foliage becoming darker green than normal. Effects of the mixture on tuber initiation were severe.

Among the other herbicides diphenamid was of interest in that it caused little visible effect on the foliage other than a slight necrosis of the leaf margins at the highest dose. Inhibition of shoot growth was slight and effects on tuber growth were erratic. 2,6-dichlorobenzontrile was highly damaging to potato. Amiben was less obviously damaging but produced a severe inhibition of root growth which would undoubtedly have affected subsequent tuber growth.

Of the three amides combining amino triazole and phenoxy groups (21-23), N-(1',2',4'-triazole)-2,4-dichlorophenoxyacetamide had the least effect at equivalent doses. At the higher doses these herbicides caused the foliage to appear darker green than normal but with marginal chlorosis of the leaflets. There were marked effects on shoot, root and tuber growth.

In view of the large number of potato varieties which are grown the simazine and monuron treatments were repeated with cores from tubers of the variety King Edward. Shoots from control cores of this variety were taller and more spindly than comparable shoots of Majestic, but otherwise seemed as healthy. However, the effect of both herbicides was much more severe on King Edward than on Majestic potatoes. There was greater reduction in shoot and root growth, no stolons were visible except at the lowest dose, and no tubers whatever could be found in any treated pot.

DISCUSSION

The experiment fulfilled its main purpose by indicating those herbicides for which the Majestic potato has greater tolerance when distributed throughout its rooting medium. A relatively small proportion could be singled out as producing less toxic symptoms than the remainder and therefore worthy of extensive testing under field conditions. It must be emphasised, however, that although the amounts of herbicide used were selected to cover the range of doses needed for weed control no comparable weed data were obtained from the present experiment, and hence precise statements on selectivity in potato cannot be made.

Thus trietazine was clearly the safest of the triazine herbicides at equivalent doses, but it is generally regarded as inferior to many other triazines in its weedkilling capacity. Nevertheless, 2.0 lb/ac of trietazine produced markedly less effect on the potato than did 0.5 lb/ac of simazine whereas the difference in dose between these two triazines required to give equivalent weed control is not generally regarded to be of this magnitude. Hence it might be supposed that the maximum safe dose of trietazine could give better weed control than the maximum safe dose of simazine.

The potato appeared to have more resistance to methylthio triazines than to other groups of triazines. There were no clear cut differences between the four tested and more precise experimentation would be required to differentiate between them. They are effective weedkillers and worthy of further investigation in this context.

Among the ureas linuron was outstanding as being safer than diuron. Both herbicides are similar in the doses required to give comparable weed control. Diuron has already been reported from many countries to have some possibilities for selective weed control in potatoes. Therefore linuron might be expected to have considerable potentiality for selective use in this crop.

Diphenamid is of interest in that the potato has considerable tolerance to doses above those regarded as necessary for weed control.

The only other herbicides in the present experiment worth following up for use in potatoes appeared to be the triazole-phenoxy-amides. N-(1',2',4'-triazole)-2-4-dichlorophenoxyacetamide was the safest on the potato but other experiments have shown that this compound requires higher doses to give comparable weed control than do the other two compounds of this type which were tested. The position is still open therefore as to which would be most selective in potato. This group of compounds had been found to be of interest in potatoes earlier by D.S.C. Erskine (unpublished information).

The difference in degree of effect of simazine and monuron between Majestic and King Edward potatoes indicates the importance of testing out potentially selective herbicide treatments on a wide range of potato varieties during any investigation into their possible use in this crop.

Acknowledgments

D.W.R. Headford provided helpful information on the growing of potatoes in pots. Many members of the staffs of the Weed Research Organisation and the A.R.C. Unit of Experimental Agronomy assisted with the experiment. The following companies kindly provided the chemicals used in this work: Amchem Products, Badische Anilin - & Soda - Fabrik, Du Pont, Eli Lilly, Geigy (through Fisons Pest Control), A.H. Marks, Shell Research.

TABLE 1 THE EFFECT OF A RANGE OF SOIL-ACTING HERBICIDES ON MAJESTIC POTATO

Herbicide	Dose in lb/ac	Dry weight of shoot as per cent of control	Root growth scored on scale 0 - 10: means to nearest 0.5	No. stolons per plant	No. tubers per plant	Dry weight of tubers as per cent of control
untreated control		-	9.5	5.7	5.1	-
1. simazine	0.5	68	6.5	3.8	2.5	8
	2.0	24	4.0	2.7	0	0
	8.0	21	4.5	2.8	0	0
2. atrazine	0.5	81*	8.5	3.7	3.0	30
	2.0	16	4.5	1.8	0	0
	8.0	16	3.5	1.0	0	0
3. propazine	0.5	100*	9.0	6.3	3.7	38
	2.0	45	5.0	2.0	0.3	<1
	8.0	20	4.0	1.8	0	0
4. trietazine	0.5	87*	9.0	5.3	4.5	65*
	2.0	96*	9.5	5.0	3.5	48
	8.0	46	5.0	1.3	0	0
5. atraton	0.5	67	7.0	4.3	2.5	15
	2.0	28	5.0	2.5	0	0
	8.0	17	4.5	2.0	0	0
6. prometon	0.5	86*	7.5	5.5	3.5	26
	2.0	21	4.5	2.5	0	0
	8.0	12	4.0	1.8	0	0
7. 4-isopropylamino-6-methylamino-2-methoxy-1,3,5-triazine	0.5	85*	8.5	4.5	2.8	9
	2.0	20	3.5	3.3	0	0
	8.0	9	3.5	2.0	0	0
8. simetryne	0.5	105*	9.5	6.7	5.3	161
	2.0	63	5.5	4.7	2.0	5
	8.0	13	3.0	2.5	0	0
9. ametryne	0.5	83*	9.0	5.3	4.0	50
	2.0	79*	7.5	6.0	4.0	40
	8.0	18	4.0	2.0	0	0
10. prometryne	0.5	75	7.0	5.0	4.0	31
	2.0	86*	7.0	4.3	2.5	38
	8.0	23	5.5	3.3	0	0
11. 4-isopropylamino-6-methylamino-2-methylthio-1,3,5-triazine	0.5	92*	10.0	4.5	4.0	43
	2.0	90*	9.5	3.7	2.0	9
	8.0	17	4.5	2.5	0	0

Table 1 (Cont'd)

Herbicide	Dose in lb/ac	Dry weight of shoot as percent of control	Root growth scored on scale 0 - 10: means to nearest 0.5	No. stolons per plant	No. tubers per plant	Dry weight of tubers as per cent of control
12. fenuron	0.5	71	6.5	3.3	0.3	<1
	2.0	14	4.5	1.5	0	0
	8.0	39	3.5	2.3	0	0
13. monuron	0.5	83*	8.5	4.8	4.3	60
	2.0	24	4.0	3.0	0	0
	8.0	25	4.5	2.3	0	0
14. diuron	0.5	85*	8.5	4.7	3.7	49
	2.0	67	7.0	3.5	2.3	9
	8.0	20	4.5	2.0	0	0
15. linuron	0.5	105*	9.5	4.3	4.3	80*
(N-(3,4-dichlorophenyl)-	2.0	68	7.0	5.0	3.8	46
N'-methoxy-N'-methylurea)	8.0	41	5.5	3.3	0.3	<1
16. CMU	0.5	92*	9.0	4.3	4.0	62*
	2.0	29	4.0	3.0	1.0	<1
	8.0	20	3.0	1.5	0	0
17. CMU + BiPC	0.5+0.33	34	2.5	4.5	2.8	37
	2.0+1.33	32	1.5	3.8	0.5	1
	8.0+5.33	6	0	0.5	0	0
18. amiben	1.0	94*	9.0	5.5	4.5	55
	4.0	46	4.5	5.0	3.3	35
	16.0	17	0.5	3.7	3.0	20
19. 2,6-dichlorobenzonitrile	0.5	53	6.0	4.0	2.0	6
	2.0	0	0	0 -	0	0
20. diphenamid	0.5	98*	8.5	4.5	3.8	58
(N,N-dimethyl-	2.0	76	7.0	4.3	2.7	20
diphenylacetamide)	8.0	105*	9.5	4.3	3.3	81*
21. N-(1',2',4'-triazole)-	0.5	104*	9.0	4.8	4.5	62*
2-(2,4-dichlorophenoxy)	2.0	107*	9.0	4.8	3.5	70*
acetamide	8.0	34	2.5	5.0	4.3	68*
22. N-(1',2',4'-triazole)-	0.5	96*	8.5	5.0	4.0	38
2-(2,4-dichlorophenoxy)	2.0	74	6.5	5.0	2.3	18
propionamide	8.0	8	0	3.0	2.3	8
23. N-(1',2',4'-triazole)-	0.5	82*	8.0	4.5	3.0	29
2-(4-chloro-2-methyl	2.0	49	3.5	3.0	1.0	4
phenoxy)propionamide	8.0	4	0	2.3	1.0	1

* indicates treatment not significantly different from control at P = 0.05 (dry weights only analysed)

Research Report

CHEMICAL WEED CONTROL IN POTATOES

(A review of National Agricultural Advisory Service trials in 1961 and 1962)

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Summary: Six trials in 1961 and ten trials in 1962 were carried out with herbicides in the potato crop. The herbicides involved are ametryne, prometryne, trietazine, diuron, linuron, dinoseb, a mixture of dinoseb and TCA, and mixtures of paraquat with trietazine or simazine. The trials indicate that all the chemicals can considerably reduce the weed population in the potato crop but that the surviving weeds can subsequently form a heavy infestation. In 1961 dinoseb + TCA and in 1962 the two mixtures based on paraquat were the most successful treatments. The trials were unable to show which treatments were safest on the crop because of the effect of weed competion but it is suggested that the dinoseb and TCA mixtures, diuron at 2 lb and prometryne at 3 lb/ac should be regarded with some suspicion.

INTRODUCTION

In the winter of 1960-61 there were several requests to the Weed Research Organisation from the N.A.A.S. for herbicides for trial in potatoes. From a large number of candidate chemicals two triazine herbicides were selected as being particularly promising and these were made available to N.A.A.S. officers. It was suggested that they should be applied at two stages of growth of the crop, the first to the soil immediately after planting and the second at the time when the first one or two potatoes could be seen to be emerging. At the second stage some seedling weeds were expected to have emerged, but it was known that the selected triazines were to some extent leaf absorbed and were likely to control weeds at this stage.

Dinoseb alone or mixed with TCA had been used successfully in Scotland (Robertson 1960 and Wood et al 1960) and the treatment had raised interest. In view of this a mixture of dinoseb and TCA was included in the trials even though the treatments had drawbacks such as high cost and the statutory requirements of the Agriculture (Poisonous substances) Regulations. Suggestions for additional herbicides were not considered appropriate because the Weed Research Organisation was planning to screen a large number of chemicals in 1961.

The herbicides selected for the 1962 series of trials were those which had appeared most promising in the Weed Research Organisation and the N.A.A.S. trials in 1961 and include two substituted urea compounds (diuron and linuron), two triazine compounds (prometryne and trietazine) and two mixtures of triazine compounds with paraquat. Again it was suggested that the chemicals were applied at one or another or both of the two growth stages of the crop which had been used in 1961.

METHODS AND MATERIALS

(i) 1961 The treatments applied at the majority of sites were:-

Stage one - immediately after planting the potatoes
Prometryne at $1\frac{1}{2}$ and $2\frac{1}{2}$ lb/ac
Ametryne at $1\frac{1}{2}$ and $2\frac{1}{2}$ lb/ac
Dinoseb at 6lb plus TCA at 12 lb/ac
Stage two - as the potatoes were about to emerge.
Prometryne at $1\frac{1}{2}$ and $2\frac{1}{2}$ lb/ac
Ametryne at $1\frac{1}{2}$ and $2\frac{1}{2}$ lb/ac
Dinoseb at 6 lb/ac
Dinoseb at 6 lb plus TCA at 12 lb/ac
Unweeded control.

Details of each site are shown in Table 1.

The prometryne at stage one was omitted at Site 2 and Site 5 consisted of ametryne and prometryne at 2 lb/ac at both stages and TCA at 10 lb/ac as a stage two treatment. The volume rates used were 20 or 30 gal/ac for the triazines and 40 to 100 gal/ac for the dinoseb treatments. Plot sizes varied but all were small plots sprayed with knapsack spraying machines. They were 3 or 4 replicates of randomised blocks. The weeds present at the time of the second spraying are listed for convenience in Table 3 and in all cases the majority of all weeds were in the young plant just past the seedling stage. The plots were not cleaned by cultivations in any experiment except at Site 2 which was cleaned up after the weeds had offered considerable competition to the crop. At Site 3 a hand weeded control was included in addition to the unweeded control.

(ii) 1962 The treatments applied in the majority of the sites were:-

Stage one - immediately after planting the potatoes.
Trietazine at 1 and 2 lb/ac
Diuron at 1 and 2 lb/ac
Stage two - as the potatoes are about to emerge.
Prometryne at $1\frac{1}{2}$ and 3 lb/ac
Paraquat at $\frac{3}{4}$ lb with wetter plus trietazine at 1 lb/ac
Paraquat at $\frac{3}{4}$ lb with wetter plus simazine at $\frac{1}{2}$ lb/ac
Linuron at 1 and 2 lb/ac
Handweeded control
Unweeded control

Details of each site are given in Table 2. The only exception was Site 16 where the treatments were trietazine at 2 lb, linuron at 2 lb and prometryne at 3 lb/ac applied at stage one and prometryne at 3 lb and both the paraquat mixtures applied at stage two. Plot size varied from 20 feet by 4 rows to 24 yards by 7 rows. Each treatment was replicated 3 times randomised blocks at all Sites except 14 and 16 where there were 4 replicates of each treatment. Volume of water per acre varied as follows. 20 and 21 gal/ac at Sites 7, 8, 9, 10 and 14, 25 gal/ac at Site 15, 45 gal/ac at Sites 11, 12, and 13 and 50 gal/ac at Site 16. The weeds present at the time of the second spray are listed for convenience in Table 4 and in all cases the stage of the weed was seedling to just past seedling stage except for Sites 9 and 14 where some Sinapis alba (yellow charlock) was up to 4 or 5 leaves.

Assessment of weed control was made by scoring on a scale 0 to 10 where 0 = No weeds and 10 = maximum density of weeds. Scores were made at 7 sites of each main individual weed and in all trials a score for the total of all weeds present was made. Assessments were generally made at two times (i) 2-6 weeks after the second spraying and (ii) nearer harvest. After weed scores had been taken, hand cleaning was carried out at 3 sites and no further assessments made as the weed growth was too severe. At Sites 10 and 17 where the whole trial was involved in each case and Site 9 where only the stage one treatments were involved.

Assessment of the crop was made by observation of growth during the season and yields.

Site 13 at Winteringham was weed free.

RESULTS

(i) Weeds

Mean scores of weed control in each treatment in each trial are shown in Tables 3 and 4. The total numbers and species of weeds present and the time of the second spray are given in each Table. In Table 4 the relative importance of each weed is indicated by the abbreviations explained in the Table and at Sites 11 and 14 weeds marked * were not apparent at the time of the second spray but assumed some importance at the first assessment. In both Tables 3 and 4 dominant weeds at the time of the second assessment are indicated by underlining the name but where a weed is not underlined it does not necessarily mean that it was absent. Where no weeds are underlined in any one trial it implies that there was no dominant weed and that a more or less similar mixture of some or all of the weeds was present. Individual weed assessments are not tabulated. They show that most of the annual weeds listed were affected by the chemical treatments to a high degree but in the following cases resistance by individual weed species to a particular chemical were shown in 1962. None being apparent in 1961.

Diuron

Veronica spp. (speedwell) was resistant at Sites 8 and 11 whilst Fumaria officinalis (fumitory) was resistant at Site 12 and Polygonum aviculare (knotgrass) at Site 10.

Linuron

Veronica spp. (speedwell) was resistant at Site 8, Polygonum aviculare (knotgrass) at Sites 9 and 10, Fumaria officinalis (fumitory) at Sites 9 and 12 and Matricaria spp. (mayweed) at Site 7.

Prometryne

This had little effect on Matricaria spp. at Site 7.

Dinoseb

This failed to control grass seedlings at Site 12.

(ii) Crop

The mean total yields of potatoes (ungraded) are compared in Tables 5 and 6 where yields are given as a percentage of those obtained in the handweeded plots. The only exception is Site 16 with no handweeded control and yields in this case are given in tons of ware potatoes per acre.

1961 (Table 3)

The yields Site 1 are affected by indiscriminate lifting of potato plants by thieves whilst Site 3 was heavy and unevenly infested with couch grass.

With the exception of Site 5 the triazines in 1961 caused some temporary check to the crop often associated with slight yellowing at the edge of some of the lower leaves. Again with the exception of Site 5, both of the Dinoseb + TCA treatments had adverse effects ranging from slight to moderate leaf deformity in most cases to at Site 1 severe distortion and check which affected yields.

1962 (Table 6)

Most of the sites recorded leaf discolouration as a result of all chemicals at the second stage spraying which appears to be associated only with the plants actually through at the time of spraying. This was recorded as slight or very slight in the majority of cases and seemed to have little or no adverse effect. At two sites, 14 and 15 crop vigour assessments suggest that diuron at 2 lb may have reduced vigor but this is not obviously reflected in the yields at Site 15. At three sites it was noted in mid season that the trial site as a whole had a more vigorous growth of potatoes than had the farmers crop - which however subsequently caught up.

DISCUSSION

(i) Weeds

It is clear from Tables 3 and 4 that the treatments are capable of giving a high degree of weed control in the initial stages approaching 100 per cent in some cases, however it is also clear that by harvest time the remaining infestation has at least doubled. In considering the origin of the weeds present at harvest it is strongly suggested by the 1962 trials that they are weeds in the initial flush, which are not controlled by the treatments and are not weeds which germinated subsequently. Those uncontrolled weeds make vigorous growth as they do not have the restriction of the other weeds controlled by the herbicide and by harvest have made the considerable increase shown by the figures. This suggests that to avoid high infestations by harvest time the initial degree of control must be very high.

The picture for the trials carried out in 1961, is similar with the exception of Site 1 where it would seem that the "at harvest" infestation was largely composed of chickweed which had germinated as the potatoes died down and is perhaps outside the residual range of the herbicides concerned.

It may be false to assume any particular degree of resistance to the herbicides by the weeds which form the greater part of the "at harvest" infestation as the species concerned. Namely Chenopodium album (fat-hen), Polygonum aviculare (knotgrass), Fumaria officinalis (Fumitory), and Matricaria spp. (mayweed), are well known both for strong summer growth (even stronger in the absence of competitive weeds) and for their presence in potatoes at harvest time and the trials results may only be a reflection of this.

In 1962 the two most successful treatments are those containing paraquat and it is unfortunate that no treatment has been included based on paraquat alone as it is impossible to determine the value of the added triazines.

(ii) Crop

It is clearly impossible at the majority of sites in Tables 5 and 6 to separate any effects of the herbicides on the crop from the competing effect of the surviving weeds. The fact that the yields in Table 6 correlate in general quite well with the weed scores tends to support the view that the main factor involved in yield variation between treatments is one of weed competition. However it is worthy of note that the only figures not to correlate with weed population are for prometryne and when individual sites including the weed free Site 13 are considered the only case in 1962 where the 3 lb out yielded the $1\frac{1}{2}$ lb was at Site 9 where the weed population was very high. The results for prometryne similarly applied in 1961 show decreased yield for the higher dose at 3 Sites out of 5. This suggested that prometryne may adversely affect the crop. Site 13 (Weed free) demonstrates a reduction in yield following diuron 2 lb/ac which is supported by the observation at two sites that vigour of potatoes was reduced by diuron. As a result diuron at 2 lb must also be regarded as possibly toxic to the potato. In 1961 crop vigour in general and at Site 1 yields were adversely affected by both of the dinoseb plus TCA treatments.

All the unweeded plots are substantially down when compared with hand weeding, with the greatest reduction 76 per cent at Site 9 with its very high weed population and a mean reduction of 36 per cent.

In the three 1962 Sites where farmers crop was assessed it is interesting to note that the results are approximately 10 per cent below the hand weeded plots. This is supported by Site 3 in 1961 which is the only trial in that year to have made these yield assessments. Whilst between row variation in yield, can be quite high and much depends on how well the sampling of the farmers crop was done this probably reflects the damaging effects of the cultivations concerned and if this is so then the figure of 10 per cent reduction shown by many of the treatments may not be do unacceptable.

REFERENCES

ROBERTSON, I.M. (1960) The use of Herbicidal Sprays in Potatoes.. Proc Proc 5 Brit Weed Control Conf 55-60

WOOD, C.A., SUTHERLAND, J.P., and STEPHENSON, R.J., (1960) Trials of Chemical Weedkillers in Potatoes. Proc 5 Brit Weed Control Conf 60-65.

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TABLE I DETAILS OF EACH SITE 1961

Site	1 Bishop Auckland Northern	2 Wilberfoss Yorks and Lancs	3 Darrington Yorks and Lancs	4 Wisbech St.Mary Eastern	5 Eastern	6 Dorney South Eastern
Potato Variety	Majestic	Majestic	Majestic	King Edward	Arran Consul	Majestic
Soil Type	Heavy Clay Loam	Sand	Medium Loam	Sandy Loam	Silt	Gravelly Loam
Date of First Application	2nd June	30th March	10th April	28th April	17th April	12th May
Soil at First Application	Fine Dry Tilth	Soil Moist	Soil Wet	Rough Moist Tilth	Fine Very Dry Tilth on Top Moist Below	Cloddy Wet Below Drying On Top
Date of Second Application	20th June	12th April	15th May	15th May	10th May	2nd June
Soil at Second Application	Fine Dry Tilth	Soil Dry on Top Moist Below	Soil Dry on Top moist below	Very Dry on Top	Fine Very Dry	Cloddy Dry on Top Moist ches.

TABLE 2

Site	7 Wilberfoss Yorks and Lancs	8 Market Weighton Yorks and Lancs	9 Darrington Yorks and Lancs	10 Ormskirk Yorks and Lancs
Potato Variety	Majestic	Majestic	Majestic	Majestic
Soil Type	Sand	Sand	Medium Loam	Sandy Loam
Date of First Application	13th April	4th April	Trietazine 3rd April Diuron 11th April	30th April
Soil Condition at First Application	Moist but dry at surface	Moist but drying at surface	Moist but dry at surface	Dry for top 4" of soil
Date of Second Application	18th May	18th May	11th May	28th May
Soil Conditions at Second Application	Moist but dry at surface	Moist but dry at surface	Moist but dry at surface	Dry and dry at surface

DETAILS OF EACH SITE 1962

11 East Bergholt Eastern	12 Spalding Eastern	13 Winteringham Eastern	14 Stokesley Northern	15 Clwmp Wales	16 East Hampstead South Eastern
Majestic	Majestic	King Edward	Majestic	Craigs Royal	Majestic
Silty Loam	Sandy Loam	Clay	Clay Loam	Medium Loam	Sandy Loam
17th April	25th April	19th April	27th April	30th April	11th May
Moist but dry at surface	Moist but dry at surface	Moist and moist at surface	Moist and moist at surface	Dry and dry at surface	Moist and moist at surface
15th May	11th May	14th May	30th May	16th May	31st May
Dry and dry at surface	Moist but dry at surface	Moist but dry at surface	Dry and dry at surface	Dry and dry at surface	Moist and moist at surface

TABLE 3 EFFECT OF TREATMENTS ON WEEDS 1961

10 = Maximum Weed   0 = No Weed

Treatments lb ai per acre	Stage at which applied (1) Immediately after planting (2) At emergence	1		2	3		4
		13th July	26th Sept	5th June	6th June	28th Sept	1st June
Prometryne 1½ lb	(1)	1.3	6.0	-	4.5	5.3	5.4
Prometryne 2½ lb	(1)	0.3	7.7	-	0.8	5.3	3.5
Ametryne 1½ lb	(1)	0.2	6.7	3.7	3.7	4.0	5.1
Ametryne 2½ lb	(1)	0	5.3	3.0	0.8	3.0	2.2
Dinoseb 6 lb + TCA 12 lb	(1)	0	6.7	5.0	0.2	7.7	0.7
Prometryne 1½ lb	(2)	0	6.0	5.3	2.1	7.7	1.7
Prometryne 2½ lb	(2)	0	6.0	2.7	1.8	4.7	1.4
Ametryne 1½ lb	(2)	0	7.7	3.0	3.2	9.0	0.5
Ametryne 2½ lb	(2)	0	5.3	1.0	0.5	6.7	0.4
Dinoseb 6 lb	(2)	0	8.3	7.7	2.8	8.3	0.4
Dinoseb 6 lb + TCA 12 lb	(2)	0	5.7	1.0	2.5	1.0	0.2
Control		7.3	9.9	10.0	5.0	4.7	10.0
No. of annual weeds present per square foot and Weeds species present at second spray. The main weeds at harvest are underlined		65 Chenopodium album Spergula arvensis Raphanus raphanistrum Stellaria media Matricaria spp		20-40 Chenopodium album Spergula arvensis Polygonum convolvulus Stellaria media Polygonum persicaria Polygonum aviculare Senecio Vulgaris	6 Polygonum aviculare Stellaria media Sinapis arvensis		10-11 Chenopodium album Polygonum aviculare Stellaria media Veronica arvensis Polygonum persicaria

	7		8		9		10	
Treatments lbs.of active Ingredient	20th June	7th Sept	20th June	7th Sept	24th June	4th July	15th June	13th Oct.
Trietazine 1 lb.	2.3	6.3	3.0	5.0	4.8	-	4.0	7.9
" 2 lb.	2.3	7.0	3.3	3.3	5.1	-	2.0	4.6
Diuron 1 lb.	2.7	8.0	4.0	2.7	9.3	-	3.8	6.5
" 1 lb.	1.7	5.0	2.7	3.3	6.0	-	3.0	4.3
Prometryne 3 lb								
Prometryne 1½lb.	1.0	6.3	3.0	2.7	4.8	6.8	1.3	4.6
" 3 lb	1.7	6.3	2.7	2.7	2.3	2.9	1.8	3.2
Paraquat ¾ lb.+ Trietazine 1 lb.	0.0	3.0	1.0	2.3	0.0	1.1	1.0	2.1
Paraquat 3 lb.+ Simazine ½ lb.	0.0	3.3	0.3	1.3	0.3	1.4	1.3	2.5
Linuron 1 lb.	1.3	6.3	2.7	2.3	6.3	10.0	3.3	6.5
" 2 lb.	2.3	7.0	1.7	1.3	3.8	7.5	2.3	6.1
Dinoseb 6 lb.								
Handweeded Control	1.0	7.3	0.7	0.7	1.0	1.0	0.0	3.6
Unweeded Control	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

	7	8	9	10
No.of annual weeds per Square Foot and	15	20	80-110	15-20
weeds present	Stellaria media H	Stellaria media H	<u>Polygonum aviculare</u> H	Polygonum aviculare H
at second appln.	<u>Chenopodium album</u> M	Raphanus raphanistrum M	<u>Fumaria officinalis</u> M	Stellaria media
H-High proportn. of infestation	Veronica spp M	Veronica spp M	Veronica spp M	Chenopodium album M
M-Moderate	Polygonum convolvulus M	Polygonum convolvulus M	Stellaria media M	Spergula arvensis M
L=Low or variable	Myosotis arvensis M	Myosotis arvensis M	Chenopodium album M	Seedling grasses M
The main needs at harvest are underlined. Weeds not present at second applicatn. which came later are marked +	Spergula arvensis M Matricaria spp L	Spergula arvensis M	Sinapis arvensis L Polygonum convolvulus L Galium aparine L	

ASSESSMENTS 1962 10 = Maximum Weed 0 = No Weed

11		12		14		15		16	
30th May		28th May	3rd July	7th Aug		5th June	28th Aug	10th July	11th Sept
3.9 2.5	No assessment but noted less weed on paraquat plots	3.0 0.8	8.7 7.7	5.5 4.5		5.0 2.1	7.7 6.0	1.5	2.3
6.0 6.3		1.7 1.5	9.0 8.7	4.3 1.5		2.5 0.3	6.3 3.7		
								3.8	3.7
2.3 1.2		1.0 0.7	6.3 2.0	2.3 0.6		1.3 0.7	3.0 1.2	1.3	1.1
1.7 0.9		0.2 0.1	2.0 4.0	0.0 0.6		0.3 0.0	0.7 1.7	2.5 2.5	5.2 4.6
1.3 1.5		2.1 0.5	9.0 7.7	4.5 0.0		1.3 1.0	3.3 2.7	1.2*	1.8*
0.7		0.7	3.0						
- 10.0		- 10.0	10.0	0.3 10.0		0.0 10.0	2.3 10.0	10.0	0.5+

7	42	6	13	12
Sinapis arvensis H Galium aparine L Polygonum aviculare L Polygonum convolvulus L Stellaria media L Seedling Grasses L Veronica spp +	Matricaria spp H Capsella bursa-pastoris H Fumaria officinalis M Veronica spp M Chenopodium album M Senecio arvensis M Polygonum aviculare L Stellaria media L Seedling grasses L	Sinapis arvensis M Seedling Grasses M Stellaria media L Polygonum aviculare L Fumaria officinalis L Chenopodium album + Polygonum persicaria + Galium aparine +	Galeopsis tetrahit M Polygonum persicaria M Sinapis arvensis M Stellaria media M Polygonum convolvulus L	Polygonum aviculare H Seedling Grasses H Stellaria media M Chenopodium album L Chenopodium album only +Farmers crop *Applied at first stage

TABLE 4 MEAN WEED ASSESSMENTS 1962 (cont'd)

10 = Maximum Weed
0 = No Weed

	Mean of 8 sites excl. 16	Mean of 5 sites Ecl. 9, 11, 14, 16	
Treatments lbs. of active Ingredient	First Assessment	First Assessment	Second Assessment
Trietazine 1 lb	3.9	3.5	7.1
" 2 lb	2.8	2.1	5.7
Diuron 1 lb	4.3	2.9	6.5
" 1 lb	2.9	1.8	5.0
Prometryne 3 lb			
Prometryne $1\frac{1}{2}$ lb	2.1	1.5	4.6
" 3 lb	1.5	1.5	3.1
Paraquat $\frac{3}{4}$ lb + Trietazine 1 lb	0.5	0.5	2.0
Paraquat 3 lb + Simazine $\frac{1}{2}$ lb	0.4	0.3	2.6
Linuron 1 lb	2.9	2.1	5.5
" 2 lb	1.6	1.6	5.0
Dinoseb 6 lb			
Handweeded Control			
Unweeded Control	10.0	10.0	10.0

TABLE 5 MEAN YIELD OF POTATOES, 1961

TREATMENTS lb per acre	Stage at which applied (1) = Immediately after planting (2) = At emergence	1	2	3	4 (as tons per acre)	5	6	Mean
Prometryne at $1\frac{1}{2}$ lb	(1)	112	-	137	16	-	105	-
" " 2 lb	(1)	-	-	-	-	111	-	-
" " $2\frac{1}{2}$ lb	(1)	123	-	119	$15\frac{1}{2}$	-	91	-
Ametryne at $1\frac{1}{2}$ lb	(1)	143	159	102	$16\frac{1}{2}$	-	109	128
" " 2 lb	(1)	-	-	-	-	106	-	-
" " $2\frac{1}{2}$ lb	(1)	128	186	124	16	-	88	132
Dinoseb at 6 lb + TCA 12 lb	(1)	25	137	111	-	-	107	95
Prometryne at $1\frac{1}{2}$ lb	(2)	105	168	140	17	-	114	132
" " 2 lb	(2)	-	-	-	-	122	-	-
" " $2\frac{1}{2}$ lb	(2)	74	159	162	16	-	126	130
Ametryne " $1\frac{1}{2}$ lb	(2)	62	155	108	18	-	117	110
" " 2 lb	(2)	-	-	-	-	132	-	-
" " $2\frac{1}{2}$ lb	(2)	83	172	117	17	-	114	121
Dinoseb at 6 lb	(2)	90	114	162	-	-	109	119
Dinoseb at 6 lb + TCA 12 lb	(2)	33	178	124	-	(120)	126	115
Hand weeded plots		-	-	186	-	-	-	-
Control (unweeded)		100	100	100	-	100	100	-
		(= 18 tons per acre)	(= $10\frac{1}{2}$ tons per acre)	(= 6 tons per acre)		(= 18 tons per acre)	(= $5\frac{3}{4}$ tons per acre)	100
Farmers crop		-	127	169	-	-	176	-

TABLE 6 - MEAN YIELD OF POTATOES 1962

Site	7	8	9	10	13	14	15	16	Mean Excluding 16
Trietazine 1 lb		89.5	Not recorded		90.4	99.4	87.0	Tons of ware per acre	91.6
Trietazine 2 lb		116.6			95.5	97.2	96.4	10.0	101.4
Diuron 1 lb		67.6			95.1	92.2	85.6		82.6
Diuron 2 lb		96.6			83.2	83.6	92.4		89.0
Prometryne 3 lb								10.7	
Prometryne $1\frac{1}{2}$ lb		110.5	60.6		99.1	101.6	90.0		92.5
Prometryne 3 lb		88.7	73.7		92.2	101.8	76.9	12.6	86.7
Paraquat $\frac{3}{4}$ lb + Trietazine 1 lb		127.1	94.1		102.1	108.8	91.3	10.6	104.7
Paraquat $\frac{3}{4}$ lb + Simazine $\frac{1}{2}$ lb		123.7	85.3		100.6	107.2	107.2	11.1	104.8
Linuron 1 lb		97.4	36.5		106.0	104.0	92.8		87.3
Linuron 2 lb		88.7	69.3		97.1	103.2	101.1	10.7*	91.9
Hand Weeded		100.0	100.0		100.0	100.0	100.0		100.0
Unweeded		63.9	23.4			83.6	84.1		63.8
Farmers Crop		92.1	91.9		89.6			14.4	
		100 = 15.0 tons per acre	100 = 15.8 tons per acre		100 = 14.8 tons per acre	100 = 17.4 tons per acre	100 = 15.4 tons per acre	*Applied at first stage	

Presentation by Mr. S. A. Evans of preceding three papers

Not many years ago to ask for a herbicide for use in potatoes would have been tantamount to admitting bad husbandry. Why then the big interest in herbicides now? The cost of post-planting cultivations is generally quite small, perhaps no more than £3 per acre. The cost of some of the herbicide treatments reported by Neild and Proctor are double this. On some farms potato cultivation may come at a time when labour is required elsewhere, but the cultivation of potatoes is a rapid process. 50 acres or so can be dealt with by a man and a tractor in 3 days and such a low labour demand is not usually embarrassing to the potato grower. Herbicides are not therefore likely to reduce the cost of post-planting cultivation or have a big effect on the labour situation as far as weed control is concerned at least. There are other reasons for wishing to eliminate post-planting cultivations.

At the last conference I.M. Robertson pointed out that the passage of tractor wheels along the rows during cultivation operations can increase the number of soil clods and that these clods are difficult to separate from tubers in mechanical potato harvesters. The stirring of soil by cultivations can also lead to moisture loss which may affect yield, particularly where repeated deep cultivations are employed. Some farmers do not consider they have cultivated well until the potato plant has been moved round 360° in the soil, a quarter of a turn with each cultivation. The Potato Marketing Boards Survey of Maincrop Potatoes in 1958 shows an average of nearly 6 post-planting cultivations in the crops they surveyed (harrowing 2.0, other cultivations 2.3, ridging 1.6). Such disturbance is bound, one would think, to have a detrimental effect on the growth of the potato. Evidence is accumulating to show that cultivations may reduce crop yield. Neild and Proctor in their paper state that at 4 of their sites where the comparison was made, the farmers normally-cultivated crop was lower in yield than the crop in the hand-weeded plots and they suggest that this probably reflects the damaging effects of cultivation. The detrimental effects of cultivations have been dramatically demonstrated at the Weed Research Organisation at Begbroke Hill this year where crop yield following a successful herbicide treatment without cultivations was 4 tons of ware per acre more than the yield following traditional cultivations. Increase in yield is probably going to be one of the major factors in the initial acceptance of herbicides in potatoes.

An interesting side effect of the lack of cultivations has been noticed in several trials by the N.A.A.S. Late frosts have damaged the foliage of potatoes grown with normal cultivations whilst potatoes in uncultivated plots have shown no symptoms of damage as a result, presumably, of greater radiation of heat from an uncultivated soil surface.

So far I have discussed herbicide usage in relation to existing methods of potato production and the field trials reported by Neild and Proctor were all carried out on potatoes grown in the normal way. However, if post-planting cultivations are superseded by sprays then the system of growing can be changed. The inter-row cultivator and ridging plough no longer dictate the row width. Indeed where soil-applied herbicides are to be used it may be desirable to avoid ridges. The application of a spray over the ridges can lead to uneven distribution of the herbicides, a higher concentration being deposited along the top and bottom of the rows than on the side of the ridge. Moreover, erosion of the ridges may lead to lack of weed control on the eroded areas.

Should a herbicide require to be mixed into the top inch or so of soil, ridges would be an embarrassment. The absence of ridges may be desirable for other reasons too. For example irrigated water is likely to accumulate in the bottom of the rows, although the water is mainly required in the ridges themselves. The argument that ridges as such play a significant part in the prevention of tuber blight infection seems now to be generally unsupported. The only vindication for ridges seems to be that they facilitate the covering of tubers and so prevent blighting and greening of tubers. The stolons of potatoes however grow out horizontally and therefore with suitable planting depth and probably suitable variety and suitable soil tilth it should not be too difficult to overcome the problem of tuber exposure on level ground.

An interesting point noticed by Barker of the N.A.A.S. at Kirton in a trial of his was that tubers from potatoes grown in ridges were a better shape than those grown in very low ridges and he attributed this to differences in soil density.

Recent work has shown that the spacing of potato plants can influence not only the total yield but also tuber size. Closer spacing than at present used may be required for maximum yield of potatoes of the right size. Work on plant density is being undertaken by the National Vegetable Research Station, National Institute of Agricultural Engineering and the N.A.A.S. Barker at Kirton for example suggests as a result of a preliminary trial that for Majestic potatoes the optimum planting pattern may be in beds with tubers set out "on the square" and quite close together.

Much of what I have been saying is still of course conjectural. We need much more information on many aspects, including for example a study of stolon behaviour and tuber formation of different varieties of potato under varying conditions. Further field trials are required to study the crops behaviour when planted at different depths and densities with and without ridging up. However, it is against such a background that we must consider herbicides. I said that improved crop yields may be one of the principal reasons for the first adoption by farmers of herbicides in potatoes; but the significance of herbicides is much greater than this. They will probably in the end become, under changed systems of husbandry, a sine qua non for potato growers.

The three papers we are now considering summarise some of the first systematic investigations in this country into discovering herbicides suitable for potatoes. It is unfortunate that the conference is held so early in the autumn because this has meant that a large amount of work done by the Weed Research Organisation this year cannot be reported as results are only now being collated. We must be particularly grateful to Neild and Proctor who have gone to some considerable trouble and burning-of-midnight-oil to rush the results of the series of N.A.A.S. trials to us.

Weeds in potatoes can be divided into three, possibly four, groups.

1) Annual weeds emerging about the same time as the crop 2) Perennial weeds such as Agropyron repens (couch); Cirsium arvense (creeping thistle) and Convolvulus arvensis (bindweed) 3) Annual weeds growing after the potato foliage has died back in late summer. The fourth group concerns weeds which become apparent during the summer when the potatoes are well grown, the most notable weed in this respect being Chenopodium album (fat hen). The concensus

of people whom I have asked and who are familiar with the potato crop seems to be that fat hen which appears in this manner has in fact germinated late in the season. Neild and Proctor however, suggest that all the weeds present in their trials at harvest time are weeds that germinated early-on. I should like to ask them if they have any evidence to support the view that fat hen in particular can germinate under a well-grown crop of potatoes. This may be important when considering the period of time over which weed control is desirable.

The three papers before us are all concerned with pre-emergence herbicides for the control of annual weeds. The papers by Milford and Pfeiffer and by Holly deal with pot experiments where the herbicide was mixed with the soil and into which potato cores were planted. In both cases the variety 'Majestic' was used, although Holly did compare 'Majestic' and 'King Edward' and found the reaction of the two varied in response to the same herbicide. Milford and Pfeiffer used sand and compost whilst Holly used a loam soil. Holly did no work with weed species in his trials but Milford and Pfeiffer sowed seed of charlock (Sinapis arvensis) chickweed (Stellaria media) and fat hen (Chenopodium album) along with the potato cores. These are undoubtedly some of the most important weeds of potato. Judging from Neild and Proctor's paper and other sources, further weeds of importance are Polygonum spp. particularly knotgrass (P.aviculare) and redshank (P.persicaria), fumitory (Fumaria officinalis) and speedwell (Veronica spp.)

Milford and Pfeiffer report only on triazine herbicides. One important point they make is that the growth of potato foliage is no indication of the effect of treatments on tuber formation and they stress that any work on the effect of herbicides on potatoes must include yield data. For example in their Figure 1 they show that simazine has little effect on foliage at up to 1 lb/ac but that reduction in the yield of tubers starts at a much lower dose than this: and a similar pattern was obtained with other triazines. I quote them: "The authors are aware of the danger of extrapolating pot experiment results to field problems, nevertheless, they are convinced that valid assessments of crop damage in field trials on potatoes can only be obtained from yield data rather than visual scores".

In their paper Milford and Pfeiffer produce a selectivity index based on a minimum dose for adequate weed control (see their figure 2). I should be interested to hear what they consider to be adequate weed control in view of the statement by Neild and Proctor - I quote - "to avoid high infestations (i.e. of weed) by harvest time the initial degree of control must be very high" They say this because of the vigorous growth observed on weeds which survived an herbicide treatment.

Are we then to demand virtually 100 per cent control of germinating weeds and if so over how long a period must the herbicide persist to achieve this? The answer will of course be influenced by the crop itself. A closely planted crop, e.g. in beds as already mentioned, will produce a competitive canopy more quickly than a traditionally spaced crop and under such conditions we may not have to ask so much of our herbicide.

The suppressive effects of weeds on potatoes is remarkable. Milford and Pfeiffer give a figure of 72 per cent reduction of tubers and Neild and Proctor show yield reductions in the field of 16 to 76 per cent.

The triazine herbicides which Holly found to be safest were trietazine and the methyl-mercapto triazines, i.e. simetryne, ametryne and prometryne. Milford and Pfeiffer however found simetryne and ametryne in particular to be poor at controlling weeds and they gave them a low selectivity index. I will however, return to these herbicides in a minute. Trietazine showed a better selectivity index and they also found similar selectivity with G 34361, atrazine, simazine and prometone.

There are certain practical aspects which these papers do not cover. One is the influence of soil type on the activity of the herbicides, a factor which is of considerable importance. Another is the problem of movement of the herbicide in the soil. In these trials the potatoes were grown in soil into which the herbicide was mixed. In practice the herbicides are likely to be applied to the soil surface or mixed only into the top layer of the soil. The mobility of the herbicides in soils is not discussed by the authors. The generally low level of the selectivity indices with triazines given by Milford and Pfeiffer suggest that for satisfactory practical use some degree of so-called 'soil protection' of the crop may be necessary. This is substantiated by the fact that these authors show atrazine as having one of the best selectivities indices, whilst field work at Begbroke Hill (unpublished data) has shown this relatively mobile triazine to be rather toxic to potatoes at doses required for reasonable weed control. On the other hand a herbicide somewhat toxic to plants might be acceptable if it were relatively immobile.

Mixing-in also affects the toxicity of herbicides to weeds. Milford and Pfeiffer show a figure of 1/3 lb/ac of atrazine in sand and compost as giving 98.2 per cent weed control but the dose of atrazine recommended for surface application in the field, i.e. for weed control in maize, is 1 to $1\frac{1}{2}$ lb/ac. At Begbroke Hill in field trials the methyl-mercapto triazines have on the other hand been reduced in toxicity to weeds when incorporated as compared to surface application. The solubility of these herbicides may make them more reliable weedkillers than, say, trietazine which is relatively insoluble and which may have the disadvantage noticed in simazine of not working too well in dry conditions. Further the methyl-mercapto triazines are effective through the leaves of weeds and prometryne has been used quite successfully in the N.A.A.S. trials as a combined contact-cum-residual herbicide, applied just prior to potato emergence. All these factors obviously affect the validity in practical terms of Milford and Pfeiffers selectivity index.

Investigations on soil-applied herbicides are full of snags (I commend you to read again the last paragraph of Milford and Pfeiffer's Paper), but the two papers on the pot-experiments are valuable in indicating promising herbicides. Other herbicides than triazines which Holly considers worthy of further investigation are linuron, dephanamid and the triazole-pheonoxy-amides. The field work at Begbroke Hill is producing corroborative evidence that trietazine, the methylmercaptotriazines and linuron are promising. They are also showing diuron as being too toxic for potatoes and this ties in with the N.A.A.S. results.

The value of herbicides depends of course on the weeds they will kill and the N.A.A.S. results give some information. An important point concerns the time of application. It seems that, with the herbicides available, their application just prior to potato emergence may be better than immediate-post-planting treatment. By the time of the later application many weeds can have germinated so that the inclusion of a contact herbicide, such as paraquat, seems necessary with simazine or trietazine which have negligible foliar activity. Sometimes a contact pre-emergence herbicide alone without an added residual herbicide can produce an effective control of weeds for some considerable time. It would have been interesting if the N.A.A.S. trials in 1962 had included paraquat on its own as well as in mixture with trietazine and simazine so that the contribution to weed control of each of the constituents of the mixture could have been ascertained. This would have been particularly interesting with regard to trietazine, which at 1 lb/ac at the immediate-post-planting application gave only a moderate weed control. The mixtures of trietazine or simazine with paraquat were generally the best treatments in the N.A.A.S. trials giving on average the best weed control and the best yields.

Finally for those of us who are looking for a practical recommendation for weed control in potatoes, the present three papers do not of course give us the answer. They do however indicate some very promising treatments amongst which is the mixture of trietazine and paraquat, which on the evidence of pot experiments seems preferable to a mixture of simazine and paraquat. More soluble triazines may be preferable to these in terms of reliable weed control, prometryne in particular must obviously be looked at further. Linuron also looks useful, but judging from the N.A.A.S. trials, it does not seem to control too well some of the important weeds of potatoes such as fumitory (Fumaria officinalis) and knotgrass (Polygonum aviculare). Diphenamid and the triazolephenoxy-amides must obviously be looked at further.

Discussion on preceding four papers

Mr. G. F. J. Milford I would like to reply to Mr. Evans concerning what we consider an adequate level of weed control. Attention has been drawn in the review to the fact that weed competition can reduce potato yield by 76 per cent. Herein lies the answer to his question. In our experiments we estimate a level of 90-100 per cent weed control to be an acceptable level. In these we were dealing with a single flush of weeds from a single sowing and under field conditions the germination of weeds within a population tends to be a continuous process and therefore we consider that residual control of weed species lasting from 6-8 weeks is more or less necessary. Furthermore, I would like to emphasize that in our experiments we were only considering the physiological selectivity of the herbicides in relation to the potato; we had no intention of considering the physical factors. The reason for this is that the problem of finding a suitable herbicide to control weeds in potatoes is difficult. In our preliminary tests we confined results to the physiological selectivity at cell level and we estimated that under field conditions the factors of physical selectivity would be additive to these.

Chairman Perhaps Professor Jones would like to comment on growing crops in a weed free environment.

Professor G. Jones I would not want to make too many comments on this particular aspect because I think it would take a good deal of time, certainly in relation to maize growing and to a lesser extent potatoes and soya beans. We are growing these crops without any inter-row cultivation and have established these practices among our growers; we could take this system one step further and try to eliminate ploughing but at this stage we have not done so. With regard to maize growing, we attempt to get the land fertilized, winter ploughed and in the following spring, disced once, enough to allow the man to go through and sow the seeds; then we spray and walk away from the crop. But the difficulty has been with potatoes that we are growing on hills and not on the flat and I was interested in the comments made in this respect. We have been trying to find pre-emergence preventative weed control for potatoes and have been reasonably successful with regard to the products mentioned. A combination of diuron and dalapon has been reasonably successful. For farm use with post-emergent weed control this year we are using Stam.F.34 post-emergence at a dose of $\frac{3}{4}$ lb per acre.

Dr. Van der Zweep I would like to express the interest of continental countries. Two weeks ago I visited Northern Ireland and the work done there I found stimulating. On the same day that there was a symposium in England there was another going on in Holland. We notice a little 'ivory tower' attitude in soil scientists and they are rather far away from this important aspect of the work at the moment, which is a challenging one; but the work is going on on the continent.

Research Summary

A NEW METHOD OF SPRAYING WHICH VIRTUALLY ELIMINATES DRIFT

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When spraying hormone weedkillers by conventional means there is a risk of drift damage to adjacent susceptible crops. Although the factors affecting the production of drift droplets are to a great extent known, there has up to the present been no drift-free method of spraying suitable for a wide range of wind conditions which is applicable to tractors. I will now describe an entirely new method of spraying which should go a long way towards solving this problem.

One method of applying hormone weedkillers without drift is to use a fine rose on a watering can, though this is hardly a method applicable to a tractor. As a first step we can take this rose and elongate it into a tube bringing the holes into a line along its length. However, to obtain an adequate ground cover it is necessary to place the holes no more than say 3/8 in. apart. Even at low pressures as when using a watering can, a high rate of liquid application is inevitable. Our problem was to obtain a similar ground cover with a much lower rate of application. This we have achieved by vibrating the tube at right angles to the direction of tractor travel. This is the new method of spraying - the vibrating boom - or as I shall now refer to it - the Vibro-boom. It enables the holes to be placed 2 in. - 4 in. apart and most important - it allows the pressure to be increased to 2 - 5 p.s.i. This increases the liquid ejection velocity which we consider aids the subsequent re-distribution within the crop. The tube may be vibrated at any practical speed and amplitude, but unless otherwise stated, the trials which have been carried out were done with a boom vibrating at approximately 1,000 v.p.m. with an amplitude of 3/8 in.

I would now like to describe some of the tests and trials that have been carried out to demonstrate the no-drift characteristics of the Vibro-boom, and its effectiveness as a sprayer. First, no-drift:-

High speed cine photographs were taken of its action which showed that an expanding wave form of droplets was produced. This indicated that all the droplets were moving at the same speed, and it could therefore be assumed that they were of approximately the same size. At least it was a fair assumption that droplets of drift potential were not being produced. This was tested in practice by arranging tomato plants at distances of 3, 6 and 9 ft from the line of travel of the end of a spray boom. MCPA was sprayed using the Vibro-boom for one set of plants, and a conventional sprayer at 30 p.s.i. for another set. The wind velocity was approximately 10 - 12 m.p.h. blowing directly from the sprayers to the plants. All the plants opposite the conventional sprayer showed severe epinasty within 1 week. Those opposite the Vibro-boom continued to grow in a normal manner.

To determine the effectiveness of the Vibro-boom as a sprayer, a limited number of field trials were laid down in both cereals and grass, and compared with adjacent plots sprayed by a conventional sprayer. In all cases we have found it to be as effective as a conventional sprayer.

I will quote a report on one of our trials.

"A crop of barley was sprayed on 24th May 1962 with the Vibro-boom. The barley had 2 - 3 tillers and was about 9 - 10 in. high when sprayed. Chickweed, mayweed, fat hen and corn pansy were the main weeds and MCPA at 1.5 lb a.e. in 25 gallons per acre was applied.

"The crop was walked on 1st June and 18th June and it was judged that a good commercial control of weeds was achieved. Fat hen and corn pansy showed severe epinasty, whilst chickweed and mayweed were checked.

"This was regarded as very satisfactory penetration in a somewhat "proud" crop and it compared very favourably with the area of the field similarly treated with a conventional type sprayer about two days later.

"Despite a strong cross wind at the time of spraying, sugar beet growing adjacent to the barley was totally unharmed, although the nearest plants were 1 - 2 ft from the spray".

We will now consider some of the characteristics of the Vibro-boom that have been indicated from our experimental investigations.

a. The droplet size appears to depend on the size of the drilled hole and not on the speed of vibration or amplitude. Quoting two droplet counts, using a 1/32 in. diameter hole the majority of droplets ranged from 350 to 1600 μ; using a 1/64 in. diameter hole droplets ranged from 400 to 1100μ.

b. Increase in the speed of vibration for a given amplitude increases the cone angle or spread of droplets from a single hole. Thus in one test the spread was increased threefold by increasing the vibrations from 1300 to 3200 v.p.m.

c. Increase in the speed of vibration theoretically improves the ground cover obtained for a given forward speed.

d. An increase in the operating pressure decreases the cone angle or spread from any hole.

Finally, although we have no experimental evidence, we expect the surface condition of the hole to affect the no-drift characteristics if high pressures are being used.

Quite apart from the elimination of drift, it is considered that this method of spraying could have the following further advantages when compared with the present methods of spraying.

a. The boom may be brought closer to the crop without the danger of complete missing. This could be useful on uneven ground. In fact, the boom can be operated in the weed foliage and yet obtain a completely even kill.

b. The blockage of a hole does not produce a complete miss as hole spacings of the order of 2 - 4 in. allow complete overlap from the spread from adjacent holes.

c. Due to the relatively low ejection speed from the holes, it is expected that the rate of wear will be reduced and that a sprayer will maintain its calibrated spraying rate for a longer period.

The Vibro-boom is being incorporated into a commercial tractor-mounted sprayer. In this model the vibrations are obtained from a cam and lever system which is made integral with the pump, and transmitted to the spray boom by means of Bowden type cables. In common with present day sprayers it is therefore possible for the pump to be simply slipped on and off the P.T.O. of the tractor. The boom is in three 6 ft sections, and due to the method of transmitting the vibrations, will continue spraying even when the break back mechanism operates on striking obstructions.

The holes 1/32 in. diameter are drilled along the spray boom at an interval of $2\frac{1}{2}$ in. An amplitude of 3/8 in. is used at approximately 1,000 v.p.m. It is therefore possible to apply 16 gallons per acre using a forward speed of 4 m.p.h. with a pressure of 2 p.s.i. The liquid application rate can of course be increased either by a reduction in the forward speed, or by increasing the liquid pressure.

In conclusion, it is considered that the Vibro-boom method could have a potential beyond the spraying of hormone weedkillers. The increasing awareness of the undesirable contamination of adjacent crops with other crop protection chemicals should be borne in mind. I submit that the Vibro-boom provides a method of spraying that is practically drift free, and from the evidence available is as effective as a conventional sprayer, with possibly some additional advantages. This method of spraying is actively receiving our attention with a view to further development.

Discussion of preceding paper

Mr. R.F. Norman The development of the vibrating boom is a most interesting one in that it does appear to provide a new method of application. However, in order that we may be able to assess it more precisely there are several questions which appear to require an answer. In order to be brief I would summarise these as follows:-

1. Can Mr. Sharp give us any indication of the S.M.D., V.M.D., or M.M.D. of the droplet spectrum.

2. There appeared on one of the slides to be a degree of droplet shatter. This might well lead to a formation of satellites.

3. Could Mr. Sharp give us any information on the effect of formulants, leaf angle, or other factors on the catch and shatter of this type of droplet. In spite of the low terminal velocity one would anticipate a fairly high shatter at least surface.

4. A final point, with such low spraying pressures the question of filtration is one which is presumably difficult. Are there individual filters to each hole or just one central filter? If the latter, will not the maintaining of a satisfactory pressure differential across the filter prove difficult and therefore rather constant filter cleaning be necessary?

Mr. D.G. Sharp I am not an engineer and I have been employed to determine the practicability of this method of spraying and to determine whether it is worth following up. I cannot give information regarding droplet size. With regard to droplet shatter, due to the method of taking the photograph by reflected light the size of the droplet shown gives no indication of actual size. With regard to filtration, I am concerned with the method of spraying and not with the sprayer.