Proc. 10th Br. Weed Control Conf. 1970

CHANGES IN THE WEED FLORA AS THE RESULT OF CONTINUOUS CROPPING OF CEREALS AND THE ANNUAL USE OF THE SAME WEED CONTROL MEASURES SINCE 1956

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Summary A study of different methods of weed control in cereals was started in autumn 1956: (1) No weed control; (2) MCPA; (3) 2,4-D; (4) DNOC; (5) calcium cyanamide; (6) annual rotation between MCPA, DNOC, calcium cyanamide, harrowing; (7) harrowing. The total number of weeds increased and a change in the relative importance of the individual species occured as the result of continuous cropping of cereals. The number is now highest in the plots without weed control, and lowest after annual application of MCPA, 2,4-D or DNOC. Veronica persica is dominant in the plots annually treated with MCPA or 2,4-D. Lamium purpureum, Stellaria media, Galium aparine and, after MCPA-treatment only, Polygonum convolvulus have all increased in relative importance in these plots. Cirsium arvense and Rumex crispus have greatly increased in abundance in all plots not treated with MCPA or DNOC.

INTRODUCTION

The trends in the size and species composition of a weed population of a field can be predicted, with a level of probability, from knowledge of crop rotations (including all the tillage and crop production measures) and a complete knowledge of the life history of the different weed species (including their behaviour in competition with other species). As is true of all predictions of future developments, the causes of which are of a complex nature, great precision cannot be expected. The prediction can be little more than a description of a tendency. It is impossible to obtain the necessary data for these predictions by studying every aspect of the whole complex situation. It should be possible, however, to deduce the long-term behaviour of a weed species from its reaction to selected individual factors. While our knowledge of inter-relationships is so limited we have no other choice but to study the future trends in weed populations in relatively simple, although still complex, model situations. A long-term experiment based on different methods of weed control in cereals was started for this purpose by Rademacher in 1956. In this paper the influence of the different weed control measures on the weed flora is considered.

METHOD AND MATERIALS

Location: Experimental field of the University of Hohenheim, Stuttgart, Southwestern Germany. Soil: Sandy loam, pH 6-6.5. Fertilisation: 90 kg/ha N, 120 kg/ha P_2O_5, 140 kg/ha K_2O. Crop rotation: Before the experiment was started: Winter wheat, summer cereals, potatoes or sugar beet; during the experiment: summer cereals with the exception of three years, when winter cereals were grown (table 1). Size of the plots: 10 x 5 m. Number of replications: 4.

The following weed control measures have been conducted annually on the same plots: (1) No weed control; (2) MCPA-dimethylamine, 1.5 l/ha U 46 M Fluid, 48 % a.e.; (3) 2,4-D-dimethylamine, 1.5 l/ha U 46 D Fluid, 49 % a.e.; (4) DNOC, 4 kg/ha Raphatox, 50 % a.e.; (5) 143 kg/ha calcium cyanamide; (6) annual rotation between MCPA, DNOC, calcium cyanamide, harrowing; (7) harrowing. The weed control measures have been applied annually at what is regarded as the optimal time.

The weeds have been counted annually after the weed control took place. In 1966, 1968 and 1970 the weeds were also counted after emergence but before their control. the counts were made in two 1 x 0.5 m squares in each plot, except for 1968 when four 1 x 0.5 m squares were used in each plot, i.e. 8 m^2 per treatment. The weights of the perennial plants, which are not recorded in detail in this paper, have been taken from the whole plots.

The significance of the differences in yield and in weed numbers has been calculated by means of an analysis of variance.

RESULTS

The yields of cereals give an indication of the severity of competition by weeds. Since competition was low for the first few years the yields were not significantly influenced by the different methods of weed control (Table 1).

Table 1

Total number of weeds and yields of the cereals

Year and crop	Number of weeds in "no weed control"		Yield (grain, no weed control = 100)						
	Plants p.8 m^2	relative 57=100	MCPA	2,4-D	DNOC	Calc. cyan.	Rotation	Harrow	LSD 5 %
57 w.wheat	109	100	100	93	99	97	95	92	7,8
58 oats	110	100	94	90	94	96	92	88	8,5
59 w.rye	79	72	103	101	106	93	93	98	8,9
60 barley	118	108	104	104	103	103	104	102	6,5
61 oats	83	75	106	95	94	89	96	94	9,1
62 w.rye	64	58	100	97	101	84	98	94	7,9
63 wheat	148	136	107	109	114	99	95	99	8,1
64 oats	161	157	113	99	108	108	96	88	10,4
65 wheat	553	511	119	113	121	108	114	99	9,1
66 oats	749	682	122	111	115	106	119	99	10,5
67 barley	--	--	113	111	119	102	105	95	8,4
68 oats	499	456	111	109	138	116	118	103	9,8
69 barley	--	--	168	180	154	119	160	113	11,0
70 wheat	548	503	145	141	150	121	144	109	9,7

Table 2

Abundance of different weed species in 1968 (number of plants per 8 m^2)

Species	No weed control	MCPA	2,4-D	DNOC	Calc. cyan.	Rota-tion	Har-row	LSD 5 %
Thlaspi[+]	1155	369	313	1237	1705	1123	1955	267
Sinapis	919	143	82	100	175	129	720	234
Veronica	922	667	1166	495	609	675	636	298
Lamium	215	118	89	103	72	89	139	60
Polygonum	162	134	52	41	56	80	112	72
Vicia	135	26	10	89	129	84	141	45
Stellaria	86	109	115	92	79	79	107	26
Matricaria	52	43	57	29	43	49	102	18
Alopecurus	48	42	50	58	40	61	64	28
Galium	3	32	18	4	3	5	3	4
Rumex	154	28	19	70	128	61	113	37
Cirsium	51	0	0	31	48	12	60	19
Total annual	3727	1736	1979	2305	2956	2431	4034	378
Total	3990	1807	2019	2436	3169	2541	4268	396

[+]For complete plant names see table 3.(see also Oberdorfer, 1968).

The total number of weeds increased markedly after 1963 when only summer cereals were grown. Since 1966 there has been no significant increase in the total number of weeds. Mechanical weed sontrol had been the standard practice before the start of the experiment and in the plots where it was continued, the total number of weeds was somewhat lower than in the plots without weed control. There was also a change in the relative importance of the different species in the plots without weed control as well as in those where harrowing was used (tables 2, 3). Twenty-six species were recorded in summer cereals in 1958 compared with 22 in 1970. Veronica hederifolia and Ranunculus arvensis which will germinate only in autumn or winter disappeared completely. Alopecurus myosuroides, Galium aparine and Papaver rhoeas, which germinate predominantly in autumn but also in spring, decreased markedly and Thlaspi arvense increased as the result of continuous growing of summer cereals. Veronica persica, easily the dominant species when the experiment was started, increased somewhat in number but decreased in relative importance due to the greater increase of Thlaspi arvense and some other species.

In most years the fewest weeds emerged in the plots treated with DNOC. Since Veronica persica is quite susceptible to DNOC, this species decreased in relative importance, while Thlaspi arvense became undoubtedly the dominant species as far as the number of plants was concerned.

The total number of weeds has not differed significantly between treatments with MCPA and 2,4-D. Both treatments favoured Veronica persica, Lamium purpureum and, although generally low in number, Galium aparine. The only clear difference between these two herbicides is the relative increase of Polygonum convolvulus and other Polygonum species in the plots treated with MCPA.

A rotation between different methods of weed control had about the same effect as MCPA, 2,4-D or DNOC on the total number of weeds.

Table 3

Relative abundance of weed species in plots with different weed control measures (total number of weeds in each treatment = 100)

Species	Year	No weed control	MCPA	2,4-D	DNOC	Calc. cyan.	Rota- tion	Har- row	LSD 5 %
Thlaspi	56	2	--	--	--	--	--	--	--
arvense L.	66	30	6	8	24	46	28	34	8
	68	29	16	16	50	54	44	46	11
	70	26	14	17	50	48	31	33	11
Sinapis	56	1	--	--	--	--	--	--	--
arvensis L.	66	20	2	1	4	2	2	5	7
	68	23	8	4	4	6	5	10	10
	70	22	6	4	6	7	8	7	7
Veronica	56	69	--	--	--	--	--	--	--
persica	66	30	49	60	32	23	38	31	14
Poir.	68	23	39	58	20	19	27	22	12
	70	21	47	50	18	22	30	23	10
Lamium	56	2	--	--	--	--	--	--	--
purpureum	66	2	2	2	2	1	2	2	--
L.	68	5	6	4	4	2	4	3	4
	70	6	12	10	6	2	5	7	4
Polygonum	56	7	--	--	--	--	--	--	--
convolvulus	66	3	8	3	2	2	3	3	3
L.	68	4	7	3	2	2	3	3	3
	70	5	8	4	2	3	3	3	3
Vicia	56	1	--	--	--	--	--	--	--
hirsuta	66	2	+	+	2	4	4	3	2
(L.) S.F.	68	4	1	+	4	4	3	3	2
Gr.	70	5	1	+	2	6	2	5	2
Stellaria	56	1	--	--	--	--	--	--	--
media (L.)	66	5	12	13	14	9	9	7	6
Vill.	68	2	8	6	4	3	3	3	8
	70	3	7	10	3	5	2	3	4
Matricaria	56	1	--	--	--	--	--	--	--
chamomilla	66	3	6	2	3	3	3	4	2
L.	68	1	2	3	1	1	2	2	2
	70	1	1	1	1	1	+	1	--
Alopecurus	56	14	--	--	--	--	--	--	--
myosuroides	66	2	6	4	2	3	2	2	2
Huds.	68	1	2	2	2	1	2	1	--
	70	0	+	+	1	+	1	0	--
Galium	56	2	--	--	--	--	--	--	--
aparine L.	66	+	1	1	+	+	+	1	--
	68	+	2	1	+	+	+	+	--
	70	+	2	2	+	+	+	+	--
Rumex	56	0	--	--	--	--	--	--	--
crispus L.	66	2	+	1	5	3	2	1	4
	68	4	2	1	4	4	2	3	4
	70	7	1	+	6	4	3	7	3

However, there are no really dominant species in 1970 due to the different selectivities of the treatments.

The infestation with perennial weeds was very low when the experiment was started. During the experiment Cirsium arvense and Rumex crispus increased markedly and became a severe problem in all plots except those treated with MCPA or 2,4-D. As compared with some of the annual species they are still not present in large numbers but their weight is high and they are highly competitive. The infestation of the plots which have had the rotation of control measures (MCPA once in four years) is not severe but is greater than in the plots treated annually with MCPA or 2,4-D which are almost free of these two species.

DISCUSSION

The results reported here are true only for the special conditions under which this experiment was conducted. The relative importance of a certain weed species is not only influenced by the treatment itself but also by all other factors such as climatic and edaphic conditions, type of crop grown and variety. It seems that the tendency is clear and there are hardly any results which could not be explained. But there are some results which had not been expected simply because not all the different factors working together were recorded until a difference between theory and practice was noticed. For example Thlaspi arvense was not expected to be less influenced by DNOC, calcium cyanamide and harrowing than Sinapis arvensis. But Thlaspi arvense was still emerging after these relatively early treatments at a much higher number than Sinapis arvensis. Galium aparine, Stellaria media and Matricaria chamomilla were expected to increase more rapidly in importance in the plots treated with MCPA or 2,4-D. Summer cereals are, however, not the best crops for their development.

Prediction: Under the conditions of continuous cropping of summer cereals the following developments in the weed flora of the area can be expected:

The perennial weeds Cirsium arvense and Rumex crispus will greatly increase in importance in all plots without MCPA or 2,4-D. The yields of the cereals will be greatly reduced if there is no reduction of these species by other means. In the plots with an annual change in the method of weed control, the application of MCPA once every four years will be sufficient to keep these two species at a low level although some yield reduction can hardly be avoided.

There will be no great changes in the plots without weed control as far as annual species are concerned. We expect that some sort of a climax stage will be reached in the near future. This does not exclude the possibility that some fluctuation in the relative importance of the different species may occur. A similar situation seems to be true in the plots with harrowing.

As well as the perennial species, Thlaspi arvense and Vicia spp. are the principal species which will still increase in number in the plots treated with DNOC. Thlaspi arvense will eventually be by far the most numerous species. Polygonum convolvulus, Matricaria chamomilla, Galium aparine and Stellaria media will almost completely disappear within a few years. Sinapis arvensis, Veronica persica and Lamium purpureum will continue to decrease slowly in absolute and relative abundance. As a whole, annual species are not likely to become a dominant problem in these plots.

Veronica persica will become by far the dominant species after long-term treatment with MCPA or 2,4-D. Lamium purpureum and Stellaria media will also become more important after both treatments and Polygonum convolvulus after MCPA. Galium aparine does not find optimum conditions for its development in summer cereals. Therefore it will not increase in abundance as much as one could expect from its high resistance to MCPA and 2,4-D. It can be concluded, that some annual species may become more dominant after long-term treatment with MCPA or 2,4-D than after long-term application of DNOC.

Weeds surviving weed control measures benefit by the reduced competition from other weeds. This is the more pronounced the lower the competitive ability of a species. For example Lamium purpureum and Matricaria chamomilla scarcely survive in the plots without weed control but grow well after the selective control of the other weeds. Avena fatua, on the other hand, does not benefit much from the selective control of species with low competitive ability such as Lamium purpureum and Matricaria chamomilla.

It can be expected (although it is not yet adequately demonstrated) that the total effect of a given weed control method will decrease with the gradual increase of the more resistant species. How quickly resistant species can dominate and whether susceptible species will disappear completely depends on many factors. It is perhaps relatively dangerous to predict the future importance of a weed from knowledge of its susceptibility alone.

Economic importance of the changes in the weed population: Thlaspi arvense, Veronica persica and Lamium purpureum are of low competitive ability in cereals. In addition they have almost completely disappeared by harvest. Crop yield is therefore hardly likely to be reduced even by high infestations and the species do not complicate the harvesting procedure. Polygonum convolvulus, Vicia spp. and Galium aparine are of greater economic importance because they have a higher competitive effect, may cause lodging and may complicate harvest.

An annual change in the method of weed control will usually prevent certain species from becoming dominant but it does not lead to complete eradication of certain species, so that the problem remains the control of a wide range of species. Under the conditions of this experiment it seems most reasonable to continue with a specific selective control practice for several more years.

Acknowledgments

I thank Miss U. Strohbach and Miss Ch. Kurtz for their help in conducting the experiment and Miss P. Jordan for her assistance in the preparation of the English translation.

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Proc. 10th Br. Weed Control Conf. 1970

SEED PRODUCTION BY AVENA FATUA POPULATIONS IN VARIOUS CROPS

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Summary Counts of the number of seeds/head of A. fatua plants growing in different crops showed that spring barley reduced seed numbers most, spring wheat less and field beans least. Two barley cultivars did not differ significantly. A pot experiment confirmed the lack of difference between the same two barleys, but in contrast to the first experiment a different spring wheat variety did not differ from them. The differences that do occur between cereals is possibly related to habit of growth and to rate of root development. In the pot experiment crop density was shown to be of considerable importance in determining the number of weed seeds/head. The number of A. fatua seeds/head in cereal crops in the field was only reduced when A. fatua plants exceeded 60/yd^2.

INTRODUCTION

Avena fatua is now one of the worst annual weeds of British agriculture, partly because of the decline in broad-leaved weeds and partly because of the difficulty of obtaining adequate control under conditions of monocropping. It has attained this position of importance despite its relatively small seed production, which implies a relatively high percentage surviving to produce new plants. As there are few records of the numbers of seeds produced under particular conditions, counts were made in four competition experiments to investigate seed production under various conditions.

METHOD AND MATERIALS

In a field experiment carried out jointly with the Agronomy Section of the Weed Research Organization, 6 ft wide strips of crop were drilled in 6 in. rows in four randomised blocks on 2/4/69 in a light sandy loam. Barley cv. Zephyr was drilled at 145 lb/ac, barley cv. Deba Abed at 129 lb/ac, spring wheat cv. Rothwell Sprite at 145 lb/ac and field beans cv. Maris Bead at 220 lb/ac to give equal population densities. The cereals received 58, 32 and 50 units/ac of NPK respectively and the beans 32, 32 and 50. Within the strips of crop, A. fatua, which had been pre-germinated in an incubator at 15°C, and then kept at 2°C, were planted on 8/4/69 (timed to emerge with the crop) in randomised square yard plots at 32 or 98/yd^2, but owing to mortality the ultimate mean densities were 20 and 61/yd^2. At harvest the seeds of 25 randomly selected heads were counted on each plot.

A second experiment was sown in a light sandy loam in 7 in. pots using barley cv. Zephyr and cv. Deba Abed and spring wheat cv. Troll at 3, 6 or 12 seeds in a single row per pot (equivalent to 56, 112 and 224 lb seed/ac). The crops were sown with and without four A. fatua plants per pot (c. 180/yd^2) arranged as two on either side of the central crop row. The top two inches of soil were mixed with fertilizer to give 60, 30 and 30 units/ac of NPK respectively. The plants were sprayed as necessary with dinocap for mildew and with liquid derris for aphids. At harvest all heads of A. fatua were counted for seed production.

In the third experiment, using a natural population of *A. fatua*, spring barley cv. Proctor was drilled on 30/3/69 in 7 in. rows at 168 lb/ac in a heavy soil overlying chalk, 39, 39 and 60 units/ac of NPK were applied. *A. fatua* plant densities were maintained by weekly hand-weeding at 0, 10, 20 and 40/yd^2 in yd^2 plots arranged in six randomised blocks.

In the fourth experiment, again with a natural population of *A. fatua*, spring barley cv. Zephyr was drilled on 10/4/69 in 7 in. rows at 140 lb/ac in a light sandy soil overlying Devonian sandstone. Sixty, 30 and 30 units/ac of NPK respectively were applied. *A. fatua* plant densities of 0, 10, 20 and 40/yd^2 were maintained from emergence by weekly hand-weeding of yd^2 plots arranged in eight randomised blocks. In these last two experiments all *A. fatua* heads per plot were counted for seed production.

RESULTS

From the first experiment the mean numbers of seeds per head of *A. fatua* in the four crops are given in Fig. 1.

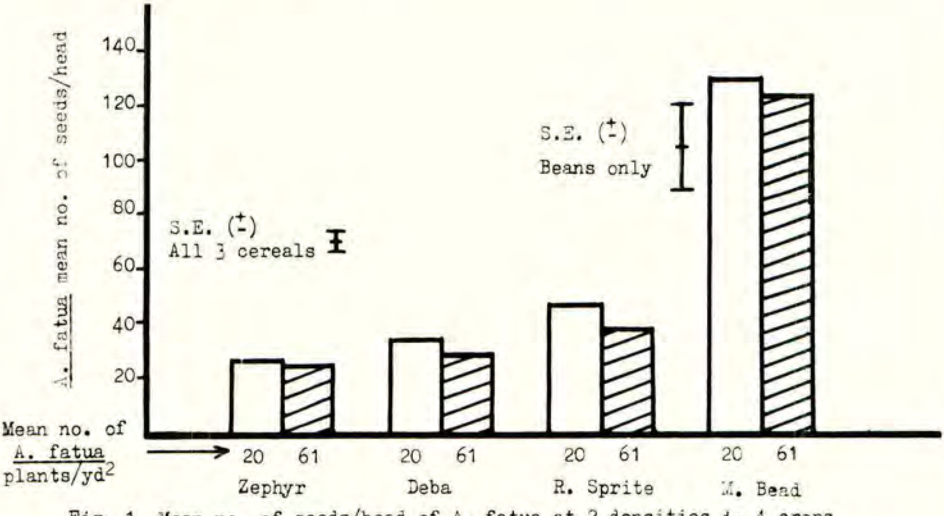

Fig. 1 Mean no. of seeds/head of *A. fatua* at 2 densities in 4 crops

The number of *A. fatua* seeds per head in Deba and in Zephyr did not differ significantly. The spring wheat was, however, less competitive than the two barleys, for the mean number of seeds per head was significantly higher. Field beans were far less competitive than wheat or barley and the number of *A. fatua* seeds per head was 3-4 times greater in beans than in the cereals.

In Deba a small percentage of the *A. fatua* plants tillered, while in Zephyr no *A. fatua* tillers were produced at all. It is interesting to note that the lower density of *A. fatua* in all four crops consistently produced slightly more seeds per head than the higher density.

In the pot experiment the number of A. fatua seeds/head produced were similar for the three cereals and the data are not presented separately here. However, the mean number of A. fatua seeds/head has been averaged for all three cereals at each density and is presented in Fig. 2.

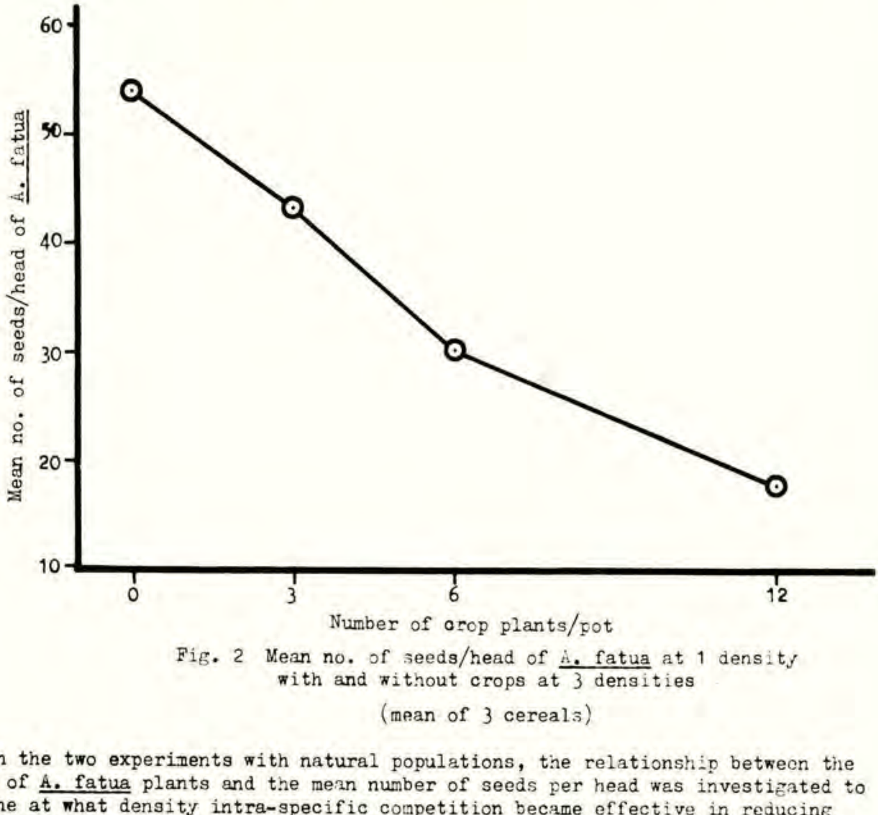

Fig. 2 Mean no. of seeds/head of A. fatua at 1 density with and without crops at 3 densities

(mean of 3 cereals)

In the two experiments with natural populations, the relationship between the density of A. fatua plants and the mean number of seeds per head was investigated to determine at what density intra-specific competition became effective in reducing A. fatua seed production in spring barley. Both these experiments surprisingly showed no reduction in the number of seeds/head at the maximum A. fatua stem densities of 40 and $60/yd^2$. In fact in the experiment with maximum densities of $60/yd^2$ there was a tendency for the number of seeds/head to increase with increasing stem number, rather than the reverse.

DISCUSSION

Although these four experiments cover a variety of conditions and so are not directly comparable, they do give some indication of the relative importance of different crops, different crop densities and different weed densities on the seed production of individual A. fatua heads.

Differences in effect between crops is shown well in the first experiment where although the two barleys did not differ significantly in their effects on seeds/head of A. fatua, there was a slight difference in their effects on tillering. Some difference was expected because of differences in their growth habit, for Deba is initially lax and spreading in contrast to Zephyr, which is erect. This difference of effect might be magnified under other conditions. Spring wheat on the other hand, differed significantly from the two barleys and allowed greater seed production by A. fatua.

To investigate these differences further, measurements were made of the rate of root development of cereals, and A. fatua, at 15°C in perspex growth chambers without soil. The results show, that after 10 days, the spring wheat cv. Rothwell Sprite had slightly longer roots than A. fatua while both Deba and Zephyr were very similar and had approximately 2½-3 times the length of roots of A. fatua. This is in agreement with earlier work with older cereal varieties. (Pavlychenko, 1937).

The lack of any difference between crops in the pot experiment may have been due at least in part to recurring mildew and aphid attacks on both crops and weed, although the possibility of Troll wheat being relatively more competitive than Rothwell Sprite under these conditions should not be ruled out.

The effects of the various crop densities in the pot experiment are considerable (Fig. 2) and emphasize the great importance of a dense crop as a suppressor of A. fatua infestations. This too, confirms earlier findings with other cereal varieties (Thurston, 1962). Although in Fig. 2 the graph appears nearly linear for the mean number of seeds/head relative to the number of crop plants/pot, there is an indication that the reduction is not maintained at the highest (higher than normal) crop density. This indication is in line with other work (McCurdy, 1958), which shows that doubling normal crop density does not halve A. fatua seed production.

In the first experiment average populations of 61 A. fatua plants/yd^2 had consistently fewer seeds/head than on plots with 20 plants/yd^2 in all four crops. However, in the two natural populations of A. fatua there was no such reduction even at densities of 40 plants/yd^2. Although these experiments are not directly comparable they do give some indication of the level of A. fatua in a crop that has to be reached before seed numbers of the weed are reduced.

From these data it appears that although seeds/head of A. fatua vary considerably, the mean number of seeds/head is not reduced in cereal crops up to quite high densities of A. fatua. However, the number of tillers may be reduced by crop competition at lower A. fatua densities. The effects of A. fatua density upon mean seed weight was investigated in the two natural populations, and no effect was apparent up to 40 plants/yd^2.

So far only the numbers of seeds/head have been considered. However, the numbers of seeds returned to the soil per unit area of land are also of considerable interest and vary greatly between the field experiments (Table 1).

Table 1

Seed production per yd^2 by 20 A. fatua plants in field-grown cereals

Experiment 1		Experiment 3		Experiment 4	
Cultivar	No. of seeds/yd^2	Cultivar	No. of seeds/yd^2	Cultivar	No. of seeds/yd^2
Zephyr	428	Proctor	1484	Zephyr	393
Deba Abed	569				
Rothwell Sprite	789				
Maris Bead	4784				

All the spring barley crops were good, the spring wheat was moderate, while the field beans were poor, which presumably had a considerable effect upon competitive ability.

The results show that none of the cereal crops prevented A. fatua seed production, although it varied greatly. In experiment 4, in which A. fatua seed production /unit area was least, to keep the population at the same density would require at least 95% mortality of the seeds returned to the soil. Therefore, positive control measures should normally be undertaken for A. fatua.

Acknowledgments

We wish to thank the Agronomy Section of the Weed Research Organization and Miss A. Morris, Miss M. Taylor and Miss P. Turner for their help in carrying out the experiments and Mr. B.C. Bartlett for carrying out the statistical analyses. We also wish to acknowledge the generosity of the farmers who allowed us the use of their fields.

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Proc. 10th Br. Weed Control Conf. 1970.

THE POPULATION DYNAMICS OF RUMEX ACETOSA L. AND RUMEX ACETOSELLA L.

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Summary Some aspects of the population dynamics of Rumex acetosa (common sorrel) and Rumex acetosella (sheep's sorrel) in grasslands of North Wales are summarised. Results of several experiments are discussed, where attempts were made to determine mechanisms of population regulation at various stages in the life cycle of the two species of Rumex.

INTRODUCTION

R. acetosa and R. acetosella are both widespread, versatile and sometimes troublesome weeds. Populations of R. acetosa are generally found in leys, permanent grassland from sea level to above 3,000 feet, and in hay meadows, on moderately acid to neutral soils. Populations of R. acetosella are also frequently found in permanent pastures, but are more typically located in disturbed habitats such as burnt areas of moorland and arable land, particularly on acid and peaty soils or on lighter sandy soils (Brenchley, 1920). R. acetosella in particular is a frequent contaminant of seed crops of white clover, perennial ryegrass and Italian ryegrass (MacKay, 1964).

Although both species are moderately susceptible to chemical control by MCPA and 2, 4-D, repeated applications are required for good long term control. Both species are perennials and have the ability to regenerate readily from fragments of root (R. acetosella) or 'rootstock' (underground portion of stem and hypocotyl tissue, R. acetosa).

These two species of sorrel are an excellent example of the kind of perennial weed which is difficult to eradicate with herbicides and which only tends to regenerate after ploughing or other cultivations. It seemed relevant to investigate experimentally the way in which populations of R. acetosa and R. acetosella are regulated in natural environments. In this report, an outline is given of some of the results of experiments which were done in a variety of upland and lowland grasslands in North Wales. It is possible that they may indicate how chemical or cultural control and pasture management can be improved.

Population regulation during the germination and seedling establishment stage of the life cycle.

Seed of R. acetosa and R. acetosella was experimentally introduced into six different types of natural plant community in North Wales. At each site the same experimental design was used and the treatments were, (a) seed sown in an undisturbed sward, (b) seed sown in plots where the existing vegetation was destroyed with the herbicide paraquat, (c) seed sown in plots where the existing sward, and soil to a depth 20 cm., were replaced by John Innes No. 1 potting compost.

The behaviour of the Rumex populations in these natural environments was studied for a period of two years. The results of the experiments demonstrated that in many habitats, population density was determined early in the life of an individual, during the phase of seedling establishment. Seeds of R. acetosa germinated mainly in autumn, whereas R. acetosella germinated intermittently in spring. The seedling flush of R. acetosa was often followed by a 'crash' in population density one to two weeks after germination. Populations density then became very stable, and this stability persisted for many months. In contrast, populations of R. acetosella were less stable and less persistent than those of

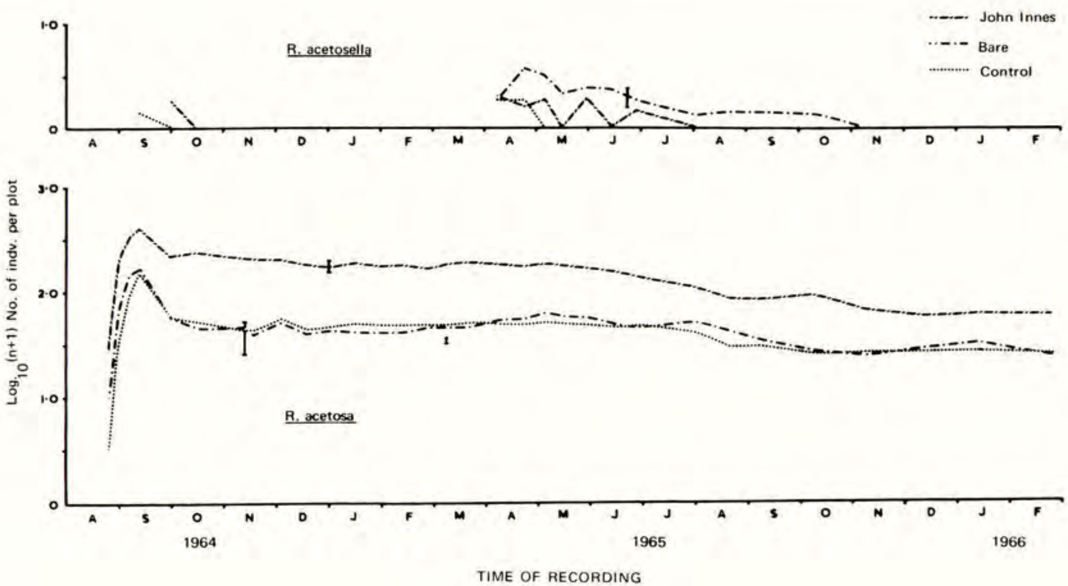

Figure 1.

Changes in the size of populations (seedlings plus mature individuals) of <u>R. acetosa</u> and <u>R. acetosella</u> over a period of 19 months in a grassland community subjected to three kinds of treatment. 95 % confidence intervals of the medians are given.

R. acetosa. Fig. 1. shows the behaviour of a population of each species of Rumex in lightly grazed neutral grassland at the Treborth Experimental Station near Bangor, Caernarvonshire. Most of the processes mentioned above occurred at this site.

Seedling establishment was apparently strongly influenced by climate. For example, at Treborth the experiment was repeated (with modifications) in the following season and the pattern of seedling establishment of R. acetosa in that year was very different from the pattern of establishment in the previous year. Seasonal differences in amounts of precipitation were implicated as the probable cause of the difference in seedling establishment. Another indication of the influence of climate were the large differences in seedling establishment on relatively uniform plots of potting compost in sites with wide differences in temperature, rainfall, snowfall and relative humidity.

Seedlings appear and disappear very quickly and therefore it was difficult to determine the exact causes of seedling mortality. In these experiments, drought, heavy rains, frost heaving, predation by slugs and snails, nutrient deficiencies and pathogenic attack, were all apparent causes of seedling mortality. At Treborth there was a significant ($P < 0.05$) increase in the size of a population of R. acetosa when it was protected by a molluscicide (metaldehyde) which suggests that predation by slugs and snails regulated the population.

Further evidence of the vulnerability of young seedlings at, or shortly after, the cotyledon stage was provided by the behaviour of 'phytometers' which were transplanted into the experimental areas during April, 1965. These were young seedlings which had been grown in small polythene cylinders (3 cm. x 1 cm. in diameter), filled with potting compost. At the time of transplanting, individual phytometers were at the three leaf stage and at each site twenty phytometers of each species were planted. The survival and growth of phytometers at each of the experimental sites over a period of six months is given in Fig. 2.

In habitats where establishment of R. acetosella from seed was poor, then growth and survival of phytometers also tended to be poor. A similar pattern of behaviour was found by Cavers (1963) for Rumex crispus and R. obtusifolius in several grassland communities. In contrast, growth of phytometers of R. acetosa was sometimes relatively good, even in habitats where there was poor establishment from seed. However, in general, recruitment to populations of both taxa from seed, was more sensitive to environmental hazards than was recruitment from phytometers. In each of the experimental sites, undisturbed populations of sorrels fluctuated within relatively narrow limits. When seeds of R. acetosa and R. acetosella were deliberately sown into several ecologically different habitats, there was no lasting effect on population size. Inability to change the density of sorrel populations by the addition to them of propagules indicated that they were subject to powerful regulatory mechanisms.

Further evidence of population regulation at the seedling stage was provided by an experiment which investigated the behaviour of populations of R. acetosa and R. acetosella in hill grassland when certain groups of species were removed from the sward. Sites in which either R. acetosa or R. acetosella were conspicuous members of the flora were treated with specific herbicides in order to remove either, (a) grasses, (b) non-gramineous species excluding Rumex spp., (c) Rumex spp., and (d) all species except Rumex spp. Seed of R. acetosa or R. acetosella was sown in the treated swards at two densities. The response of the vegetative and seedling population was followed over a period of twelve months. When grasses, or all species (except sorrels), were removed from the sward, there was an explosive increase in seedling density (particularly R. acetosa Fig. 3.).

Deliberate sowing of seed into plots where grasses were killed caused a further increase in the density of seedlings, and there were permanent additions to populations of R. acetosa. It was clear that associated species in the plant community (particularly grasses) played an important role in controlling populations of sorrels at the seedling stage.

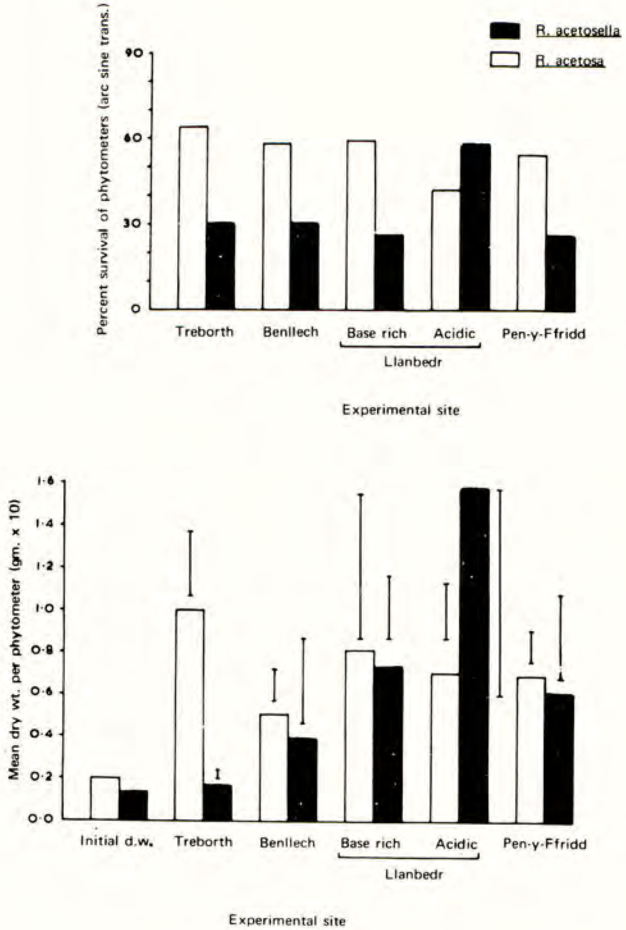

Figure 2.

The percentage of phytometers of R.acetosa and R. acetosella that survived for six months from planting in five plant communities, and their mean dry weights.
L.S.D's are given for P = 0.05 and they refer to a comparison of the initial dry weight to dry weight at time of harvest.

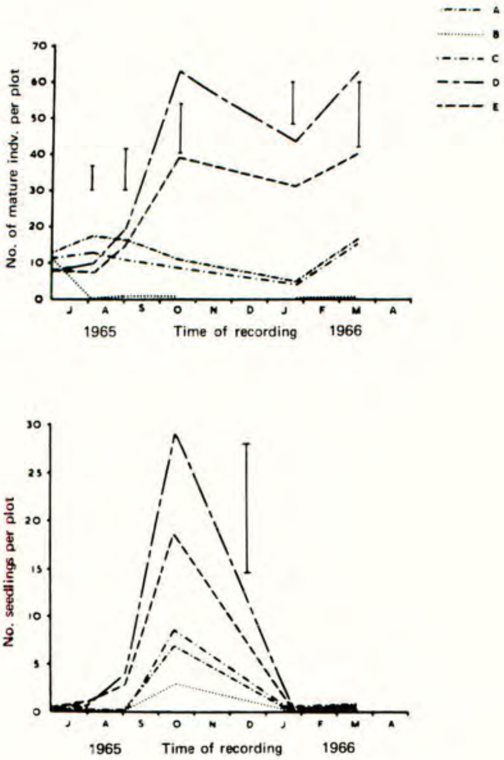

Figure 3.

The response of a population of R. acetosa to removal of certain components of the sward.

Key to treatments of the sward.
(A) control, (B) existing population of R. acetosa removed, (C) all non-gramineous species except R. acetosa removed, (D) grasses removed, (E) all species except R. acetosa removed.

Population regulation during the reproductive stages of the life cycle.

An increase in the density of a plant population may result in the death of a portion of the population. Alternatively the growth rate of individual plants may be reduced with a consequent decrease in the ultimate size or number of plant parts such as offshoots, stems, inflorescences, flowers or seeds. This plastic response to density will reduce the rate of recruitment to a population either by a reduction in seed output or a decrease in the rate of vegetative reproduction.

There is evidence of plasticity responses of seed output and vegetative reproduction in both populations of R. acetosa and R. acetosella. However, an example is given of an experiment which estimated the relative contributions made to the size of a pasture population of R. acetosella by, (a) dormant seed, (b) naturally disseminated seed, (c) experimentally sown seed and (d) vegetative reproduction, and which determined which sources of recruitment were subject to density dependent control.

The experiment was carried out in grassland situated near Bangor, and treatments included, the prevention of natural seed dispersal, either by cutting and removing inflorescences, or by enclosing them in polythene bags; and the addition to the sward of seed of R. acetosella at six sowing densities. There was also a control in which seed was sown into an undisturbed sward. The behaviour of the population of R. acetosella was studied by recording at three to four week intervals from March to August, the number of seedlings and vegetative shoots per plot. An estimate of the amount of seed produced and shed naturally within each plot was made by counting the number of inflorescences per plot in the preceding summer.

Selective multiple regression analysis was used to select out those sources of reproduction which contributed significantly to maintenance of the population, and to search for evidence of density dependent regulation. Some of the more interesting results of the regression analysis are given in Table 1.

Table 1

The regression coefficients

Date of recording	Probability of regression equation	Constant	Regression coefficients significant at P = 0.05 or less.			
Control		a	x_m	$-x_m^2$	x_f	x_f^2
April 15th	≤ 0.001	+2.1	+1.0		+0.61	-0.012
June 3rd.	≤ 0.001	+7.8	+2.8	-0.029		
'Inflorescences removed' August 20th.	<0.05	-5.0	+1.6	-0.023		
'Inflorescences bagged' April 15th.	<0.001	-0.007	+4.1	-0.028		

The equation (a simplified version) $Y_t = a + b_1 x_m + b_2 x_m^2 + b_3 x_s + b_4 x_s^2 + b_5 x_f + b_6 x_f^2$ which relates the total number of individuals (Y_t) to the number of vegetative shoots present in early spring (x_m), the number of seeds experimentally sown (x_s) and the number of inflorescences (x_f) at various sampling dates.

In the regression analyses, the negative quadratic relationship between the total number of individuals (y_t) and the number of vegetative shoots ($-x_m^2$) suggests that the denser the initial population, the less was its relative increase. The positive linear function of the number of inflorescences (x_f) indicates that the total population was partially directly proportional to the number of inflorescences and probably therefore to the number of seed shed in the previous summer and autumn. There are two possible interpretations of the negative quadratic function of the inflorescences ($-x_f^2$). Either there was density dependent mortality of seed or seedlings during the dormant, germination or early establishment phase or there was a proportionate reduction in the number of seeds ripened and shed by each inflorescence with increase in density.

Very few seedlings became established in the experimental sward and the population of R. acetosella was maintained mainly bv vegetative reproduction. The mechanism of population control was mainly a plastic reduction in vegetative reproduction at high density. Deliberate sowing of seed into the sward in autumn at a wide range of densities had no effect on the population in the following spring although there is evidence that seed naturally produced and dispersed during the previous season did germinate and establish on the control plots. It is of interest that other weedy taxa in the genus Rumex (R. obtusifolius and R. crispus) reacted to variations in density by plasticity rather than mortality (Cavers, 1963).

DISCUSSION

Most populations of R. acetosella were regulated by a plastic reduction in vegetative reproduction at high densities whereas in populations of R. acetosa regulation appeared to be more effective at the germination and seedling establishment stage of the life cycle. In both species the entry of new genetic individuals into established grassland communities probably depends on a localised disturbance of the sward when hoof marks or molehills may allow germination, establishment and rapid vegetative spread to take place.

In relation to this initial colonisation stage, Chippindale and Milton (1934) have found substantial populations of viable seeds of both species in old pastures where neither species was present in the sward. Reserves of dormant seed help to maintain the stability of population size by always being available to exploit conditions suitable for germination and establishment, such as those previously mentioned, that may occur in space or time. However, this tendency to maintain or increase population size is counterbalanced by the influence of other species in the grassland community. Populations of R. acetosa, and to a lesser extent R. acetosella, spread rapidly when grasses were removed from the sward and clearly seedlings and mature individuals of both species are sensitive to any kind of management which increases the growth rate of the grass component of a sward.

The weak link in the population dynamics of sorrels, the germination and seedling establishment phase, during initial colonisation of a sward, is difficult to exploit. A combination of careful grazing management, avoiding overgrazing, and application of selective herbicides in spring (to eliminate newly established seedlings) in combination with fertilizer application to stimulate the growth of grasses would appear to offer the best chance of reducing the size of Rumex populations.

To achieve greater success, by exploiting the most vulnerable times in the life cycle of a weed, manipulative experiments are required which test computer models of the effects of a range of chemical control measures in combination with specific cultural, grazing management and fertilizer treatments.

Acknowledgments

The work embodied in this report was carried out during the tenure of a Department of Scientific and Industrial Research Studentship.

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A STUDY OF THE POPULATION DYNAMICS OF THREE RANUNCULUS SPECIES

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Summary The population approach to the study of species' behaviour under natural conditions has a preeminent place in modern biology; however studies of plant populations have been largely neglected. A preliminary research report on the dynamics of natural populations of *Ranunculus acris*, *R. bulbosus* and *R. repens* in a coastal grassland in Caernarvonshire is presented.

The results derive from continuous observation and mapping of individuals in 21 1m² permanent sites and from experiments on the dynamics of seed populations in the soil. Complementary information about germination and establishment requirements, changes in the allocation of dry matter of the plants in a growing cycle and the effect of the grazing animals on the species' potential reproduction is being obtained.

An example of some of the preliminary results is presented in a simplified and tentative population flux diagram and attention is drawn to the extreme changes occurring within the apparently stable plant populations.

INTRODUCTION

One of the few biological phenomena which is known to act as a common denominator in all living organisms is evolution. As more biologists realize this, population studies of species become increasingly frequent for it is only through the observation of a number of individuals within a population that meaningful information can be gathered towards the understanding of the ways in which individuals are reacting to the selective forces of the environment and, subsequently, of the evolutionary fate of the species. The development of the study of population ecology has been disproportionately greater in animal species than in plants. A number of reasons account to some extent for this difference (Harper, 1967, 1967a) such as the plastic response of plants to different environmental conditions and the fact that many plants reproduce vegetatively in a way which makes it difficult to distinguish objectively between vegetative units. However, a great advantage possessed by plants has been frequently overlooked and this is their fixity in space which facilitates enormously the task of continuous individual recordings that in animals are often impossible.

The very few pioneer studies on plant population dynamics (Tamm, 1948, 1956; Sagar, 1959; Antonovics, 1966) have shown that the obstacles presented by plasticity and vegetative reproduction of plants are not insurmountable; they have also provided the only actuarian data so far available for plants.

The present research, of which this paper presents a selection of topics and results, has two main aims: a) the detailed study and comparison of the population dynamics of closely related species living in the same area and of some of the main factors that regulate their numbers and b) the production of a population model in which a series of variables could be manipulated and the reaction of the population to these variations predicted. It should be emphasized that this report is only preliminary and the results and opinions expressed are subject to correction as more data are accumulated.

METHOD AND MATERIALS

At the time of selecting the species it was felt that certain criteria must be satisfied: e.g. taxonomic and ecologic affinity, extremes of reproductive behaviour, species present in large numbers in an extensive ecosystem.

The three grassland species commonly grouped as "buttercups" (Ranunculus acris L., R. bulbosus L. and R. repens L.) were found to meet these requirements exceptionally well. They represent species of close taxonomic relationship (the three belong to the same section of the genus); it is very common to find them growing abundantly in the same field and they have widely different modes of reproduction. R. repens depends mostly on the establishment of vegetative propagules to maintain its population size while R. acris and particularly R. bulbosus rely almost exclusively on seed production to maintain their numbers. Other advantages, important from the practical point of view, are that the vegetative units produced by R. repens are usually readily distinguishable from the mother and from other daughter plants and that the seed of the three species presents few dormancy problems. In addition, buttercups, in particular R. bulbosus, are undesirable species in the sward because of toxicity to cattle and reduction of grassland productivity, (Harper, 1957).

A field of coastal grassland at College Farm, U.C.N.W., Aber, Caerns. containing the three species was chosen for the study. The field has been under continuous traditional sheep and cattle grazing for over 50 years. Topographical peculiarities of the field allowed the selection of a range of sites of different drainage and different densities and mixtures of buttercups. The study is planned to cover the period between March, 1969 and June, 1971.

The individuals of a plant population fall into two fractions. The fraction A where the plants are in various stages of development from seedlings to mature organisms and the fraction B where the individuals are in the form of seeds. In studies of population dynamics it is fundamental to measure in detail the changes in the number of individuals with time in a particular area and to be able to identify each component of the population as a separate unit so that it becomes possible to know the fate of an individual. A number of methods can be used depending on the conditions in which the study is being carried out. In the case of grassland, where it is necessary to keep grazing activities normal, the use of pegs or visible marks for the location of sites and labelling and tagging the plants is unsuitable.

The best method of locating each plant within the permanent site for the purposes of the study was found to be the use of an old cartographic device, the pantograph. Pantographs have been used before in similar studies (Sagar, 1959). The actual location of the permanent sites was achieved by using a triangular aluminium frame with sides 5m long which is fixed onto metallic rods sunk into concrete cylinders buried in the ground at the corners of the triangle. A grid $1m^2$ is fastened in appropriate positions to delimit three sites, two at the base of the triangle and one towards the apex. The frame is fully portable and once removed from each site nothing protrudes above the ground that could attract or repel the animals from grazing that particular area. Seven groups of three $1m^2$ sites were selected over the field to represent different conditions of soil drainage and a wide range of densities for each species.

At each date of observation a map of the position of all the buttercups (seedlings, mature plants and vegetative propagules) present in the site was obtained with the pantograph at a scale of 1:5 on tracing paper. This allowed the maps of different dates to be superimposed in order to ascertain the changes in number of plants and the fate of individuals for each plant has a particular number and a record on a punched card, where observations of its behaviour in the community are entered. These observations include the date of its first record, whether the plant originated from a seedling or a vegetative propagule, the number of flowers and seeds produced at different intervals, the number of stolons, internodes and rooted nodes in the case of R. repens and, eventually, the date of its disappearance from the community. Since it is impossible, without causing severe disturbance in the permanent sites, to record the number of seeds falling on the ground and whether they remain viable in different states of dormancy or are decaying it is necessary to study the dynamics of seed populations experimentally. For this purpose an experiment was set up in which seed of the three species was sown in recorded positions and in sufficient quantity to allow bimonthly samples of soil to be taken up to one year after the experiment started. The seeds are extracted by sieving and washing the soil samples and floating all the organic matter which is sorted by hand. Once separated, the seed which still appears "healthy" is put to germinate under favourable conditions. The fraction of seeds that germinate under these conditions is considered to have been under a state of induced dormancy. After four weeks the seeds which have not germinated are tested using the tetrazolium technique (Isely, 1952) to discover if they are still alive but dormant or have died. The living fraction is regarded as having been in enforced dormancy. Continuous observation of this experiment in the field gives a record of all the seedlings that emerge where seeds have been sown. Thus it is possible to determine for each harvesting date the proportion of seeds that have germinated in the field, the fractions of seeds that are in the states of induced or enforced dormancy and the number of seeds that have died. This enables one to build a picture of the trend of rate of decay, of germination and of changes in dormancy states for a yearly cycle.

RESULTS

The mean results of a partial analysis of three selected $1m^2$ sites, in which R. repens is the most common buttercup are illustrated in the form of a very simplified flux diagram (Fig. 1). The data for Fraction A originates from the means of the observations recorded in the maps for the three permanent sites from March, 1969 to January, 1970 (Table 1). In Fraction B, the original seed population in the soil was assessed by sampling cores of soil in the three sites and the dynamics of this population was estimated from the first harvest of the experiment on seed decay, (Table 2).

DISCUSSION

Although it is clear that these data have several limitations and cannot be analysed at length, it is convenient to draw attention to a few points. It is interesting to observe that the figure obtained experimentally for the germinating fraction of the seed population (18 plants/m^2) is not too different from the figure actually observed germinating in the permanent sites (14 plants/m^2); similarly, the seed output recorded in the permanent sites (287 seeds/m^2) fits reasonably well with that obtained from the soil samples (230 seeds/m^2).

Table I

Population parameters on R. repens in three $1m^2$ sites from March, 1969 to January, 1970. (units/m^2)

	Sites 1	2	3	Mean
ADULT POPULATION AT MARCH, 1969	148	208	61	139
Total seedlings from 3/69 to 1/70	11	18	12	14
Seedlings established during 1969	4	7	4	5
Original adult plants dead by 1/70	121	175	26	107
Vegetative units gained by 1/70	180	224	55	153
Vegetative units failed to establish by 1/70	35	35	9	26
Total vegetative output	215	259	64	179
Total seed output	331	326	205	287
ADULT POPULATION AT JANUARY, 1970	207	257	90	184

The mean values of the three sites in Table I show that the original population in March, 1969 was 139; a mean of 14 seedlings/m^2 was recorded of which only five became 'established' in the population. Of the original 139 adult plants 107 had died by January, 1970 but 157 daughter plants out of the total vegetative output of 179 daughters survived. The remaining 26 daughters failed to 'establish'. Thus the new population at the beginning of the 1970 growth season was increased to 184 plants. The total seed output was 287 achenes/m^2.

Table 2

Estimated dynamics of the seed population in the soil

	seed/m^2	%
Total seed population in the soil	230	100
Decayed	88	38
Acquired induced dormancy	118	51
Acquired enforced dormancy	6	3
Germinating	18	8

The mean seed population found in the soil samples from sites 1, 2 and 3 was 230/m^2. Using this figure as 100%it was estimated from the preliminary results of the experiment on seed decay, that 38%(88 seeds/m^2) decayed, 51%(118/m^2) acquired induced dormancy and 3%(6/m^2) went into a state of enforced dormancy. It was estimated that 8%of the seed population (18/m^2) germinated in the appropriate season.

Perhaps more interesting is the fact that the numbers for the three $1m^2$ sites, although with markedly different population sizes, behaved in a very similar way when the proportions are considered. For example, mortality percentages for seedlings in the three sites were 63.6, 61.1 and 66.6; the rates of increase of the population from March, 1969 to January, 1970 were 1.3, 1.2 and 1.4. Although the total vegetative output varied greatly, the percentages of surviving daughters remains remarkably similar (83.7, 86.6 and 86.0).

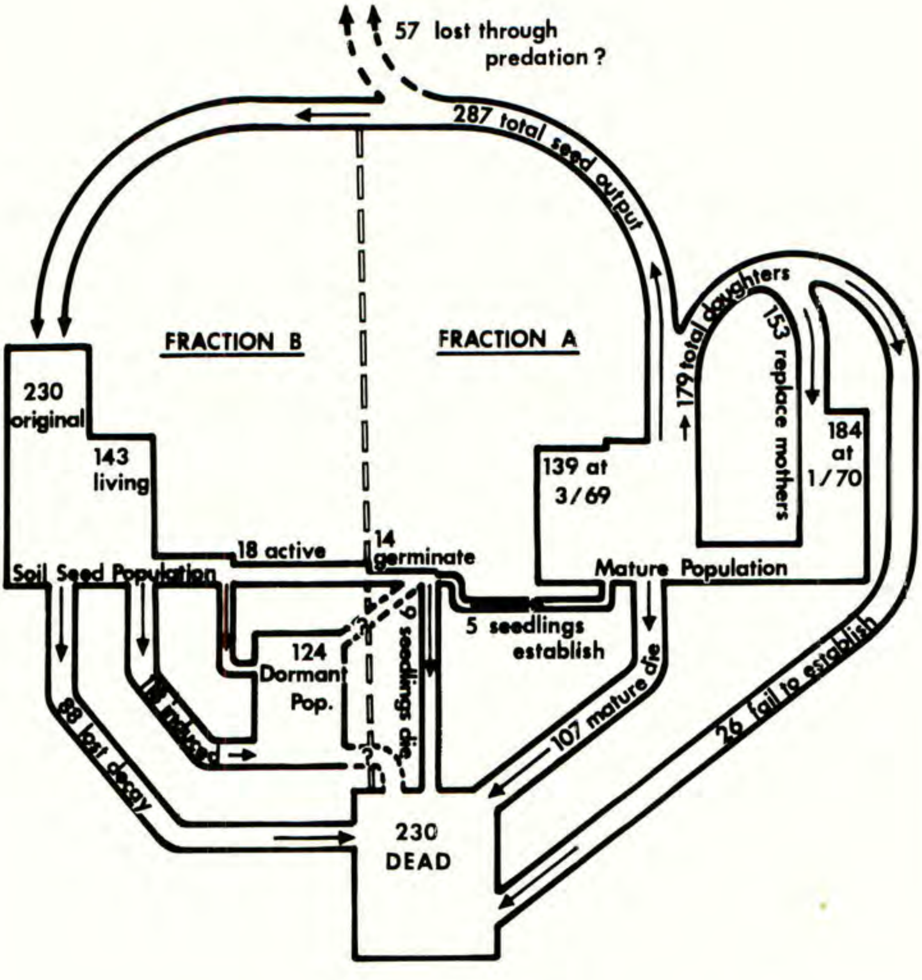

Fig. 1. A tentative and simplified flux diagram for the mean of three $1 m^2$ populations of Ranunculus repens in a coastal grassland in Caernarvonshire, for the period March 1969 to January 1970. Data for Fraction A from maps of permanent sites; data for original seed population in Fraction B obtained by sampling of site soil; dynamics of seed population estimated experimentally. All data in units/m^2. (See text for details).

The data also suggest that there are density-dependent mechanisms acting upon seed production and on the death rate of mature plants. Seed production per plant decreased sharply as the population density increased (3.3 seeds/plant in the less dense down to 1.5 seeds/plant in the densest). Percentage mortality of adults rose from 42.7 in the less densely populated site to nearly 85 in the more dense. Non-dependability on seed production, a characteristic often associated with active vegetative reproducers, is seen very clearly for the total absence of seed output would apparently leave the population size virtually unchanged. (Fig. I)

I believe that this approach to the study of plant populations gives comprehensive information on the flux of the whole population through the continued observation of individuals growing under different environmental conditions. It shows the populations as a fluctuating entity, rather than just a gathering of plants, in which the apparent stability observed in sporadic surveys is, in reality, the result of very dramatic changes in numbers of individuals. It also presents the opportunity to synthesise working models of populations in which it is possible to predict reactions of the populations to selected conditions. Finally it provides meaningful information to suggest which factors or agencies are likely to be responsible for controlling the short-term selection of individuals in a species' population. It is, in the end, this short-term selection that determines the long-term evolution of a species.

A series of lateral observations is being carried out in order to complement the central information obtained from the permanent sites and the experiment with seed populations. One group of these deals mainly with the effects of the grazing animals on the sexual and vegetative propagation of the species by the use of enclosed areas and experiments to determine the effect of ingestion by cattle on the viability of the seed. Also extensive samples of buttercups have been taken in the field during a growing season and their dry matter partitioned in order to find the amount of energy allocated by the plants to different organs at different times in the year and in different environmental conditions.

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WEED PREDICTIVE INDICES

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Summary Results of investigations over three seasons have confirmed the possibility of predicting the infestation level of blackgrass in winter cereal crops. Assessment of the viable weed seed content of soil samples taken before the crop is sown have been used to calculate a Weed Predictive Index (WPI) for a number of fields. Up to 98% of the subsequent variation in blackgrass density between the fields is forecast by WPI. The development and modification of present WPI techniques for other species and types of weeds is discussed.

INTRODUCTION

However desirable the control of pest species in crops may be, in practice the control measures taken against such species must be economically justifiable. The grower must decide whether it is cheaper to take the necessary control measures, or to accept some reduction in yield of the useful parts of his crop.

The efficient planning of future pest control measures during a crop growing season demands an accurate assessment of the probable future level of pest infestation. Easily measurable weather criteria have already been used in predicting the onset of plant diseases such as potato blight, *Phytophthora infestans* (Beaumont 1947) and apple scab *Venturia inaequalis* (Smith 1964) and recently for the insect pest *Glossina morsitans orientalis* (Phelps & Burrows 1969). A scheme which bases a decision on whether to spray sugar beet against yellows virus on economic predictive criteria has been developed by Hull (1968, 1969). Counts of the aphid vector, which had previously been used as the basis for issuing spray warnings were shown not to be in proportion to the eventual incidence of yellows.

When dealing with weed species, the justification for using pre-emergence herbicides is often difficult. It is here that predictive techniques are of value, by preventing the unnecessary use of such compounds merely as insurance policies.

The winter annual grass weed *Alopecurus myosuroides* Huds. (blackgrass), was used in a study to determine the possibility of developing Weed Predictive Index techniques, and it was chosen because of the large fluctuations experienced in different seasons, and its increasing importance in cereal production. Also at the start of the study, the only effective chemical control was using the pre-emergence herbicide terbutryne (4-ethylamino-2-methylthio-6-*t*-butylamino-1,3,5-triazine).

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METHOD AND MATERIALS

Soil samples were taken from each plot on a semi-random basis and bulked. Nine 300 g subsamples were taken from each bulk sample, spread out on John Innes potting Compost No 1 and placed in a greenhouse where they were regularly watered, and the temperature kept above 18°C. Emerging seedlings of A. myosuroides were counted and removed at intervals (Naylor 1970).

The Weed Predictive Index (WPI) of a plot is an assessment of the expected future density of a weed species in a defined area. It has been here calculated as the mean number of seedlings of A. myosuroides emerging from one subsample of the field bulk sample.

RESULTS

A pilot survey in 1967/68 on twenty-four fields showed that a significant correlation existed between the calculated WPI, and the levels of infestation that developed in the subsequent seasons in the respective fields. A more critical series of field trials in 1968/69 involved sampling twenty-four fields before crop drilling, and it was found that the WPI value for A. myosuroides for each field was positively correlated with the density of blackgrass plants at each site in the following May. The variation in WPI values accounted for 63% of the variation subsequently observed between fields.

The field trials in 1969/70 involved twenty fields. Each was sampled twice, first in September and later in October. There was no cultivation or disturbance of the soil surface between the October sampling and crop drilling. It had previously been demonstrated that in field populations of blackgrass, 90% of the plants were derived from seeds present in the top inch of the soil (Naylor 1970), and consequently sampling methods were modified in this series of trials: the depth to which samples were taken was reduced from 5 cm to 2.5 cm.

The results (Table 1) indicate the best prediction to be obtained from samples taken nearest to the time of drilling of the crop, and also that it is the level of infestation in summer that is most accurately predicted. The density of the weed in autumn and winter is not satisfactorily forecast by WPI values obtained from samples taken in October, but is better predicted by the WPI value obtained from the earlier samples.

Table 1

Efficiency of prediction of blackgrass density 1969/70

Month forecast	Sampling time	% field variation accounted for	Probability
January	September	51.28	0.1-0.01%
April	September	22.68	< 10%
April	October	97.04	> 0.01%
May	October	97.87	> 0.01%
June	October	84.28	~ 0.01%

The prediction of the levels of blackgrass infestation in April, May and June by WPI values from the October soil samples accounted for 97%, 98% and 84%

respectively of the variance observed between fields in these months. This increase in accuracy of the WPI estimation of weed density may have been due to the improved soil sampling technique and also partly to the less extreme weather conditions encountered in the 1969/70 growing season compared to those of the previous one.

DISCUSSION

At present one can predict the relative infestation levels of blackgrass in a series of fields in a particular growing season. It remains to be determined whether the relationship between WPI values and actual number of plants of *A. myosuroides* in the crop is constant from one season to another. One imagines that it is this aspect of the WPI technique that will be most affected by weather conditions which may determine both the total number of blackgrass seeds germinating throughout the season, and also the proportions that germinate in autumn and spring. It is here that long-range weather forecasts might be most usefully included in WPI calculations.

Information on the effect of density of blackgrass infestations on crop yield may easily be included in the WPI calculations, with the result that the grower can be told the potential yield loss of his crop if he takes no control measures against blackgrass. This may be a more meaningful measure than information on weed density. Yield reduction may be more accurately related to counts of the numbers of heads of *A. myosuroides* per unit area than the number of plants. This then takes account of the different sizes of individual plants. Results from the pilot survey indicate that the prediction of head density is possible, though perhaps less accurately than prediction of plant density.

The prediction of potential yield loss is the most useful information that could be supplied to a grower. Yield increases of up to 30% over non-sprayed plots have often been reported for blackgrass control. In a field experiment at Bangor it was shown that 10 plants of blackgrass per m^2 gives no significant yield reduction of wheat, while 30, 100 and 300 plants per m^2 gave yield reductions of 12.7%, 31.9% and 36.6% respectively.

The technique of WPI's has yet to be applied critically to other weed species. It is envisaged that soil sample estimates of viable seed will not be efficient at predicting the infestation level of perennial species, with high levels of vegetative spread. It may be possible instead to use the density of individuals (however defined) in one season combined with control measures taken in an assessment of probable levels in future seasons. For annual species the sampling technique and germination test procedures may have to be altered to suit individual weed species. In this respect the study of field populations and especially their germination behaviour is of primary importance.

In conclusion one can but hope that by the development of WPI techniques growers may be presented with information on the potential yield loss through weeds of their crops. They are then able to base decisions on control measures involving pre-emergence herbicides on knowledge rather than on fear.

Acknowledgments

My thanks are due to Professor J. L. Harper and Mr. S. D. Hocombe for their encouragement. I am indebted to the Science Research Council for the award of a C.A.P.S. Studentship, and to the Agricultural Chemicals Division of Geigy (U.K.) Ltd., for their close collaboration in this project.

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Proc. 10th Br. Weed Control Conf. 1970

YIELD RESPONSE TO SPRAYING FOR WEED CONTROL IN BARLEY

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Summary The effect on yield of farm spraying for weed control was studied in relation to the number and species of weeds present. An average increase in yield was recorded which was not correlated with total weed numbers but showed a strong correlation with the presence of certain weed species.

INTRODUCTION

Following reports from N.A.A.S. trials (Hughes R. G. 1966) that yields in cereals had not been increased by weed control spraying it was decided to investigate the effects of spraying on yield of barley in N.E. Scotland and if possible to relate this to the density and composition of the weed flora.

The work was carried out in the 1967 and 1968 season when fields of non-undersown spring barley, which the farmer considered likely to require spraying for weed control, were examined and the weed floras recorded. If the crop was in fact sprayed, estimates of yield were obtained from sprayed and non-sprayed areas. The results discussed relate to a total of 41 such crops, 29 in 1967 and 12 in 1968 of which 7 occupied fields which had also been recorded in 1967.

METHOD AND MATERIALS

At every centre a strip 100 x 4 yd subdivided into 4 plots each of 25 x 4 yd was left unsprayed by the farmer who treated the remainder of the field in accordance with his normal farm practice. Spray drift damage as assessed by the visual appearance of the weeds in the unsprayed area was only encountered at one site and then its effects were so slight as to be ignored. Counts of annual dicotyledonous seedlings were made in the marked area as late as possible before spraying took place. It is possible that the figures given for late emerging species such as *Chrysanthemum segetum* are below the true level of infestation. In each plot 5 random one foot square quadrats were counted giving a total of 20 counts for each site. In 1967 counts were made in both unsprayed and sprayed areas but this practice was discontinued in 1968 due to the close similarity of the results of the two counts.

Plot yield was determined by cutting two random samples of one square yard each, which were added together for threshing. The samples from the unsprayed area were paired with similar samples taken from the sprayed crop alongside. Care was taken to avoid obvious wheeltracks in the sprayed area. All samples were stored in paper sacks in a well ventilated shed for several weeks before threshing, so that any difference in grain moisture content due to variation in ripening between sprayed and unsprayed treatments would have disappeared before threshing.

RESULTS

The results of the weed recording from 40 different fields (not always the same as those from which yield were taken) are given in Table 1. They cannot be taken as a true picture of the weed flora in barley in N.E. Scotland since the fields were deliberately selected as being likely to require weed control spraying. Nevertheless it is interesting to note that the results broadly agree with those reported by Edwards C. J. (1968) in showing the outstanding importance of Stellaria media and Galeopsis spp. as weed problems in the area. The frequency of Polygonum persicaria and Polygonum aviculare is also revealed although the levels of infestation encountered are very much lower than those of Stellaria media and Galeopsis spp. Spergula arvensis is still very common but when compared with results obtained by Wyllie S. M. (1957) this weed has declined from its former position as the most frequently encountered weed in N.E. Scotland cereal fields. The incidence of Brassica sinapis and Raphanus raphanistrum has also declined and they are now comparatively uncommon. Chrysanthemum segetum and Lycopsis arvensis were found mainly on sandy soils in the Moray Firth area and although their frequency and density of infestation are both recorded as very low they present a serious problem wherever they occur.

Table 1

Annual dicotyledonous weeds in barley in N.E. Scotland

Weed Species	Frequency i.e. % sites where present at 1 or more/sq ft	Average density where present plants/sq ft	Max. density recorded plants/sq ft
Stellaria media	82	16.4	47.8
Galeopsis spp.	55	15.9	43.3
Spergula arvensis	52	3.3	8.1
Polygonum aviculare	40	2.3	4.4
Polygonum persicaria	32	3.0	5.7
Viola tricolour	22	4.0	10.0
Brassica sinapis	17	2.3	5.9
Chenopodium album and Atriplex patula	15	3.0	4.6
Ranunculus repens	15	3.0	9.7
Matricaria spp.	15	2.5	6.5
Raphanus raphanistrum	12.5	2.4	4.5
Fumaria officinalis	7	4.0	5.9
Myosotis arvensis	7	4.8	6.1
Lycopsis arvensis	5	2.6	2.8
Chrysanthemum segetum	2.5	4.0	4.0
Veronica spp.	2.5	1.6	1.6
Polygonum convolvulus	2.5	1.3	1.3

Also recorded - Trifolium repens, Senecio vulgaris, Capsella bursa-pastoris, Aphanes arvensis, Euphorbia spp., Papaver dubium, Lamium purpureum, Thlaspi arvense

Not found - Galium aparine

Yield response

The results given in Table 2 show that on the 29 sites successfully harvested in 1967 there was a significant average yield increase of 2.5 cwt/ac resulting from spraying. In 1968 with only 12 sites harvested the yield difference was again in favour of the sprayed treatment with an average yield increase of 1.3 cwt/ac; this figure was not however statistically significant.

No evidence was found of association of yield increase with total weed numbers. Separation of sites where Brassica sinapis, Raphanus raphanistrum, Lycopsis arvensis or Chrysanthemum segetum were present from the remainder showed that the bulk of the yield increase had arisen from those where these weeds were present. The remaining sites showed no appreciable yield increase.

Increases in yield were recorded on 31 sites and decreases on 10 sites. The largest increase was recorded in 1967 at a site where a troublesome infestation of Lycopsis arvensis in the cultivar Golden Promise was sprayed with MCPA. In spite of incomplete weed control the yield of the sprayed area was twice that of the unsprayed area. A 20% increase was recorded in the same field in 1968 when the cv Pallas was grown.

Table 2

Relationship of grain yield to spraying and weed flora

	All Centres		Raphanus raphinistrum, Chrysanthemum segetum, Brassica sinapis and Lycopsis arvensis			
	1967	1968	1967		1968	
			Present	Absent	Present	Absent
	29 fields	12 fields	14 fields	15 fields	8 fields	4 fields
	cwt/ac	cwt/ac	cwt/ac	cwt/ac	cwt/ac	cwt/ac
Mean Yield Sprayed (S)	38.0	25.8	39.0	37.1	27.6	22.1
Mean Yield Unsprayed (U)	35.5	24.5	35.0	35.9	26.3	20.9
S - U	+2.5*	+1.3	+4.0*	+1.2	+1.3	+1.2
S.E. of S - U	0.67	0.66	0.91	0.88	0.66	1.7

*significant increase at 5% level

DISCUSSION

The results indicate that spraying for weed control is likely to give beneficial results in the N.E. of Scotland. When comparing these results with those reported by Evans (1968) it should be borne in mind that the weed flora in the area surveyed is still a predominantly MCPA sensitive one and that this chemical was used in 31 out of the 41 sites from which yield results were obtained. No evidence was found in the survey of gross misuse of chemicals and spraying was generally correctly timed in relation to the stage of crop and weed growth.

Acknowledgments

The author gratefully acknowledges the assistance of Dr. G. M. Jolly of the A.R.C. Unit of Statistics, Edinburgh for his advice regarding layout of the survey and for statistical analysis of the results, and the co-operation of farmers who permitted their crops to be used for this work.

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Proc. 10th Br. Weed Control Conf. 1970

EFFECT OF DIFFERENT WEED SPECIES AND POPULATIONS ON CEREAL YIELDS

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Summary No clear relationship was demonstrated between crop yield and the numbers and species of broad leaved weeds included in the trials. It is conceivable that the hand weeding techniques employed masked some effects of treatments and the experimental design might be inadequate.

INTRODUCTION

There are few published data as to the effects under field conditions of different weed species and weed populations on cereal yields. The small plot trials reported here were carried out in an attempt to obtain some knowledge of herbicide, weed and crop relationships in order to better gauge the practical situations where herbicide treatment of crops is worthwhile.

METHOD AND MATERIALS

To make hand weeding a practical proposition plots were necessarily small, normally 4 ft by 6 ft, with a discard between plots to enable the operator to remove weeds without himself encroaching on the plot. A guard strip of at least 6 in. or one row of crop was discarded at harvest. Weeds were removed by hand pulling in the first trial but this was abandoned as the results suggested that this might have sufficiently disturbed the soil to affect yields. In the second trial weeds were killed by touching them with diquat on a small brush: while this very effectively killed the weeds there was a very occasional scorching of the crop either by spillage or contact of crop with treated weeds arising from wind movement. In consequence weeds in all further trials were removed by cutting below the cotyledons with small scissors; this technique may occasionally have resulted in very minor physical damage to the crop but would appear to be the most satisfactory.

RESULTS

Table 1

1963 trial: spring barley: four replications

Treatment	Yield: cwt/acre
Weeds hand pulled from crop 5 leaf stage onwards "A"	47.4
Weeds hand pulled at crop 5 leaf stage only "B"	47.5
Mecoprop applied at 32 oz ai/acre at crop 5 leaf stage "C"	48.5
As "A" but also sprayed as "C" "D"	47.0
Mecoprop applied at 40 oz ai/acre at crop 5 leaf stage "E"	48.4
Untreated "F"	47.2
Mean	47.7

SE ± 0.79 SE as per cent G.M. 3.3

Weeds at spraying were *Veronica persica* up to 2 true leaf stage at $12.6/ft^2$; *Stellaria media* up to the small plants at $6.0/ft^2$ and *Chenopodium album* up to 2 true leaves at $6.6/ft^2$. The weeds in the untreated crops remained below the level of the crop. Maturity was slightly delayed on treatment E.

Table 2

1966 Trial: spring barley: three replications

Treatment	Yield: cwt/acre
All weeds removed at crop 2-3 leaf stage onwards (1 May)	29.8
Population of 5 *Sinapis arvensis*/ft^2) established by 5 leaf	33.0
Population of 5 *Stellaria media*/ft^2) stage of crop by) removal of other weeds	30.9
All weeds removed at about crop growth stage 6 (1 June)	31.1
Untreated	30.3
Mean	31.0

SE ± 2.37 SE as per cent G.M. 13.2

Table 3

1967 trial: spring wheat: four replications

Treatments Number of weeds per ft^2 at 5 leaf stage of crop	Polygonum convolvulus	Tripleurospermum maritimum Ssp inodorum	Galeopsis tetrahit	Stellaria media	Veronica spp	Polygonum aviculare	Chenopodium album	Misc spp	Total Weeds	Yield: cwt/acre
3 Polygonum convolvulus	2.0	0.6	0.1	0.7	0.1	0.0	0.1	0.3	3.8	37.7
3 (Tripleurospermum maritimum Ssp inodorum)	1.4	2.8	0.0	0.9	0.2	0.0	0.3	0.1	5.6	38.7
9 (Tripleurospermum maritimum Ssp inodorum)	1.1	2.7	0.1	1.1	0.3	0.3	0.4	0.3	6.4	40.2
3 Galeopsis tetrahit	0.7	1.8	1.5	0.7	0.1	0.2	0.0	0.1	5.0	35.2
No weed	1.8	1.8	0.0	1.2	0.3	0.2	0.1	0.6	6.0	38.8
									Mean	38.1

SE ± 2.25 SE as per cent G.M. 11.8

Table 4

1968 trials: four replications: A - spring barley and *Polygonum lapathifolium*

B - spring wheat and *Polygonum convolvulus*

Trial A		Trial B	
Weeds/ft^2	Yield: cwt/acre	Weeds/ft^2	Yield: cwt/acre
0	37.6	0	42.0
12	34.5	6	42.5
36	36.4	18	39.9
Mean:	36.2	Mean	41.5

SE ± 1.13 SE as per cent G.M. 6.26 SE ± 1.40 SE as per cent G.M. 6.76

DISCUSSION

The 1963 trial yields suggest that the action of pulling out the weeds may have caused some crop damage. The 1966 trial was imprecise but the lack of yield depression by *Sinapis arvensis* is of note though this weed failed to dominate the crop. In the 1967 trial it is possible that the lower yield of the *Galeopsis tetrahit* treatment is a real effect since this weed was observed to be co-dominant with the crop and could therefore have competed for light to a greater degree than the other species. The lack of relationship in the 1967 trial between the populations initially established and those recorded at harvest implies an appreciable degree of weed kill by crop competition and also some late germination, probably mainly after the commencement of crop senescence.

There is no clear relationship in these trials between yield and weed population and species. It is not possible to be sure that the action of weed removal did not constitute a negative effect on crop growth which would explain the apparently higher yields from the higher weed population plots which naturally received less handling. It is difficult however to conceive of more gentle methods of weed removal than those employed in the last two years. It is reluctantly concluded that trials of this nature seem unlikely to be able to provide guide lines as to situations where action against broadleaved weeds is justifiable.

Acknowledgements

Thanks are due to the farmers who allowed the work to be carried out in their crops.

RESULTS OBTAINED FROM USE OF 3-ISOPROPYL-2,1,3-BENZO THIADIAZINON-4-2,2-DIOXIDE IN CEREALS

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Summary 3-isopropyl-2,1,3-benzo thiadiazinon-4-2,2-dioxide (BAS 3510H) is a contact herbicide. Toxicity to warm-blooded animals is moderate to slight. It does not colour the spray mixture. It is active against broad-leaved weeds including *Chrysanthemum segetum*, *Anthemis* spp. and *Matricaria* spp. A mixture of this chemical with dichlorprop (BAS 3580H) improved the weed control especially of *Polygonum* spp. Selectivity in spring and winter cereals was good.

INTRODUCTION

The increase in *Matricaria* and *Anthemis* spp. and particularly *Galium aparine* in the weed flora of cereal fields caused us to search for a herbicidal substance effective against these and other weeds. The substance 3-isopropyl-2,1,3-benzo thiadiazinon-4-2,2-dioxide is in our opinion admirably suited to the purpose. This report gives details of the results obtained.

METHOD AND MATERIALS

The trials were carried out by the BASF Agricultural Advisory Centres in Belgium, Germany, France, Netherlands, Austria and Switzerland, using BAS 3510H, a wettable powder containing 50% of the active ingredient*, and BAS 3580H, a wettable powder containing 26% of the active ingredient plus 34% of the mono-ethyl amine salt of dichlorprop.

The layout was randomised. Each plot was 20-25 m^2 in area.

The product was applied post-emergence in spring, when the crop had reached the 4-5 leaf stage. A compressed air knapsack sprayer with a pressure of ca 2.5 atm was used.

Weed control was assessed according to the EWRC scale and converted to percentages.

* Basagran - Registered Trade Mark of BASF AG.

Selectivity was assessed according to the following scale:

Damage to crop	% thinning
1. No damage	0
2. Traces of damage	2.5
3. Very slight damage	5
4. Slight damage	10
5. Moderate damage	15
6. Serious damage	25
7. Very serious damage	35
8. Extremely serious damage	67.5
9. Total loss	100

Toxicology Investigations carried out by the BASF Institute for Industrial Hygiene and Pharmacology showed that the LD 50 of the pure active ingredient is approximately 850 mg/kg for rats p.o. The LD 50 of the technical active ingredient is ca. 1000 mg/kg for rats p.o. and 750 mg/kg for rabbits p.o.

Mode of Action This chemical is mainly absorbed through the green parts of the plant. It has practically no effect on the radicle and pre-emergence treatment is therefore impossible.

It is most effective during periods of active growth. Cool weather generally delays effectiveness.

Because of its mode of action BAS 3510H should be regarded as a contact herbicide. It is not as corrosive as DNOC and other derivatives and does not give a yellow colour to the spray mixture.

RESULTS

Tables 1 and 3 show the herbicidal activity of BAS 3510H and its effect on the yield. Plant compatibility was assessed at 1/1 in almost every case. These results have not been included in the table.

Table 1

Herbicidal Efficacy in % and Yield after Treatment with BAS 3510H

Crop	Efficacy kg/ha a.i. 0.75-1.0	1.25-1.5	2.0	Yield (relative) kg/ha a.i. 0.75-1.0	1.25-1.5	2.0	Control dz/ha
Winter wheat	93 (27)	95 (36)	97 (10)	102 (7)	101 (7)	98 (7)	44.6
Winter barley	88 (8)	89 (11)	90 (6)	110 (3)	110 (3)	110 (3)	42.9
Winter rye	98 (3)	97 (3)	-	-	-	-	-

( ) = number of trials.

0.75-1.0 kg/ha BAS 3510H controlled 93-98% of the weeds present in winter wheat and winter rye. In winter barley it was slightly less effective, controlling only 88-90% of the weeds. This result is explained by the difference in weed age, which was greater in barley (stage D.6) than in wheat and rye.

Weed control produced a 10% yield increase in winter barley. In winter wheat, on the other hand, there was little or no increase, as some trial plots contained very few weeds. These results may however be taken as proof of BAS 3510H's high selectivity in winter cereals.

In order to control older weeds and thus obtain a better overall effect, BAS 3510H was mixed with dichlorprop. (Table 2) Except for two cases where the result was 2/1, plant compatibility was assessed at 1/1 and these results have not been included.

Table 2

Herbicidal Efficacy in % and Yield after Treatment with BAS 3580H (1:1,5)

Crop	Efficacy kg/ha a.i 1.5-1.8,	2.0-2.5,	3.0	Yield (relative) kg/ha a.i. 1.5-1.8,	2.0-2.5,	3.0	Control dz/ha
Winter wheat	$96_{(17)}$	$96_{(17)}$	$98_{(17)}$	$105_{(6)}$	$100_{(6)}$	$103_{(6)}$	45.0
Winter barley	$90_{(14)}$	$94_{(14)}$	$95_{(14)}$	$107_{(4)}$	$109_{(4)}$	$104_{(4)}$	41.5
Winter rye	$98_{(13)}$	$97_{(3)}$	$98_{(3)}$	$108_{(1)}$	$102_{(1)}$	$103_{(1)}$	36.5

( ) = number of trials.

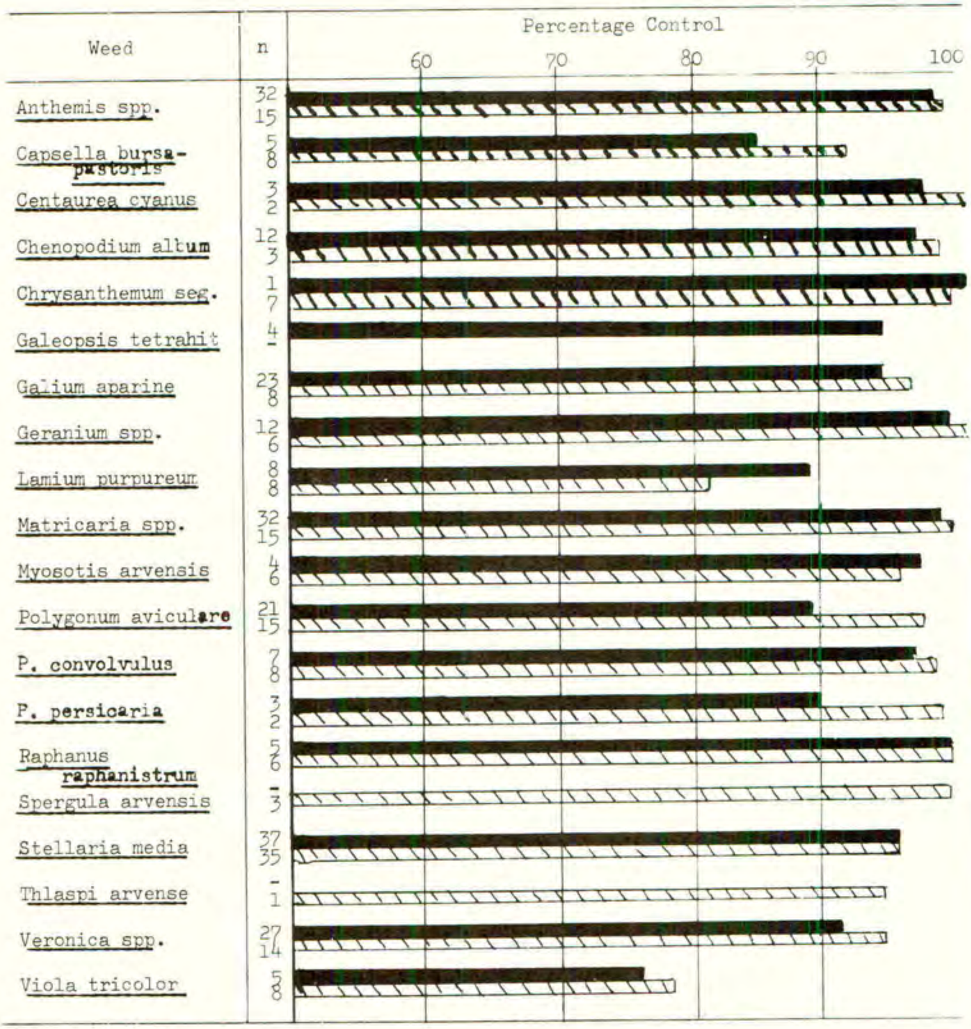
A control level of 90-98% was obtained with the mixture. In the trials on winter barley the mixture proved successful against older weeds, which had been controlled only with difficulty by BAS 3510H.

Elimination of the weeds brought about a yield increase of up to 9% (Table 2) depending on the type of cereal.

The weed spectra of BAS 3510H and BAS 3580H are shown in Table 3.

Table 3

Weed spectrum of BAS 3510H and BAS 3580H



n = number of trials

(solid bar) = 1.5-2.0 kg/ha BAS 3510H

(hatched bar) = 2.0-2.5 kg/ha BAS 3580H

Control of over 90% of the following species was obtained with 1.5-2.0 kg/ha a.i. BAS 3510H: Anthemis spp., Chenopodium album, Galium aparine, Matricaria spp., Myosotis arvensis, Raphanus raphanistrum and Stellaria media. The addition of dichlorprop generally improved efficacy, especially in Polygonum spp. and Veronica spp.

DISCUSSION

The results prove that BAS 3510H may be used to control weeds in winter cereals. Good results were also obtained in spring cereals. Special emphasis should be placed on the effect obtained against Anthemis spp., Matricaria spp. and Chrysanthemum segetum, which were controlled up to stage D.8. This is the great advantage of BAS 3510H over the hormone-based products, which often fail to control Anthemis spp. and Matricaria spp. after the small rosette stage.

Stellaria media and Galium aparine were also controlled. The latter in particular is becoming more widespread; it is undesirable as it impedes harvesting.

The addition of dichlorprop to BAS 3510H improved the overall efficacy, especially against Polygonum spp. which are increasingly becoming a problem.

The efficacy of BAS 3510H and BAS 3580H is reflected in yield increases up to 10%, depending on the type of cereal. The increase naturally depends on the number of weeds present and on the absolute yield.

Acknowledgements

We wish to thank our agencies in Belgium, France, the Netherlands, Austria and Switzerland for their assistance.

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FIELD TRIALS IN THE U.K. WITH 3-ISOPROPYL-2,1,3-BENZO THIADIAZINON-4-2,2-DIOXIDE (BAS 351H) FOR THE CONTROL OF BROADLEAVED WEEDS IN CEREALS

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Summary Two formulations of BAS 351H were tested, BAS 3510H (50% BAS 351H) and BAS 3580H (26% BAS 351H + 34% dichlorprop salt). BAS 3510H at 3 lb/ac and BAS 3580H at 2.5, 3.5, 4.5 and 9 lb/ac were tested for the control of broadleaved weeds, particularly Chrysanthemum segetum, Matricaria spp. and Galium aparine. Formulated mixtures of a) dicamba + mecoprop, b) TBA + mecoprop + dicamba + MCPA and c) a tank mixture of dinoseb + MCPA were used as comparison materials. BAS 3580H and BAS 3510H at all rates tested showed good control of the above mentioned weeds, and also of Stellaria media, Chenopodium album and Polygonum convolvulus and was superior to all other treatments. Polygonum aviculare and Veronica spp. were only partially susceptible to BAS 3510H and BAS 3580H, the latter formulation giving the better control. All materials showed poor control of Viola tricolor.

Slight scorching occurred on upper leaves of the crops on several sites (mainly winter wheat) with BAS 3580H at 9 lb/ac, but no symptoms of phytotoxicity were recorded with lower rates.

Yield results showed no significant differences between treatments.

INTRODUCTION

BAS 3510H is a wettable powder containing 50% BAS 351H. This chemical has formerly been referred to as thianon. The acute toxicity of the pure ingredient to rat (p.o.) is approximately 850 mg/kg and to rabbit (p.o.) 350 mg/kg.

Screening tests at BASF Limburgerhof, Germany, showed that BAS 3510H was very effective as a contact herbicide against Chrysanthemum segetum, Matricaria spp. and other dicotyledonous weeds. Monocotyledons, with the exception of Cyperaceae, appeared to be resistant: Fisher (1968), Fisher (1969) and Behrendt and Sipos (1969).

In trials in the U.K., 1969, BAS 3510H and a formulation of 26% BAS 351H + 34% dichlorprop salt (BAS 3580H) on winter wheat and spring barley gave very good control of Chrysanthemum segetum, Tripleurospermum maritimum and Galium aparine. The dichlorprop was added to 3510H to obtain a broader spectrum of weed control.

In 1970 BAS 3510H and BAS 3580H were tested further in various cereal crops for the control of broadleaved weeds. The results of these trials are presented below.

METHOD AND MATERIALS

Sixteen trials on cereals located in East Anglia, Lincolnshire, Oxfordshire and the South West were laid down in 1970. Sites were selected where Chrysanthemum segetum, Galium aparine or Matricaria spp. dominated.

In all trials a randomised plot design with four replicates was used, each plot measuring $25m^2$. Treatments were applied with a Van der Weij knapsack sprayer fitted with cone nozzles.

Weed control and crop tolerance were scored visually 3-4 weeks after application. These assessments were made according to the methods set out by the E.W.R.C. Method Group.

Trials were harvested using a Hege 125 small plot combine harvester. A strip measuring 11.25m by 1.25m was cut from each plot.

Two formulations containing 3-isopropyl-2,1,3-benzo thiadiazinon-4-2,2-dioxide (BAS 351H) were tested in the trials and compared with three standard materials.

Formulations: (a) BAS 3510H, a wettable powder containing 50% w.w. BAS 351H.

(b) BAS 3580H, a wettable powder containing 26% w.w. BAS 351H plus 34% of the mono-ethyl amine salt of dichlorprop.

RESULTS

Table 1

Site Details

Site No.	Soil Type	Crop	Cultivar	Date of Application	Crop Stage at Application*
1	Loamy Coarse Sand	Sp. Barley	Mosane	12.5.70	3-4
2	Sandy Clay Loam	W. Wheat	Cappelle	12.5.70	4-5
3	Loamy Medium Sand	W. Wheat	Joss Cambier	12.5.70	4-5
4	Clay Loam	W. Barley	Maris Otter	14.5.70	4-5
5	Fine Sandy Loam	W. Barley	Proctor	18.5.70	4-5
6	Medium Sandy Loam	W. Wheat	Cappelle	18.5.70	4-5
7	Loamy Coarse Sand	W. Wheat	Cama	18.5.70	4-5
8	Loamy Coarse Sand	Sp. Barley	Sultan	28.5.70	5-6
9	Medium Sand	Sp. Wheat	Janus	29.5.70	5-6
10	Coarse Sand	Sp. Barley	Zephyr	2.6.70	3-4
11	Coarse Sand	Sp. Wheat	Kolibri	1.6.70	4-5
12	Clay Loam	W. Wheat	Joss Cambier	12.5.70	5-6
13	Sandy Loam	W. Wheat	Joss Cambier	13.5.70	5-6
14	Loamy Fine Sand	Sp. Barley	Proctor	19.5.70	2-3
15	Sandy Loam	Sp. Barley	Sultan	20.5.70	5-6
16	Sandy Loam	Sp. Barley	Zephyr	27.5.70	4-5

* Feekes - Large Scale.

Table 2

Weed Control Assessed 3-4 weeks after treatment

Weed Species and No. of sites occurring		Growth Stage Range	3510 3lb/ac	3580 2½lb/ac	3580 3½lb/ac	3580 4½lb/ac	3580 9lb/ac	A	B	C
Chrysanthemum segetum	(7)	Cot. - 8 in	2.6	3.4	2.3	1.9	1.1	7.9	-	3.9
Matricaria spp.	(10)	Cot. -15 in	1.6	2.0	1.4	1.3	1.1	5.2	3.6	3.1
Galium aparine	(3)	1-18 in	1.2	1.1	1.0	1.0	1.0	2.8	2.1	-
Chenopodium album	(4)	1-12 in	1.5	1.1	1.0	1.0	1.0	1.3	-	-
Polygonum aviculare	(11)	Cot. - 8 in	6.3	4.6	3.8	2.7	2.4	2.0	2.0	6.1
Polygonum convolvulus	(5)	1- 5 in	3.3	2.5	2.3	1.9	1.4	1.0	1.0	1.9
Stellaria media	(9)	Cot. -12 in	1.6	1.7	1.6	1.3	1.2	1.2	1.2	-
Veronica spp.	(2)	3-12 in	5.9	4.6	4.1	3.1	2.9	-	2.0	-
Viola tricolor	(5)	2- 5 in	7.1	6.1	4.9	4.7	3.3	4.8	5.0	5.8

Treatment A: Formulated mixture of dicamba + CMPP, 4 pint/ac
Treatment B: Formulated mixture of TBA + dicamba + MCPA + CMPP, 4 pint/ac
Treatment C: Tank mixture of dinoseb 5 pint + MCPA 1 pint/ac

Table 3

Overall Weed Control Score (mean) 3-4 Weeks After Treatment

Site No.	Dominating Weed spp.*	3510 3lb/ac	3580 2½lb/ac	3580 3½lb/ac	3580 4½lb/ac	3580 9lb/ac	A	B	C
1	a,d	6.0	5.7	4.5	4.0	3.0	-	-	5.8
2	e,h,c	4.3	3.3	3.0	2.3	1.3	-	1.3	-
3	b,e	2.5	2.5	2.0	2.0	1.5	5.3	-	-
4	c,e	2.0	1.8	1.0	1.3	1.0	2.8	1.8	-
5	b,d	4.8	4.3	3.5	2.8	2.3	5.3	4.3	-
6	f,g,d	5.0	3.5	3.3	2.5	2.0	3.0	-	-
7	b,d	4.0	2.8	2.3	2.8	2.0	4.8	4.3	-
8	a,b,f,g	2.5	2.5	2.0	2.0	2.0	-	-	3.5
11	a,b	2.5	2.5	2.0	2.0	2.0	-	-	2.8

* Weed Species given in order of dominance

Weed spp.
a) Chrysanthemum segetum
b) Matricaria spp.
c) Galium aparine
d) Polygonum aviculare
e) Stellaria media
f) Polygonum convolvulus
g) Chenopodium album
h) Veronica spp.

Overall weed control score was not carried out on sites nos. 9,10, and 12 to 16.

Crop tolerance observations

Slight scorch was observed on upper leaves with 3580H at 9 lb/ac on Site nos. 2, 3, 6, 7, 9, 12, 13, 15, 16. Severe scorch occurred with all DNBP/MCPA treatments.

Table 4

Yield Assessments (cwt/ac)

Site No.	Control	3510 3lb/ac	3580 2½lb/ac	3580 3½lb/ac	3580 4½lb/ac	3580 9lb/ac	A	B	C
3	54.0	56.9	57.4	56.4	54.7	55.2	54.5	-	-
4	31.7	30.9	29.6	29.4	29.0	28.9	29.6	29.1	-
5	23.8	25.0	24.2	23.2	23.7	24.3	23.2	23.5	-
6	49.9	51.1	51.8	50.3	49.9	51.8	49.5	-	-
10	14.0	15.6	15.0	14.1	14.1	14.5	-	-	14.0
11	17.9	19.8	18.6	18.6	18.6	19.5	-	-	20.2
16	20.5	22.3	23.9	24.7	24.8	24.5	23.2	-	-

None of these trials showed significant yield difference at the 5% level.

DISCUSSION

Weed Control: Very good control (table 2) of *Chrysanthemum segetum*, *Matricaria* spp. and *Galium aparine* was obtained with 3510H at 3 lb/ac and 3580H at $2\frac{1}{2}$ lb/ac, both being superior to comparison materials. *Chrysanthemum segetum* up to 8 in high was controlled but on some sites where spraying was delayed in order to cover its long germination period, some of the older plants were able to recover from the $2\frac{1}{2}$ lb and $3\frac{1}{2}$ lb/ac rate of 3580H. *Matricaria* spp. up to 15 in high and *Galium aparine* up to 18 in were very well controlled by all rates of 3510H and 3580H. *Stellaria media* and *Chenopodium album* were very susceptible to all treatments. *Polygonum aviculare* and *Veronica* spp. were partially resistant to 3510H at 3 lb/ac and the low rates of 3580H. As the rate was increased control became more satisfactory, but still inferior to comparison materials. *Polygonum convolvulus* was well controlled by 3510H and 3580H but more susceptible to comparison materials.

Viola tricolor showed a high degree of resistance to all treatments, 3510H at 3 lb/ac being the least effective.

The overall weed control scores (table 3) show that 3510H at 3 lb/ac has a limited weed spectrum. 3580H at $3\frac{1}{2}$ lb/ac and above compared favourably with comparison materials except in some trials where *Polygonum aviculare* or *Veronica* spp. dominated.

Crop Tolerance: 3580H at 9 lb/ac caused slight scorching of the upper leaves on all winter wheat, one spring wheat and two spring barley trials; the symptoms appearing soon after application and disappearing about five weeks later. There was no sign of crop depression or thinning except on Site No. 9 (spring wheat) where a slight depression occurred.

No signs of phytotoxicity were observed with other rates of 3580H, 3510H at 3 lb/ac and comparison materials except where DNBP/MCPA was applied which caused severe scorching.

Seven trials (2 winter wheat, 2 spring barley, 1 spring wheat and 2 winter barley) were taken to yield. 3510H and 3580H at the highest rate tested caused no adverse effect on yield.

From these trials, it emerges that 3510H is effective against *Chrysanthemum segetum*, *Galium aparine* and *Matricaria* spp. and a range of other weed species.

The mixture with dichlorprop (3580H) improved the degree of control considerably, although greater activity against *Polygonum aviculare* would be desirable.

Work is planned with other mixtures containing 3510H which are likely to be more effective against the latter species.

Acknowledgements

The authors wish to thank Mr. A. J. P. Frost and Mr. J. L. Bedford for their help in carrying out the trials programme. Thanks are also due to the farmers who co-operated with us in these trials.

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APERA SPICA-VENTI IN SWEDEN: OCCURRENCE, BIOLOGY AND CONTROL

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Summary Apera spica-venti is a troublesome weed in southern and southeastern Sweden. It develops faster than the cereal crop and ripe seeds fall to the ground before harvest. The seeds germinate at shallow depths, generally during the autumn. The effect of different urea and triazine herbicides used for the control of Apera in winter cereals was studied during five years (1965-69) in trials on different soils and under different climatic conditions. The herbicides gave 80-90 % control of Apera and 75-80 % control of dicotyledonous weeds. Pre-emergence treatments gave 10 % better control of Apera than post-emergence treatment in early spring. Pre-emergence treatment increased the grain yield of both winter rye and winter wheat. Post-emergence spring treatment gave yield increases only in wheat, while rye generally seemed to be inhibited. BAS 2440 H was mildest on rye, while methabenzthiazuron and monolinuron were more aggressive.

INTRODUCTION

Occurrence Apera spica-venti has long been a serious problem in several districts of southern Sweden. In 1968 a questionnaire was sent to all the county agricultural boards in Sweden asking for information on the occurrence of Apera as a weed in different crops. The replies indicated that Apera occurs as a troublesome weed mainly in the southern and southeastern parts of the country and that about 75,000 ha (3 % of the arable land in Sweden) were infested. Apera occurs especially on loams and sandy soils and mainly in winter cereals being rarely seen in spring cereals. In some districts Apera has increased considerably during recent years.

Control In field trials carried out earlier than 1965 the effects on Apera spica-venti of calcium cyanamide and dichlobenil amongst others, was studied. Both substances were more selective at spring treatment than autumn treatment. When 300 kg/ha of calcium cyanamide was applied early in the spring, Apera was controlled to about 60 %. Spring treatment with 4 kg dichlobenil gave a 90 % control of Apera but was liable to damage the crop. These substances are no longer marketed in Sweden.

During the five-year period 1965-69 official Swedish field trials were carried out to study the effects of various new herbicides, for example, BAS 2440 H (25% bromopyrazone + 25% isonoruron), buturon, fluometuron, Gesaran 2079 (22.5 % methoprotryne + 5 % simazine), linuron, Lumeton 2412 (24.3 % mecoprop + 15 % methoprotryne + 3.34 % simazine), methabenzthiazuron, monolinuron and terbutryne. The results of these trials are given below.

METHOD AND MATERIALS

Germination tests in soil were carried out in plastic pots in the laboratory or the greenhouse. Each experimental treatment comprised 4x100 seeds.

A systematic block design with four replicates was used in the field trials. The size of the plot was 50 m^2. The trials were located in different parts of south Sweden.

Pre-emergence treatment was carried out between sowing and emergence and post-emergence treatment in early spring when cereal growth had started again. Weeds were counted and weighed in the spring on an area of 2x0.25 m^2 per plot. Only relative weights of surviving weeds are given in the tables. The experimental data was subjected to analysis of variance. The sum of squares of the treatments was subdivided into the number of components with one degree of freedom each.

Buturon was used as standard for comparison with other herbicides in corresponding trials. The herbicides were applied in 400 l.water/ha.

RESULTS

Biology Apera spica-venti germinates in the autumn and requires good moisture conditions for its development. A germination experiment in soil with different moisture contents gave the following results:

Moisture content, % of max.	15	21	32	50	65	95
Germination per cent	0	11	21	31	26	15

The influence of seeding depth on germination was demonstrated in a sandy soil (moisture content about 50 % of maximum water capacity). None of the seeds placed deeper than 2 cm germinated, while highest germination was obtained when seeds were placed on the soil surface without being covered with soil.

The influence of temperature can be seen in the following data from an experiment in a growth cabinet:

Temperature	25° C	18° C	11° C	5° C	
Germination started after	5	6	10	16	days
Germinated after 5 weeks	40	53	55	42	%

After the seed has germinated in the autumn the plant over-winters in the 2-3 leaf stage.

It is possible for the seed to germinate even in the spring if the moisture conditions are favourable but it is a fact that well-developed plants of Apera seldom occur in spring cereals. This can partly be explained by secondary dormancy as demonstrated by the following experiment.

Apera seeds collected in August 1969 were (a) germinated immediately, (b) germinated in November 1969, (c) stored indoors under dry conditions and germinated in June 1970, (d) buried in the soil during the winter, then taken up and germinated in June 1970. The following germination results were obtained:

	Per cent germination after								
	5	7	10	20	30	40	50	60	70 days
(a)	0	3	6	7	9	12	12		
(b)	14	21	24	26	27	27			
(c)	7	9	11	12	15	18	18		
(d)	0	0	0	0.5	0.5	2	10	15	15

These figures suggest that seeds of Apera buried in the soil developed a secondary dormancy. This result indicates that Apera seeds do not reach germinating ripeness before the spring cereals have developed to such a stage that they can compete with Apera by killing the seedlings.

Seedlings of Apera growing without competition can reach a very considerable development, with up to as many as 100 tillers per plant. However, in cereal crops the tillering is slight, generally 2-5 tillers per plant.

Plants of Apera develop during the spring at about the same rate as the winter cereal, so that flowering in both Apera and the cereal crop occur at about the same time. Seed ripening, however, is much more rapid in Apera and the seeds have generally ripened and fallen to the ground by about one or two weeks before harvest.

Control The influence of BAS 2440 H, buturon, Gesaran 2075, linuron, methabenzthiazuron, monolinuron and terbutryne on Apera spica-venti, dicotyledonous weeds and winter cereals are given in tables below.

The effects of these herbicides at pre-emergence application are summarized in table 1, and the effects of post-emergence application in early spring in table 2. Table 1 shows that the herbicides used in pre-emergence treatment have given, on average, 90 % control of Apera and 75 % control of dicotyledonous weeds, which have usually been Centaurea cyanus, Capsella bursa pastoris, Matricaria spp., Myosotis arvensis, Stellaria media, Veronica spp., Viola arvensis. After normal over-wintering the crop has such a good competition ability that no additional spring weed control is necessary. However, all the herbicides give insufficient control of Galium aparine, Veronica spp., Viola arvensis. The good weed control obtained by the pre-emergence treatments was usually followed by significant yield increases in both winter rye and winter wheat. Certain differences appear to exist between the herbicides in weed control and in influence on yield, but these differences were seldom statistically significant.

According to the results given in table 2 the herbicides have given, on average, 80 % control of both Apera and dicotyledonous weeds. Thus, post-emergence treatment in spring gave about 10 % lesser control of Apera and 5 % better control of dicotyledons than pre-emergence treatment in the autumn. Certain differences in the control of Apera seem to exist between the herbicides. Linuron and terbutryne gave poorer control of Apera than buturon while Gesaran 2079 and methabenzthiazuron were more effective. The differences in the control of dicotyledonous weeds were more noticable. Accordingly, Gesaran 2079, methabenzthiazuron, monolinuron and terbutryne gave better control than buturon. They were mainly more effective against Matricaria spp.. Gesaran 2079, methabenzthiazuron and terbutryne were, in addition, more effective than buturon in controlling Centaurea cyanus. None of these herbicides gave satisfactory control in spring of Galium aparine, Lamium spp., Veronica spp. or Viola arvensis.

The relatively good weed control generally did not result in increased yields from winter rye. Differences in grain yield between herbicides appear to exist. All the herbicides, with the exception of BAS 2440 H, seem to have retarded rye to larger or smaller degrees, especially methabenzthiazuron. Monolinuron also affected the rye.

The spring treatments of winter wheat have resulted in significant yield increases which were invariably smaller than the increases following autumn treatment. Gesaran 2079 and methabenzthiazuron gave clearly higher yields in comparison with buturon while monolinuron slightly inhibited the wheat.

Both rye and wheat appear to be more susceptible to these herbicides in the spring than in the autumn, inspite of lower doses generally being used in the spring.

Fluometuron and Lumeton 2412 were also included in some trials during the five-year period. When applied in the spring fluometuron gave excellent control of Apera, but as it inhibited the winter cereals and lowered the yield it was rejected.

Lumeton 2412 as a spring treatment gave about the same control of Apera as buturon and was clearly better than buturon on dicotyledons. However, the herbicide seemed to be more aggressive than buturon on rye and was thus rejected.

DISCUSSION

It is interesting to note that both rye and wheat have been more susceptible to herbicides in spring than in autumn. The natural explanation can be that the condition of the crop in spring is lowered owing to damage from frost, water or parasites and the tolerance of the crop has decreased.

It is evident from the field trials that rye is inhibited more than wheat, which seems to indicate that rye is the more susceptible species. Preliminary results from the laboratory show that rye and wheat plants with roots soaked in buturon solutions and grown in nutrient solution show about the same susceptibility.

Differences in tolerance between rye and wheat are therefore considered to depend on a type of environmental resistance. Rye is usually grown on light soils and therefore is more exposed to damage from soil herbicides than wheat, which is more frequently grown on heavier soils. However, this cannot be the only explanation, as autumn-treated rye responds to the same degree as wheat. The most probable explanation is that rye has developed a shallower root system than wheat and thus more easily comes into contact with the herbicide, causing greater risks of damage.

Table 1

Effect of herbicides in winter cereals, pre-emergence treatment in the autumn

Treatment	a.i. kg/ha	Grain yield (85 % dm) – Winter rye – No. of trials	Winter rye – kg/ha	Winter rye – Signific. level	Winter wheat – No. of trials	Winter wheat – kg/ha	Winter wheat – Signific. level	Surviving weeds in rye and wheat – Apera sp. v. – No. of trials	Apera sp. v. – Rel. weight	Apera sp. v. – Signific. level	Dicotyledons – No. of trials	Dicotyledons – Rel. weight	Dicotyledons – Signific. level
A Untreated	0	15	2390	A-Bx	29	4050	A-Bxx	38	100	A-Bxxx	39	100	A-Bxxx
B Buturon	1.25		2690			4400			8			28	
A Untreated	0		-			4140	A-Bx		100	A-Bxxx		100	A-Bxx
B Linuron	0.7	-	-		8	4540	A-Cx	6	3	A-Cxxx	7	15	A-Cx
C Buturon	1.25		-			4540			9			39	
A Untreated	0		3700	A-B+		4140	A-B+		100	A-Bxxx		100	A-Bxxx
B Monolinuron	0.7	13	3910	A-Cx	8	4470	A-Cx	10	20	A-Cxxx	11	38	A-Cxxx
C Buturon	1.25		4030			4540			12			34	
A Untreated	0		2750			4520	A-Bx		100	A-Bxxx		100	A-Bxxx
B Gesaran 2079	0.83	3	3170	A-C+	7	5190	A-C+	9	11	A-Cxxx	9	30	A-Cxxx
C Buturon	1.25		3210			4950			5	B-C+		8	B-C+
A Untreated	0		2560	A-Bxxx		3990	A-Bxxx		100	A-Bxxx		100	A-Bxxx
B Terbutryne	1.5	13	3140	A-Cxx	20	4500	A-Cxx	29	13	A-Cxxx	31	23	A-Cxxx
C Buturon	1.25		2890	B-Cx		4350			9			26	
A Untreated	0		2560	A-Bxxx		3990	A-Bxxx		100	A-Bxxx		100	A-Bxxx
B Methabenzthiazuron	2.0	13	3060	A-Cxx	20	4530	A-Cxx	29	8	A-Cxxx	31	22	A-Cxxx
C Buturon	1.25		2890	B-C+		4350	B-C+		8			26	
A Untreated	0		-			3130			100	A-Bx		100	A-Bxx
B BAS 2240 H	1.5	-	-		4	3330		4	58	A-Cxx	4	47	A-Cxx
C Buturon	1.25		-			3410			16			35	

\+ Significant at the 0,2 level of probability
x "- 0,05 "-
xx "- 0,01 "-
xxx "- 0,001 "-

Gesaran 2075: 22,5 % methoprotryne +
5,0 % simazine

BAS 2440 H: 25,0 % bromopyrazone +
25,0 % isonoruron

Table 2

Effect of herbicides in winter cereals, early treatment in the spring

Treatment	a.i. kg/ha	Grain yield (85 % dm)						Surviving weeds in rye and wheat					
		Winter rye			Winter wheat			Apera sp. v.			Dicotyledons		
		No. of trials	kg/ha	Signific. level	No. of trials	kg/ha	Signific. level	No. of trials	Rel. weight	Signific. level	No. of trials	Rel. weight	Signific. level
A Untreated	0	20	2790		40	4390	A-Bxx	62	100	A-Bxxx	61	100	A-Bxxx
B Buturon	1.0		2760			4640			15			25	
A Untreated	0		1030			4200	A-Bxx		100	A-Bxxx		100	A-Bxxx
B Linuron	0.6	5	870		25	4470	A-Cxx	23	21	A-Cxxx	24	22	A-Cxxx
C Buturon	1.0		980			4490			11	B-C+		26	
A Untreated	0		1300			4000			100	A-Bxxx		100	A-Bxxx
B Monolinuron	0.6	2	840		15	4130	A-C+	18	10	A-Cxxx	19	17	A-Cxxx
C Buturon	1.0		970			4180			12			27	B-C+
A Untreated	0		3360			4460	A-Bxxx		100	A-Bxxx		100	A-Bxxx
B Gesaran 2075	0.35	7	3360		27	4980	A-Cxx	34	16	A-Cxxx	31	15	A-Cxxx
C Buturon	1.0		3320			4770	B-C+		19			27	B-C+
A Untreated	0		3360			4320	A-Bxx		100	A-Bxxx		100	A-Bxxx
B Terbutryne	1.[illegible]	7	3340		22	4750	A-Cx	28	33	A-Cxxx	25	14	A-Cxxx
C Buturon	1.0		3320			4640			21	B-C+		30	B-Cx
A Untreated	0		3360			4320	A-Bxxx		100	A-Bxxx		100	A-Bxxx
B Methabenzthiazuron	2.[illegible]	7	3350		22	4990	A-Cx	29	16	A-Cxxx	26	13	A-Cxxx
C Buturon	1.0		3320			4640	B-Cxx		20			29	B-Cxx
A Untreated	0		3060			4400	A-Bxx		100	A-Bxxx		100	A-Bxxx
B BAS 2440 H	1.0	15	3130		27	4700	A-Cx	39	13	A-Cxxx	39	29	A-Cxxx
C Buturon	1.0		2990	B-C+		4610			16			29	

+ Significant at the 0,2 level of probability
x "- 0,05 "-
xx "- 0,01 "-
xxx "- 0,001 "-

Gesaran 2075: 22,5 % methoprotryne + 5,0 % simazine

BAS 2440 H: 25,0 % bromopyrazone + 25,0 % isomeruron

Proc. 10th Brit. Weed Control Conf. 1970

WEED CONTROL IN WINTER WHEAT WITH TRIFLURALIN IN ITALY

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Summary Results of randomised trials and field applications of trifluralin to winter wheat during 1965-1970, showed that a pre-sowing incorporated application of 445 g/ha a.i. was phytotoxic to the crop. A post-sowing application before the crop had emerged also had inadequate selectivity. Post-emergence applications at either 668 g/ha a.i. or 890 g/ha a.i. gave good control of broadleaved weeds and Poa spp, some control of Alopecurus myosuroides. Avena fatua was resistant.

INTRODUCTION

Winter wheat is one of the most important crops in Italy. Soft wheat occupies about 3 million hectares and the durum wheat area, which is expanding, is about 1.3 million hectares. The use of herbicides is very limited only about 10% of the crop is treated. The situation is static and has remained unchanged for the last 20 years. 2,4-D and DNOC are the most commonly used herbicides, however in recent times new pre-emergence herbicides have been introduced. The reasons for restricted herbicide use are very complex and are not discussed in this paper.

In 1965 American friends asked us to carry out herbicide trials in wheat against A. myosuroides, but there were no infestations. However by 1967/68 it had become a serious problem.

Trifluralin, known to be active against grass weeds, was included in our field trials programme along with other well known herbicides.

METHOD AND MATERIALS

Trifluralin 44.5% w/w a.i. as "Treflan 4EC" was used in all the trials. Where reference is made to granular formulation, "4 EC" was absorbed on inert granular material. Most of the trials were carried out using a randomized block design with 4 replications, and were evaluated with Duncan's multiple range test. Pre-seeding incorporation was by a rotary cultivator; pre-emergence incorporation was carried out by very light straight toothed harrow. The randomized experiments were mainly conducted in the southern Po Valley and in Central Italy; trials without replicates were also carried out in other areas. A pressurized knapsack sprayer fitted with a boom was normally used; herbicides were applied in 600-800 l. water/hectare.

During the trial period (1966-1970) trials and semi-commercial applications were carried out on a range of soil types excluding sandy soils.

RESULTS

1965-66 Pre-seeding and post emergence applications of 690 g/ha a.i. of a granular formulation at 50 kg/ha, in a single trial demonstrated the selectivity and herbicidal activity of trifluralin as a post-emergence application.
The pre-seeding application reduced the germination of the crop and produced yellowing.

1966-67 A single trial compared four dates of post emergence application of the E.C. formulation on 15/11/66, 25/11/66, 30/1/67 and 22/2/67, the crop having emerged on 1/11/66. Two rates of trifluralin were applied, 0.696 kg/ha and 1.380 kg/ha. Only the earliest treatment showed signs of crop phytotoxicity.

1967-68 The results of the four trials are shown in Table 1, application of 890 g/ha being made at the 1-2 leaf stage of the crop. There were no signs of phytotoxicity.

Table 1

Effect of trifluralin in post emergence application on weeds and on wheat yield. 1967/68

Locality	Treatment	Dose g/ha a.i.	Days between seeding and application	Coverage %	Weight of weeds kg/ha Dicots	Weight of weeds kg/ha Grass	Yield ton/ha	Yield % of Control
S. Pietro in Casale	E.C.	890	S + 30	2.8	84	47		
	Control	-		35.3	1739	345		
Galliera	E.C.	890	S + 47	19.2		1522	5.59	109.6
	Control	-		36.0		2886	5.10	
Bologna	E.C.	890	S + 33	2.0	118	22	6.31	185.0
	Control	-		42.0	836	1436	3.41	
Sala Bolognese	E.C.	890	S + 56	10.0	1200	430	5.60	113.3
	Control	-		36.0	1360	2240	4.94	
MEAN	E.C.	890		8.5	467	505	5.83	130.1
	Control	-		37.3	1312	1727	4.48	

1968-69 In addition to the treatments recorded in Table 2 a pre-seeding incorporated treatment at 445 g/ha was also included, but proved highly phytotoxic.

Table 2

Effect of trifluralin 668 g/ha a.i. (L) and 890 g/ha a.i. (H) on the principal weeds and on wheat yield when applied in the 1-2 or 3-5 leaf stage of wheat. 1968/69

Locality	Grass(✗) weeds		Veronica spp.		Stellaria m.		Lepidium spp.		Coverage %			Yield ton/ha		
	1-2 leaves	3-5	1-2 leaves	3-5	1-2 leaves	3-5	1-2 leaves	3-5	1-2 leaves	3-5	Control	1-2 leaves	3-5	Control
Molinella														
L	6.7	-	6.2	5.7	6.7	5.2	5.1	6.5	5.7	8.0	13.70	-	-	-
H	8.5	-	6.3	6.5	7.0	6.5	6.6	4.7	4.7	7.2				
Galliera														
L	4.7	4.5	7.2	7.2	7.7	7.5	4.5	4.5	13.2	14.0	23.70	4.38	4.16	4.18
H	4.7	3.7	7.5	7.2	7.5	6.7	4.7	4.5	13.5	17.5		4.18	3.73	
Mascarino														
L	5.7	3.7	-	-	8.5	6.2	7.0	3.5	11.3	18.0	23.50	-	-	-
H	5.0	5.0	-	-	9.0	8.0	3.0	3.5	11.3	14.0				
Sala Bolognese														
L	5.5	6.5	-	-	-	-	-	-	8.8	16.3	30.00	3.48	3.34	3.46
H	7.5	6.5	-	-	-	-	-	-	10.0	12.5		3.66	3.31	
S. Pietro in Casale														
L	6.4	6.7	8.6	7.9	-	-	-	-	23.8	13.8	92.50	3.37	3.27	2.45
H	6.8	6.5	8.8	6.9	-	-	-	-	17.5	15.0		3.12	3.27	
Ravarino														
L	7.1	6.6	9.1	9.5	8.4	7.0	9.0	6.7	5.0	25.0	71.25	-	-	-
H	7.3	6.1	8.8	8.6	8.2	7.5	9.0	7.5	5.0	15.0		-	-	
Rovereto														
L	7.3	5.9	9.1	8.5	-	-	-	-	4.3	17.5	65.00	5.25	4.97	4.80
H	7.3	6.5	9.1	8.6	-	-	-	-	6.3	6.3		5.12	4.85	
Calderara di Reno														
L	-	-	6.8	4.2	7.9	5.2	-	-	6.8	8.3	31.75	-	-	-
H	-	-	6.6	2.3	7.9	5.5	-	-	8.8	12.8		-	-	
Galliera														
L	8.3	5.6	9.0	8.8	-	-	8.1	7.4	6.3	13.8	38.75	4.65	4.82	4.86
H	8.2	5.8	9.0	8.8	-	-	8.4	7.9	5.0	11.3		4.70	4.80	
Pegola														
L	9.0	8.0	8.3	8.2	8.5	8.3	-	-	7.3	6.8	23.75	-	-	-
H	4.5	5.5	8.9	8.4	8.7	8.3	-	-	7.8	6.8		-	-	
Galliera														
L	6.2	4.0	9.0	8.5	-	-	-	-	8.0	10.5	31.50	4.51	4.58	4.18
H	7.7	5.2	9.0	8.5	-	-	-	-	4.7	11.0		4.51	4.58	
MEAN L	6.4	5.7	8.1	7.6	7.9	6.5	6.7	5.7	9.1	13.8	40.40	4.27	4.19	3.99
MEAN H	6.7	5.6	8.2	7.3	8.0	7.0	6.3	5.6	8.6	11.7		4.21	4.09	

(✗) mainly Alopecurus spp.

Assessment scale: 0 = No response
10 = Complete kill

1969-70 Results are given in Table 3, the treatments included a new and more active granular formulation. In addition practical applications were also made as well as a single aerial application near Rome applying 2 kg/m e.c. in 60 l.water/ha. All these gave good results.

Table 3
Effect of trifluralin e.c. and granular on weeds and on wheat yield. 1969/70

Locality	Treatment	Dose g/ha a.i.	Days between seeding and application	Coverage %	Weight of weeds kg/ha Dicots	Weight of weeds kg/ha Grass	Yield ton/ha	Yield % of Control
Chiesa-nuova	EC	890	S + 1	3.0	70	14	4.98	98.8
	Gran.	800	S + 44	4.5	165	46	5.11	101.3
	Control			12.0	345	144	5.04	
Sala Bo-lognese	EC	890	S + 0	3.2	276	32	4.26	97.9
	Gran.	800	S + 95	6.0	191	189	4.46	102.5
	Control			7.5	573	525	4.35	
Sala Bo-lognese	EC	890	S + 0	5.5	14	60	4.78	100.6
	Gran.	800	S + 43	4.5	32	60	4.82	101.4
	Control			24.5	687	680	4.75	
Poggio Renatico	EC	667.5	S + 43	2.7	367	869	4.46	108.5
	Gran.	800	S + 43	3.2	352	953	4.48	109.0
	Control			20.5	1145	2065	4.11	
Poggio Renatico	EC	890	S + 54	2.7	200	464	4.72	87.7
	Gran.	800	S + 54	3.7	213	337	5.75	101.6
	Control			5.5	575	1067	5.39	
Massuma-tico	EC	890	S + 87	12.5	575	866		
	Control			20.7	1240	536		
Le Contane	EC	667.5	S + 41					
	Gran.	800	S + 41					
	Control							
Baricel-la	EC	890	S + 36	5.5	368	333	3.10	100.3
	EC	890	S + 136	15.2	836	712	3.35	108.4
	Control			15.7	1475	483	3.09	
Galliera	EC	890	S + 102	4.2		799	5.19	97.7
	EC	890	S + 168	7.7		1386	5.10	96.0
	Control			10.0		1269	5.31	
Galliera	EC	890	S + 38	1.5			4.10	103.2
	EC	890	S + 158	5.0			4.30	108.3
	Control			9.5			3.97	
MEAN	EC			5.7	338	553	4.39	97.6
	Gran.			4.3	190	317	4.92	109.3
	Control			13.9	862	846	4.50	

During the five year period in trials and practical applications, the following cultivars were involved (between brackets: the number of trials) :

- Argelato (19)
- S. Pastore (12)
- Marzotto (12)
- Campeiti MP (5)
- Gallini (4)
- Generoso (5)
- Mara (5)
- Cappelli (2)
- Damia Mer (2)
- Autonomia (2)
- Farnese (2)
- Libellula (2)
- Nazareno Strampelli (2)
- Patrizio 6 (2)
- Abbondanza (1)
- Funo (1)
- Funello (1)
- Leone (1)
- Lontra (1)
- Meliani (1)
- Marimp 3 (1)
- Padre Gemelli (1)
- R-37 (1)
- SAS 449 MP (1)
- S. Prospero (1)
- Argelato Marzotto (1)

The performance against the different annual weeds is reported in Table 4 on the basis of 88 trials. In no case, in the post emergence treatments, was phytotoxicity observed.

Table 4

Response of a number of annual weeds to trifluralin from winter application (88 trials)

Weeds	Very good	Good	Sufficient	Insufficient
Alopecurus myosuroides	4	16	8	8
Arthemisis arvensis		2	3	3
Avena fatua			3	4
Capsella b.p.	5	5	2	6
Cardamine spp		2	1	
Centaurea cyan.			1	1
Draba verna	1	1		
Fumaria officinalis	5	3		
Galium aparine	1			
Geranium spp		1	1	
Lepidium draba		4		5
Matricaria cham.	2	1		
Papaver rhoeas	35	9	3	3
Polygonum aviculare	1	2		
Polygonum convolvulus		4	2	
Polygonum persicaria	1	1		
Ranunculus spp	1	3		3
Specularia spec. ven.	1	1		
Stellaria media	18	7	3	3
Veronica spp	31	11	6	5
Viola tricolor	1	2		

Some limited applications were made in very early springtime with trifluralin e.c. 2 kg/ha, absorbed on granular nitrogen fertilizer. The granular fertilizer was applied by a spinning disc distributor. The uniformity was not perfect nevertheless no phytotoxicity was observed and farmers were satisfied with the results.

Samples of the treated wheat were analysed for residues in both the Lilly Research Centre Ltd in England and in our Galliera (Bologna) laboratory by chromatography. The sensitivity of the method is 0.005 ppm. In two samples 0.006 ppm trifluralin were detected while no traces were detected in the other samples.

DISCUSSION

During five year trials carried out in Italy, trifluralin was applied in various formulations and by different methods of application to winter wheat and some surprising results were obtained.

Selectivity - Trifluralin destroyed or severely damaged winter wheat if applied pre-seeding with and incorporated by a rotary cultivator to 5-7 cm depth. However the selectivity in all the post-emergence applications was good. Only in one case, with a very early application (immediately after emergence) and at a high rate, was some temporary yellowing and dwarfing observed. Applications from the 1 to 5 leaf stage produced no phytotoxicity.

Weed Control - Trifluralin was included in our trials to find a new herbicide against *A. myosuroides* and other grass weeds, no activity against dicots was expected. Surprisingly the most important dicots (*Papaver*, *Veronica*, *Fumaria*, *Stellaria* etc.) were well controlled in nearly all the trials, whereas *A. myosuroides* was only partly controlled. Early applications were more effective against *A. myosuroides*. *Poa spp.* were susceptible but *Avena fatua* was highly resistant. Some species like *Matricaria chamomilla* and *Fumaria officinalis* were also susceptible.

Timing - Pre-seeding incorporated applications were highly phytotoxic to the wheat even at 445 g/ha a.i. in 8 trials out of 10, so this method cannot be used under the Italian conditions. Pre-emergence applications without incorporation will probably not provide reliable results during the sowing period in Italy as the soil is often hot and the weather dry and windy, so trifluralin may disappear quickly. Pre-emergence application with shallow incorporation could be tried, however our 1965/66 trials demonstrated that early application could be phytotoxic to the wheat.

Late autumn post emergence applications without incorporation gave very reliable results. Early applications (wheat at 1-2 leaf stage) are better as far as *A.myosuroides* control is concerned. This is often difficult to carry out because of adverse soil conditions. Very good results were obtained when the soil was frozen; aerial applications are also promising as no drift hazards exist in winter. Aircraft are not busy and there is a long period (from November to February) for treatment. Granular formulation may also help in solving the problem of application.

Formulation - The e.c. formulation was mostly used, formulation studies allowed us to develop granules which are as effective as e.c. formulations.

Rate - Over the range studied, the application rate effect was small. In pre-seeding very low dose rates were phytotoxic. In post emergence, 668 g/ha a.i. and 890 g/ha a.i. left only 9.1% and 8.6% ground coverage by weeds at the 1-2 leaf stage applications, and 13.8 and 11.7% coverage at the 3-5 leaf stage applications respectively.

Crop yields from the same 11 trials were 4.27 and 4.19 ton/ha with early and late applications of 668 g/ha a.i. and 4.21 and 4.09 ton/ha with 890 g/ha a.i. It seems therefore that 668 g/ha a.i. is the right dosage as the higher rate might reduce the yield.

Soil type - With the post emergence applications no influence of the soil type was observed, but with pre-seeding applications phytotoxicity was more severe on lighter soils.

CONCLUSIONS

In 5 years of trials carried out in Italy, trifluralin showed to be a promising herbicide for winter wheat for post emergence applications, (1 to the 5 leaf stage). Early applications are preferable especially when the weed emergence occurs and *A. myosuroides* is the main problem.

Trifluralin applied in the winter period has quite different properties compared to spring and summer applications. Incorporation is unnecessary, it is highly selective in winter wheat and controls *Matricaria chamomilla*, *Fumaria officinalis* and some *Brassica spp.*, which are resistant in other periods of the year.

Aerial applications made when the soil is frozen and using special granular formulations may overcome the practical difficulties of spraying during periods when soils are likely to be wet.

Proc. 10th Br. Weed Control Conf. 1970.

CONTROL OF ALOPECURUS MYOSUROIDES, AVENA FATUA AND OTHER WEEDS IN WINTER CEREALS 1968-1970 WITH DICHLOBENIL/FLUOMETURON AND 3- ISOPROPYL -2, 1, 3, BENZO THIADIAZINON-(4)-2, 2 - DIOXIDE

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Summary Among a number of herbicides investigated for the control of Alopecurus myosuroides, Avena spp and annual broad-leaved weeds in winter wheat and barley during 1968 - 1970, two products, namely a combination of dichlobenil/fluometuron, and BAS 2160 H both attained commercially acceptable standards. Trials indicate the optimum rate of the dichlobenil/fluometuron combination to be $1\frac{1}{2} + \frac{3}{4}$ lb/ac respectively, and of 2160 H to be $2\frac{1}{4}$ lb/ac. At these rates, Alopecurus myosuroides control averaged 91.4% and 91.9% respectively, with satisfactory control of most species of annual broad-leaved weeds. Avena spp control varied with time of germination from 23% to 90%. Crop phytotoxicity was negligible and transient. Yields were substantially increased.

INTRODUCTION

Trials in the U.K. since 1965 have included investigation into the use of straight dichlobenil and of various mixtures for the control of Alopecurus myosuroides and other weeds in winter cereals. In 1968, the combination of dichlobenil with fluometuron (Trade name Diclotron) applied logarithmically was superior to other mixtures at respective optimum rates of $1\frac{1}{2} + \frac{3}{4}$ lb/ac. Consequently, in 1969, finite farmer-applied trials at these rates were laid down in addition to further replicated trials at a range of rates. In 1970, further replicated trials were conducted to repeat earlier work and to investigate other aspects such as control of Avena spp, timing of application, the effect on weed free crops and to extend the list of crop varieties tested.

Similarly, BAS 2160 H, (30% buturon + 20% isonoruron)first tested in 1968, was included in the 1969 and 1970 trials to determine optimum rate and to obtain data on crop phytotoxicity, weed control and effect on yield.

METHOD AND MATERIALS

Details of trials, sited on clay soils in Essex and Suffolk, are given in Table 1. Plot size on the finite trials was $7\frac{1}{2}$ x 3 yd in 1968 and 1969, and $7\frac{1}{2}$ x 5 yd in 1970, and on the logarithmic trials was 20 x 3 yd. All trials had 4 replications. Comparison was made with an untreated control and recognized standard herbicides (methoprotryne/simazine in 1968 and 1969 and metoxuron in 1969 and 1970). Application was made with an Oxford Precision Sprayer at 50 gal/ac, or a Chesterford Mini-log Sprayer at 18 gal/ac. Date of application was conditioned by crop stage and weather.

The 1970 programme included one trial in which the dichlobenil/fluometuron combination was applied at single and double rates to wheat at the 3 leaf, 5 leaf and tillering stages and a further trial to show its effect on a crop where all weeds were totally absent. Also in 1970, a further 6 replicated trials were laid down specifically to investigate control of Avena spp using metoxuron as a standard.

Crop vigour and control of Alopecurus myosuroides, other weeds and Avena spp (1970) were assessed at monthly intervals after application by scoring on a scale of 0 - 10 where 0 = dead plant and 10 = healthy plant. At maturity, a count of Alopecurus myosuroides and Avena spp (1970) seed heads was made by random replicated sampling on all trials using 5 x 1 yd^2. quadrats per plot for Alopecurus myosuroides and counting all the Avena spp in each plot.

Crop yields were obtained by hand sampling followed by bench threshing (replicated trials) and by combine harvesting in addition to hand sampling and bench threshing, (farmer-applied trials). The hand sampling was conducted by a method devised by the Ministry of Agriculture (North) and samples comprising eight 3 ft x 2 row cuts per plot at equidistant points along a diagonal across each plot. On the logarithmic trials, 2000 grains from each plot were collected at the position of optimum rate and converted to g/1000 grains. Additionally in 1970, crop ear counts were recorded by counting all ears in the samples taken for yield.

Table 1

<u>Details of trials</u>

Year	Type of trial.	No. of sites.	Varieties	Crop leaf stage at application.	*A. myosuroides* No/yd^2.	Leaf stage. at application	Treatment	Dosage rate lb/ac a.i.
1968	Replicated Logarithmic	4	Cappelle.	4	25-70	2 - 6	Dichlobenil	6 - ½ log
			Elite				Fluometuron	6 - ½ "
			Lepeuple				Dichlobenil/fluometuron	1½ (const) + 3-¼ (log)
							Fluometuron/dichlobenil	¼ (const) + 6-½ (")
1969	Replicated Finite	6	Cappelle	4	20-90	2 - 5	Methoprotryne/simazine	3¾ (product) Const
			Champlein.				Metoxuron	4 "
			Maris				Dichlobenil/fluometuron	1½ + ½ "
			Widgeon				" "	1½ + ¾ "
							" "	3 + 1½ "
							BAS 2160 H	1¾
							" "	2¼
							" "	3½
	Farmer-applied.	12x1ac	Cappelle	3 - 4	20-80	1½- 5	Dichlobenil/fluometuron	1½ + ¾ "
			Champlein.					
			Maris					
			Widgeon					
1970	Replicated Finite	6	Cappelle.	3 - 4	30-140	2 - 4	Metoxuron	4 "
			Maris				Dichlobenil/fluometuron	1½ + ¾ "
			Ranger.				" "	3 + 1½ "
			Joss				BAS 2160 H	2 "
			Cambier				" "	2½ "
							" "	4½ "
	Replicated Finite (for *Avena* spp control)	6	Cappelle	3 - 4½	-	-	Metoxuron	4 "
							Dichlobenil/fluometuron	1½ + ¾ "

RESULTS

Table 2

1968 logarithmic trials. Dose in lb/ac a.i. below which the crop shows nil phytotoxicity and at which Alopecurus myosuroides and annual broad-leaved weeds show 95% control and comparative yields. Means of 4 trials.
BG = Alopecurus myosuroides

Treatment	1 month post appln.			2 months post appln			3 months post appln			Yield mean 1000 corn weights in g.
	Crop	BG	Other weeds.	Crop	BG	Other weeds	Crop	BG	Other weeds	
Untreated control	-	-	-	-	-	-	-	-	-	69.9
Dichlobenil	3.2	2.6	4.4	5.1	4.3	5.0	4.7	4.4	4.3	71.6
Fluometuron	1.5	1.8	2.4	1.5	1.6	1.8	1.3	1.0	1.2	71.1
Dichlobenil at $1\frac{1}{2}$ lb + fluometuron at:-	1.4	1.0	2.0	1.0	0.8	1.6	1.4	0.8	0.9	73.6
Fluometuron at $\frac{1}{4}$ lb + dichlobenil at:-	2.7	2.9	4.6	3.3	3.1	3.9	4.6	4.9	3.6	-

Table 2 shows that dichlobenil alone requires uneconomic rates for satisfactory control and that fluometuron alone gives insufficient selectivity margin. The mixture including $\frac{1}{4}$ lb fluometuron requires uneconomic and damaging rates of dichlobenil. It appeared that a combination of dichlobenil at $1\frac{1}{2}$ lb/ac with fluometuron at approx. $\frac{3}{4}$ lb/ac was satisfactory.

In 1969 and 1970, finite replicated and farmer-applied trials were conducted with dichlobenil/fluometuron and with BAS 2160 H at a range of rates as shown in Table 1. Results are given in Table 3.

Table 3

1969 and 1970 finite trials. Crop phytotoxicity (on scale 0 -10 where 0= dead plant and 10 = healthy plant); <u>Alopecurus myosuroides</u> control (on scale 0 -10 with final % control based on seed head count at 3 months post application); broad-leaved weed control (on scale 0 - 10) and yield. Mean of 6 trials in 1969 and 4 trials in 1970.

Crop phytotoxicity and yields.

Treatment	1 month p.a.		2 months p.a.		3 months p.a.		Yield cwt/acre dry weight	
	1969	1970	1969	1970	1969	1970	1969	1970
Untreated control	9.8	9.5	9.9	9.9	10.0	9.3	18.09	19.92
Methoprotryne/simazine	9.2	-	9.6	-	9.9	-	24.86	-
Metoxuron 4 lb/ac	9.3	9.8	9.8	10.0	9.9	9.7	26.06	23.29
Dichlobenil/fluometuron								
$1\frac{1}{2} + \frac{1}{2}$ lb/ac	8.0	-	9.6	-	9.6	-	-	-
$1\frac{1}{2} + \frac{3}{4}$ "	8.0	9.7	9.3	9.9	8.9	9.0	26.35	23.83
$3 + 1\frac{1}{2}$ "	6.3	7.5	5.3	8.0	5.9	8.4	19.73	20.65
2160 H $1\frac{3}{4}$ lb/ac	9.0	-	9.9	-	9.9	-	26.60	-
" 2 "	-	9.6	-	9.9	-	9.4	-	23.72
" $2\frac{1}{4}$ "	9.0	-	9.6	-	9.3	-	26.36	-
" $2\frac{1}{2}$ "	-	9.5	-	9.7	-	9.4	-	24.32
" $3\frac{1}{2}$ "	7.9	-	7.7	-	7.9	-	26.11	-
" $4\frac{1}{2}$ "	-	8.2	-	7.6	-	8.1	-	19.44

Control of <u>Alopecurus myosuroides</u>

Treatment	1 month 1969	1 month 1970	2 months 1969	2 months 1970	seed head count given as % control 1969	seed head count given as % control 1970
Untreated control	10.0	10.0	10.0	10.0	127.5	167.4/yd^2
Methoprotryne/simazine	5.7	-	5.6	-	67.9%	-
Metoxuron 4 lb/ac	5.5	3.9	3.8	1.5	82.6%	91.0%
Dichlobenil/fluometuron						
$1\frac{1}{2} + \frac{1}{2}$ lb/ac	4.8	-	3.8	-	82.7%	-
$1\frac{1}{2} + \frac{3}{4}$ "	4.4	3.5	1.9	1.4	93.1%	89.7%
$3 + 1\frac{1}{2}$ "	2.5	2.0	0.8	0.2	96.2%	96.4%
2160 H $1\frac{3}{4}$ lb/ac	5.8	-	4.9	-	86.4%	-
" 2 "	-	4.6	-	1.6	-	88.9%
" $2\frac{1}{4}$ "	5.3	-	2.8	-	91.9%	-
" $2\frac{1}{2}$ "	-	4.1	-	1.0	-	94.0%
" $3\frac{1}{2}$ "	5.3	-	1.2	-	95.0%	-
" $4\frac{1}{2}$ "	-	1.6	-	0.2	-	98.3%

continued

Table 3 continued

Control of broad-leaved weeds

Treatment	1 month p.a. 1969	1 month p.a. 1970	2 months p.a. 1969	2 months p.a. 1970	3 months p.a. 1969	3 months p.a. 1970	wheat ear counts 1969	wheat ear counts 1970
Untreated control	10.0	10.0	10.0	10.0	10.0	-	1996	
Methoprotryne/simazine	8.9	-	5.5	-	2.6	-	-	
Metoxuron 4 lb/ac	8.0	4.7	4.1	2.7	2.3	-	2222	
Dichlobenil/fluometuron								
$1\frac{1}{2} + \frac{1}{2}$ lb/ac	7.6	-	5.3	-	2.5	-	-	
$1\frac{1}{2} + \frac{3}{4}$ "	6.7	4.9	3.8	2.6	1.7	-	2204	
$3 + 1\frac{1}{2}$ "	5.6	3.0	2.0	0.8	0.7	-	1841	
2160 H $1\frac{3}{4}$ lb/ac	7.2	-	4.3	-	2.8	-	-	
" 2 "	-	5.6	-	2.2	-	-	2107	
" $2\frac{1}{4}$ "	7.2	-	2.8	-	1.7	-	-	
" $2\frac{1}{2}$ "	-	5.0	-	1.2	-	-	2223	
" $3\frac{1}{2}$ "	5.8	-	1.6	-	0.8	-	-	
" $4\frac{1}{2}$ "	-	3.6	-	0.3	-	-	1641	

Note 1. Untreated control assessments of the crop from 1970 were often below the score of 10, probably due, at 1 month to over wet conditions, and at 3 months to over dry conditions and treatment assessments must be viewed in relation to these.

Note 2. At 3 months (1970), all susceptible species had virtually disappeared due to dry weather conditions.

Note 3. 12 x 1 acre farmer-applied trials in 1969 using dichlobenil/fluometuron at $1\frac{1}{2} + \frac{3}{4}$ lb/ac gave nil crop phytotoxicity, 89% control of *Alopecurus myosuroides*, 63% control of annual broad-leaved weeds and increased crop yield from 25.8 to 31.5 cwt/ac (actual yield, dry weight) and from 36.0 to 38.9 cwt/ac (farmer estimate, 15% moisture).

In view of the fact that a separate statistical analysis was made for each trial, shortage of space precludes the presentation in full of such data. Accordingly, statistical data is presented in Table 4 on the number of trials out of 6 (1969) and 4 (1970) where significant differences occurred.

Table 4

The number of trials out of 6 where significant (P= 0.05) treatment differences occurred.

Above oblique line - crop yield - Treatments across top outyielding treatments in column on left.

Below oblique line - *A. myosuroides* - Treatments in column on left giving greater control than treatments across top.

Minus figures show where differences are reversed.

1969	Untreated	Meth/ simazine.	Metox- uron.	Dich/fluo. 1½+½	1½+¾	3+1½	2160 H. 1¾	2¼	3½
Untreated		3	3		3	-2 2	3	2	3
Meth/simazine	2		0		1	-3 1	1	0	-1 1
Metoxuron 4	5	2			0	-3	0	0	-1
Dich/fluo 1½ + ½	6	1	0						
" 1½ + ¾	6	5	1	1		-3	0	0	0
" 3 + 1½	6	5	4	5	2		3	2	3
2160 H 1¾	5	2	1	-1	-3	1		0	0
" 2¼	6	2	1	0	0	-2	0		0
" 3½	6	6	3	3	0	-1	5	3	

The number of trials out of 4 where significant (P= 0.05) treatment differences occurred

1970	Untreated	Metoxuron	Dich/fluo. 1½ + ¾	3 + 1½	2160 H 2	2½	4½
Untreated		1	1	1	1	1	1 -1
Metoxuron 4	4		0	0	0	0	-1
Dich/fluo 1½ + ¾	4	-1		0	0	0	-1
" 3 + 1½	4	0	1		0	0	-1
2160 H 2	4	-1	0	-2		0	-1
" 2½	4	0	1	-1	1		-1
" 4½	4	0	1	0	1	0	

Table 5 shows the Avena spp seed head counts as percentage control from individual sites where these weeds were present irrespective of whether the trial was originally designed for Avena spp or Alopecurus myosuroides investigation. Differentiation is made into predominantly winter or spring germinating Avena spp. Due to extreme variability in the counts, no statistical analysis was made.

Table 5

Avena spp counts on 1970 trials given as percentage control

		Winter germinating					Spring germinating				Mean Winter	Mean Spring	Mean All
Untreated control No./yd^2		2.5	1.0	2.2	0.8	1.3	2.0	1.5	4.2	5.1	1.6	3.2	2.3
Metoxuron		44.0	72.6	44.3	51.0	0.0	88.7	70.9	84.6	97.9	42.4	85.5	61.5
Dich/fluo	$1\frac{1}{2} + \frac{3}{4}$	26.7	33.9	26.9	45.0	25.0	74.6	42.8	43.8	90.0	31.5	62.8	45.4
"	$3 + 1\frac{1}{2}$	70.0	-	-	-	-	80.9	56.6	61.6	-	70.0	66.4	67.3
2160 H	2	30.0	-	-	-	-	64.6	22.9	-	-	30.0	43.7	39.2
"	$2\frac{1}{2}$	41.0	-	-	-	-	61.7	65.7	-	-	41.0	63.7	56.1
"	$4\frac{1}{2}$	16.7	-	-	-	-	70.4	67.4	-	-	16.7	68.9	51.5

DISCUSSION

The dichlobenil/fluometuron combination at the respective rates of $1\frac{1}{2} + \frac{3}{4}$ lb/ac has been shown over 3 consecutive years to be safe on all varieties of winter wheat and winter barley tested and to give an acceptable control of Alopecurus myosuroides. Most species of annual broad-leaved weeds were also controlled, but there was a variable control of Avena spp.

Crop assessments have shown only negligible phytotoxicity, but ear number was unaffected and yields were substantially increased over untreated by 46% in 1969 and 20% in 1970 in all trials, of which four gave increases that were significant, attaining 74%. Compared to the standards, differences were, with one exception, not significant. The double rate substantially reduced yields compared to the standard rate, significantly so in three trials, but still marginally outyielded untreated.

Although specific data are not here presented, the results from the timing of application trial show that application can safely be made from the 3 leaf stage to tillering, both yield and ear number being increased over untreated, with no significant difference compared to the standard. Although Alopecurus myosuroides control in all trials exceeded 90%, the timing trial showed that application to Alopecurus myosuroides after the 4 leaf stage gave only 60% control.

The trial totally absent of weeds on an even stand of Joss Cambier showed slight straw shortening throughout the season, but yields and ear number were not affected. The double dose reduced tillering, significantly reduced yield and induced slight lodging at maturity and should therefore be avoided.

No susceptible varieties of wheat or barley have been encountered; those to which application has been made are:- Winter wheat - Benoist 6994, Cama, Cappelle, Champlein, Elite Lepeuple, Joss Cambier, Maris Beacon, Maris Nimrod, Maris Ranger, Maris Settler, Maris Widgeon, Mildress, Rothwell 355, Zorba, and Winter barley - Inka, Malta, Maris Otter, Senta.

Annual broad-leaved weed control averaged 83% after 3 months in 1969, and 74% after 2 months in 1970. These susceptible species included Brassica sinapis, Chenopodium album, Polygonum aviculare, Raphanus raphanistrum, Senecio vulgaris, Stellaria media, Triplospermum maritimum and Veronica spp. Resistant species included Cirsium arvense, Convolvulus arvensis, Equisetum arvense, Galium aparine, Heracleum spp and perennial grasses.

The control of Avena spp in 1970 attained 31.5% of winter germinating and 62.8% of spring germinating, inferior to the standard (42.4% and 85.5%). No further distinctions into depth of germination or sub-species variability were made.

BAS 2160 H is shown by the results in this paper to provide acceptable control of Alopecurus myosuroides (approx. 92% control over 2 years) at $2\frac{1}{4}$ lb/ac a.i., 2 lb/ac giving slightly sub-standard grass control, and $2\frac{1}{2}$ lb/ac giving slight visual crop phytotoxicity although yield and ear counts were satisfactory.

Acknowledgments

Thanks are due to the Guinness Barley Research Station for the loan of a bench thresher and to the Statistical Department of N.V. Philips-Duphar for statistical analysis.

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N'-(3-CHLORO-4-METHYLPHENYL)-NN-DIMETHYLUREA A NEW RESIDUAL AND CONTACT HERBICIDE FOR CONTROL OF ANNUAL GRASS AND BROADLEAVED WEEDS IN CEREALS

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Summary Logarithmic, replicated yield and demonstration trials together with limited commercial usage show that N'-(3-chloro-4-methylphenyl)-NN-dimethylurea (proposed common name chlortoluron; C 2242) at 2.4 to 3.2 lb a.i./ac pre or post weed or cereal crop emergence gave good control of *Alopecurus myosuroides*, other annual grasses and some broadleaved weeds with a promising effect against *Avena fatua*. There was no effect on most winter wheat or barley cultivars with the exception of Zorba, Mildress, Maris Nimrod and Maris Beacon. Oats were also susceptible.

INTRODUCTION

N'-(3-chloro-4-methylphenyl)-NN-dimethylurea (proposed common name chlortoluron which is used hereafter) was first reported in 1969 (L'Hermite et al) and first tested in the United Kingdom in 1968 under the code C 2242. Since then it has been intensively tested primarily for control of grass weeds in winter cereals and commercially used as such in the spring of 1970; this paper reports the U.K. results.

METHOD AND MATERIALS

Chlortoluron was applied as a 50% w.p. (early 1968) or as 80% w.p. (late 1968 onwards). Trials had generally three- or four-fold replication with a plot size of 44 yd^2 being taken for yield by combine harvesting. These trials as well as the logarithmic plots were sprayed with 22 gal water/ac at 30 p.s.i. Demonstration trials were sprayed and harvested with standard farm machines.

Weed control was assessed by either counts or scores in late spring plus head counts in early summer. Crop effect was assessed by a crop vigour score and either a plant or head count. In log. plots the effective doses were calculated from the points giving 95% control of each weed species and no effect on the crop.

The scoring system used was the 1-9 system as proposed to the EWRC and the scale denoting growth stage is as devised by Keller and Baggiolini (1954).

In each trial or demonstration a standard commercial herbicide (usually terbutryne or metoxuron) was applied for comparison.

RESULTS

Weed Control

Two years logarithmic trials showed that *Alopecurus myosuroides* was susceptible to chlortoluron from pre-emergence up to growth stage G (end of tillering) with selectivity factors of 4.8 to 6.0. Beyond stage G there was a sharp increase in the tolerance of *A. myosuroides* indicating a critical stage in the timing of the spray.

Fig. 1 demonstrates the control of *A. myosuroides* on 12 or 14 sites over two years by chlortoluron applied either pre-emergence or before the end of tillering. Each line represents one treatment at the dose stated with percent control measured by seed head counts in July. It will be seen that an application of 3.2 lb/ac prior to emergence of the weed gave both good and reliable control; this dose rate being preferable to the equally good 5.6 lb/ac rate on economic grounds yet at the same time superior to the standard reference herbicide. From the same Fig. 1 will also be seen that the treatment of 2.4 lb/ac applied to the emerged *A. myosuroides* matched the pre-emergence rate of 3.2 lb/ac in performance and reliability when applied to susceptible stages of the weed and was marginally superior to the standard reference product.

The dosage rates shown in Fig. 1 are not comprehensive, many intermediate rates being omitted for brevity and clarity.

Evaluation of the broad spectrum activity of chlortoluron can be made from Table 1 which is a summary of results taken from trials and demonstrations.

Table 1

Weed Control Summary Table 1968-70

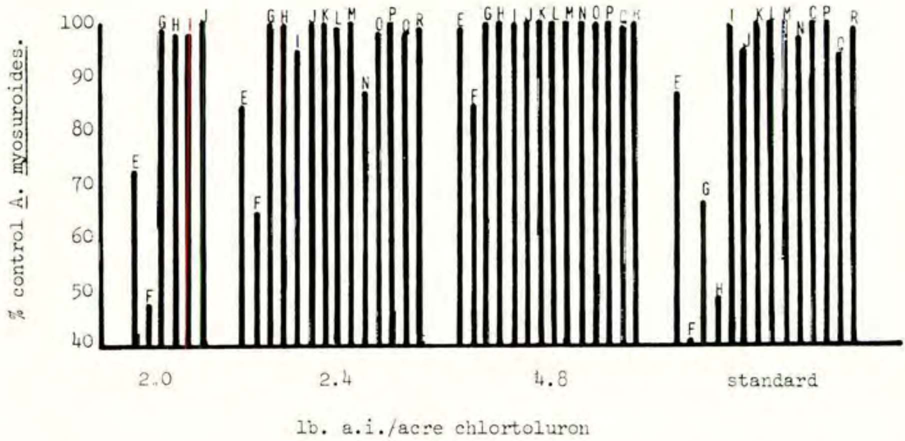
	Pre-weed emergence C 2242 at 2.8-3.2 lb				Post-weed emergence C 2242 at 2.4 lb				
	No. of sites occurring	% Weed Control 100-85	84-50	49-25	No. of sites occurring	% Weed Control 100-85	84-50	49-25	24-0
Alopecurus myosuroides	28	28	-	-	25	20	3	1	1
Avena fatua	13	12	1	-	14	6	7	-	1
Agrostis tenuis	1	1	-	-	1	-	-	-	1
Dactylis glomerata	2	2	-	-	2	-	-	-	2
Lolium perenne	5	5	-	-	5	3	-	1	1
Lolium multiflorum	1	1	-	-	1	-	-	-	1
Festuca pratense	2	2	-	-	2	-	-	-	2
Phleum pratense	2	2	-	-	2	-	-	1	1
Poa annua	1	-	1	-	2	2	-	-	-
Poa trivialis	6	5	1	-	4	3	1	-	-
Chenopodium album	1	1	-	-	2	2	-	-	-
Galium aparine	3	2	1	-	6	2	-	2	2
Matricaria spp.	4	4	-	-	4	3	1	-	-
Papaver rhoeas	3	2	-	1	6	4	-	1	1
Polygonum aviculare	4	4	-	-	3	2	1	-	-
P. convolvulus	3	2	-	1	4	4	-	-	-
Sinapis arvensis	-	-	-	-	1	1	-	-	-
Stellaria media	10	10	-	-	3	3	-	-	-
Veronica spp.	8	2	3	3	7	3	3	-	1
Viola arvensis	-	-	-	-	1	1	-	-	-
Vicia faba	-	-	-	-	2	2	-	-	-

Fig. 1

Percentage control of Alopecurus myosuroides with chlortoluron.

Pre-emergence.

Post-emergence (treated at growth stage D - G).



Note: Letters on histograms denote individual trials in which treatments occurred.

It will be seen that chlortoluron is active, at the dose rates to which *A. myosuroides* is susceptible, against a number of other grasses and broadleaved weeds likely to be found in winter cereals. The effect of chlortoluron on *A. fatua* is interesting and confirmation of susceptibility is being sought in current trial work. Whilst little lasting effect on established perennial broadleaved weeds has been found to date another promising line of enquiry is the suppression of *Agropyron repens* by post-emergence treatment.

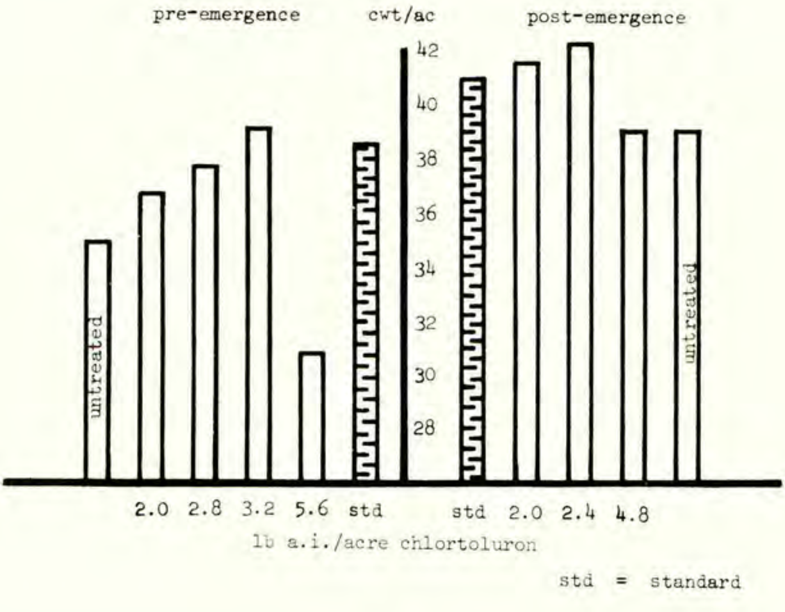
Crop Tolerance

The logarithmic work demonstrated good selectivity in both winter wheat and winter barley either pre- or post-emergence at growth stages C to H but a poor selectivity factor (<1.0) in cultivated oats. Rye has not yet been tested.

Yields of replicated trials are expressed as a mean of each dose in Fig. 2. It will be seen that within the range of pre-emergence doses 2.0 to 3.2 lb/ac there was little variation in yield; the preferred dose of 3.2 lb/ac giving a marginally better yield than the standard and improved yields over untreated. Similar results have been obtained with post-emergence treatments within the dosage range 2 to 2.8 lb/ac. The depression of yield following the 5.6 lb/ac pre-emergence dose comes from the 1970 results being very low due to very heavy rainfall at and following treatment. The statistical analyses of the 1970 results are not yet available. Analysis of the 1969 results showed significant increases in yield over untreated with 3.2 lb/ac pre-emergence or 2.4 lb/ac post-emergence on three sites. No significant depression in yield occurred on any site with these doses.

Fig. 2

Mean yields of 14 trials 1969-1970



The benefits in yield increases arising from control of A. myosuroides are not seen in Fig. 2. They are obscured by inclusion of the 1970 data established in a year when the weed germinated almost entirely in the spring and was reduced in competitiveness because of the exceptionally dry weather.

Varietal tolerance tests with chlortoluron have shown that wheat cultivars: Zorba, Mildress, Maris Nimbrod and Maris Beacon are to some degree susceptible whereas the following wheat and barley cultivars are tolerant: Cappelle Desprez, Joss Cambier, Champlein, Cama, Maris Ranger, Maris Widgeon, Malta, Maris Otter, Inka and Senta.

Demonstration and Commercial Use

The results available from the demonstration plots and 1000 acres of commercial use confirm the results from the trial plots. Satisfactory and consistent weed control came from either 3.2 lb/ac pre-crop emergence or 2.4 lb/ac post-crop emergence without any deleterious effect on the wheat or barley under the conditions prevailing. There were no difficulties in mixing or applying the 80% w.p. formulation.

DISCUSSION

This report shows the potential of chlortoluron for the selective control of A. myosuroides in winter cereals. Development work to establish effectiveness in spring sown cereals and other arable crops is underway. Particular attention is to be paid to effectiveness against A. fatua and A. repens.

We conclude by stating that chlortoluron is a valuable new addition to the present range of cereal herbicides. It is characterised by both residual and contact activity against A. myosuroides with selectivity in winter sown wheat or barley pre- or post-emergence. This flexibility in use coupled with a broad spectrum of weed control should ensure wide spread acceptance of chlortoluron by the farming community.

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AN EVALUATION OF METOXURON FOR THE CONTROL OF ALOPECURUS MYOSUROIDES IN CEREALS IN THE UNITED KINGDOM

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Summary Pre- and post emergence applications of metoxuron were evaluated in field trials during 1968 - 1970 for the control of A. myosuroides. Pre-emergence treatments were found to be inferior to post emergence and the dose rate required for satisfactory control was generally 25-30% higher than that for post emergence. Generally acceptable control was obtained with 4.8 lb/ac applied pre-emergence and 4.0 lb applied late post emergence. Lower doses 2.0 lb/ac applied when A. myosuroides was between the 1-2 leaf stage of growth were found to be very successful. Mixtures of metoxuron and liquid fertilizers applied post emergence in the spring were both safe and successful. The tolerance of winter wheat varieties was found to be variable.

INTRODUCTION

Metoxuron is manufactured by Sandoz Ltd., Basle, Switzerland. Evaluation of the commercial product (DOSANEX) containing 80% a.i. commenced in the U.K. in 1967, when Farm Protection Ltd., initiated an extensive field trials programme. Results for the 1967/68 season were reported by Glenister and Griffiths (1968). The present report describes trials which were carried out during 1968/69 and 1969/70.

METHOD AND MATERIALS

All trials reported, except those coded BG/DW were sprayed with the Oxford Precision Sprayer using a spray volume of 40 gal/ac. Plot size was 45.5 ft x 6 ft = 1/160 ac. and treatments replicated six times in 1968/69 and four times in 1969/70. Trials coded BG/DW were sprayed with a Dorman Wheelaway unit, using a plot size of 1/40 ac. and treatments were replicated twice.

Visual assessments of the control of A. myosuroides have been carried out according to the enclosed scale.

Yield data were obtained by harvesting the entire plot with a mini-combine harvester.

Score	% Control of A. myosuroides
1	100
2	97.5 - 100
3	95 - 97.5
4	90 - 95
5	85 - 90
6	75 - 85
7	65 - 75
8	32.5 - 65
9	0 - 32.5

The following number of trials were carried out during the two seasons.

Treatments	Number of Trial Sites 1968/69	1969/70
Pre-emergence	3	7
Early & late post emergence	11	-
Split Application	-	6
Metoxuron/liquid Fertilizer	-	3

All dose rates are quoted lb. a.i./ac, and L.S.D. calculated for P = 0.05

Pre-emergence treatments were applied between one and nine days after sowing the crop and compared with terbutryne applied pre-emergence and metoxuron applied post emergence. Early post emergence treatments were applied between the two and four leaf stage of growth of A. myosuroides and compared with barban. Late post emergence treatments were applied when A. myosuroides were from five leaves to commencement of tillering.

In addition, varietal tolerance was examined at four sites in 1968/69 and ten sites in 1969/70.

RESULTS

Pre-emergence control of A. myosuroides.

Table 1

Visual Assessment of Control of A. myosuroides 1968/69 & 1969/70 results.

Treatment	Rate lb/ac.	1968/69 mean of 3 trials	1969/70 mean of 6 trials
Untreated	-	9.0	8.7
Metoxuron	2.0	-	7.8
Metoxuron	3.2	6.8	-
Metoxuron	4.0	6.0	6.5
Metoxuron	4.8	4.3	6.1
Metoxuron	6.4	-	4.8
Metoxuron	8.0	3.7	-
Metoxuron	9.6	-	3.7
Terbutryne	2.0	6.0	3.8
Metoxuron (post em)	3.6	-	3.7
Metoxuron (post em)	4.0	4.0	-
S.E.		1.11	0.81
L.S.D.		2.47	1.65

The very dry autumn in 1969 delayed the germination of A. myosuroides until mid-winter and hence the control obtained with pre-emergence treatments during 1969/70 season was inferior to that for the 1968/69 season. As shown in table 1 acceptable control was obtained with 6.4 and 9.6 lb in 1969/70 but dose rates as low as 4.8 lb produced acceptable control in 1968/69. In general 4.0 lb and 9.6 lb metoxuron were comparable with terbutryne in 1968/69 and 1969/70 respectively. Metoxuron applied post emergence at 4.0 lb was comparable with 4.8 lb applied pre-emergence in 1968/69 and 3.6 lb applied post emergence was comparable with 9.6 lb applied pre-emergence in 1969/70.

Table 2

Yield Data

Treatment	Rate lb/ac.	Relative Yield: 1969 Trials BG/DW/1	Relative Yield: 1969 Trials BG/DW/3	Relative Yield: 1970 Trial BG/5
Metoxuron	2.0	-	-	105
Metoxuron	3.2	148	107	-
Metoxuron	4.0	151	105	108
Metoxuron	4.8	143	111	107
Metoxuron	6.4	-	-	113
Metoxuron	8.0	141	113	-
Metoxuron	9.6	-	-	112
Terbutryne	2.0	138	117	113
Metoxuron (post em.)	4.0	141	108	-
Metoxuron (post em.)	3.6	-	-	108
Untreated	-	100 (22.4 cwt/ac)	100 (28.0 cwt/ac)	100 (44.4 cwt/ac)
S.E.		7.9	5.0	3.7
L.S.D.		19.5	NS	6.1

All treatments produced an increase in yield, although the degree of control was not satisfactory at the lower dose rates (Table 2). Pre-emergence treatments produced a similar yield response to post emergence treatments.

Post emergence control of A. myosuroides.

At some of the trial sites the stage of growth of A. myosuroides was very variable at the time of applying the early post emergence treatments. As shown in table 3, dose rates below 3.6 lb applied early post emergence did not produce consistently acceptable control, but at 6.4 lb the degree of control was highly acceptable. When applied late post emergence the results were more variable but acceptable control was obtained with 3.2 lb at the majority of sites. In general the early post emergence treatments were applied when soil temperature was low and there was no active growth. Under these conditions the control of tillered plants of A. myosuroides was rather poor, but control of seedling plants was virtually complete. Soil temperature had increased considerably and plants had commenced active growth at the time of applying the late post emergence treatments. Under these conditions the control of both seedling and established plants was highly acceptable at 3.6 lb. It appears that a plant in a static phase of growth as a result of low soil temperature, is more tolerant to metoxuron than a similar plant which is actively growing.

Table 3

Visual Assessment of Control of *A. myosuroides* and Yields - 1969

Treatment	Rate lb/ac	Early Post emergence Control of *A. myosuroides*	Early Post emergence Yield (relative)	Late Post emergence Control of *A. myosuroides*	Late Post emergence Yield (relative)
Untreated	-	8.9	100 (30.4 cwt/ac)	8.9	100 (30.4 cwt/ac)
Metoxuron	2.0	7.4	124	-	-
Metoxuron	2.4	6.9	126	6.9	119
Metoxuron	2.8	6.6	122	6.2	124
Metoxuron	3.2	6.1	126	5.5	127
Metoxuron	3.6	5.5	131	4.9	126
Metoxuron	4.0	-	-	4.8	127
Metoxuron	4.8	-	-	3.9	131
Metoxuron	6.4	3.2	132	2.5	128
Barban	0.3	7.0	115	-	-
S.E.		0.46	3.5	0.46	3.5
L.S.D.		0.9	6.9	0.9	6.9

Visual Assessment of Control from 11 trials
Yield Data from 8 trials

Split Applications for Control of *A. myosuroides*.

Table 4

Visual Assessment of Control of *A. myosuroides* and Yields - 1970

Treatment	Dose Rate lb/ac Pre-em.	Dose Rate lb/ac Winter Post em.		Dose Rate lb/ac Spring Post em.	Control of *A. myosuroides* 6 trials	Relative Yield (one trial)
Metoxuron	4.8	-		-	6.6	107
Metoxuron	9.6	-		-	4.0	112
Metoxuron	2.0	-		-	7.8	105
Split 1 Metoxuron	2.0			2.0	3.5	107
Split 2 Metoxuron	-	2.0	+	2.0	2.0	117
Metoxuron	-	2.0		-	3.6	112
Metoxuron	-	-		3.6	3.7	108
Terbutryne	2.0	-		-	3.8	113
Untreated						100 (44.4 cwt/ac)
S.E.					0.89	4.7
L.S.D.					1.81	NS

As a result of the exceptionally dry conditions during the autumn of 1969, very little A. myosuroides germinated before Christmas. Consequently applications made during January coincided with the main phase of germination and emergence. After this period there was little further germination. Both the split applications produced better control of A. myosuroides than 4.8 and 9.6 lb applied pre-emergence (Table 4). Split 1 was similar in performance to 3.6 lb applied post emergence, but Split 2 was superior. The application of 2.0 lb post emergence in the winter was comparable to 9.6 lb applied pre-emergence, terbutryne applied pre-emergence and metoxuron applied at 3.6 lb post emergence in the spring. This suggests that the 2.0 lb applied post emergence in the winter, in treatment Split 2, is mainly responsible for the good control achieved with this treatment.

Table 5

Control of A. myosuroides with metoxuron/liquid fertilizer mixture (1970)

Treatment, rate/ac	Relative Yield (mean 3 trials)
60 units N	118
120 units N	125
60 units N + 3.6 lb metoxuron	160
120 units N + 3.6 lb metoxuron	169
240 units N + 7.2 lb metoxuron	158
- 3.6 lb metoxuron	144
Untreated	100 (28.4 cwt/ac)
S.E.	19.0
L.S.D.	40.9

Visual assessments made three weeks after application indicated that the inclusion of metoxuron with liquid fertilizer did not increase the extent of leaf scorch. Conversely, the addition of liquid fertilizer to metoxuron did not influence the degree of control of A. myosuroides. The addition of metoxuron to liquid fertilizer resulted in a significant increase in yield.

Tolerance of winter wheat cultivars to metoxuron.

Table 6

Resistant	Moderately Resistant	Susceptible
Armentieres	Apex	Chalk
Cappelle Desprez	Bouquet	Heima Desprez
Elite Lepeuple	Cama	Maris Beacon
Hybrid 46	Champlein	Maris Huntsman
Maris Widgeon	Joss Cambier	Maris Nimrod
Prof. Marchal	Maris Ranger	Maris Templer
	Maris Settler	Mildress
	Maris Teal	Femois
	West Desprez	Splendeur

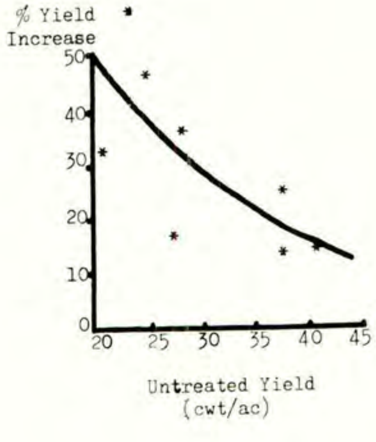
The tolerance of other cereal cultivars is still being investigated.

DISCUSSION

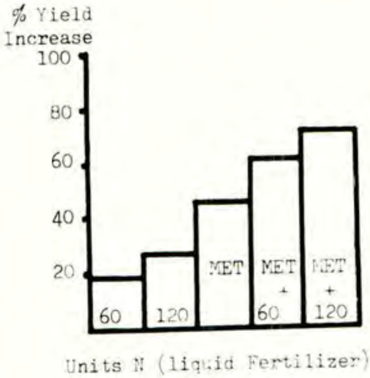
Metoxuron applied pre-emergence at dosages below 4.8 lb/ac does not produce adequate control of A. myosuroides. Post emergence treatments however are much more effective. Dosages as low as 2.0 lb/ac applied when A. myosuroides is between 1 and 2 leaves have resulted in over 90% control. The effectiveness of this particular treatment may be assisted by cold weather having previously weakened the growth of the plants. Higher dose rates, between 3.2 and 4.0 lb/ac, are necessary for adequate control when applied between the 4 leaf stage and the commencement of tillering of A. myosuroides.

The extent of the yield increase obtained with 4.0 lb/ac applied late post emergence at the commencement of tillering is directly related to the yield of the untreated crop (graph 1 and data summarised in Table 3). Even when the untreated crop produced a yield of 40 cwt/ac, this treatment resulted in yield increase of 15%.

GRAPH 1



GRAPH 2



The evidence obtained from the liquid fertilizer trials indicates that the removal of A. myosuroides by the application of metoxuron results in a greater yield response than that obtained with 120 units of nitrogen (graph 2). The response to nitrogen applied after the removal of A. myosuroides, through treatment with metoxuron, is additive to the response due to the removal of A. myosuroides. This suggests that in dense infestations the removal of A. myosuroides is of greater importance than the application of nitrogenous fertilizer.

Acknowledgments

The authors wish to thank all members of staff who have assisted with the field trials, and the farmers who kindly co-operated.

References

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CHEMICAL CONTROL OF ALOPECURUS MYOSUROIDES IN WINTER WHEAT

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Summary Nine chemicals or mixtures were compared at 7 centres in 1968/69 and eleven at 8 centres in 1969/70. In 1968/69, terbutryne and methabenzthiazuron gave the best results in terms of A. myosuroides control and yield response, 89% and 86% control and 16% and 13% yield improvement respectively. Chlortoluron applied pre-emergence gave 99% control and a 6% yield improvement and was marginally the best treatment in 1969/70. Of the 8 treatments used in both years terbutryne and metoxuron post emergence gave on average a 90% control and a yield improvement of 10%

INTRODUCTION

Recently a number of new herbicides have become available for use in winter wheat for the control of A. myosuroides. The NAAS Crop Husbandry department at Cambridge has been screening candidate materials in both logarithmic and finite dose experiments since 1964. As and when herbicides become available commercially, the adviser is frequently called upon to recommend to the farmer the best chemical for his own particular situation. These two years results provide additional information, as almost the whole range of herbicides available have been directly compared over a range of commercial conditions.

METHOD AND MATERIALS

In 1968/69 7 experiments were completed, in 1969/70 there were 8 experiments. All the experiments were superimposed on commercial crops where naturally occurring infestations of Alopecurus myosuroides were expected.

Site details, treatment application dates, stage of growth of the winter wheat and A. myosuroides are given in tables 1 and 2. Herbicides used are listed below, all dose rates are in terms of active ingredient per acre.

Treatment 1968/69

1	terbutryne	2.02 lb
2	barban	0.35 lb
3	methabenzthiazuron	2.82 lb
4	2440 (pre-emergence)	1.80 lb
5	2440 (spring)	1.80 lb
6	dichlobenil/fluometuron 2:1	2.25 lb
7	nitrofen	2.11 lb
8	noruron	1.60 lb
9	metoxuron (pre-emergence)	4.27 lb
10	metoxuron (spring)	3.23 lb
11	tri-allate granules (autumn)	1.50 lb
12	tri-allate granules (spring)	1.50 lb

Treatment 1969/70

1	terbutryne	2.02 lb
2	barban	0.35 lb
3	methabenzthiazuron	2.82 lb
4	nitrofen	2.11 lb
5	metoxuron (pre-emergence)	4.27 lb
6	metoxuron (spring)	3.23 lb
7	metoxuron (spring)	3.63 lb
8	chlortoluron (pre-emergence)	3.23 lb
9	chlortoluron (spring)	2.42 lb
10	dichlobenil/fluometuron 2:1	2.25 lb
11	WL 19805	2.02 lb
12	701	2.52 lb
13	2440	1.34 lb
14	lenacil + ioxynil	0.81 + 0.40 lb

WL 19805 = 2-(4-chloro-6-ethylamino-s-triazine-2-ylamine)-2-methyl proprionitrile
2440 = 1:1 mixture brompyrazone + isonoruron
701 = a substituted urea

Table 1 1968/69

Site	1	2	3	4	5	6	7
Soil Texture	ZyCL	ZyCL	SCL	CL	ZyCL	ZyCL	ZyCL
Variety	--		Cappelle	--			
Date Drilled	30/10	26-28/10	29 & 30/10	28/10	31/10	25/10	4/11
Seedbed at first spray	moist clods	moist	very solid large clods	good	solid	moist	moist
Treatment date							
1	1/11	1/11	6/11	7/11	7/11	8/11	10/11
2	16/1	16/1	5/1	15/1	15/1	3/1	23/1
3	1/11	1/11	6/11	7/11	7/11	8/11	10/11
4	5/11	5/11	6/11	7/11	7/11	8/11	10/11
5	5/3	5/3	6/3	26/2	6/3	26/2	5/3
6	20/3	20/3	20/3	20/3	20/3	26/3	20/3
7	1/11	1/11	6/11	7/11	7/11	8/11	10/11
8	5/3	5/3	6/3	26/2	6/3	26/2	5/3
9	5/11	5/11	6/11	7/11	7/11	8/11	10/11
10	5/3	5/3	6/3	26/2	6/3	26/2	5/3
11	5/3	5/3	6/3	26/2	6/3	26/2	5/3
12	20/11	20/11	19/11	20/11	3/12	19/11	20/11

Table 2 1969/70

Site	1	2	3	4	5	6	7	8
Soil Texture	ZL	FSL	CL	CL	ZyCL	ZyCL	ZL	ZL
Variety	C	Ca	C	Ca	Ch	JC	Ch	WD
Date drilled	20/10	21/10	21/11	27/10	11/11	20/11	14/11	20/11
Seedbed at first spray	moist	dry & rough	wet rain	moist	moist rough	moist	moist	wet
Treatment date								
1	28/10	28/10	27/11	5/11	12/11	24/11	20/11	4/12
2	27/2	27/2	16/3	17/3	16/3	16/3	16/3	27/3
3	28/10	28/10	27/11	5/11	12/11	24/11	20/11	4/12
4	28/10	28/10	27/11	5/11	12/11	24/11	20/11	4/12
5	28/10	28/10	27/11	5/11	12/11	24/11	20/11	4/12
6	27/3	27/3	25/3	25/3	25/3	25/3	26/3	27/3
7	7/4	7/4	7/4	15/4	14/4	10/4	17/4	15/4
8	28/10	28/10	27/11	5/11	12/11	24/11	20/11	7/12
9	7/4	7/4	4/2	15/4	14/4	10/4	4/2	15/4
10	27/3	27/3	25/3	25/3	25/3	25/3	26/3	27/3
11	7/4	7/4	7/4	15/4	14/4	10/4	4/4	15/4
12	27/3	27/3	25/3	25/3	25/3	25/3	26/3	27/3
13	7/4	7/4	8/4	15/4	14/4	10/4	17/4	15/4
14	14/4	14/4	8/4	15/4	14/4	10/4	17/4	15/4

Growth stage of crop (no. of leaves)

Spray date									
	2	3	3	2	3	3	3	3½	3½
	3	3½	4	3	3	3½	3	3/4	3½
	4	4½	T	4	T	T	4/5	T	T

Growth stage of <u>A. myosuroides</u> (no. of leaves)

Spray date									
	2	2½	2	2½	2½	2½	2½	3	2½
	3	3	3	3	3	3	2½	3	3
	4	T	4	T	T	4	3½	T	T

Varieties

T = tillering

C = Cappelle Desprez
Ca = Cama
Ch = Champlein
JC = Joss Cambier
WD = West Desprez

Plot size was 30 ft x 6 ft, all treatments were applied using a modified van der Weij sprayer with fan jets. Application rate was 20 gal/ac. A randomised block design was used, treatments replicated 3 times.

The overall A. myosuroides infestation was assessed on the 6 control plots in late March, broadleaved weed control (1970 only) in early May. Treatment effects assessed by removing all the A. myosuroides plants in a number of quadrats from each plot in late June/early July and crop yields measured by a sample harvest technique avoiding areas where A. myosuroides plants had been removed. Seed head counts were made and the total length of the seed heads per plot measured to give some indication of the seed return. Total dry weights of A. myosuroides were also recorded.

RESULTS

These are summarised in tables 3 and 4 for trials in which A. myosuroides was present, trials omitted where little or no A. myosuroides appeared. In the first year all the herbicides except tri-allate granules gave a significant reduction (65%-89%) of A. myosuroides overall and at all centres, on average the differences between the effective chemicals was not significant. The dichlobenil/fluometuron mixture gave an inferior control at two sites, but was applied at the tillering stage. On average, pre-emergence applications of the herbicides increased crop yields by 5.2 cwt/ac, excluding metoxuron and noruron which appeared to produce a reduced yield response at some sites; spring applications improved yields by 3.8 cwt/ac.

In 1969/70 sites 4 and 8 have been omitted from the overall mean for flowering heads and site 8 from the overall mean for grain yield as the standard errors were excessively large. Site 1 has also been omitted from the grain yield mean as there was a competitive infestation of A. fatua. On average all the herbicides gave a significant level of control of A. myosuroides, probably the levels achieved with barban and the lenacil/ioxynil mixture would be commercially unacceptable. Only chlortoluron applied pre-emergence gave a significant yield increase. Previous work has shown that large increases in yield are only obtained when the control yields are low; when the control yields exceed 40 to 45 cwts yield responses have seldom been recorded. Generally, autumn applied chemicals increased yields by 1.5 cwt/ac, the response to spring applications was 0.7 cwt/ac.

The two trials in 1968/69 with only a light A. myosuroides infestation produced no significant yield differences, indicating generally their selectivity with cv Cappelle.

Metoxuron applied late in the spring and WL 19805 gave the best control of annual breadleaved weeds, table 5, but chlortoluron (spring) and the early spring metoxuron also gave an acceptable level of control of the major species. Control was even better on sites where Veronica spp were absent.

Table 3 1968/69

Grain Yield cwt/ac 85% DM

Treatment	Site 3	4	5	6	7	Mean	%
Control	28.7	36.3	35.0	29.8	34.0	32.8	100
1	33.9	39.8	40.4	36.6	38.7	37.9	116
2	30.6	40.1	41.0	36.1	36.3	36.8	112
3	35.0	40.8	38.3	38.1	36.4	37.7	115
4	35.4	43.5	39.3	35.2	35.8	37.8	115
5	31.6	38.8	38.1	32.0	39.2	35.9	109
6	34.3	35.4	38.0	35.6	38.4	36.3	111
7	32.8	41.7	40.8	35.4	36.3	38.2	116
8	31.5	42.6	32.0	36.5	36.4	35.8	109
9	31.8	37.7	39.0	32.7	36.3	35.5	108
10	30.6	45.3	40.5	35.9	41.4	38.7	118
11	32.3	38.8	41.8	42.5	37.8	38.6	118
12	30.0	36.1	38.6	35.3	36.6	35.3	108
s.e.	1.49	3.08	1.61	2.00	1.70	0.92	

<u>A. myosuroides</u> control

Total Length of Flowering Heads in m/m^2

Treatment	Site 3	4	5	6	7	Mean	% Control
Control	2.61	10.7	13.24	26.2	7.07	11.96	0
1	0.58	1.3	0.91	3.0	0.74	1.31	89
2	1.11	2.4	3.48	6.0	0.37	2.67	78
3	0.30	1.2	0.57	6.0	0.17	1.65	86
4	0.08	3.0	1.02	5.6	1.39	2.22	81
5	0.70	2.4	0.23	5.4	0.58	1.86	84
6	0.19	4.4	4.69	11.0	0.99	4.25	65
7	0.40	2.3	1.74	7.1	4.63	3.23	73
8	0.67	1.1	0.96	3.8	1.10	1.53	87
9	0.06	2.5	1.78	7.9	2.15	2.88	76
10	0.20	1.9	1.23	11.3	0.25	2.98	75
11	1.00	1.6	3.36	9.3	1.53	3.36	72
12	2.37	7.3	6.51	29.0	4.14	9.86	18
s.e.	0.381	1.50	1.252	4.81	1.117	1.09	

<u>No. of A myosuroides/m^2</u> in March

171.14	150.70	104.41	134.55	192.68

Table 4 1969/70

Grain Yield cwt/ac 85% DM

Treatment	site 1	2	3	4	5	6	7	8	Mean *	%
Control	27.6	42.9	34.2	41.2	42.4	38.3	54.0	27.8	42.2	100
1	36.0	44.3	34.3	44.9	41.4	41.0	57.7	30.2	43.9	104
2	30.5	43.4	33.4	43.3	44.9	36.7	57.4	28.8	43.2	102
3	37.5	42.1	36.1	43.5	42.4	41.5	56.5	36.2	43.7	104
4	38.2	46.4	34.6	40.7	43.2	40.2	52.5	37.0	42.9	102
5	38.2	43.5	34.5	43.5	44.8	38.3	53.4	29.6	43.0	102
6	38.6	45.3	37.2	44.9	42.1	40.2	57.0	36.1	44.5	105
7	39.8	41.2	35.8	42.2	43.1	37.2	50.9	32.0	41.7	99
8	38.9	41.7	37.6	50.0	44.3	38.4	57.0	27.5	44.8	106
9	40.2	45.0	31.6	46.1	42.9	36.5	52.0	35.6	42.4	100
10	36.4	43.1	28.7	43.8	40.5	37.8	53.4	30.3	41.2	98
11	30.4	42.9	32.7	35.5	42.0	38.0	52.4	30.4	40.6	96
12	35.0	45.4	34.7	41.8	40.7	41.9	53.9	34.9	43.1	102
13	36.1	43.2	33.3	41.8	43.5	37.0	50.4	26.3	41.5	98
14	34.8	45.4	34.4	41.0	39.1	41.6	53.8	31.0	42.6	101
s.e.	1.99	2.24	1.76	2.72	2.55	1.57	1.70	4.45	0.86	

* excludes sites 1 and 8

<u>A. myosuroides</u> control

Total Length of Flowering Heads in m/m² 1969/70

Treatment	1	2	3	4	5	6	7	8	Mean*	% Control
Control	101.5	2.82	8.01	42.22	10.33	6.23	5.14	20.77	22.34	0
1	4.92	0.92	0.58	14.45	1.37	0.58	0.40	3.44	1.46	93.5
2	34.5	1.12	2.62	44.71	4.30	3.37	2.77	25.59	8.11	63.7
3	25.0	0.05	0.85	14.87	2.03	0.98	0.95	5.43	4.98	77.7
4	6.8	0.60	1.10	16.52	2.77	0.76	0.23	1.67	2.04	90.9
5	5.0	0.54	0.53	5.10	2.60	0.24	0.15	0.55	1.51	93.2
6	0.39	0.02	0.43	6.97	1.15	0.26	0.22	9.06	0.41	98.2
7	0.8	0.00	0.69	13.16	2.55	0.37	0.72	20.64	0.86	96.2
8	1.3	0.04	0.05	0.51	0.17	0.03	0.05	0.27	0.27	98.8
9	1.6	0.00	0.24	23.31	2.65	0.64	0.22	6.00	0.89	96.0
10	11.0	0.03	1.32	13.83	1.98	0.64	0.71	5.01	2.61	88.3
11	6.2	0.13	0.93	38.28	7.45	1.73	0.74	20.02	2.86	87.2
12	6.8	0.07	0.76	11.27	3.40	0.37	0.62	3.45	2.00	91.0
13	7.6	0.07	1.92	36.86	11.21	2.21	1.73	13.99	4.12	81.6
14	28.6	0.65	1.78	51.18	4.17	1.54	3.26	20.93	6.67	70.1
s.e.	17.3	0.39	1.61	9.60	1.13	0.63	0.51	4.98	2.09	

No. of <u>A. myosuroides</u>/m² in spring

429.5	613.6	131.2	195.9	293.9	174.4	104.4	296.0

* excludes sites 4 and 8

Table 5 1970 only

Control of Annual Broadleaved Weeds (11 trials)

Mean Control %	Treatments All spp.	Galium aparine	Polygonum aviculare	Polygonum convolvulus	Polygonum persicara	Veronica spp.
+50	1	11,12	1	13	5	1,6,7,12, 14
+60	4,10,12,13	4	13	1	1,4,6,13	13
+70	6,9,	14		4,6,14	3,7	
+80	7,11	6	8	9,10,11	11,12	11
+90		7	6,7,9,10, 11,12,14	7,12	9,10,14	4

DISCUSSION

In terms of the control of A. myosuroides a large number of the chemicals gave a high level of control. Choice in practice will depend on other factors, varietal susceptibility, time of application and in many instances the possibility of a bonus control of A. fatua and also annual broadleaved weeds. Economically the cost of the chemical will also be important.

Earlier experimental work in the department, has shown that the larger yield increases from the control of A. myosuroides are obtained when the unweeded controls are low yielding. The results reported here generally support this thesis. Early removal of A. myosuroides also gives larger yield increases indicating the competition from this weed during the winter.

Acknowledgements

The authors wish to thank especially the farmers who provided the experimental sites for this work; NAAS colleagues who assisted and Rothamsted Experimental Station for the statistical analysis. In addition we would like to thank the firms who provided us with experimental materials.

Proc. 10th Br. Weed Control Conf. 1970

THE USE OF 2-(4-CHLORO-6-ETHYLAMINO-S-TRIAZINE-2-YLAMINO)-2-METHYL PROPRIONITRILE (WL 19805) FOR THE CONTROL OF ALOPECURUS MYOSUROIDES IN CEREALS

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Summary In experiments carried out during the last four years, the use of WL 19805* 2-(4-chloro-6-ethylamino-s-triazine-2-ylamino)-2-methyl proprionitrile, for controlling blackgrass in cereals was investigated. Definite correlations between factors affecting performance have been established and equations for crop yield and weed control obtained from regression analyses are presented. It has been established that maximum control of *A.myosuroides* and yield increase occurs with a Spring post-emergence treatment of Winter cereals at a rate of 1.5 lb/acre a.i.

INTRODUCTION

WL 19805* was first investigated for control of *Alopecurus myosuroides* in 1967 (Chapman et al. 1968). At that time knowledge of its spectrum of activity was limited and trials were instituted to ascertain more specific data on its performance. Dose rates as high as 4 kg/ha and as low as 0.5 kg/ha were used at various timings of application, both pre and post-emergence in Colombia, England, France, Germany and Spain. As a result it was decided to direct further work more particularly to:

a. The use of WL 19805 as a pre-emergence herbicide for autumn applications.

b. Earlier Spring applications to Winter cereals with special reference to timing/dosage relationships.

French results (Loubaresse et al. 1969) indicated that 1 kg/ha applied pre or post-emergence gave very good control with significant yield increases, but this pattern did not emerge under U.K. conditions.

Work carried out during the winter 1967/68 in this country was severely limited by weather conditions. A wet December and January were followed by a cold, snowy February and conditions restricted applications to the early spring. These were applied from February 20th to April 17th at doses varying from 0.5 kg/ha to 3.0 kg/ha.

*Also known in U.K. as DW 3418, in U.S.A. as SD 15418, and in Europe and America as Bladex.

This work led to trials in 1968 being limited to a smaller range of application rates; of 132 experiments, only 7 had application rates outside the range of 1.5 to 2.5 kg/ha. Despite poor weather conditions, it was possible to apply treatments in the autumn at early post-emergence stage of the crop (1-2 leaf stage) between November 12th and December 12th, 1968, while later work was carried out between February 6th and April 29th, 1969.

Results followed a rather different pattern from previous work in U.K., so data from the three years 1967-1969 was subjected to regression analyses in order to ascertain the cause of this variability and determine the basis of the 1970 trials programme. Due to the practical considerations regarding difficulty of application and the variability of previous results, pre-emergence and very early post-emergence treatments were omitted. Despite the successful control of Alopecurus myosuroides germinating within the period of activity of the compound, due to the short persistence of WL 19805, later germination in the spring was not adequately controlled. Interest therefore focussed on spring post-emergence treatments at crop stages as early as 3 leaf up to mid-tillering.

METHOD AND MATERIALS

Equipment used varied according to field conditions and the team carrying out the application. The majority of the applications was by means of the Woodstock 'Hervey' precision sprayer fitted with Allman 00 jets having a spread of 25 cm.; operated at 30 p.s.i., delivering 45 gal/ac. Engine-driven sprayers were also used fitted with Spraying Systems 6503 jets with a spread of 18 in.; these also operated at 30 p.s.i., delivering 25 gal/ac.

Trials were laid out as randomised block with 4 replicates. Earlier work was on plot sizes of 5m x 3m, later plot size was increased and in 1970 was 30m x 3m. In addition, some earlier work used split plot design with varying rates in the sub-plots; log plots also were used.

For the three years 1967-69, all formulations used were wettable powders, with concentrations of 25%, 50%, 75% and 80% being examined. In 1970, a 50% w/w suspension concentrate was compared with the 50% wettable powder.

Crops were scored for health and vigour, where possible before the start of active spring growth, using the EWRC scale 1-9 (1 = best crop, 9 = complete kill). Quadrat counts were made of heads of Alopecurus myosuroides when in ear and weed control expressed as a percentage reduction of the population in the untreated plots.

Weighed yields of all plots were taken using a six foot cut combine harvester. Yields were expressed as a percentage of untreated plots, which until 1970, were usually treated for broad-leaf weed control only. The standard product used for comparison was a commercial mixture of methoprotryne and simazine.

RESULTS

Table 1 summarises the results of all trials carried out in U.K. in 1970 for which yield data are available. Rates of WL 19805 are expressed in lb/ac a.i. Trials 105-123 were applied as 1.00, 1.25 and 1.75 kg/ha a.i. and have been converted to simplify comparison. The methoprotryne/simazine mixture was applied at the

Table 1

Population of Alopecurus myosuroides and crop yields expressed as percentages of population and yield in untreated control plots

Trial No.	App Day	WL 19805 (lb/ac)			Meth. +Sim.	L.S.R.	G.V.S. L.T.C.	Cont. Pop.	WL 19805 (lb/ac)			Meth. +Sim.	L.S.D.
		0.89	1.12	1.56					0.89	1.12	1.56		
105	121	84	-	78.5	72	1.59	68	319	87.3	-	91.8	91.7	11.5
*106	106	-	27	16	28	1.74	63	189	-	98.1	88.1	109.3	13.9
*108	84	42	-	17	28	2.92	41	139	108.6	-	104.7	112.0	8.8
110	114	73	-	50.5	58	1.53	70	243	98.6	-	96.4	99.3	10.1
*111	99	-	9.7	4.3	7.3	2.19	52	357	-	107.7	104.4	107.5	4.1
112	105	52.5	-	30	39	2.12	54	33	121.4	-	118.5	118.0	11.0
*113	92	-	25	29.5	6.8	2.14	53	89	-	105.3	99.4	104.4	6.3
*114	105	-	15	6.5	3.6	3.19	38	99	-	94.9	96.6	99.6	9.3
116	99	-	10.3	8.4	3.2	2.00	56	52	-	89.8	89.3	93.9	8.3
117	105	-	12.3	8.6	7.4	2.16	85	53	-	97.5	92.6	96.7	4.3
118	114	-	13.5	7.0	18	2.22	52	276	-	96.5	86.3	100.6	11.4
119	57	31	-	22	11	4.46	29	55	99.9	-	99.6	99.6	8.7
120	82	9.8	-	4.4	4.6	3.33	37	38	104.4	-	106.3	106.4	7.4
121	127	71	-	59.5	71	2.71	44	158	96.9	-	83.1	92.7	14.4
123	114	87.5	-	61	61	1.56	69	340	103.6	-	102.2	100.5	12.9
		1.25	1.50	1.75					1.25	1.50	1.75		
*201	56	29	26	16	28	1.66	66	563	114.2	111.4	122.3	114.6	8.8
*202	57	NOT ANALYSED						>800	-	138.1	139.4	120.6	21.4
203	63	NOT ANALYSED						221	88.3	80.8	82.0	74.4	8.9
204	98	3.6	1.7	0.5	8.1	2.91	41	240	100.4	90.2	78.2	104.9	12.2
*205	99	4.0	3.2	1.4	1.0	3.16	39	650	118.1	118.9	116.5	117.7	7.1
*206	99	NOT ANALYSED						82	118.3	123.9	118.3	119.3	13.2
*207	107	25	11	2.9	23	3.46	36	562	113.8	113.4	110.7	113.4	6.1
208	110	-	6.1	3.9	3.7	2.78	43	125	83.3	80.0	82.0	83.7	6.6
209	120	89	62	72	102	1.74	63	108	94.8	100.0	94.0	99.1	6.0
210	120	43	64	32	85	3.22	38	72	103.5	97.2	95.8	116.0	19.3
211	121	-	91	83	54	1.71	64	74	-	92.5	93.5	93.5	5.1
212	121	107	91	83	77	1.75	63	164	91.8	100.0	97.8	98.5	6.2
213	123	NOT ANALYSED						170	78.9	90.4	78.3	86.1	13.2
214	125	49	50	49	57	1.29	81	518	95.1	91.0	94.8	98.1	6.1
215	125	73	60	45	83	2.12	54	40	95.1	98.2	97.8	96.9	5.3
216	126	23	12	16	20	2.19	52	102	88.6	88.9	82.7	86.2	4.8
217	126	144	66	86	98	3.43	36	12	90.7	87.5	85.2	89.8	5.4
218	127	46	47	16	50	2.41	48	245	84.6	100.0	84.6	88.9	18.9

recommended rate of 3.75 lb/ac of formulated product. No discernible differences in biological activity have been observed between the various formulations of WL 19805 and results for trials 105-123 are the means of two applications, each rate having been applied with the 50% wettable powder and the 50% suspension concentrate. Trials 105-123 were applied at 45 gal/ac and trials 201-218 at 25 gal/ac; no differences were observed from using different volumes.

Abbreviations used in Table 1 are:

L.S.R.	Least significant ratio between treatments.
G.V.S.L.T.C.	Greatest value significantly lower than control.
L.S.D.	Least significant difference between treatments.
Cont. Pop.	Mean value of population of *A. myosuroides* in control plots, expressed as inflorescences per square metre.
App. Day	Date of application (January 1st = 1, February 1st = 32 etc.)

Population data for certain trials was not analysed.

Trial 202	It was found impossible to count inflorescences as crop and blackgrass were badly laid.
Trials 203 & 206	Showed virtually 100% control with all treatments.
Trial 213	Showed no effect with any treatment.

Other than two trials in North Kent and two in mid-Sussex, all trials were in East Anglia, with Sleaford as the Northern limit. Sites varied in soil type from 2.88% clay (trial 111) to 55.2% clay (trial 123), with organic matter ranging from 1.66% (trials 211 & 217) to 6.3% (trials 207 & 212) with 24 trials on soil with an organic matter content within the range 2.00% to 3.5%.

DISCUSSION

Data were derived from those trials carried out in U.K. in the three years 1967-9 where applications were made between late winter and early spring for which harvest information was available. This enabled data from 10 results in 1967, 78 results in 1968 and 132 results in 1969 to be subjected to regression analyses. The information estimated to have an effect on the performance of the herbicide was grouped as follows:

Basic variables imposed by site - not alterable by choice of treatment

i Soil organic matter content % (OM)
ii Soil clay content % (C)
iii Crop variety
iv Year of trial

Variables allowing choice at treatment time

v Applied dose rate in kg/ha a.i.
vi Application date (expressed on the scale January 1st = 1, February 1st = 32 etc.)
vii Rainfall in week preceding application, expressed in inches.
viii Soil moisture condition at application (dry - 1, wet or moist + 1).
ix Crop growth stage at application, based on a numerical modification of the Feekes scale.
x Blackgrass infestation. The value used was a post-spraying assessment of the control infestation at flowering time (heads per m^2).

Variable not known at time of treatment

xi Weather following application - rainfall in inches for one week following application.

The aim of the analyses was to obtain relationships for yield and blackgrass infestation as a function of the dose of WL 19805 and the conditions obtaining at the time of application. The following relationships were established:-

(a) Yield = 102.5 - 0.227 x Application Date - 20.847 x log (dose) + 3.16 x soil moisture + 9.59 log (control infestation + 10)

For this equation, the residual standard deviation = $\pm$ 12.57 and the correlation coefficient = 0.49

(b) Log (blackgrass remaining + 1) = - 1.0576 + 0.0673 x OM - 0.724 log (dose) + 0.0719 x soil moisture + 1.0985 log (control infestation + 10)

For this equation, the residual standard deviation = $\pm$ 0.36 and the correlation coefficient = 0.78

In these equations, each variable is in the units stated above.

These equations are presented graphically in Figures 1 and 2. The examples illustrated by the dotted lines in the figures assume known factors of a rate of 1.5 kg/ha applied on March 18th (Day 77) to a crop with a medium-heavy blackgrass infestation (estimated at equivalent to about 300 flower-heads/m^2) with a soil organic matter content of 3%. Line AB is drawn from application rate to infestation curve, and BC is drawn horizontally to meet XY (Spray date in Figure 1, OM in Figure 2) at C. CZ is drawn parallel to the yield line and the blackgrass percentage curve, indicating an expected yield of 109 or a 9% increase over the untreated crop and an expected blackgrass population of 66% of the population in an untreated area. If the soil at spray time is wet, the expected yield increase will be only 3%, and the blackgrass population reduced to 49% of untreated area.

The object of the 1970 trials programme was to check the validity of the equations and improve on its precision and was based on provisional recommendations derived from the following considerations:-

(a) Dose rate. As might be expected, an increase in the amount of herbicide applied results in an increase of weed control and a decrease of crop yield. The expected performance shown by the equations, indicated that a rate of about 1.5 lb/acre a.i. was most likely to achieve acceptable weed control and yield increases, with minimum risk over a reasonably wide range of soil types.

(b) Application date and crop stage. These two factors are clearly related, the relationship varying according to weather conditions. Earlier applications had given greater yield increases and mid-February to the end of March appeared to be the optimum period for application, with limits for crop stages as 3-leaf to mid-tillering between these dates.

(c) Organic matter content. In earlier regression analyses, this factor and soil clay content were so closely correlated that either could be used in the equation with a negligible difference in precision. However, in equation B, a 1% increase in OM increases the expected survival of blackgrass by 17% of the calculated value. This is obviously a highly important factor in deciding what doses are to be recommended.

(d) Soil moisture. Increasing soil moisture results in increased activity against both blackgrass and crop. Indications were that for maximum crop safety, very wet or poorly-drained soil and soil liable to flooding

Figure 1. Yield as a function of application rate, spray date and infestation.

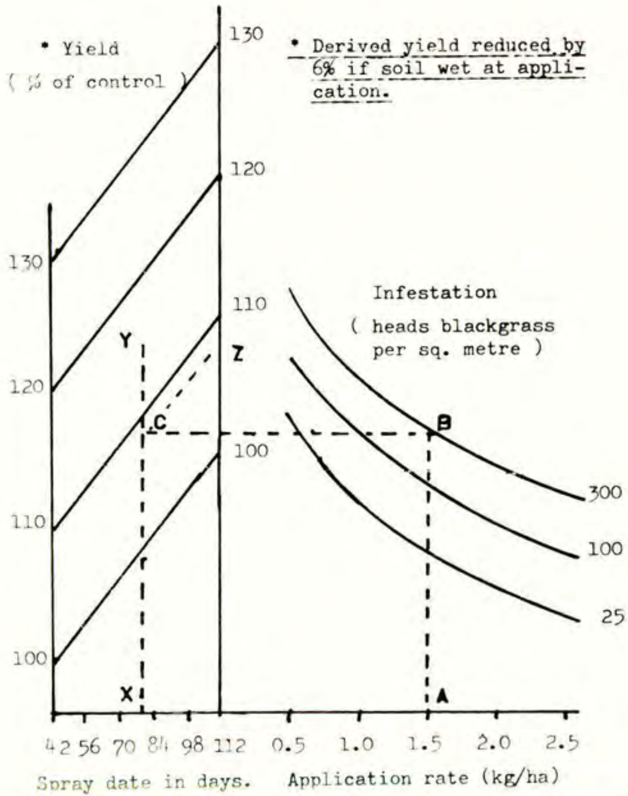
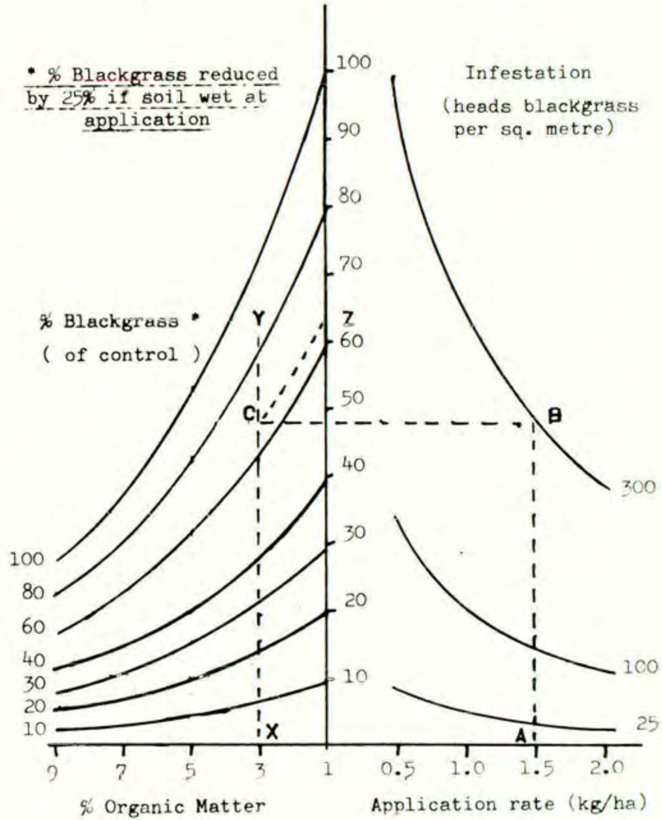


Figure 2. % Blackgrass as a function of application rate, infestation and organic matter.



and water-logging should be avoided.

(e) Weed infestation. The greater the infestation, the greater the benefit from the application of WL 19805. Normal farm practice appears to consider spraying to control a blackgrass population of less than about 40 per square yard economically unjustifiable.

(f) Crop health. The normal considerations of not applying any herbicide to a crop that is not healthy or in a checked condition.

Due to the cold and snow at the beginning of March, 1970, neither ground nor crop was fit for spraying. The majority of crops were only at the 2-leaf stage by the end of March, when less than 20% of the trials had been sprayed. Consequently the majority of this year's trials were sprayed outside our recommended time and many of the earlier trials under conditions that would have been considered impossible for farm spraying. Because of the late season, application time was extended to April 17th for this year.

The yield reductions obtained in the later trials were probably the result of the lack of competition experienced this year. Much of the A. myosuroides germinated late and only in the case of an extremely heavy infestation in a poor crop of winter barley were heads seen above the crop. In every other trial, the A. myosuroides was below the level of the crop and reducing this limited competition was not sufficient to overcome the crop check occasioned by late spraying and produce a yield increase. Yield reductions noted in trials 203 and 204 were the result of ignoring the restrictions suggested under soil moisture. Both were free draining soils, but very wet. The first had snow within an hour of spraying, and the second had snow during the time of application. The control recorded is interesting in view of Barralis' comments (1968) on the effect of field capacity.

This year's work confirms the provisional recommendations as correct. Only 10 trials of the 33 recorded in Table 1 (marked *) fall within the proposed constraints and the mean yield increase in these trials was 9.9%.

Acknowledgments

Grateful acknowledgment is made for the help of F. R. Stovell, colleagues whose work made these results possible and the numerous farmers who co-operated by providing sites. The statistics section of Shell Research Limited who analysed the data is acknowledged for their particular help.

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A SYSTEM FOR THE CONTROL OF GRASS WEEDS AFTER CEREAL HARVEST WHICH PREPARES THE LAND FOR RESOWING

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Summary A system is described which has allowed an integrated approach to all the necessary field activities between the harvesting of a cereal crop and the preparation of the land for the next crop at Begbroke Hill. Measures for the control of perennial grass weeds are included in the system which takes account of man and tractor power available, the weather and the future use of the land. Figures for the requirements of various operations and the performance of various machines are included.

INTRODUCTION

During the past five years or so there has been a great deal of new research at the Weed Research Organization and elsewhere to develop improved measures for the control of perennial grass weeds in cereal rotational systems. Håkansson (1968) has indicated the importance of soil disturbance for the encouragement of bud activity in *Agropyron repens*. Turner (1968) has demonstrated this species' sensitivity to repeated defoliation. Roebuck and Hughes (1968) compared chemical and cultural operations for the control of *A. repens* and Cussans (1968) and Chancellor (1968) have provided new biological information that adds to an understanding of the weed's response. In consequence there is a greatly increased interest on the part of the British farmer in management systems for cereal stubble. However, apart from one contribution (Evans 1968), there has been very little publication of integrated systems that cover all aspects of land management from the harvest of the cereal to the onset of winter. The experiences described in this report are a continuation to this subject.

METHOD AND MATERIALS

The site

Begbroke Hill Farm, which is the home farm of the Weed Research Organization, extends to 280 acres of which 170 acres is good arable land and 110 acres is low lying grassland. Although the primary purpose of the arable land is to provide facilities for field experiments, there is an important secondary object that all the land not in experiments shall be farmed to a good commercial standard. To this end the short term experiments are accommodated in an 8 year rotation that involves: experiments - spring barley - experiments - spring barley - spring barley - winter oats - potatoes - winter wheat. In consequence there are each year about 100 acres of land from which cereals are harvested. All the work on the farm is done by ordinary farm equipment and the inputs of tractor power and man hours are recorded.

The soil is a sandy loam which is free working and free draining and overlies gravel at depths varying from 1-3 ft. The annual rainfall consists of 26 in. falling more or less evenly throughout the 12 months of the year: variation from year to year can provide autumn conditions (August-November) varying from wet to dry. The topography is either flat or gently sloping; and the fields are rectangular in shape and 12-25 acres in size.

The Weed and the Crops

The perennial grass weed most frequently occurring on the farm is *Agropyron repens* (couch). Some of this weed is indigenous having been present for many years; but the remainder has been imported and planted in the fields for short term experiments. The requirements of the experiments often allow the weed to build up its presence on the land and it is then the function of the farm to reduce the weed while the land is being farmed commercially.

The crop rotation, which has been described, calls for the transition of land from cereals back into autumn or spring sown cereal, into experiments for which the land must be mouldboard ploughed to leave a clean surface or into potatoes for which farmyard manure is applied to the uncultivated stubble and ploughing follows. Grass weed control is thus needed in a variety of situations.

Although straw burning is regarded as an acceptable form of straw disposal on a commercial farm; it is not permitted on Begbroke Hill because of its uneven effect on weed seeds and therefore on the variation in the emergence of future weed populations.

Field Equipment

Combine harvester	width of cut 8ft 6in.	engine 52 HP		
tractors	2 wheel drive.	max B.H.P. at 2000 rpm 58 and 45		
baler	PTO driven	output 2-3 ac/hr		
straw chopper	PTO driven	" 2-3 ac/hr		
disc cultivator	linkage mounted.	discs 20 in. diam.	working width	8ft 6in
tined cultivator	" "	tines 11in. apart	" "	8ft 3in
rotary cultivator	2 blade rotor speed 153 rpm	ground speed 2 mph	"	5ft
mouldboard plough	no. of furrows 2.	furrow size 15in. reversible.		

RESULTS

An integrated approach to perennial grass weed control and land preparation has to be concerned with the following requirements:

1. grain retrieval by combine harvester.
2. straw disposal, by baling, chopping (or burning)
3. stubble break up to stimulate dormant rhizomes into activity
4. weed suppression by cultivation or chemical
5. seedbed preparation over a period and as economically as possible.

When planning to meet these requirements a farm manager has, at the time of grain harvest, to take many decisions on how to achieve the desired end. The decisions will depend on his knowledge of such factors as machinery and labour supply, future labour peaks, current weather pattern, extent of weed infestation and the future use of the land. The decision taking at Begbroke Hill follows the diagram in figure 1.

The grain and straw harvest

One point upon which recent research has been emphatic is that the quicker the start of the weed control measure after cereal harvest the more successful is it likely to be. A successful system requires therefore that stubble break up (3 abo[ve]) should occur very soon after grain retrieval; this has implications for the intermediate step of straw disposal. The performance of the combine harvester varies with the thickness of the crop but has an average of about 1 ac/hour: this output dictates the pace at which straw disposal and stubble break up should proceed if grain retrieval is not to out-pace the follow up operations. The choice of straw disposal is between baling or chopping: reference to table 2 shows that the labour content/ac of baling and bale removal is much more than that of chopping. To this may be added that chopping can occur in periods of light rain or dew and is therefore easier and quicker to achieve than is baling. In consequence baling is limited to the minimum requirement for stock and other purposes (about 2000 bales) and occurs as far as possible on land judged to be little contaminated with perennial grass weeds. Whatever the method, straw disposal endeavours to proceed at an average rate of 2 ac/hour. Once cleared of straw obstructions, the land is open to cultivation and the next decision relates to the distribution of farmyard manure in September or October for the potato crop (figure 1). Transport of the manure over the ground requires that the soil surface shall be firm and it cannot therefore be cultivated; the relative acreages can be seen in table 1.

Table 1

Operations at Begbroke Hill - acreages of land

	1968	1969	1970
Commercial cereal harvest	74	83	90
Straw baled	40	41	55
Straw chopped	34	42	35
Stubble retained for manure distribution	19	15	14
Stubble broken up by: disc cultivation	55	34	-
rotary "	-	19	-
tined "	-	15	76

Perennial Grass Weed Control

After straw disposal, the decisions on weed control relate to land that may o[r] may not be cultivable. On land that cannot be cultivated, appreciable infestatio[ns] of grass weed are allowed to grow fresh leaf and are then sprayed with a standard rate of dalapon or aminotriazole before the application of manure, Fryer and Evans (1968). When the infestation is minor or absent the stubble is sprayed with a low dose of paraquat to defoliate the weed and prevent further rhizome growth and to kill any seedlings, annual weeds and cereals, figure 1.

Where cultivation is permissible, all the stubbles are broken up as a matter [of] routine. The requirements for this operation have been the subject of much trial and error: they are as follows. All the soil must be disturbed to a depth of 4-5 in. so as to disrupt and break up the rhizome system (preferably with one pass of the implement): rhizomes should be bruised and cut into lengths of about 6 in.: chopped straw should be partially incorporated in the soil to encourage decomposition. If one man is to achieve straw chopping and stubble break up, the[n] the rate of work of each operation must be at least 2 ac/hr. Over the years thre[e] types of implement have been tried. The rotary cultivator achieved all the requirements except one: its output using a 58 HP tractor fell short of that required. The disc cultivator was fast but did not penetrate sufficiently at one pass, particularly under dry conditions and where straw is present; extra weighti[ng] of the discs increased the difference in penetration between soft and hard parts [of] the fields. Rigid tined cultivators of the chisel plough type would go through chopped straw but penetrated deeper than required and did not move all the ground

FIGURE 1. DIAGRAM OF DECISIONS ON STUBBLE TREATMENTS

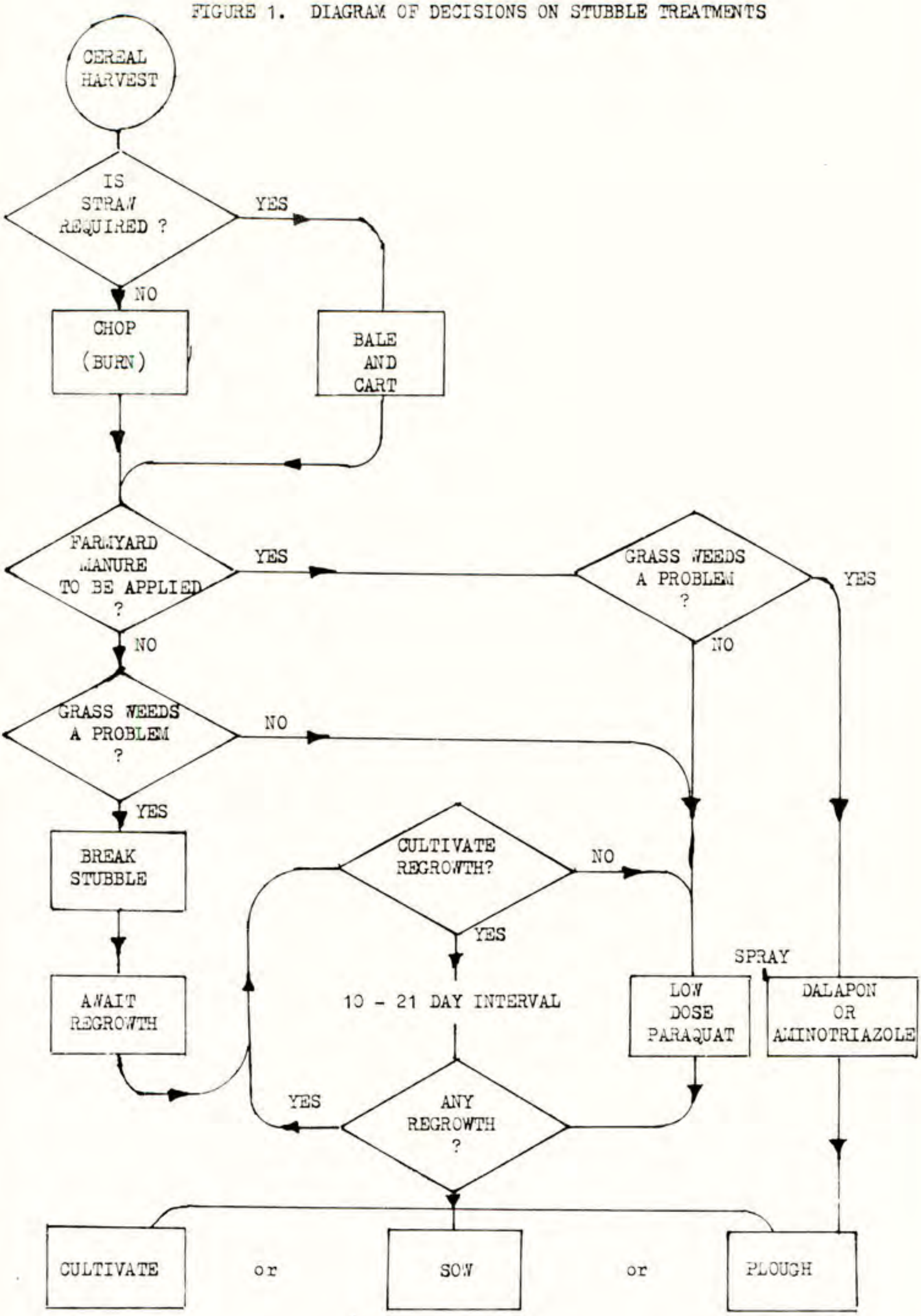

Table 2

Man-hours worked on operations over the whole cereal acreage (see table 1)

description of operation	1968	1969	1970
combine harvesting	105	101	70
conveying grain to storage	52	61	43
straw baling and carting	241	184	204
straw chopping	18	22	16
spraying stubble before manure distribution	3	3	2
1st stubble cultivation	43	64	34
subsequent cultivation or spraying	42	54	40 est.
Total man-hours (all operations)	504	489	409

Table 3

Tractor work on field operations

Horsepower hours/ac

period	description of operation	Boddington Barn 1964	Field Wrenches 1969	Wrenches 1970
	acreage	21	13	13
Aug/Sep	1st stubble cultivation - disc twice	-	42	-
	- rigid tine once	-	-	29
Sept	control of regrowth (spray or cultivate	-	36	36
late Sept	mouldboard plough	58	-	-
"	seedbed cultivation disc twice	42	-	-
early Oct	drill seed and fertiliser	20	20	20*
"	harrow	8	8	8*
Seedbed cultivations before drilling H.P. hours/ac		100	78	65

* nominal figures

or cut the rhizomes in short lengths: the straw was not incorporated. Cultivators for shallow working with tines set 9 in. apart tended to get blocked by straw. The best compromise has been achieved in 1970 by using a rigid tine cultivator with high clearance and 3 rows of tines set 33 in. apart within the row. A single pass has moved all the ground to the required depth and broken up the rhizomes: the implement achieved an average rate of work of 2 ac/hour attached to a 58 HP tractor and did not block with straw. Its one deficiency was a failure to incorporate the straw: to rectify this the next cultivation 2-3 weeks later was with a disc cultivator going fast.

Once the stubble is broken the land enters the recurring cycle (fig. 1) of re-cultivation or spraying with a low dose of paraquat every 3 weeks or so until the onset of winter. The choice of cultivation or chemical is dictated on each occasion by the weather and the tractor power available. In wet weather cultivation may be difficult and often ineffective because rhizomes do not desiccate but re-root, so spraying is the choice. In dry weather there is little vegetative regrowth so spraying may be ineffective but cultivation is easy and desiccates rhizomes. When tractor power is in demand as for example during potato harvest in October; spraying, which can be carried out with a small tractor, economises in both tractor power and man hours while allowing the control programme to continue.

The Preparation of Seedbeds

Although the cultural systems have been described in terms of weed control, it will be appreciated that they are also the first acts in the preparation of the soil for the sowing of the next crop. Some of the land has just come out of experiments or is about to enter experiments and some is being prepared for potatoes: nearly all such land has to be mouldboard ploughed at the end of the autumn and seedbed preparation follows conventional patterns in the spring. But much of the remainder is to be sown to a cereal in autumn or spring. Where the grain harvest has occurred at the normal time (mid-August) and is followed by an efficient stubble break up and 1 or 2 subsequent cultivations, no additional cultivation is necessary for the preparation of the seedbed and the sowing of an autumn crop (table 3). A suitable tilth occurs during the 6-8 weeks of natural weathering. As can be seen in table 3 such a method of preparation results in considerable economy of effort compared with ploughing. The same is true of spring sowing: barley has been grown successfully without further cultivation, but it is usual to give a shallow cultivation in spring to level and loosen the seedbed before sowing.

The system that has been described has been developed over the past five years. It has ensured the relative freedom of Begbroke Hill from problems over perennial grasses in the arable land in spite of the sowing of **A. repens** by experimenters, while avoiding excessive use of cultivation or purchase of chemical. The system has also been used successfully on a number of neighbouring farms.

Acknowledgments

The authors wish to acknowledge the assistance of many members of the staff of WRO but particularly A. Penfold, H. Hunt, C. Woodhams and M. Pearson, who carried out the operations that have been described.

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COMPARISON OF SYSTEMS OF PERENNIAL GRASS WEED CONTROL IN SPRING BARLEY

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Summary A comparison was made of various methods of control of perennial grass weeds applied soon after harvest. Herbicides were compared applied direct to the cereal stubble and to the regrowth of grass weeds initiated by earlier cultivation. Two systems of cultivation without herbicides were compared, one was based on rotary cultivation to fragment the rhizomes of the grass weeds in the stubble and the other was based on tined cultivations aimed at shaking the rhizomes free of soil to be controlled by desiccation. Responses in yield were obtained in the barley crop grown in the following year where treatments were effective in reducing the dry weight of rhizomes per unit volume of soil.

INTRODUCTION

Perennial grass weeds (Agropyron repens, Agrostis gigantea and A. stolonifera) remain the dominant weed problem on the mainly cereal farms of the South. The effect of competition in reducing yield is accentuated by the carry-over of soil-borne diseases associated with weed grasses (Brooks, 1965). The problem in cereals becomes acute in wet years because the smaller farm labour force has reduced the potential of cultivations as the traditional method of grass weed control.

Rotary cultivation has proved to be a satisfactory method of fragmenting rhizomes and subsequently destroying shoots arising from dormant buds on the rhizomes (Fail, 1956, Proctor, 1960, Roebuck and Hughes, 1968). If the degree of rotor chop is sufficiently fine the rhizomes may be killed by desiccation (Roebuck 1968) without necessarily relying on exhaustion of carbohydrate reserves by the production of new shoots. The destruction of rhizomatous grass weeds is traditionally achieved by fixed and spring tine implements combing the weeds to the surface of the soil and desiccation is rapid if the rhizomes are free of soil. Tine cultivation of stubble is a relatively speedy operation, but when the soil is wet it is difficult to free the rhizomes and on heavy land it is difficult to break down clods protecting the rhizomes when the soil is dry.

There is considerable variation in the efficiency of the present range of herbicides used for perennial grass weed control in cereal stubble. This has been discussed by Sagar (1961) and Hughes (1966) with reference to the translocation of dalapon and aminotriazole in Agropyron repens. It is apparent that activation of rhizome dormant buds is a necessary prerequisite for efficient herbicide translocation. The same principle applies to paraquat, which is mainly desiccatory in action when applied as a single dose. Recent work has shown greater activity of paraquat against perennial grass weeds when applied in small doses at intervals in the autumn to cultivated or undisturbed cereal stubble (Banks 1968, Cussans, 1969).

METHOD AND MATERIALS

The treatments were laid down on large single plots (20 yd x 120 yd) on a silty clay loam soil over Upper Chalk (Colemore, Hants). Assessments prior to treatment showed 40% of <u>Agropyron repens</u> and 60% of <u>Agrostis gigantea</u> present in the stubble. The amount of rhizome dry weight in the soil after sampling was 64.4 g/ft^3. The straw from the previous spring barley crop was baled and removed before treatments were applied, apart from one treatment where it was burnt.

Treatments applied in the autumn of 1968 were as follows:-

1. Herbicides applied direct to stubble (a.i. per acre)
   a) $4\frac{1}{2}$ lb dalapon + 2 lb aminotriazole
   b) 12 oz paraquat
   c) 6 oz paraquat
   d) 6 oz paraquat applied three times at intervals
   e) $27\frac{1}{2}$ lb TCA cultivated into stubble.

2. Herbicides applied to regrowth of grass weeds produced by rotary cultivation shortly after harvest (a.i. per acre)
   a) $4\frac{1}{2}$ lb dalapon + 2 lb aminotriazole
   b) 12 oz paraquat
   c) 6 oz paraquat applied three times at intervals
   d) $27\frac{1}{2}$ lb TCA

3. Rotary cultivation at intervals.

4. Tine cultivation at intervals.
   a) After straw and stubble burnt
   b) After straw baled and removed
   c) After one rotary cultivation to stubble
   d) Initial tine cultivation followed by 6 oz paraquat applied to regrowth.
   e) Initial tine cultivation followed by 6 oz paraquat applied twice to regrowth.

5. Shallow ploughing to 4 in. to produce regrowth
   a) 6 oz paraquat to regrowth.
   b) no chemical applied.

6. No stubble treatment except mouldboard ploughing.

To initiate regrowth of the grass weeds on treatment 2 before application of herbicides the stubble was worked twice with a rotary cultivator to the depth of live rhizomes (4-6 in.). A rotor speed of 180 r.p.m. was used with a tractor speed of 2 m.p.h. and the rhizomes were chopped to a length of 3-4 in. This was also carried out on the repeated rotary cultivation area on treatment 3. A heavy duty spring tine cultivator was used for repeated tine cultivation and this was effective in freeing the rhizomes from soil.

Dates of application of treatments were as follows:

Table 1

Details of Operations

Stubble Treatment	Date
1. Herbicides direct	5.9.68
Repeat paraquat	2.10.68, 10.10.68, 11.11.68
2. Herbicides to regrowth (Shoots 9-12 in.)	2.10.68
Repeat paraquat	2.10.68, 10.10.68, 11.11.68
3. Rotary cultivation	Twice on 5.9.68 2.10.68
4. Tine Cultivation	Twice on 5.9.68 2.10.68 and 23.10.68
Repeat paraquat	16.10.68 and 13.11.68
5. Shallow ploughed	18.9.68
Paraquat	16.10.68

Ploughing was carried out across all plots on 10 and 11 December, 1968, burial of trash was considerably better where surface cultivation had been carried out but wheel traction was reduced on the rotary cultivated area. Spring barley cv Vada was drilled across all plots on 26 March 1969 at a seed rate of 140 lb/ac. To obtain yields of barley, two sample combine cuts of 12 ft by 150 ft were taken from the herbicide treatments and four such cuts from the cultivation areas. To assess the effect of treatment on the grass weeds 6 x 1 ft^3 were dug on each area, the rhizomes washed free of soil and the aerial shoots removed. The rhizomes were oven dried and weighed.

RESULTS

Yield of grain per acre of spring barley in the year following treatment and the dry weight of rhizomes after harvest is shown in table 2.

Table 2

Effect of herbicides and cultivations on rhizome weight and on the yield of spring barley in the following year

Stubble Treatment	Yield of Grain at 85% DM % of control		Rhizome Dry weight g/ft³ % of control	
1. Herbicides to stubble				
a) Dalapon + aminotriazole	121	115	31	58
b) 12 oz paraquat	107		102	
c) 6 oz paraquat	117		63	
d) 6 oz paraquat repeated	116		47	
e) TCA	116		49	
2. Herbicides to regrowth				
a) Dalapon + aminotriazole	122	121	18	42
b) 12 oz paraquat	122		74	
c) 6 oz paraquat repeated	117		23	
d) TCA	124		52	
3. Rotary Cultivation	119		29	
4. Tine Cultivation				
a) Stubble/straw burnt	126	123	23	49
b) Straw baled	122		44	
c) One rotary cultivation	122		56	
d) + 6 oz paraquat	118		62	
e) + 6 oz paraquat repeated	123		61	
5. Shallow ploughing				
a) + 6 oz paraquat	111	109	55	
b) No chemical	108		85	
6. No stubble treatment	(100) 36.6 cwt/ac		(100) 61.5 g/ft³	

The herbicides applied to the regrowth of grass weed were more effective in reducing rhizome density in the year following treatment than herbicides applied direct to uncultivated stubble, particularly with dalapon/aminotriazole and repeated small doses of paraquat. A single large dose of paraquat destroyed the aerial shoots and tended to render the rhizomes dormant as further regrowth was negligible compared to the low dose treatments. Low doses of paraquat did not entirely destroy the aerial shoots after each spray and this may have assisted in more rapid regrowth, a factor which would tend to reduce rhizome reserves. TCA appeared to be as effective applied to regrowth as application to stubble with cultivation incorporation.

Both tine cultivation and rotary cultivation on their own achieved large reductions in rhizome density in an autumn of above average rainfall. Tine cultivation was noticeably more effective where the straw and stubble was burnt than where the straw was baled and carted. The application of paraquat after tined cultivation was not as effective as after rotary because there was less regrowth from dormant buds. Similarly shallow ploughing was not effective in promoting regrowth.

Yields of barley tended to follow the effects of treatment on rhizome density but differences were not marked because of the relatively high yield on the control area. The yield after rotary cultivation tended to be lower than anticipated from the degree of grass weed control, probably because of the adverse effects on soil structure in the wet conditions which made ploughing difficult on this treatment. In addition to the outright kill of rhizome most of the treatments retarded the development of new rhizome and weakened the subsequent growth of grass weed. Although not fully reflected in the differences in dry weight of rhizome at harvest the weakening effect of certain treatments may have contributed to differences in the yield of barley and may have accounted for inconsistency in the direct relationship of rhizome dry weight and cereal yield.

DISCUSSION

Previous work (Roebuck 1968) has shown the value of repeated tine cultivation in the control of rhizomatous grass weeds. Cultivations assist in the control of cereal pests and diseases by the rapid incorporation and breakdown of the residues of the previous cereal (Hughes 1966). If weather conditions prevent further effective cultivations then translocated or desiccatory herbicides can be used effectively on the regrowth. This allows flexibility in control methods as herbicides are generally more effective when applied to regrowth following cultivations. In the absence of cultivations, repeated small doses of paraquat showed promise in reducing rhizome density in cereal stubbles.

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CULTIVAR DIFFERENCES IN HERBICIDE TOLERANCE AND THEIR EXPLOITATION

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Summary The winter wheat cultivars Manella, Caribo, Tadorna and Eno were grown in a glasshouse on a sandy clay soil in trays under the following conditions: temperature: 17°C day, 5°C night, light: normal and 40% reduced, nitrogen: no application and 100 kg/ha. They were treated with C2242* 80% a.i., 0, 2.5 and 5 kg/ha, pre- and post-emergence. Weed control was perfect. Caribo was very tolerant to C2242. At a rate of 2 kg a.i./ha C2242 reduced sprout dry weight by 7% at about 2 months after emergence. The other cultivars were reduced by at least 50%. A double dose resulted into 30 and 65% reduction respectively. Root dry weight was damaged more. Post-emergence application was more aggressive. It is suggested to profit from cultivars with exceptional tolerance, by using them as cleaning crops on heavily infested fields.

INTRODUCTION

There should be a wide margin of safety between the concentrations of acceptable weed control and first signs of injury to the crop. Cultivars with exceptional tolerance to a certain herbicide will enable weed control to be more effective as higher rates can be used. Differences in cultivars have been reported repeatedly. Fiddian (1962), Strijckers and Van Himme (1968) (1970), Dufour et al.(1970), Maas (1970), Lindegaard and Christensen (1970). Kolbe (1970) reports no difference in behaviour to methabenzthiazuron within winter wheat and some between cultivars of spring wheat.

The existence of cultivars that are more or less susceptible to a certain herbicide is mentioned very generally in weed control literature. When the majority appears to be susceptible, the outlook for the herbicide is very meagre. Perhaps insufficient attention has been paid to exceptional high tolerances.

For an orientation on this subject the responses of some specially chosen cultivars of winter wheat to a new herbicide of the substituted urea group were compared under glasshouse conditions. The herbicide Ciba nr. 2242 is a substituted urea now named chlortoluron. Its solubility in water is 10 ppm. More details are given by l'Hermite et al. (1969). It is a soil herbicide with a rather long lasting residual effect but also has contact activity on leaves. It controls grass weeds such as Alopecurus myosuroides, Apera spica-venti and Poa annua, as well as a range of broadleaved weeds. It appears selective up to about 4 kg a.i./ha. in winter cereals. In spring cereals it can be applied only pre-emergence. Experiments in Switzerland and France have shown some cultivar differences. In spring cereals and especially at post-emergence application the selectivity is relative small, so that no more than about 1.8 kg/ha can be applied. The rate and time of application, the nitrogen level and the light intensity were varied, to ascertain if the condition of the plants revealed modifications of the general effect of the herbicide or of the cultivar differences.

* Accepted common name for C2242 is chlortoluron

METHOD AND MATERIALS

The experiment was carried out as a factorial design in a glasshouse with all combinations of the factors:

cultivars of winter wheat: Manella, Caribo, Tadorna and Eno,

nitrogen: no dressing and 100 kg N/ha; N_0 and N_1,

rates of the herbicide C2242 80% a.i.: 0, 2.5 and 5 kg/ha; C_0, C_1 and C_2,

Time of application: pre-emergence (t_1) and post-emergence (late tillering stage) 21st April, (t_2)

light intensity: natural light reduced to 60% and normal; l_1 and l_2.

There were two replications. The wheat was sown March 6th 1970 in trays, in rows of 25 grains. The seeds were treated with an organo mercury compound 2 g/kg seed. The soil was a medium heavy marine clay, mixed 2 : 1 with a rather coarse sand. The analysis of this mixture was: pH 7.4, organic matter 2%, $CaCO_3$ 4.5%, < 2 µ 10%, P_2O_5 0.001%, K_2O 0.018%, N-total 0.08%.

The average recommended rate of the herbicide C2242 and twice this dose were chosen: 2 and 4 kg a.i./ha respectively. The solution was applied with a propane sprayer at a rate of 1.000 l/ha. Half the nitrogen as calcium ammonium nitrate 23%, was applied just before sowing and lightly worked in, the remainder three weeks later.

The difference in light intensity was obtained by shading one half of the glasshouse with a double layer of black plastic gauze. Besides the natural light intensity of the late spring in the glasshouse, a reduced intensity was desired to resemble normal intensities during seedling growth of winter wheat. A day temperature of 15°C and a night temperature of 5°C were chosen though the actual average day temperature was 17°C.

Relative air humidity was kept as high as possible, but most of the time did not exceed 80% and evaporation was high. The trays were flat and sprinkler irrigation was necessary on nearly all days in the unshaded compartment, twice as much as in the other. Soil structure stayed optimal. The herbicide could not be washed out of the trays, so the roots remained in contact with the herbicide.

The crop reaction was assessed by: counting plant emergence, visual assessments, tiller counts and a final harvest about two months after sowing. At this time several rows of plants had died. Nevertheless fresh and dry weights of sprouts and roots were obtained from all the plants; the sprouts were cut off from the roots just above the seeds, the roots were washed, centrifuged, weighed and dried.

RESULTS

Germination was slow due to low temperatures, but emergence was regular and nearly complete. Slightly reduced emergence was not correlated with treatments. There was some evidence of retardation by the herbicide applied pre-emergence. Caribo emerged somewhat slower than the other cultivars. Few weeds survived in the trays treated pre-emergence with C2242. Weeds were abundant in the untreated trays, especially Chenopodium rubrum, Sonchus asper, Polygonum, Stellaria media and some grasses. These were removed by hand. Weeds also died quickly, following the post-emergence application.

At the low light intensity the wheat plants showed more leaf elongation and tillered less. The first signs of injury to the wheat did not appear until one month after the pre-emergence application or two weeks after full crop emergence. Most of the wheat plants had developed three or more leaves and had started tillering in normal light. In the cultivar Caribo the symptoms were slight and late. The leaves of susceptible wheat plants turned pale green, gradually followed by tip scorching, some stunting, reduced tillering and, in cases of severe damage, wilting and death of the plants. The rate of progress of the symptoms was dependent upon the action of the several experimental factors as will be illustrated by the dry weights of the plants.

Following the post-emergence treatment the first signs of damage to the wheat plants became visible within ten days. There was some browning and wilting of the leaves and they became somewhat transparant. Generally the damage developed quicker thans after pre-emergence application. After another eight days the damage was already severe in some cases, the leaves were slack, turned grayish and were dying. Symptoms in Caribo were again less.

Although the experiment was set up as a complete factorial design, there were technical factors by which it could not be laid out completely at random. Therefore the analysis of variance was done separately for all figures within each of the four combinations of light intensity and time of application. Within these combinations some effects were consistently very significant; see table 1.

Table 1

Significance* of main effects and interactions from 4 separate groups of treatment combinations. Dry weights of sprouts (spr.) and roots (rts) and total (tot.)

	l_1 low light 60%						l_2 normal light					
	t_1 pre-emerg.			t_2 post-emerg.			t_1 pre-emerg.			t_2 post-emerg.		
	spr.	rts	tot.	spr.	rts	tot.	spr.	rts	tot.	spr.	rts.	tot.
cultivars	4	-	4	4	3	4	4	2	4	4	3	4
nitrogen	4	-	4	4	-	3	2	-	1	3	-	.
C2242	4	4	4	4	4	4	4	4	4	4	4	4
cv x nitrogen	-	-	-	-	.	-	-	-	-	-	-	1
cv x C2242	3	2	3	4	2	4	.	2	1	3	-	3
nitr. x C2242	2	-	2	2	2	2	1	-	1	-	1	-
coef. of var.%	20	43	19	19	32	19	28	33	27	12	26	13

*sign. at: . P ± < 0.2, 1 P < 0.10, 2 P < 0.05, 3 P < 0.01, 4 P < 0.001

For brevity only the dry weights of roots and sprouts of one row of about 25 plants are given in the tables.

Table 2 shows the effects of the different factors. The effect of the herbicide is very consistent and independent of all the other treatments. The relative damage to the roots is regularly higher than to the sprouts.

Table 2

The effect of C2242 at 2 light intensities, 2 times of application and 2 levels of nitrogen on the dry weights - g/25 plants - of sprouts and roots averaged over 4 cultivars of wheat

	light intensity				time of application				nitrogen level			
sprouts	l_1	%	l_2	%	t_1	%	t_2	%	N_0	%	N_1	%
c_0 untreated	9.0	100	9.6	100	10.0	100	8.7	100	8.1	100	10.6	100
c_1 2 kg a.i.	5.1	56	6.1	63	6.3	63	5.0	57	5.4	66	5.8	55
c_2 4 kg a.i.	3.8	43	4.3	45	4.5	45	3.7	42	3.8	46	4.4	42
mean	6.0		6.7						5.7		6.9	
$\frac{c_1+c_2}{2}$		50		54		54		50		56		48
roots												
c_0 untreated	3.4	100	4.7	100	4.3	100	3.8	100	4.0	100	4.1	100
c_1 2 kg a.i.	1.5	44	2.3	50	2.2	51	1.7	44	2.0	51	1.8	44
c_2 4 kg a.i.	1.1	32	1.5	32	1.4	34	1.2	30	1.1	28	1.5	56
mean	2.0		2.8		-				2.4		2.5	
$\frac{c_1+c_2}{2}$		38		41		42		37		40		40

Table 1 also shows the differences between cultivars to be highly significant. Because of the high coefficients of variation these differences could not be caused by normal cultivar differences in growth rate.

Table 3

The effect of C2242 on the dry weights of sprouts and roots of 4 cultivars of winter wheat for 2 light intensities, pre- and post-emergence application, averaged for 2 levels of nitrogen

			sprouts				roots			
a)			Man.	Car.	Tad.	Eno	Man.	Car.	Tad.	Eno
l_1	t_1	c_0	10.2	9.6	9.5	10.5	4.7	3.0	2.9	3.9
		c_1	4.5	7.8	4.2	4.8	1.3	2.3	1.6	1.2
		c_2	3.1	7.5	3.4	3.1	0.7	1.9	0.9	1.5
	t_2	c_0	7.3	8.3	8.4	8.3	3.4	3.1	3.0	3.4
		c_1	3.6	8.8	3.6	3.4	1.3	2.7	0.7	1.1
		c_2	2.7	5.0	3.0	2.9	0.6	1.6	0.7	0.8
l_2	t_1	c_0	8.9	10.3	9.7	11.0	5.1	4.5	5.2	4.9
		c_1	5.3	10.6	6.4	6.4	2.0	4.9	2.2	1.9
		c_2	2.9	8.4	4.1	3.5	0.9	2.8	1.4	1.4
	t_2	c_0	9.0	10.5	8.4	9.1	4.0	4.8	3.8	5.0
		c_1	3.5	8.6	4.0	3.9	1.5	3.0	1.3	1.7
		c_2	3.0	5.9	3.3	3.4	1.0	1.9	1.4	1.1
b) means		c_0	8.9	9.7	9.0	9.7	4.3	3.8	3.7	4.3
$l_{1,2}$	$t_{1,2}$	c_1	4.3	9.0	4.6	4.6	1.5	3.2	1.5	1.4
		c_2	2.9	6.7	3.5	3.3	0.8	2.1	1.1	1.2

The effects shown in Table 3 illustrate the rather high tolerance of the cultivar Caribo, which explains the high significance of cultivar differences. Under all conditions of the experiment, Caribo demonstrated a higher tolerance to C2242 than the other cultivars. The average reduction in dry matter production of the sprouts and roots caused by 2 kg a.i. was about 7 and 16% respectively, against 50 and 64% for the other cultivars. At 4 kg a.i. the reduction for Caribo was 31 and 55%, for the other cultivars it was 65 and 75%. This gives the explanation for the cultivar effect and for the interaction of cultivars and C2242.

From this experiment it is very obvious that light, nitrogen and time of herbicide application do not greatly modify the tolerance of Caribo relative to that of the other cultivars. Some minor changes in relative tolerance can be expected, such as some interaction of nitrogen and C2242 (Tabel 1). From table 4 we get the impression that the interaction for the sprouts differs from that for the roots.

Table 4

The dry weights of sprouts and roots obtained with 4 kg a.i. C2242 as percentages of untreated at two levels of nitrogen at 8 combinations of light intensity, times of application and levels of nitrogen. Averages of 4 cultivars

light intensity	l_1				l_2			
time of appl.	t_1		t_2		t_1		t_2	
nitrogen	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1
sprouts	43.5	41.7	43.5	40.9	55.4	41.9	43.5	42.3
roots	27.3	40.0	27.6	31.4	29.2	36.0	25.5	38.1

In the four l and t combinations nitrogen increased sprout damage from C2242 but reduced root damage.

Analysing the data for the tolerant cultivar Caribo, the significances obtained from a clear picture (table 5).

Table 5

Significance[x] of main effects and interactions for the tolerant cultivar Caribo on the basis of dry weights of sprouts, roots and whole plants

main effects	spr.	rts	tot.	interactions	spr.	rts	tot.
nitrogen (N)	2	-	-	N x C2242	-	-	-
C2242 (dio)	4	4	4	N x t	-	-	-
time of appl. (t)	2	-	2	N x l	-	-	-
light intensity (l)	2	4	3	C2242 x t	-	-	-
coef. of var. %	21	32	21	C2242 x l	-	-	-
				t x l	-	-	-

[x] sign. at: 2 $P < 0.05$, 3 $P < 0.01$, 4 $P < 0.001$

The effects of light and time of application are significant, whilst that of nitrogen is present only in the sprouts. None of the interactions observed for the group of cultivars (table 1) are present in the figures for Caribo, including the interaction of nitrogen and C2242. Yet table 6 suggests that the influence of nitrogen on the damage to sprouts or roots may also apply to Caribo as well as for the other cultivars.

Table 6

The dry weights of sprouts and roots obtained with 4 kg a.i. as percentages of untreated at two levels of nitrogen. Averages from 2 light intensities and 2 times of application

	Caribo		averages of Man., Tad., Enc	
	N_0	N_1	N_0	N_1
sprouts	82.2	79.3	46.8	38.7
roots	63.1	75.7	30.8	31.4

DISCUSSION

The tolerance of the winter wheat cultivar Caribo to C2242 was clearly demonstrated by a rather quick method. This tolerance appeared to be consistent under different growing conditions. Nitrogen influences the tolerance of the sprouts relative to the roots as expressed by the dry weights.

The availability of an acceptable crop cultivar with high tolerance to an effective herbicide undoubtedly would be welcome in many situations, as it could be used as a cleaning crop. The results support some recent information given by Mr. Debije and Mr. Sedlarik about the tolerance of Caribo in field experiments. Further information on the behaviour of Caribo in the field is still required. In a single experiment with large Mitscherlich pots, in which the 4 cultivars were treated with 8 kg a.i./ha pre- and post-emergence, Caribo showed tolerance to the very high dose and yielded at maturity about 50% of the untreated plants. The other cultivars were all killed.

Acknowledgments

The authors wish to thank Mr. M. Keuls who was very helpful with the computer analysis. Thanksare due to Ir. J.B.H. Debije and Mr. Zd. Sedlarik of Ligtermoet, Rotterdam for information, demonstration and supplies of C2242.

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LEACHING AS A TOOL IN THE EVALUATION OF HERBICIDES

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Summary A chromatographic method to compare the leachability of herbicides using thick layers of soil and a bio-assay to spot the herbicides is described. In the standard soil used the results are readily reproducible. Leaching results for commercialized herbicides as well as for a number of experimental products are given and discussed in terms of practical implications.

INTRODUCTION

The knowledge of the leachability of a herbicide in the soil is a most important element to help interpret or predict its field performance. Also, leachability may be an argument for selecting a product out of a group of chemically and biologically closely related compounds.

Many experimental methods to study the leaching behaviour of herbicides in soils have been published (Harris 1966; Lambert et al. 1965; Helling and Turner 1968). All the methods involving soil columns are rather time-consuming, and it is difficult to pack columns sufficiently uniformly to obtain reproducible results. A more elegant and rapid method is, of course, the chromatography on soil in thin layers. Until recently the tracing of the product on such soil layers was only reproducible with radioactive materials, but Chapman et al. (1970) recently reported that they were able to trace herbicides on thin layers of soil by means of a biological test.

We have started out from the soil thin layer method, and in trying to develop methods to trace unlabelled herbicides, have arrived at a 'soil thick layer chromatographic method'. We think that it has a good reproducibility, is quick and yet sufficiently accurate.

METHODS

An aluminium plate, 30 by 5 cm, with walls 0.5 cm high along both the longer sides, is evenly covered with 80 g air-dried soil with a maximum particle size of 1 mm. The 'Möhlin' soil which is most often used has the following composition: organic C 3.2 %, clay 37 %, silt 32 %, sand 31 %, pH 6.4. The herbicide is applied at a distance of 3 cm from one end of the plate in the following way. First, a metallic frame 1 x 5 cm is inserted into the soil layer covering the cross-section where the herbicide will be placed. The soil within this frame is sucked away by a vacuum pump and replaced by 2.5 g of similar soil into which 0.4 mg of the herbicide has been evenly mixed. The small metallic frame is carefully removed and the plate placed in the 'leaching box' (Figure 1). At the upper end of the plate a small piece of cotton cloth, pasted to the plate, dips into a water container and draws up the water for the development of the chromatogram. With 'Möhlin' soil the plate is inclined at 5° to obtain movement of water down the soil layer. After 12 ml of water have passed down the plate and fallen into the beaker, the plate is removed from the leaching box. The total quantity of water on the wet soil plate plus the water percolated into the beaker now amounts to 62 ml $\pm$ 2 ml. The whole leaching process takes about two hours.

For each compound 3 plates are simultaneously leached in the same way. The soil, while still wet, is carefully removed from the plate in sections of 2 cm along the plate, giving a total of 15 individual portions of soil. They are dried at 30°C, the corresponding ones from 3 plates pooled and thoroughly mixed. For each individual section a total of 16 g of dried soil is obtained, which is divided into portions of 8, 4, 2 and 1 g and placed in 100 ml plastic beakers. To each beaker 50 ml of Hewitt hydroponic solution is added and the bio-assay plants are then introduced as shown in Figure 2. Sinapis alba, tomato or oats proved to be useful test plants.

The method of assessing the bio-assay is shown in Figure 3. The beakers are arranged in four rows containing either the 8, 4, 2 or 1 g soil portions, with the 15 individual sections consecutively arranged. The beakers with killed plants normally form a triangle. The peak of the triangle indicates the leaching distance, which is measured in cm.

As atrazine has a moderate mobility (10 cm in 'Möhlin' soil), it is practical to express the leaching of a given herbicide in relation to the leaching of atrazine by the leaching index $L_A=(l_X/l_A)10$. The expressions l_X and l_A represent the leaching distances in cm obtained under identical experimental conditions for compound X and atrazine, respectively.

For germination inhibitors, such as carbamates and α-chloracetamides, it is necessary to modify the bio-assay. Lolium multiflorum is used as a test plant, and is directly sown into the individual leached soil sections. Since more leached soil is required in this case, 9 instead of 3 plates are leached for each compound. After pooling, amounts of 20, 10, 5 and 2.5 g of soil for each individual section are placed in the beakers. The soil with the seeds of the test plant is kept moist with Hewitt hydroponic solution for even germination.

RESULTS

The reproducibility of the leaching method described is illustrated by the leaching distances obtained for atrazine in different runs on different days, using 'Möhlin' soil and absolutely the same procedure. The distances were 9 cm, 10 cm, 11 cm and 10 cm. Out of these values an average of 10 cm has been taken for atrazine.

FIGURE 1 "LEACHING BOX" FOR DEVELOPMENT OF SOIL CHROMATOGRAMS

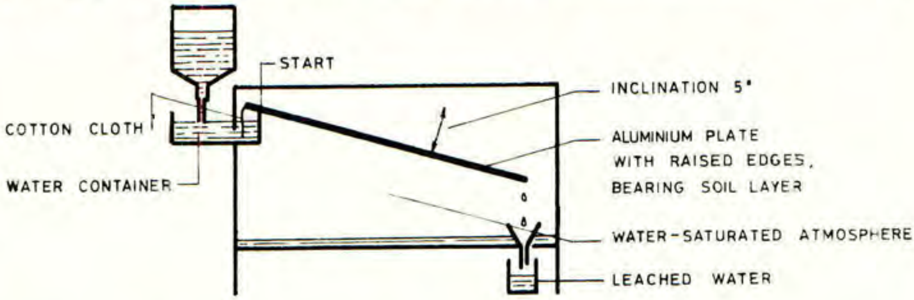


FIGURE 2 BIO-ASSAY FOR SEPARATED SOIL SAMPLES

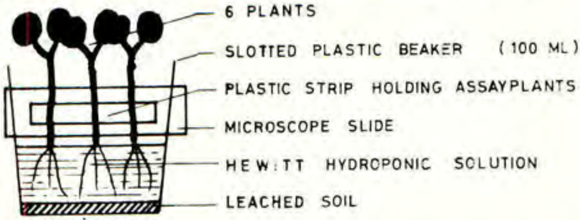
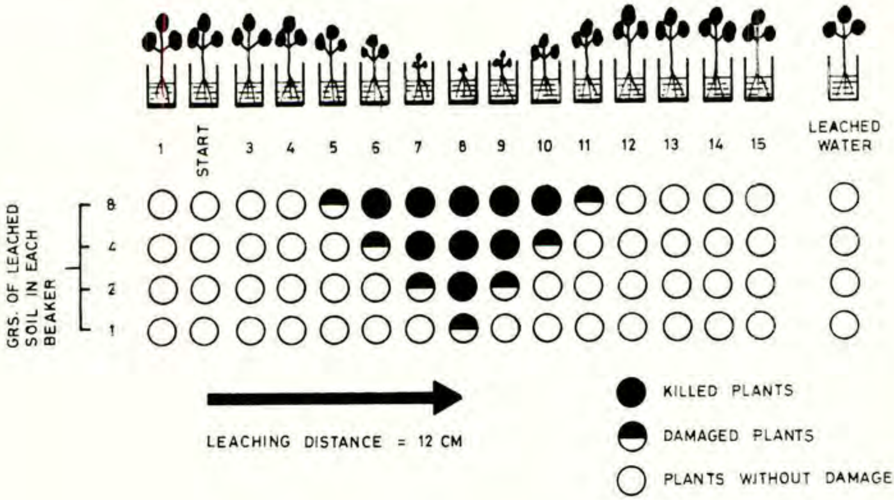


FIGURE 3 ARRANGEMENT OF BEAKERS AT END OF BIO-ASSAY, TO SHOW LEACHING DISTANCE



For a number of triazine and urea herbicides the L_A-values have been determined in the standard 'Möhlin' soil. They are listed in Tables 1 and 2. R_F-values, considered as a measure of hydrophilic-hydrophobic balance and determined after the method of Hance (1967), have also been added to Tables 1 and 2. The leaching indices found for atrazine, prometryne and terbutryne are confirmed by the experiments of Chapman et al. (1970). These products show in their experiments the same relative mobility as in ours.

DISCUSSION

The results obtained offer an opportunity to speculate on the relationship between leachability and the chemical structures of the compounds tested, which are quoted in Tables 1 and 2 with the leaching data.

For triazines some general tendencies are clearly noticeable. The leaching of triazines with identical substituents in the amino side chains is influenced by the group in the 2-position of the triazine-ring, the methoxytriazines generally being the most, chlorotriazines intermediate and methylthio-triazines the least leached compounds. This ranking emerges clearly when the following groups are considered (L_A in brackets):

atratone	(15)	>	atrazine	(10)	>	ametryne	(7)
prometone	(11)	>	propazine	(5)	>	prometryne	(4)
GS 14254	(9)	>	GS 13528	(5)			
			GS 26379	(10)	>	GS 26575	(4)

This relationship, however, does not show up in the following groups:

simetryne	(7)	>	simazine	(5)			
methoprotryne	(7)	>	G 34698	(5)			
GS 13529	(3)	>	terbutryne	(2)	=	GS 14259	(2)

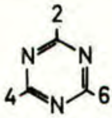
Weber (1970) found the following ranking for adsorptability of triazine herbicides: $SCH_3 > OCH_3 > Cl$. A similar ranking in leaching behaviour is only seen in the 4-ethyl-6-t-butyl substituted series, where terbutryne = GS 14259 < GS 13529. With all the other series the adsorptability ranking found by Weber is at variance with the L_A-values reported in this paper. This finding demonstrates quite clearly that adsorptability per se is just as bad an indicator of leaching as is water solubility (Table 1). Leaching must therefore be regarded as a resultant of adsorptability and water solubility.

With urea type herbicides (Table 2) only a few L_A-values have been determined. They demonstrate that the ureas with saturated cyclic substituents are much more mobile in the soil than are ureas substituted by aromatic ring systems.

Although water solubility, as we have already stated, is not a reliable indicator of the leachability of a given compound, it may all the same be helpful to some extent for predications within a group of very closely related chemicals, for instance within the methoxytriazines, methylthiotriazines and ureas. But the chlorotriazines simazine and G 34698, which show identical leaching behaviour but a wide difference in water solubility, are examples of how misleading information

Table 1

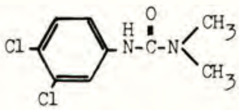
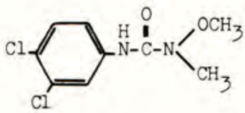
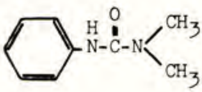
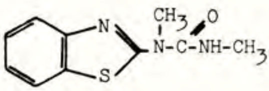
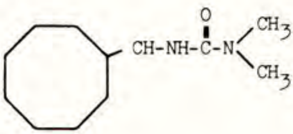
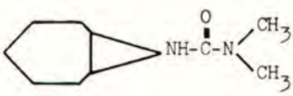
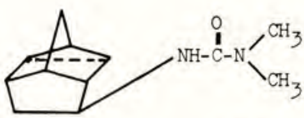
Leaching indices, water solubility and Rf-values (method used by Hance 1967) of triazine herbicides



Product	Substituents 2 position	4 position	6 position	Leaching index L_A	Solubility ppm	Rf-value
GS 13529	Cl	NHC_2H_5	NH-tert.C_4H_9	3	8,5	0,49
Trietazine	Cl	NHC_2H_5	$N(C_2H_5)_2$	3	20	0,28
Simazine	Cl	NHC_2H_5	NHC_2H_5	5	5	0,86
GS 13528	Cl	NHC_2H_5	NH-sec.C_4H_9	5	40	0,60
G 28509	Cl	NHC_2H_5	$NHCH_3$	7	-	-
Atrazine	Cl	NHC_2H_5	NH-iso C_3H_7	10	33	0,70
SD 15418	Cl	NHC_2H_5	$NHC(CH_3)_2CN$	10	171	0,68
Ipazine	Cl	NH-iso C_3H_7	$N(C_2H_5)_2$	2	40	-
G 34698	Cl	NH-iso C_3H_7	$NH(CH_2)_3OCH_3$	5	120	0,50
Propazine	Cl	NH-iso C_3H_7	NH-iso C_3H_7	5	8,6	0,56
G 30026	Cl	NH-iso C_3H_7	$NHCH_3$	14	260	0,84
G 30033	Cl	NH-iso C_3H_7	NH_2	16	2700	-
GS 18183	Cl	$NHCH_3$	NH-tert.C_4H_9	6	30	-
GS 18182	Cl	$NHCH_3$	NH-sec.C_4H_9	9	-	0,50
GS 26379	Cl	NH_2	NH-tert.C_4H_9	10	-	-
Prometryne	SCH_3	NH-iso C_3H_7	NH-iso C_3H_7	4	48	0,37
Ametryne	SCH_3	NH-iso C_3H_7	NHC_2H_5	7	193	0,51
Methoprotryne	SCH_3	NH-iso C_3H_7	$NH(CH_2)_3OCH_3$	7	320	0,52
Terbutryne	SCH_3	NHC_2H_5	NH-tert.C_4H_9	2	58	0,33
GS 13638	SCH_3	NH-iso C_3H_7	NH-tert.C_4H_9	1	3	0,16
Simetryne	SCH_3	NHC_2H_5	NHC_2H_5	7	450	0,66
GS 26575	SCH_3	NH_2	NH-tert.C_4H_9	4	-	-
Atratone	OCH_3	NH-iso C_3H_7	NHC_2H_5	15	1654	0,66
Prometone	OCH_3	NH-iso C_3H_7	NH-iso C_3H_7	11	750	0,53
GS 14254	OCH_3	NHC_2H_5	NH-sec.C_4H_9	9	620	0,53
GS 14259	OCH_3	NHC_2H_5	NH-tert.C_4H_9	2	130	0,44

Table 2

Leaching indices, water solubility and Rf-values (method of Hance, 1967) of urea herbicides

		Leaching index L_A	Solubility ppm	Rf-value
Diuron		2	42	0,46
Linuron		2	75	0,42
Fenuron		21	6400	1,0
Methabenz-thiazuron		2	60	0,67
Cycluron		20	1100	-
GS 31564		20	-	-
GS 21704		20	-	-

on water solubility can be. On the other hand, it seems that compounds with a high solubility (e.g. > 1000 ppm) have a high leaching index regardless of their chemistry. Exempt from this statement, of course, are cationic compounds, such as paraquat which, while being completely soluble in water, stay absolutely immobile in soil.

Hance (1967) has found a relationship between adsorptability and hydrophilic-hydrophobic balance of a series of ureas and triazines. The R_F-values in Tables 1 and 2, determined by his method, are indicators of hydrophilic-hydrophobic balance, and can therefore be regarded as an indication of adsorptability. Within certain groups the hydrophilic-hydrophobic balance may correlate quite well with the leaching behaviour, for instance for the methoxytriazines and methylthiotriazines. However, completely out of line results have been obtained with simazine and methabenzthiazuron, and a comparison amongst different chemical groups seems to be impossible.

To what extent can leaching be a tool in the evaluation of herbicides? It can be observed that compounds with extremely high and extremely low leaching respond very sensitively to changing properties of the soil: they may show excellent or poor activity according to the adsorptive capacity of the soil. The activity of the compounds with intermediate leaching is much less dependent on soil properties. Therefore, amongst products with about equally excellent physiological selectivity, one could be lead to select a product with an intermediate L_A-value: for instance, atrazine (L_A=10) to a great extent replaced simazine (L_A=5) as a selective herbicide in maize, mainly due to the fact that it gives more consistent weed control under a given range of soil and climatic conditions than does simazine.

L_A-values are also a good means to exploit very efficiently the potential of positional selectivity within a group of compounds with closely related chemistry, but equally low physiological selectivity. Out of such a group the compound with the lowest L_A, still giving acceptable weed control, will most likely be the best choice. Post festum, this approach can be demonstrated with terbutryne, which has proved to be an excellent pre-emergence herbicide for wheat. Table 3 shows clearly that terbutryne is not any more physiologically selective in hydroponic solution than the other closely related methylthiotriazines. Terbutryne has the second lowest L_A-value of the group and still gives acceptable weed control, whereas GS 13638 with the lowest L_A-value, gives poor weed control. Simetryne, ametryne, prometryne and methoprotryne, with higher leaching indices, are shown to be more likely to cause phytotoxicity to wheat in pre-emergence applications in unfavourable conditions - for instance when followed by high rainfall or on very light soil.

Table 3

Concentrations of various methylthiotriazine herbicides giving 50 % growth reduction in hydroponic solution

Product	L_A	Wheat variety Probus (ppm)	Sinapis alba (ppm)	Cucumis sativa (ppm)
Simetryne	7	0,11	0,57	0,09
Ametryne	7	0,07	0,24	0,08
Prometryne	4	0,10	0,44	0,10
Methoprotryne	7	0,05	0,06	0,18
Terbutryne	2	0,13	0,30	0,28
GS 13638	1	0,28	0,48	0,55

Last but not least, a rapid assessment of leaching behaviour will show whether a compound may cause undesirable pollution of the drainage or ground water.

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Proc. 10th Br. Weed Control Conf. 1970

THE EVALUATION OF HERBICIDES ON PERENNIAL WEEDS WITH SPECIAL REFERENCE TO AGROPYRON REPENS

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Summary A multi-stage programme for the evaluation of herbicides on Agropyron repens is described and discussed. This includes laboratory experiments, pot experiments, and field experiments on both specially planted and natural stands. The procedures described could be adapted for other perennial weeds.

INTRODUCTION

Evaluating the potential of new herbicides for the control of perennial weeds presents greater complexities than when annual weeds are involved. The plant is more complicated, with the more important part below ground, and thus not readily accessible for continuous observation. A diversity of types of effect are of potential interest and these may occur over a long time period. Control is often required in a wide range of situations, the economic circumstances of which sometimes make cheap treatments giving less than complete control more attractive than those which are more effective, but more expensive.

Agropyron repens, because of its importance in British agriculture, has been the subject of an intensive research programme at the Weed Research Organization. This covers many aspects of the evaluation of herbicides for its control. A. repens typifies the problems of herbicide evaluation on almost any rhizomatous perennial weed or perennial with a regenerative root system.

The present paper describes the techniques used at the Weed Research Organization (WRO) with A. repens, most of which could be modified for use with many other perennial weeds. When assessing effectiveness of chemicals on a perennial weed, laboratory or model systems such as are described in other papers in this Session are of only limited applicability. The test organism is itself complicated, and can behave in widely different ways in response to differences in environmental and agronomic factors. Hence although the perennial weed system can be simplified, it cannot be completely dismantled into component parts if the resultant information is still to reflect what will happen in practical situations, when the above factors are permitted to interact freely. The overriding need is to simulate reality as closely as possible. The types of experiment discussed here form part of a sequential evaluation process in which elimination of candidate herbicides can occur at any stage.

POT EXPERIMENTS WITH SMALL RHIZOME FRAGMENTS

The initial requirement for the first stage of such an evaluation system is for an experimental technique using as simple, compact and standardised a plant unit as possible. This technique must be suitable for testing large numbers of compounds to ascertain whether they have any inherent toxicity to the weed, thus providing grounds for eliminating compounds of no further interest.

In the WRO system, separate tests are run for activity on unsprouted rhizome and for activity when applied to foliage. Planting material for both is provided from stock pots of clonal material. Great care is necessary to maintain clonal purity, for A. repens in common with many other perennial weeds exists in a great variety of clonal forms capable of differing among themselves in response to herbicides. The clone selected for WRO experiments does not show extremes in either morphological characters or response to established herbicides. Stock pots (25 cm diameter) are started from a small portion of rhizome; ultimately long lengths of rhizome grow around the periphery of the pot and are used between 9 months and 2 years after planting.

For the pre-emergence experiment single-node pieces of rhizome are used. The rhizome is cut with the node central in a uniform length of rhizome, e.g. 4 cm. The first two nodes at the apical end and the most basal node are discarded, as are any damaged buds or those which are abnormally large or small. Six fragments are planted in a 9 cm pot in soil into which the test herbicide has been completely mixed. The edges of the pot should be avoided in the planting pattern. The buds on these rhizome fragments start into growth rapidly at any time of year, although other perennial weeds may pose seasonal problems in this respect (Henson, 1969). The pots are maintained in the greenhouse for up to 5 weeks for observation and measurement of shoot emergence, growth, and development of secondary buds and tillers. The root and rhizome system can then be washed out of the soil, examined for death and rotting of the original rhizome fragment, existence of dormant but possibly viable buds and development of new roots and rhizomes. Rhizome fragments whose buds are of uncertain viability can be replanted in fresh soil free of herbicide or placed on moist fibre-glass 'beds' for further observation.

For the post-emergence experiment, similar rhizome fragments are planted 2 cm deep in herbicide-free soil in 9 cm pots and sprayed with a laboratory sprayer about 3 weeks later when at the 2-3 leaf stage. Routinely these pots are kept a further 2-3 weeks for observation. In interesting cases they can be retained much longer providing adequate supplies of water and liquid nutrient are maintained.

This type of experimentation using a simple system of single bud or shoot and adjacent rhizome allows determination of comparative inherent susceptibility. It is easy to observe direct kill of shoots and buds, inhibition of root or bud development, and ultimate kill of the original rhizome fragment. It may also be used for more detailed studies on such topics as optimum placement of soil-acting herbicides in relation to the rhizome. Advantages of this form of experiment are 1) ready procurement of large quantities of uniform experimental material; 2) ease of recording effects of herbicide, both initially and during recovery; 3) simple determination by transplanting whether buds are only inhibited in growth and will recommence activity after the herbicide has disappeared; 4) ease of handling, through use of small pots and small amounts of experimental herbicides. The main disadvantages are 1) the plant material used is not representative of field situations other than that following very intensive rotary cultivation; 2) A. repens in this form is susceptible to many herbicides which are not always so effective under field conditions and hence a further elimination of the less active compounds is required.

LONG DURATION POT EXPERIMENTS ON ESTABLISHED PLANTS

For further evaluation of promising herbicides experimentation is conducted at WRO in 20 cm or 25 cm pots. There is closer simulation of field conditions in that for pre-emergence work 4-node portions of rhizome are used, a length which occurs frequently after cultivation. For post-emergence work 2-node clonal rhizome fragments are planted in March-April and treated in July when a large number of shoots 20-30 cm high and vigorous new rhizome growth are present. Observations are made continuously from 2-3 days after spraying until the autumn. Care is taken to provide sufficient nutrient and to prevent establishment of seedlings of A. repens in the pots. One useful form of assessment is to cut the foliage in early autumn and determine the potential for regrowth by weighing the amount of vegetative growth made during the subsequent month or so. Observation of rhizome growth can be made non-destructively because most of it occurs around the periphery of the soil mass which can be removed and replaced in the pot intact. Ultimately the rhizome system can be washed out for more detailed observation and viability determined, if necessary, by replanting in whole or in part in herbicide-free soil or on moist fibre-glass pads.

The advantages of such experiments are that they represent a closer simulation of the complex field situation, with both old and new rhizome present. The material is still reasonably uniform, and detailed investigation can be made of effects over a long period of time. The main disadvantage is that the post-emergence simulation is of the undisturbed field situation rather than the situation where the A. repens is subjected to a sequence of cultivations, some of them after treatment. A minor problem is that the rhizome concentrates artificially at the periphery of the pot and hence pots must be completely opaque to prevent chlorophyll development in the rhizome.

LABORATORY TECHNIQUE FOR DETAILED STUDY OF RHIZOME RESPONSE TO CHEMICALS

In the evaluation of some compounds there has been a need for an in vitro technique to allow continuous observation of the effects of chemicals or environmental factors upon the growth of individual shoots arising from rhizome fragments. Various methods of growing rhizome or root fragments without soil have been devised. For example, small fragments of rhizomes have been stuck in agar in Erhlenmeyer flasks (Johnson and Buchholtz, 1961), impaled on steel nails in mist chambers (Beasley and Fox, 1970), hung from the roof of ventilated compartments (Grummer, 1963) or sewn onto paper in perspex boxes (Chancellor, 1968). The system described here is a development of the last method, for perspex was considered liable to chemical contamination. Tall glass jars are used in this technique to allow the longest shoots from rhizomes to grow unhindered for the 20 days normally used in these tests.

Most of the tests have been on A. repens, although roots and rhizomes of other species have been used successfully. In A. repens 7-node fragments are used as representative of the size which occurs in the field after cultivation. The fragments are obtained from large-scale, field plantings of clonal material. Before use they are stripped of scale leaves and roots to allow accurate measurement of new growth. Glass plates 50 x 7 cm are covered with a sheet of Whatmans 3MM chromatographic paper and the rhizome fragments are strapped or tied onto them using elastic bands or cotton thread. Two of these glass plates are then placed back to back and more or less vertically in two square glass jars (11 x 13 x 30 cm) sealed mouth to mouth by 2.5 cm self-adhesive PVC tape (Fig. 1A). In the bottom jar are 200 ml of water or chemical solution which at each assessment is poured over the paper and rhizome to wet them thoroughly. The bottom end of the paper is in contact with the liquid. The apical end of the fragments is placed uppermost, which makes measurement easier and has no apparent effect upon shoot dominance or bud dormancy. Some chemicals cause extensive curling of the shoots and to make measurement easier another glass plate is then placed on top as a sandwich with two narrow glass strips down the edges to hold them apart (Fig. 1B). The jars are usually incubated in an unlit constant-temperature room at 23°C although occasional use has been made of cooled incubators to obtain other temperatures.

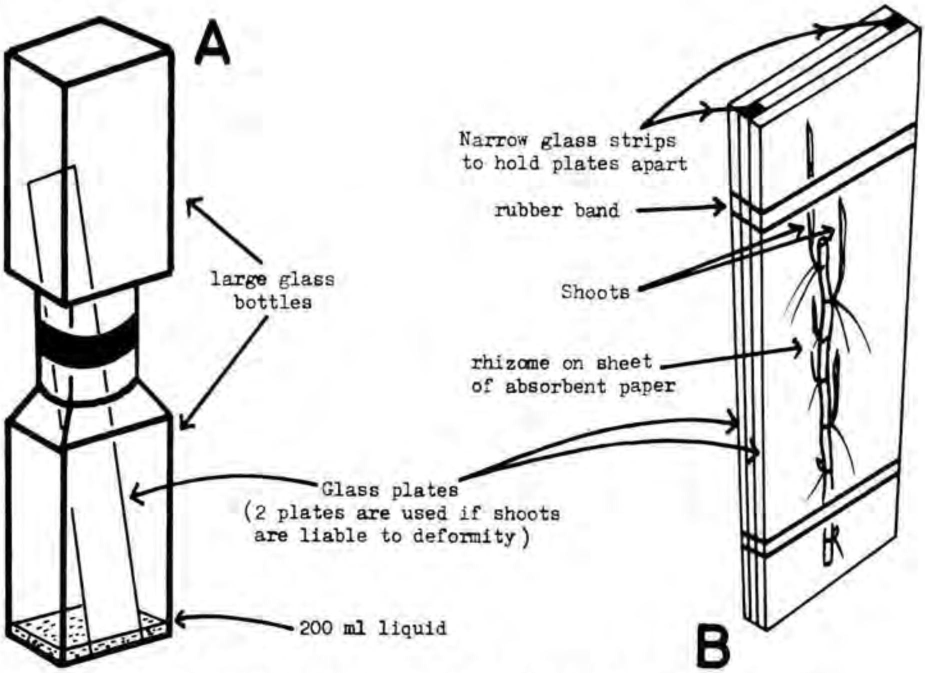

Fig. 1 Apparatus for testing the effects of growth-regulator chemicals on bud dormancy in Agropyron repens

This type of testing has a number of advantages over those using plants in soil. The main one is that shoots and roots can grow undisturbed, but be frequently observed and measured. Data on the growth of individual shoots are essential when assessing the effects of growth-regulator chemicals on the dominance/dormancy system. Environmental factors such as light and temperature, which can affect chemical action and even perhaps the dominance/dormancy system, can be controlled closely.

The rhizomes in these jars remain apparently healthy with little evidence of fungi or bacteria, although unsterilized. However, some species, e.g. Convolvulus arvensis, are less tolerant and their shoots are liable to rot. The experiments are not normally prolonged beyond 20 days because by then the nutrient reserves in the rhizomes are becoming depleted and growth rates decline, although some shoots can grow for 30 days or more. This technique has proved simple and successful and the first results obtained by it are published elsewhere in this Conference (Chancellor, 1970).

EXPERIMENTS ON SPECIALLY PLANTED FIELD PLOTS

In preliminary evaluation experiments in the field with herbicides for the control of A. repens it is only practical to look at a large number of treatments if the plots are small. Because natural stands are of unknown clonal composition and tend to be variable in density and vigour and because plots tend to be invaded by rhizomes from untreated pathways artificial planted populations are now used for early screening experiments at WRO, a technique also described by Waterson et al. (1964). The system used at WRO is to draw out three furrows at 33 cm spacings using a ridger mounted behind a small tractor. 0.84 m^2 plots are laid out along the ridges with a discard between adjacent plots. Four 15 cm rhizome pieces are planted per furrow at about 7.5 cm depth, making 12 rhizome pieces per plot. It is also possible with care to have 4 furrows at 22.5 cm spacing thus giving 16 rhizome pieces per plot. Unbranched healthy rhizome material is taken from single clone stock-beds maintained at WRO.

Treatments are applied at 220-330 l./ha using a hand-sprayer specially designed for small plots. This requires a small nozzle and in consequence the droplet spectrum is not typical of normal agricultural practice at this volume rate. Assessment is usually by shoot counts per plot or per centre 0.19 m^2 of plot and this can be related to a pre-spray shoot count in the case of foliar treatments. Rhizomes can be dug up for detailed examination on termination of the experiment if required. The advantages of this system are that a uniform population, both in respect of density and clone, is established which can be closely observed throughout the experiment. The effects of a large number of herbicide treatments can be examined easily using this system, which can also prove useful for early screening of herbicide mixtures. Rows of plots can be sprayed at right angles to each other with different treatments, thus giving all combinations thereof. There are also some disadvantages to this system. At the moment a suitable sprayer to give a realistic volume rate and droplet spectrum is not available. Treatments requiring incorporation are very difficult to simulate and hand-forking in two directions over the plots is the somewhat unsatisfactory compromise which has been adopted. Careful management and constant surveillance to control other weeds is required; hand-weeding can cause considerable disturbance in such a small plot. It is possible in the early stages when the shoots are small and restricted to cover them with pots and use paraquat to kill off the other weeds. As this system is largely applicable to a small plot layout it is difficult to combine other agronomic treatments with that of the herbicide. Larger areas can be planted but as the plot size is increased it becomes more difficult to maintain adequate stocks of clonal material and to ensure uniformity of the planted area. One experiment of 2.5 ac has been planted with a clone of <u>A. repens</u> at WRO, but it is rarely possible to find sites suitable for such experiments, even if the manpower is available.

EXPERIMENTS ON NATURAL FIELD STANDS

Eventually the evaluation process must progress on to natural field stands, where it is possible to use plots of sufficient size to combine herbicide treatment with other, agronomic, treatments. This is important, for <u>Agropyron repens</u> is so sensitive to cultivation that it must be considered carefully throughout the evaluation process and cultivation or simulated cultivation brought into the experimentation. Ultimately a herbicide must be considered as part of a practicable and economic system of crop production.

Where experiments are to be ploughed, cultivated, and sown to a crop it is vital to minimise the risk of transferring rhizome pieces from plot to plot. At WRO a system has been adopted whereby a nominal plot width of 7.6 m is reduced to 6.1 m by a barrier strip on either side. If this barrier strip is maintained by frequent rotary cultivation the weed is almost eliminated from it and, in practice, transference of rhizome has been negligible.

The need for large plots, and hence large experiments, may be antagonistic to the need for site uniformity. Large uniform areas of natural infestation are uncommon and if possible the site should be assessed before treatment to record density and distribution of the weed. Results in subsequent years may then be expressed either relative to the population on untreated control plots or relative to the population at the start of the experiment.

ASSESSMENT OF FIELD EXPERIMENTS - GENERAL

The earlier stages of the evaluation programme should have determined the type of effect produced by the candidate herbicide(s). This experience of persistence of effect, type of formative effects, if any, and so on, may affect the field assessment programme. In any case assessment should attempt to separate two aspects of the control and recovery of the weed: 1) the effect of treatment on the 'old rhizome' - i.e. that present at the time of treatment. This may be determined by a viability test on the 'old rhizome' or by assessment of the emergence of primary shoots (from rhizome axillary buds) at the commencement of the growing season. 2) The effect on development of tillers and new rhizome from these primary shoots. This will be a function of treatment, climate and competition from a crop.

ASSESSMENT OF AERIAL PARTS

Normally the spring flush of primary shoot emergence will be complete within 1-3 months of the final spring cultivation. Emergence is notably slow and protracted compared with the emergence of seedlings of barley (Cussans, 1968). Many herbicide treatments can affect speed of primary shoot emergence and thus, the competitive balance between crop and weed. Speed of emergence can be assessed by repeated counts, preferably colour marking the emerged shoots in some way. A quicker alternative is to make a count at or towards the end of the flush of emergence and to classify the shoots by stage of growth. Categories found useful, without involving a laborious task of leaf counting, are as follows: 1) rolled spikes without expanded leaves; 2) untillered shoots with 1 or more expanded leaves; 3) tillered shoots. This is not a perfect system. In a barley crop it is not often possible to delay counts long enough for a high proportion of shoots to tiller. Such a system will, however, serve to identify any gross differences in speed of emergence.

Normally quadrats are thrown at random for assessments, the number and size being chosen so as to give a count of at least 100 shoots on the most densely infested plots. The time taken to make such counts increases with increasing size of the accompanying cereal crop, if any, and where _A. repens_ and _Agrostis gigantea_ occur together.

It is possible, even in a dense cereal crop, to assess the emergence of flower heads but this may be of limited value. _A. repens_ and _A. gigantea_ are characterised by the ability to produce erect culms with the apex above the ground, but no flower head. The ratio of flowering to non-flowering culms may not be constant.

The farmer often judges the effectiveness of a herbicide or control system for _A. repens_ by the appearance of the stubble. Assessment of the foliage present after cereal harvest is complicated by the variety of material present, ranging from very new tillers to old, moribund, culms which have been beheaded by the combine harvester. The technique used at WRO is to assess, separately, the number of 'shoot complexes' (i.e. everything derived from one primary shoot constituting a unit) and the total green tillers. This is made much easier if the stubble can be burnt over immediately after harvest and assessments made 10 days or so later. A uniform burn has been obtained by chopping and spreading the straw straight behind the combine.

Square quadrats are normally used as described above. However, the point quadrat has the advantage, in principle, of providing an assessment of leaf area (Warren Wilson, 1969). This is very relevant to pre-assessment of an area to be treated and to assessment of treatment effects. Unfortunately leaf area is very much influenced by seasonal variations and is, therefore, not quite so suitable for year to year comparisons as the more absolute shoot population assessments. In addition at WRO the point quadrat technique has not been found easy or rapid to apply to cereal stubbles.

ASSESSMENT OF RHIZOME DENSITY

The main problem attendant on these assessments is that large quantities of soil must be examined in order to obtain an adequate sample. The preferred method of sampling at WRO is to use a 12.5 cm diameter soil corer. This is protected by a steel cap and driven in to a depth of approximately 20 cm by means of a sledge hammer. For the corer to be withdrawn a handle is attached to it by means of a simple 'bayonet' type fitting. Normally 12 to 15 cores are taken per plot, selected by means of a pre-randomised sampling grid. A greater number of cores per plot are desirable when population densities are low or irregular.

The rhizome derived from the cores should be separated into old rhizome and current season's rhizome. Shoot bases are usually discarded although they do bear some viable buds. Rhizome assessment is laborious work. In addition the 'new rhizome fraction', the most important, is increasing throughout the season. There is no clearly definable end point, for example analogous to counts of seed return of wild oats, although it can be predicted that in general there will be no further rhizome growth after the early part of November. In many cases rhizome assessment may be necessary, but if the aerial parts can be studied intensively over a period of years this may often be as valuable and more economical of manpower.

GENERAL

A multi-stage programme has been described for the evaluation of herbicides for the control of Agropyron repens. Much discretion and judgement has to be exercised as to which compounds to include at each stage. With suitable modification as to detail this programme could be applied to many other perennial weeds.

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Proc. 10th Br. Weed Conf. 1970

SOME USES OF THE COMPUTER IN A HERBICIDE RESEARCH PROGRAMME

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Summary Computerised methods are discussed and described for recording, storing, retrieving and searching the results of biological screening tests with candidate pesticides, and for handling information on the chemical structures of the compounds concerned. Methods of combining these data in a single computer file to allow the elucidation of structure-activity relationships are outlined.

INTRODUCTION

The function of most pesticide evaluation or screening programmes is twofold. The first and obvious one is to select active compounds from the large number of new materials prepared by the organic chemist. The second is to provide information on the interaction between chemical structure and biological activity so that the future lines of synthesis can be directed along pathways which offer the most promise.

Pesticide screening programmes usually involve large numbers of compounds many of which have only mediocre performance. About 95% of these compounds must be eliminated at an early stage if the subsequent evaluation experiments are not to be too costly and unwieldy. The aim of initial tests is to achieve this elimination using simple techniques to measure activity, under conditions which are standardised to ensure repeatability. The tests should provide accurate information even for compounds of low activity, since in the elucidation of structure-activity relationships negative results may be as important as positive ones.

The value of the computer for statistical analysis, information storage, retrieval and abstracting in other fields is well known. This report describes some methods which have been developed to use the computer in the initial examination of candidate pesticide chemicals, and illustrates some of the special problems, pitfalls and occasional bonuses encountered.

Before the computer can be used, however, the information must be presented to it in an acceptable form.

RECORDING OF BIOLOGICAL DATA

The choice of input medium is one of the key factors in the successful application of the computer. There are three main types of input media available today; punched paper tape, magnetic tape and punched cards. Although both sorts of tape are compact, easily stored and offer a very rapid means of feeding in a large amount of data they have the disadvantage that they can only be read with ease, and therefore checked, by the computer. Thus they put the research worker at the mercy of the machine.

Punched cards, however, can be designed to resemble a standard report sheet and although it may be fractionally slower to record the data on them the ability to read them directly, or search them using a punched card sorter, more than outweighs the disadvantages. In addition they allow the operator considerable freedom to vary his data collection system to match the needs of a particular problem. He is thus not the slave of the computer. For these reasons we have ourselves chosen punched cards for recording our biological screening data.

The standard punched card measures 82mm x 187mm. It is divided into 80 vertical columns and 12 horizontal rows giving in all a total of 960 separate punch positions per card. Codes have been developed by the computer manufacturers for representing numbers, the alphabet and punctuation marks on cards by single or combinations of two or three holes in a single column. The ICL system we have adopted for recording our biological data employs a symbol set of 63 characters and all information must be capable of description by one of these characters. The computer is programmed to give different interpretations to the same character according to the biological test being recorded.

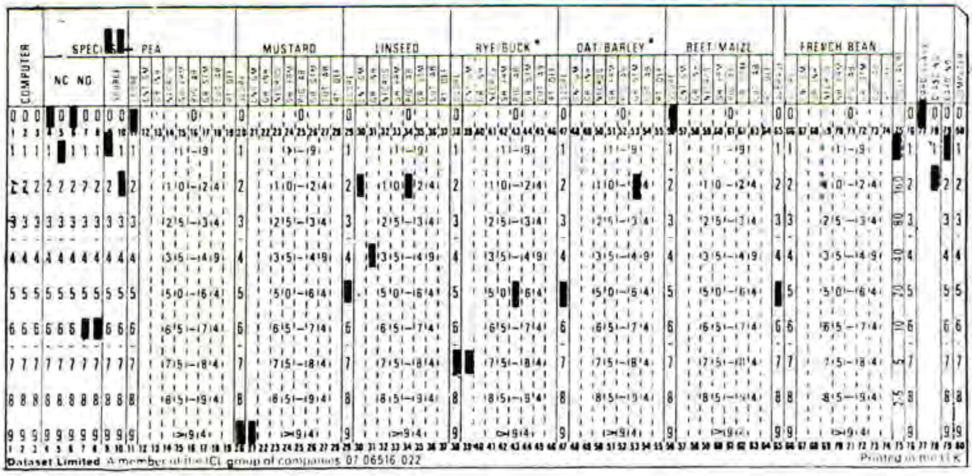
Our normal primary herbicide screen consists of separate pre- and post-emergence tests. In the pre-emergence tests the candidate compounds are mixed with a standardised compost in which are sown the test species. The initial test rate is equivalent to an application rate of 800 oz/ac. [c.55 kg/hectare]. The species used are peas, mustard, linseed, ryegrass, oats and maize. They are planted in the treated soil and are grown for three weeks in a controlled environment room before final assessment of the effect. In the post-emergence tests the species used are similar to those used pre-emergence except that sugarbeet is substituted for maize. The plants are grown for two weeks before they are sprayed with the candidate compound at a rate equivalent to 160 oz/ac. [c.11 kg/hectare]. After a further seven days growth the effects on the plants are assessed. If a high level of activity is recorded at the initial dose rate repeat tests are carried out at lower rates.

The herbicidal record card illustrated (Fig.1) has been designed to accommodate records from both pre- and post-emergence tests. In addition, as is often the case when it is required to record earlier work, alternative species which have now been superseded are also allowed for (e.g. buckwheat in place of ryegrass post-emergence and barley in place of oats pre- and post-emergence). The first three and last columns of this card are allocated to office purposes and need not concern us here. Columns 4-8 are used to record the code number of the chemical structure. Columns 9-10 record the two letter code allocated to the chemist or company of origin. Columns 77-78 are used to indicate to the computer what type of card, i.e. insecticide, herbicide pre- or post-emergence, fungicide etc., is being read.

Columns 11-74 are used to describe the herbicidal response. This space or field is divided into 7 sections each allocated to a test species and for each species columns are allocated for a quantitative and qualitative description of the response. Column 75 is used to indicate the particular dosage rate employed in oz/ac.

Of the 9 columns allocated to each species the first describes the overall herbicidal activity or score, whilst the remaining eight give a qualitative description of the response. In the case of post-emergence herbicide activity the columns record contact effect (or scorch), growth inhibition, necrosis, formative effects on stem or foliage, abnormal pigmentation (e.g. chlorosis), growth stimulation (e.g. tillering), cuticular abnormality (e.g. wax reduction) and root deformities. In the pre-emergence record the first column allocated to contact effect is used instead, to describe the degree of germination inhibition.

Fig.1 80 column punch card for recording herbicidal activity



In Fig.1 the punched card record of the results of a typical pre-emergence test are shown. The compound is coded 1066. The fact that it is a herbicide record is indicated by a punch in row 0 of column 77 and that it is a pre-emergence test by a punch in row 2 of column 78. The species printed on the card can therefore be interpreted by eye as the appropriate pre-emergence range and the computer also is programmed to make the necessary adjustment. A 1 punched in column 78 instead of 2 would have redefined the card as a post-emergence record and the appropriate species would again be read by eye or recorded in the computer memory store. This dual use of the card reduced the number of types which are kept in stock. A 1 punched in row 79 indicates that this is the first test of this compound at the dosage rate indicated. Repeat tests would be punched 2, 3 etc., in this column.

The dosage rate employed - 800 oz/ac. - is indicated by a 1 punched in column 75. The letters AB in columns 9 and 10 indicate that the compound was synthesised by A.C. Brown. Under the pea record the overall score value (column 11) was zero and consequently the 0 is punched. No symptoms of effect are recorded. Mustard was completely suppressed (100%) and this is indicated by a punch in row 9 of column 20. Normally the herbicidal activity is recorded in the laboratory on a 0-100 scale but this had to be modified to a 0-9 scale in order to accommodate it within the card. The 0-100 scale is printed on the card in the appropriate 0-9 rows for easy reference. Since the effect was complete germination suppression a 9 is also punched in column 21; the germination inhibition record for mustard. Linseed was assessed as 60% affected; 40% of this score was attributed to growth suppression, about 10% chlorosis was recorded and 20% germination inhibition was noted. To record this a 5 is punched in the total score column 29, a 2 is punched in column 30 for germination inhibition, a 4 is punched in column 31 for growth inhibition and a 2 is punched in column 34 for abnormal pigmentation. The remaining species are recorded in a like manner. The mean activity for all six species is included in column 65. Columns 66 to 74 are used to report the results from a growth inhibition screen on French beans which is included in the routine post-emergence test programme.

Similar cards, again designed to cover more than one type of test, are used to record other stages of pesticide evaluation. At present we have 10 different card types to record results from 22 different biological screens involving 55 species as well as 3 cards to record chemistry.

HANDLING, STORAGE AND RETRIEVAL OF BIOLOGICAL DATA

The technician measuring herbicidal activity normally fills in an experimental record sheet as he is making his observations, the layout of which follows the punched card. The completed report sheet is given to a punched card operator who interprets the results directly onto cards. The completed card acts as the departmental record of the experiment and the detailed laboratory records are available in case of queries. Normally two copies of the card are made. One is kept in the appropriate screen file in compound code number order, the second is kept in a master file where all the biological and chemical results are brought together from which the complete picture of the biological spectrum can be obtained.

Even without using the computer several minor, but time saving, advantages for recording the routine experimental data on these cards have been observed. Firstly, it is possible to file results on compounds according to their numerical sequence using a standard punched card sorter. This will put in order a random file of 350 compounds within 5 minutes. Secondly, the cards are easier to handle and less space consuming than the standard report sheets they replaced. The results of approximately a quarter of a million screening tests can be stored in a space 70" long x 18" deep x 40" high. This does not compare with microfilm but all results are readily available for inspection. Thirdly, once the result is recorded on cards additional copies can be made by a standard punched card reproducer at the rate of 120 per minute. This is faster and cheaper than most office copiers. The reproducer can also be made to summarise results onto a second card if required. The final benefit in the office routine is that the results can be read and printed by the computer. A report on the results of 1000 compounds which would normally take a typist several hours to produce can be printed in under 5 minutes directly from the cards. The card punch, sorter and reproducer can be hired for less than £1000 p.a.

Part of a print-out from a series of herbicidal screening cards is shown in Fig.2. In this it will be seen that the activity of the compound against each species over the whole dosage range is summarised on a single line. The figures quoted in this particular print-out merely list the overall herbicidal index for each species. Details of the qualitative effects are not included since space is not available. However, on the right-hand side of the print-out under the heading 'Symptoms', space is available for 8 single letter symbols corresponding to the 8 types of symptoms recorded on the card for each species. Should any of the individual species show a particular symptom at a pre-determined significant level this will cause an appropriate letter to be printed under the 'Symptom' heading. This qualitative coding allows the reader of the print-out to determine the nature of the herbicidal response when scanning the print-out. If necessary it is also possible to record abnormal responses or other statements in the print-out by simply overpunching in column 78 and entering a remark on the card in normal code, as shown in Fig. 2 for compound 19833.

The two punched card files compiled have been found to satisfy the needs of most of the day-to-day operations of biological screening - that is reporting the latest results of a particular screen or the total spectrum of activity of a single or limited group of compounds.

Before, however, the system can be applied to structure-activity research it is necessary to link the biological results with the chemical structure.

Fig.2. Sample print-out from screening cards for a series of herbicides

DATE : 11/07/69 HERBICIDES : PRE-EMERGENT DATA

ITEM	NC	SCE	800 0							160 0							80 0							40 0							20 0							SYMPTOMS
APPLICATION RATES IN OZ PER ACRE			P E A	M S T	L N D	M Z E	T / B A*	R Y E	M E A N	P E A	M S T	L N D	M Z E	T / B A*	R Y E	M E A N	P E A	M S T	L N D	M Z E	T / B A*	R Y E	M E A N	P E A	M S T	L N D	M Z E	T / B A*	R Y E	M E A N	P E A	M S T	L N D	M Z E	T / B A*	R Y E	M E A N	
1	19827	SN	0	0	0	0	0	3	1																													
2	19828	AB	1	2	7	2	3	9	4																													IG
3	19829	AB	9	9	9	9	9	9	9	3	8	9	2	9	9	6	2	7	9	2	9	9	6	0	9	9	0	2	4	4								IGC N
4	19830	GL	0	0	0	0	0	0	0																													
5	19831	XL	0	9	9	6	6	9	6	0	4	9	2	0	3	3	0	2	4	4	2	2	2	0	2	0	3	0	0	1								I FAN
6	19832	AB	9	9	9	9	9	9	9	9	9	9	9	9	9	9	5	9	9	5	9	9	8	2	8	9	3	2	7	5	0	5	9	0	2	3	3	IGC N
7	19833	FB	COMPOUND DECOMPOSED																																			
8	19834	FB	0	8	7	0	1	4	3	0	7	6	0	0	0	2								0	2	2	0	0	0	1								TF R
9	19835	AB	9	9	9	9	9	9	9	7	9	9	8	8	8	8	2	9	8	2	3	2	4	0	7	7	0	1	0	3								IG N

Key to Symptoms :

- I = Germination inhibition
- G = Growth inhibition
- C = Chlorosis or abnormal pigmentation
- T = Growth stimulation
- F = Formative effects
- A = Cuticular abnormality
- N = Necrosis
- R = Root deformity

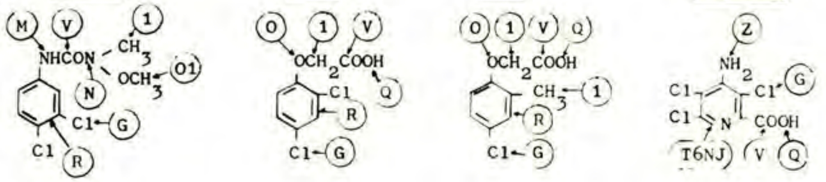
In recent years considerable advances have been made in the development of systems which allow a description of the three dimensional structure of a compound to be made so that it can be accepted by the computer. The method that we have found most suitable for our studies is the Wiswesser Linear Notation (WLN). This system was developed around standard punched card handling equipment and the computer. WLN, which is described in detail elsewhere by Smith (1968), represents chemical groups and their arrangement by alpha-numeric symbols. Unbranched saturated hydrocarbon chains and ring sizes are indicated by numbers. Letters preceded by a space indicate the relative positions of the structures represented by the succeeding symbols whilst numbers preceded by a space act as multipliers. About 40 symbols which can be transcribed directly onto punched cards and printed by the standard computer line printer, are all that is required to represent the greater bulk of organic chemicals. In contrast to normal chemical nomenclature a structure can only be represented in WLN by a single unique and unambiguous notation. Fig.3 shows structural formulae for four well known herbicides - linuron, 2,4-D, MCPA and picloram. Row a) of this figure shows the structural formula with the WLN code letters allocated to the compounds enclosed within circles; row b) gives the two-dimensional graphical representation of the Wiswesser code and row c) the final Wiswesser linear notation.

Once a series of compounds has been translated into WLN and entered on punched cards the data can be used in a number of ways. The first immediate use is to produce an alpha-numerically arranged index. This can be done by hand, punched card sorter, or by computer. The list produced is superior to one derived from a molecular formula or chemical name index since it is unambiguous and unique as each compound can only have one Wiswesser notation which will appear in one place in the list.

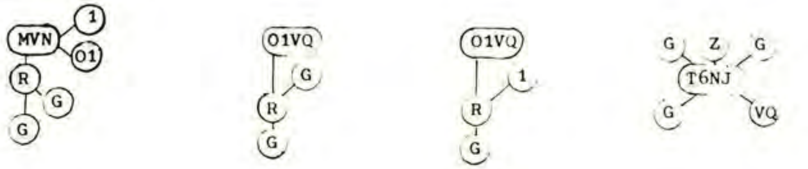
Fig.3 Representation of some well-known herbicides by structural formulae, graphic formulae and Wiswesser Linear Notation.

a) Structural formula

1. Linuron 2. 2,4-D 3. MCPA 4. Picloram



b) Graphic formula



c) WLN

GR BG DMVN1&O1 QV1OR BG DG QV1OR DG B T6NJ BVQ CG DZ EG FG

Probably the most important use of WLN is, however, to allow the researcher to obtain the exact structure of all compounds containing a given sub-structure which are present in the file. This is essential before making any attempts to correlate chemical structure with physical properties, and to the correlation of chemical structure with biological properties, which is described later.

Several methods exist for chemical sub-structure searching involving WLN; of these probably the most valuable and convenient is the permuted index. This is similar to the multiple indexing of text :- the keyword-in-context-index (KWIC). Instead of each notation being listed in one place only, i.e. at its first symbol, it is entered under each chemically meaningful symbol in it. Each entry is printed with the key symbol at the centre of the page with the rest of the notation spaced around it. The entries are then arranged in alpha-numeric sequence rightwards from the key symbol. In Fig.4 part of a permuted index for the four herbicides listed in Fig.3 is shown.

Fig.4 Example of a WLN permuted index, based on the herbicides listed in Fig.4.

```
Compound No.                       WLN Permuted Index

                                        Key Symbol
                                            |
                                            v
     1                          GR BG DMVN1&O1
     1                             GR BG DMVN1&O1
     2                                    QV1OR BG DG
     3                                    QV1OR DG B
     4                                     T6NJ BVQ CG DZ EG FG
     2                             QV1OR BG DG
     4                    T6NJ BVQ CG DZ EG FG
     3                                QV1OR DG B
     2                                QV1OR BG DG
     1                                   GR BG DMVN1&O1
     4                             T6NJ BVQ CG DZ EG FG
     4                      T6NJ BVQ CG  DZ EG
     1                                       GR BG DMVN1&O1
     1                                GR BG DMVN1&O1
     1                              GR BG DMVN1&O1
     4                                    T6NJ BVQ CG DZ EG FG
     1                           GR BG DMVN1&O1
```

The whole process of indexing by selecting key symbols, arranging them in sequence and printing out around the key symbol can only be done cheaply by the computer. We have found that the average number of entries in a typical index is ten per compound. Thus a file of 10,000 compounds produces 100,000 entries and fills about 2,000 pages of computer print-out.

With this index it is possible to look for the occurrence of specified structural fragments anywhere in the notation. For example if it were required to search for all structures with a trichloromethyl group this group can appear in two ways in the index either as GXGG.... or as ....XGGG. So a search of the permuted index at the key symbol G with XGG following or X with GGG following produced all the relevant structures. This is a fairly simple case, but in order to find all ureas for example, it would be necessary to search under the key symbols M, N and Z, each of which could be followed by VM, VN or VZ. However, again this would be considerably quicker than scanning a chemical name index by eye.

Thus it can be seen that the WLN permuted index offers a powerful tool to the research worker as a means of bringing together all related chemical structures in a complete index. Simple questions can be answered by referring to the printed chemical index and then looking separately at the related biological data in another file. Or one can go a stage further and link the permuted index with a summary of the biological data.

ELUCIDATION OF STRUCTURE/ACTIVITY RELATIONSHIPS

To combine the chemical and biological data we have created a complete file on magnetic tape which includes under each chemical code number the Wiswesser code of chemical structure, the empirical formula, physical properties, a list of the biological screens requested followed by the results of each of the biological screens compiled from the punched cards. This information is presented to the computer in random sequence as it becomes available and is assembled in strict sequence on the tape by the computer. From this master file it is a simple process for the computer to construct a permuted WLN index and to include with it a full or partial description of the biological activity. From a print-out of this process the trends in biological activity with changes in structure may be seen.

Alternatively the file of chemical and biological information may be searched using a programme such as ICL's "FIND" for answers to specific questions, for example "what are the structures (in WLN) of all compounds which will selectively control graminaceous species in the presence of peas?". One might even add "with a rat oral LD 50 of not less than 200 mg /kg.".

Another development which is only feasible when the data have been translated into a computer compatible form is to regard the information acquired for each compound in the same way as the taxonomist regards the properties of his specimens when he classifies them. For each compound a profile of the biological activity against all or part of the 55 test species is built up as a result of the screening tests. The whole profile, or just a part, say that concerned with the activity against the plant species, may be treated by the computer as a series of variable measurements of certain properties. These variable measurements for a single compound can be compared with those recorded for other compounds and the series classified into groups of similar properties by such statistical techniques as correlation co-efficients, cluster analysis and principal components analysis. These methods have become well established in the science of numerical taxonomy (Sokal and Sneath (1963), Gower (1969)) for the classification of a wide range of organisms. When the individual structures of chemical compounds are grouped together according to their biological properties the research worker can look at structure/activity relationships from a viewpoint not influenced by preconceived notions of chemical classification. In these studies even inactivity is of significance as well as the mass of mediocre results accumulated in most screening programmes. In addition the analysis of biological responses over a wide range of organisms often allows the prediction of activity in apparently completely unrelated areas. This may save time or indicate further profitable lines of research.

It is in this area that we are currently working.

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THE USE OF MYRIOPHYLLUM VERTICILLATUM TURIONS FOR EVALUATION EXPERIMENTS IN THE LABORATORY

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Summary A method of using *Myriophyllum verticillatum* turions for laboratory experiments has been developed. The turions can be stored for over 12 months after collection if kept at a temperature between 2-4°C and not allowed to dry out. Germination is initiated and growth maintained by increasing the temperature and providing a source of nutrients. Under these conditions algal growth may occur and interfere with the experiments, but it is possible to control this without adversely affecting the growth of *M. verticillatum* by reducing light intensity to 7250 lux. The technique may be used for the evaluation of candidate aquatic herbicides or retardants, or for more general physiological studies. The effects of treatments are assessed either by subjective scoring for colour and vigour or by the measurement of growth increments.

INTRODUCTION

One of the difficulties encountered when studying submerged aquatic plants is the collection and storage of propogating material. Seeds are usually difficult to collect and much of the primary evaluation work on herbicides has been with shoot cuttings taken as required from bulk material maintained for this purpose (Blackburn, 1963). The main species used have been *Elodea* spp., *Egeria densa*, *Hydrilla* sp. and *Lemna* spp. In the United States and perhaps elsewhere *Potamogeton pectinatus* has proved to be a valuable test plant because it has tubers than can be collected and stored at low temperatures until required. At the Weed Research Organization, Oxford, a method of using the vegetative perennating organs (turions) of *Myriophyllum verticillatum* in a similar manner has been developed and this report describes the main features of the technique now being used.

COLLECTION AND STORAGE OF TURIONS

Myriophyllum verticillatum is found in ponds, lakes and slow streams of lowland districts of England. By mid August rudimentary turions (winter buds) begin to form on the lower part of the parent stem. These mature and drop off into the mud when the parent plant disintegrates in October. In March (mid March in 1970) they germinate and begin to grow rapidly.

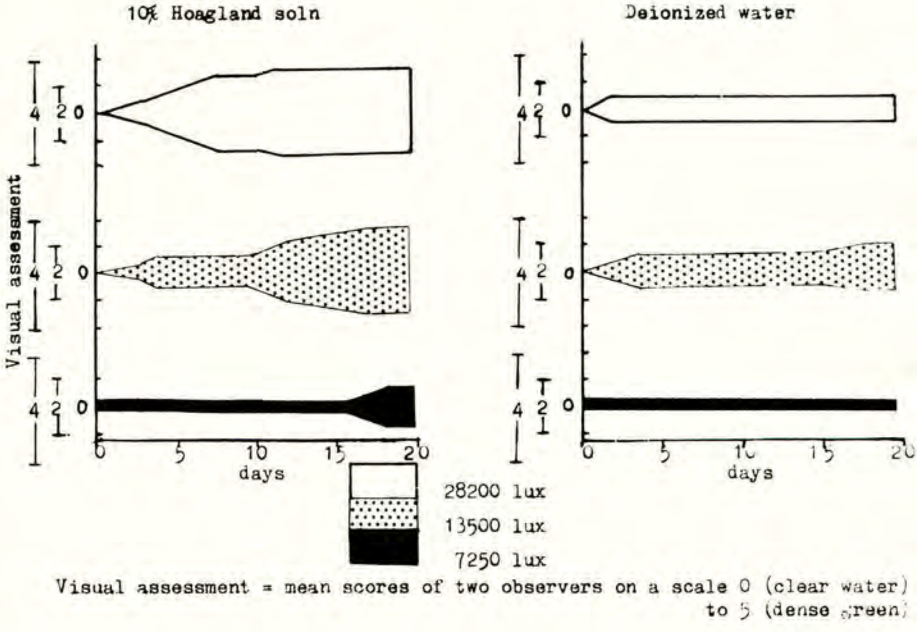
The dormant turions are compact clavate buds varying in length between 20 and 55 mm and containing an average of about 30 incipient nodes. In this form they are easily handled and can usually be collected in the field when mature but before they fall off the parent plant. They should then be put into plastic bags and stored at a temperature of 2-4°C. Under these conditions they remain moist and as long as the temperature is within these limits they will retain their viability for 12 months or more. Freezing and drying, however, must be avoided. If the temperature is increased above 4°C growth will start but can usually be arrested by lowering the temperature again.

GERMINATION AND CULTURE

When required for an experiment turions uniform in length and thickness should be selected and placed in 500 ml beakers containing 400 ml of 10% Hoagland solution No.1 (Hoagland and Arnon, 1950) with iron (in the form of EDTA) and micro-nutrients added as recommended by Hoagland and Arnon. Temperatures should usually be kept between 18–20°C during the day and above 10°C at night with a day length of 16 hours. Unless adequate precautions are taken unicellular algae of various forms grow in these cultures and may seriously interfere with the growth of the turions and the reliability of the results. Algal growth is dependent upon both the light and available nutrients and can be controlled by reducing either of these below certain levels. In a recent experiment in which turions were grown in three levels of Hoagland solution (10%, 1% and 0) and three levels of light provided by a bank of 80 w warm white fluorescent tubes, with each beaker inoculated with the same amount of actively growing <u>Chlorella</u> sp., it was found that adequate control of algal growth was only achieved at the lowest light level (7250 lux) or where no nutrients were added (fig. 1).

Fig 1

<u>Effect of light intensity and nutrient level on algal growth</u>

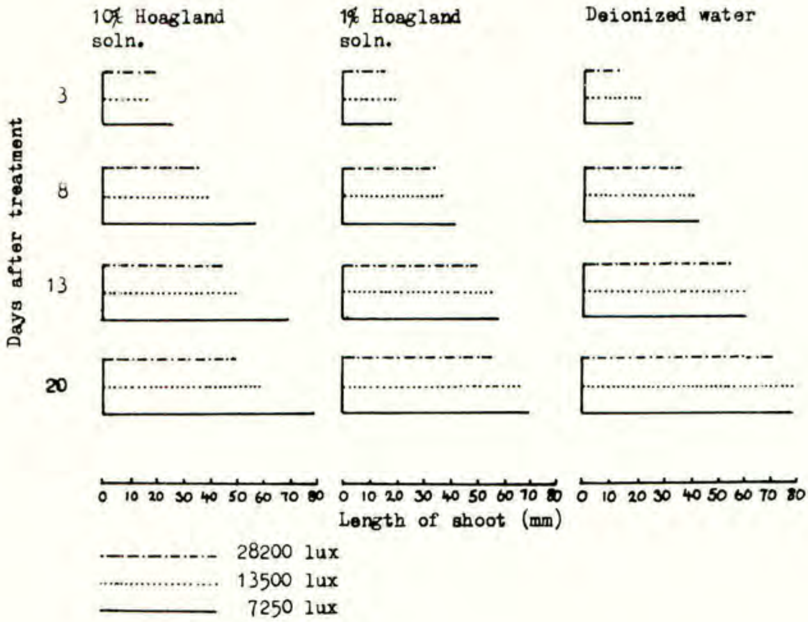


Visual assessment = mean scores of two observers on a scale 0 (clear water) to 5 (dense green)

The effect of light intensity and nutrient level on the elongation of the turions is illustrated in Fig 2. At all nutrient levels the low light intensity (7250 lux) gave the most rapid growth. At the earlier stages (day 8) growth under the combination of high nutrient/low light was significantly greater than under any of the others but as the rate of growth diminished the difference between nutrient levels decreased.

Fig 2.

The effect of light and nutrient level on the growth of turions



To meet the light requirement in practice black plastic sheeting is wrapped round each beaker and cut level with the top. The beakers are each covered with two discs of perforated zinc sheeting (12 holes of 2 mm diameter per cm^2) placed one on top of the other and then exposed to a vertical light of about 28000 lux. Each layer of perforated zinc reduces light intensity by about a factor of 2 and with a brighter light source it may be necessary to add further thicknesses to promote optimum elongation and to prevent algal growth.

MEASUREMENT OF TURION ELONGATION

Some care is needed when measuring turions to standardise the points from which measurements are taken. At the base of dormant turions a short portion (1 - 2 mm) of stem often persists. As the new plant develops this breaks off and consequently measurements should be taken from the lowermost whorl of leaves and not the base of the stem. As the turion grows the leaves expand from the base and the apical bud remains compact and well defined for 2-3 weeks. During this period reliable measurements can be made to the apex of the plant, but as the bud becomes less compact satisfactory length measurements are not possible.

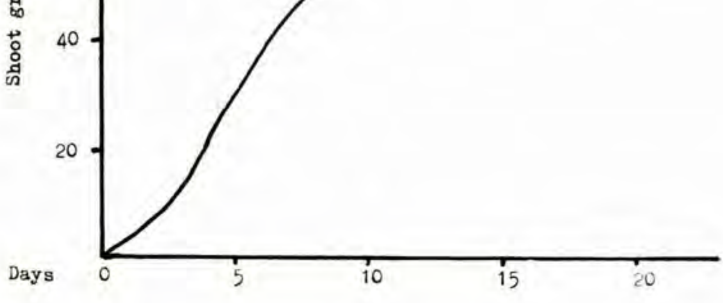
For measuring the plant, it should be removed from the culture solution. The slightest bruising of the stem, however, is likely to cause it to break a few days later and result in the disruption of length records. Hence great care is needed. Apart from this the plants do not appear to suffer from handling. Initially long handled tongs should be used to hold the unexpanded turion, but as it grows it can be lifted with any curved blunt instrument.. When measuring strict precautions must, of course, be taken to avoid contamination between treatments. The risk is greater than when handling terrestrial plants and careful thought has to be given to the decontamination of equipment and the sequence in which treatments are measured.

THE USE OF TURIONS FOR HERBICIDE AND GROWTH RETARDANT STUDIES

Myriophyllum verticillatum turions can be used as test plants in a variety of short term-laboratory experiments. When they are used to assess the phytotoxicity of a herbicide they should normally be allowed to grow for seven days before applying the treatment. This ensures that all the selected turions are viable and actively growing. Results are usually assessed by subjective scoring for greenness and vigour but length increments are often included as well to pick up any differences in growth rate. In experiments with growth retardant chemicals or nutrient solutions growth increments are the main form of assessment. Growth begins as soon as the turion is placed in conditions suitable for germination but a constant rate of elongation is not reached until after the second day. Usually treatments should be applied and measurements started on the third day and continued during the time untreated plants show an adequate rate of growth or until the apical buds open. This is usually for 10-14 days after treatment.

Fig 3

Growth of turions under high nutrient light conditions



Myriophyllum verticillatum turions provide a useful means of maintaining a source of uniform propagules for use in short term experiments on submerged aquatic plants. They are particularly suited to early phytotoxicity and growth retardant studies on new chemicals but may also prove of value in more general biological and physiological work. The main limitations are the short length of time in which reliable observations may be made (up to about 14 days) and the need to take precautions to control algal growth. However, they offer important advantages over shoot cuttings in ease of handling, storage and uniformity.

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SWEDE HERBICIDE TRIALS IN THE WEST OF SCOTLAND, 1962-1970

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Summary Following screening trials 1962-64, herbicide treatments for the swede crop were evaluated in 26 field trials over the period 1964-1970. Only under ideal conditions did the stale seed-bed technique using paraquat or dimexan give useful results, and it was too often unsatisfactory or unmanageable. Attempts to increase the duration of weed control by combining contact and soil acting herbicides caused excessive crop damage. Pre- and post-emergence herbicides generally were either damaging to the crop or gave poor weed control. Nitrofen + chlorpropham and nitrofen + propachlor gave best results but were not wholly satisfactory. Trifluralin, given proper incorporation and a non-organic soil, was capable of good early season weed control but like other treatments its effect did not always persist long enough.

INTRODUCTION

One reason for the rapidly decreasing acreage of swedes in Scotland (1960, 244,000; 1969, 146,000) is the heavy labour demand of the crop. Singling frequently causes a peak labour requirement, but under weed free conditions this can be reduced to a low level or even dispensed with when roots are to be fed, in situ, to sheep. Prytherch and Toulson (1960) described a stale seed-bed technique for weed control in brassicas using PCP and diquat to kill seedling weeds before the crop was sown. Local experience with this method in 1961 suggested that it had serious limitations under wet conditions, and a trial series to explore alternatives was started. Screening trials were carried out at Auchincruive in 1962, 1963 and 1964; field trials have been run at Auchincruive and on commercial farms from 1964 to 1970. Observations have been made concurrently on farmers' use of herbicides.

MATERIALS AND METHODS

Commercial or experimental herbicide formulations were used as appropriate; treatments are shown in tables 2 and 3. Screening trials were carried out 1962-4 on some 25 herbicides using duplicate plots 3 ft x 9 ft sprayed by Oxford Precision Sprayer at a volume rate of 40 gal/ac. Assessment was by establishment counts on weeds, and on swedes sown along the centre line of each plot. In 1963 and 1964 sowings and sprayings on three separate dates were included. The results were used to select herbicides to be included in the 1964 and 1965 field trials but are not reported here. The field trial plots were 13 ft x 27 ft with 3 ft discards between plots. A duplicate randomised block layout was standard with unsprayed, uncultivated plots always included. More successful treatments would have permitted increased replication. Treatments were applied by Drake and Fletcher knapsack sprayer at a volume rate of 40 gal/ac. Chemical weed control throughout the series was generally poor and cultivations were necessary; the idea of taking yield data from the trials was abandoned early on. Weed cover was assessed 3 and 6 weeks after treatment by a dual scoring method. Overall weed cover was scored visually on a 0-10 scale (0 = no weed cover, 10 = 100% weed cover) and the weed species present were recorded by scoring individually to a total of 10. For interpretive purposes a weed cover score of 0 or 1 may be regarded as satisfactory, and 2 as tolerable. Crop plants were scored for size on a 0-10 scale and any reduced populations or abnormalities were noted.

This report quotes weed cover scores at the most representative date before any necessary cleaning by cultivation was carried out, generally 4-6 weeks after spraying.

RESULTS

Results from 26 trials are available, four of them on kale rather than swedes. Their locations are shown in table 1, which details the main weed species found and indicates potential weed cover by quoting the control plot scores. Polygonum persicaria, Spergula arvensis, and Stellaria media occurred most frequently, followed by Chenopodium album, Geleopsis tetrahit, Polygonum aviculare and Ranunculus repens. Most sites had potential for heavy weed growth. Tables 2 and 3 present weed cover and crop scores for all treatments and all sites. To save space individual centres are not named in these tables but they are in sequence as in table 1 and may be identified by using table 1 as a key. The assessment methods used provided evidence of the effects of herbicide treatments only on well distributed weed species, and any pattern of "resistant" and "susceptible" species was somewhat disguised by erratic herbicide performance from trial to trial. Results for the more interesting treatments are summarised in table 4.

1964 Trials : Four trials were carried out, using five pre-emergence herbicides, paraquat applied to a stale seed-bed, and picloram applied post-emergence.

Trietazine applied pre-emergence achieved consistent acceptable weed control but seriously stunted or killed the swedes. Simazine gave good weed control at three sites but was poor at the Stirling centre where a heavy weed infestation was associated with a soil of high organic matter content; it too damaged the swedes. The paraquat stale seed-bed technique gave only short term weed control and in 1964 failed to keep the crop reasonably clean up to singling time. The one apparently favourable (Lanark) assessment of this treatment was made only some ten days after spraying these plots. In general weed control was poor, although variable from site to site; crop damage was excessive from simazine, trietazine and linuron.

1965 Trials : These three trials were based on the 1964 field trials and screening trials, and were intended to evaluate mainly the stale seed-bed method using chemicals with some residual activity. Good weed control was associated with excessive crop damage, and dimexan appeared to offer the best combination of (rather poor) weed control and an undamaged crop.

1966 Trials : Stale seed-bed applications of paraquat and dimexan were continued and a new range of treatments introduced. Trifluralin incorporation at most sites had to be done by drag harrows or by hand, and results were unsatisfactory. Nitrofen with and without chlorpropham was tested pre- and post-emergence, and a commercial mixture of sulfallate and chlorpropham was used pre-emergence. Relatively little crop damage was noted and the results from two trials on kale have been included along with those from the three trials on swedes. Dimexan and paraquat gave better weed control in 1966 than in 1965 although dimexan was now the less successful material. None of the other materials was particularly successful, nitrofen + chlorpropham being the best but with some check to the crops when used post-emergence. It was observed that the trifluralin was most effective along the tops of the ridges.

1967 Trials : The nitrofen treatments of 1966 were repeated in 1967 and two new materials, aziprotryne and propachlor were introduced as pre- and post-emergence treatments. It was considered that sufficient experience of the stale seed-bed technique had been obtained and no further testing of it was included. Three experiments were completed. None of the treatments gave adequate weed control and aziprotryne in particular was damaging to swedes.

1968 Trials : In view of their poor performance in 1967 increased doses of nitrofen and propachlor were used in 1968; alachlor was introduced for trial at two rates pre- and post-emergence. Chlorpropham was included with all treatments in an attempt to improve weed control. Two trials were carried out on swedes, and results from two kale trials are also included in the tables. The swede and kale crops suffered less damage than was anticipated, but weed control was still poor.

1969 Trials : A new set of treatments was tested in 1969. Two mixtures of nitrofen and propachlor were tested pre- and post-emergence, and a new compound, haloxydine, was included at three rates pre-emergence. Because rotovators and other implements capable of thorough soil mixing were being used increasingly in the area trifluralin was again tested at the Ayrshire site.

The best weed control associated with good swede establishment came from the higher dosage mixture of nitrofen and propachlor used pre-emergence. None of the treatments worked well at the Argyll centre and this mixture was no exception, but its performance averaged over the other three sites was reasonable. Tripleurospermum maritimum ssp. inodorum was not controlled. Trifluralin incorporated by rotovation worked well at the 16 oz/ac rate and caused no crop damage. Haloxydine gave reasonable weed control at the higher dosage rates but caused severe crop damage.

1970 Trials : The mixtures of nitrofen and propachlor were tested again, and a material coded DW 3418 * was included at two rates pre- and post-emergence. Results are available from three sites. Trifluralin was used on a field scale only.

The higher rate nitrofen + propachlor mixture again gave a satisfactory overall result from the three trials, being poorer in Ayrshire than at the other two centres. Swedes were checked at one site but recovered. The post-emergence treatment with the same mixture gave good results at two centres but with some check to growth of the swedes. DW 3418 proved extremely phytotoxic. On field scale plots at two sites trifluralin gave good initial weed control which gradually deteriorated as the season progressed.

DISCUSSION

To have real merit a herbicide must be consistently capable of bringing swedes to the singling stage with few if any weeds present. Preferably it will give sufficiently good weed control to allow the farmer to sow the crop to a stand without the necessity for singling. The crop must not be damaged.

In the West of Scotland the stale seed-bed technique using a herbicide with little or no residual activity cannot be relied upon to meet these needs, and in 5 of the 12 trials in which paraquat was included as an individual treatment (8 or 16 oz/ac) weed cover exceeded 20% at assessment. Practical experience supports this finding and too dry or too wet weather conditions have resulted in many field-scale failures of the technique. In 1965 results suggested that dimexan might have sufficient residual activity to overcome problems of rapid re-growth of weeds after spraying, but this appeared to be so in only one of six trials the following year. Mixtures of paraquat and soil-acting herbicides proved too damaging to the crop.

The pre- and post-emergence commercial herbicides tested in these experiments at recommended rates only occasionally gave acceptable weed control. The best was the pre-emergence treatment with nitrofen + chlorpropham which gave good control of weeds in only one of eight trials, and reasonable weed control in a further two. Increasing the rate of nitrofen from 50 to 64 oz/ac (plus chlorpropham) gave good weed control in two of four 1968 trials, but with a check to the swedes at one centre.

The trials did not suggest that any material tested which was not sold as a swede herbicide had sufficient safety margin to enable it to be so used. DW 3418, haloxydine, Chlorbufam + cycluron + dimexan, pyrazon, chlorthiamid, linuron, monolinuron, simazine and trietazine all gave weed control but with some swede damage,

*2-(4 chloro - 6 - ethylamine - s - triazin - 2 ylamine - 2 - methyl - propionitrile) whereas picloram, aziprotryne, sodium pentachlorophenate and sodium chlorate gave inadequate weed control. Aziprotryne and sodium pentachlorophenate damaged the swedes badly at some centres. Granular chloramben was included only in the 1964 trials when there was still hope of quickly finding a really effective swede herbicid and there may be a case for looking again at this product, which gave reasonable weed control on two of four sites and damaged swedes only slightly.

Mixtures of nitrofen and propachlor are unlikely to be commercially viable but have performed slightly better than nitrofen with or without chlorpropham. The higher dosage pre-emergence treatment has done best, with satisfactory weed control in four of seven trials. This performance might perhaps be improved by a chlorpropham addition. Trifluralin, properly incorporated into the soil is one of the most interesting materials available and it is hoped that further experience will enable a more consistent performance to be obtained. Growing swedes on the flat may help to avoid uneven distribution of "treated" soil but may not be suitable under wet conditions. Further evidence is needed on the relationship between soil type and the success or otherwise of trifluralin treatment.

A general feature of the trials has been that herbicides have been more successful on sites where the basic level of weed infestation has been low. They have rarely produced weed free plots in a really dirty field, and they have been quite unable to cope with perennial weeds such as Agropyron repens and Cirsium arvense.

Chenopodium album is a fast growing weed which is difficult to control. Where i occurs it often becomes the dominant species. Post-emergence spraying with nitrofen + chlorpropham was effective at two sites. Polygonum aviculare and Poly onum persicaria were also generally difficult to control but the latter appears relatively susceptible to the nitrofen + propachlor mixtures, certainly more so than to nitrofen + chlorpropham. In view of the wide distribution of P. persicaria this difference is o some importance. The remaining species all are sometimes susceptible to the herbicides shown in the table, but not reliably so. Against this species were sometimes recorded as potentially troublesome when their growth had been more or less halted, and they would have reduced yields little even though they were unsightly.

Overall the results of these trials indicate that no herbicide is available which is completely reliable for swedes in western Scotland, and the cost of any treatment must be weighed carefully against the likely benefits. Omitting the stale seed-bed technique because of its extreme dependence upon suitable weather conditions the most useful treatments tested have been trifluralin (soil incorporated), nitrofen + propachlor and nitrofen + chlorpropham (pre- or post-emergence). Herbicides are not effective against perennial weeds and cultivations should be used where such weeds are numerous.

Acknowledgments

The writer would like to thank the farmers who provided facilities for these trials, the manufacturers who supplied experimental herbicides, and his colleagues who were responsible for most of the field work.

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Table 1 Location of trials, and weeds in each trial as main species (+) and as well distributed but less numerous species (o). * Denotes kale trial. Control plot weed cover on 0-10 scale (0 - no weeds, 10 - full weed cover).

	1964				1965			1966					1967			1968				1969				1970		
	Argyll (Cowal)	Ayr	Lanark	Stirling	Argyll (Cowal)	Argyll (Kintyre)	Ayr	Argyll (Kintyre)	Ayr	Bute *	Kirkcudbright *	Lanark	Argyll (Kintyre)	Ayr	West Perth	Argyll (Kintyre)	Argyll (Lorn) *	Ayr	Kirkcudbright *	Argyll (Kintyre)	Ayr	Dumfries	West Perth	Argyll (Kintyre)	Ayr	Dumfries
Achillea millefolium											+															
Capsella bursa-pastoris																			o		o					o
Chenopodium album		+						o	+									+	o		+		+		+	+
Chrysanthemum segetum								o									+									
Fumaria officinalis															o					o			o	+	o	
Galeopsis tetrahit	o		+					+			+		o		+		+			+			+	+		
Polygonum aviculare		+		o	o		o		+					+		+						+			+	+
Polygonum convolvulus		o																+								
Polygonum persicaria	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+	+	+	+	+	+	
Potentilla anserina				o																						
Ranunculus repens	o		o	+		o	+	o				o								+				+		
Senecio vulgaris															o						o					
Sinapis arvensis			o										+			+	+									
Spergula arvensis	+			o	+	+	+	+	+	+	+		+	+	+	+	+			+	+	+	+	+	+	+
Stellaria media	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+			o	+	+	+	+	+	
Tripleurospermum maritimum ssp. inodorum								o	o				+	o					+		o	+		+		
Viola arvensis		o												+												
Weed cover on control plots	10	4	4	9	9	9	8	9	10	10	9	7	10	10	9	8	10	9	8	10	10	5	7	10	9	7

Table 2 Herbicides soil incorporated pre-sowing; herbicides applied to stale seed-bed; and herbicides applied post crop emergence.

Weed cover scores, 0-10 (0 - no weeds, 10 - full weed cover)
Crop scores, 0-10 (0 - no crop, 10 - normal full crop)

Herbicide oz. a.i. per acre	Year(s)	Weed cover scores								Crop scores							
SOIL INCORPORATED PRE-SOWING																	
† Trifluralin 4	(1969)						5								10		
† Trifluralin 8	(1969)						4								10		
† Trifluralin 16	(1966 and 1969)	5	5	6	6	4	2			9	9	9	9	9	10		
TO STALE SEEDBED																	
Chlorthiamid 16 + paraquat 8	(1965)	2	2	1						2	1	<1					
Dimexan (16 pints)	(1965-6)	4	5	1	3	1	5	2	1	10	10	10	7	7	7	7	7
Linuron 16 + paraquat 8	(1965)	1	2	1						0	0	1					
Monolinuron 16 + paraquat 8	(1965)	1	2	1						0	0	8					
Paraquat 8	(1965-6)	3	10	2	1	1	1	1	2	10	10	10	7	7	7	7	7
Paraquat 16	(1964)	3	3	1	6					6	8	6	3				
Pyrazon 12 + paraquat 8	(1965)	2	5	2						5	5	10					
Sodium pentachlorophenate 192	(1965)	4	7	2						10	1	5					
Chlorbufam + cycluron + dimexan 10 pints	(1965)	2	3	2						8	7	5					
POST CROP EMERGENCE (1-4 TRUE LEAVES)																	
Alachlor 24 + chlorpropham 8	(1968)	6	9	8	-					4	7	9	-				
Alachlor 48 + chlorpropham 8	(1968)	7	9	6	-					4	7	7	-				
Aziprotryne 32	(1967)	8	9	9						0	6	2					
DW 3418 16	(1970)	5	2	2						3	2	3					
DW 3418 24	(1970)	5	3	2						2	1	3					
Nitrofen 17.5	(1966-7)	7	3	8	3	3	10	9	5	6	6	6	6	6	2	6	8
Nitrofen 17.5 + chlorpropham 8	(1966-7)	4	2	9	5	2	8	9	3	6	4	4	4	6	5	6	8
Nitrofen 32 + chlorpropham 8	(1968)	3	9	4	3					2	7	9	8				
Nitrofen 16 + propachlor 24	(1969-70)	8	7	3	3	6	3	9		9	9	9	10	7	8	10	
Nitrofen 32 + propachlor 48	(1969-70)	10	5	2	3	2	2	5		8	9	9	7	7	7	9	
Picloram 2	(1964-5)	6	2	3	6	6	8	5		8	9	6	5	8	8	10	
Propachlor 62.4	(1967)	9	10	5						5	6	5					
Propachlor 96 + chlorpropham 8	(1968)	3	9	7	6					4	7	9	9				
Sodium chlorate 160 (v.h. vol.)	(1965)	8	6	6						8	8	10					

† 1969 Trifluralin treatments were at the Ayr centre only.

Table 3 Herbicides applied post-sowing but pre crop emergence.

Weed cover scores 0-10 (0 - no weeds, 10 - full weed cover)
Crop scores 0-10 (0 - no crop, 10 - normal full crop)

Herbicide oz. a. i. per acre	Year(s)	Weed cover scores	Crop scores
PRE-EMERGENCE			
Alachlor 24 + chlorpropham 8	(1968)	- - 5 4	- - 8 8
Alachlor 48 + chlorpropham 8	(1968)	- - 5 1	- - 5 8
Aziprotryne 32	(1967)	3 9 10	0 6 1
Chloramben 48 (gran.)	(1964)	5 4 1 2	6 8 8 4
Chlorthiamid 16	(1964)	4 4 2 6	6 8 8 6
DW 3418 16	(1970)	6 3 <2	5 5 1
DW 3418 24	(1970)	2 1 <1	4 1 <1
Haloxydine 4	(1969)	6 5 3 4	7 9 7 9
Haloxydine 8	(1969)	5 2 2 3	2 7 7 7
Haloxydine 16	(1969)	4 1 0 3	1 1 6 7
Linuron 16	(1964)	2 2 3 6	2 8 6 4
Nitrofen 50	(1966-7)	4 5 7 6 3 10 8 3	6 9 9 9 6 5 6 8
Nitrofen 50 + chlorpropham 8	(1966-7)	1 4 3 5 2 6 5 2	6 9 9 6 6 8 6 8
Nitrofen 64 + chlorpropham 8	(1968)	1 3 6 1	4 9 9 9
Nitrofen 16 + propachlor 24	(1969-70)	9 10 2 3 4 4 4	9 9 9 9 7 9 10
Nitrofen 32 + propachlor 48	(1969-70)	7 4 1 2 3 1 2	9 10 9 8 8 10 6
Propachlor 62.4	(1967)	7 9 7	8 6 2
Propachlor 96 + chlorpropham 8	(1968)	1 3 7 1	2 9 5 9
Simazine 16	(1964)	1 1 1 9	2 4 6 3
Sulfallate 28.8 + chlorpropham 8	(1966)	6 8 2 8 6	9 9 9 6 9
Trietazine 16	(1964)	2 2 2 2	2 5 2 0

Table 4 The control of individual weed species by herbicides. Left hand figures indicate numbers of trials in which weed was well distributed and right hand figures the numbers of trials in which weed was still considered potentially troublesome after spraying.

Selected treatments according to frequencies.

	Chenopodium album	*Fumaria officinalis*	*Galeopsis tetrahit*	*Polygonum aviculare*	*Polygonum persicaria*	*Ranunculus repens*	*Spergula arvensis*	*Stellaria media*	*Tripleurospermum maritimum ssp. inodorum*
SOIL INCORPORATED PRE-SOWING									
Trifluralin 16	2 2	-	2 2	1 0	6 5	2 1	5 2	6 4	1 0
PRE-EMERGENCE									
Nitrofen 50 + chlorpropham 8	2 2	1 0	3 1	2 1	7 5	2 1	7 1	7 4	4 3
Propachlor 62.4	-	1 0	2 2	1 1	2 2	-	3 1	2 0	2 0
Nitrofen 32 + propachlor 48	4 3	3 2	3 1	3 3	6 2	2 0	7 2	6 1	3 1
POST-EMERGENCE									
Nitrofen 17.5 + chlorpropham 8	2 0	1 0	3 1	2 1	7 5	2 1	7 2	7 6	4 1
Propachlor 62.4	-	1 0	2 0	1 1	2 2	-	3 2	2 1	2 0
Nitrofen 16 + propachlor 24	4 3	3 0	3 0	3 1	6 2	2 0	7 4	6 5	3 2

Proc. 10th Br. Weed Control Conf.1970

SOME EXPERIMENTS ON THE USE OF HERBICIDES ON SWEDES

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Summary During the four year period 1965-68, six replicated trials were laid down to test the efficiency of the commercially available herbicides for weed control in swedes (*Brassica napus*). The quantities of herbicides used were those recommended by the manufacturers. Paraquat, endothal/propham and dimexan/chlorbufam/cycluron were used in 1965-66. Nitrofen was used in 1966-68. Each trial included a hand weeding treatment. Both pre-emergence and post-emergence cultivation treatments were included in the last 3 years. In general all herbicide and mechanical treatments were inferior to hand-weeding. Of the herbicides tested, paraquat applied during the last week in May to the three-week old, well prepared seedbed, gave the most consistent results.

INTRODUCTION

The results of previous investigations have been reported (Leonard 1965) and they show that paraquat applied to the stale seedbed gave inconsistent results and this prompted an investigation into the optimum age of the seedbed at sowing time.

RESULTS

The main weeds in the trials described in this paper were *Chenopodium album*, *Polygonum* spp., *Capsella bursa pastoris*, *Fumaria officinalis*, *Poa annua*, *Stellaria media*, *Senecio vulgaris*, *Sonchus oleraceus*, *Veronica agrestis*.

In 1966 two trials were laid down (a) Age of Seedbed (paraquat) (b) Pre-emergence and post-emergence herbicides.

Trial (a)

The object of this trial was to ascertain the most suitable time interval between preparation of seedbed and sowing of the seeds, using the stale seedbed technique. There were four sowing dates. The plots were 70yd X 2yd, with four rows in each. There were six randomised blocks and the seed was precision sown to an 8 - inch stand. Paraquat at 0.875 lb in 50 gal water/ac. was applied to all the plots. All seedbeds were prepared on May 2.

The herbicide was very effective in burning off the overground portion of the weeds in all 4 treatments but the roots of the *Polygonum aviculare* and *Polygonum persicaria* plants survived in the D treatment and regrowth occurred. After six weeks the D treatment was completely colonised with these two weeds. In the A treatment new seedling weeds appeared after 10 days and these later colonised the treatment. In the B treatment weed control was good. In the C treatment weed control was excellent but the yield of roots was reduced (not significantly).

Table 1
Trial details and crop records - 1966 (a)

Date of Spraying	Age of Seedbed (weeks)	Date of Sowing	No. of Roots 1000/ac	Yield of Roots tons/ac	No. of Weeds 1000/ac
A - May 18	2	May 18	30	8.9	17
B - June 1	4	May 30	37	27.2	3
C - June 15	6	June 16	35	25.4.	-
D - June 27	8	June 30	-	-	
S.E.	-	--	±1.0	±1.108	±1.6

Trial (b)

There were 6 randomised blocks. The plot size was similar to that of trial (a). All plots were sown to an 8-inch stand except the L plots which were sown 1 inch apart.

The outstanding feature of this trial was that an economic crop could not be grown without effective weed control. The value of tilling the stale seedbed as a means of reducing weed competition was clearly demonstrated in the M plots. The advantage of post emergence steerage hoeing was demonstrated in the N plots (in comparison with the M plots); where steerage hoeing was employed it reduced the weed population and increased the weight of roots per acre. Dimexan/chlorbufam/cycluron failed to control Chenopodium album and Polygonum persicaria. It had a depressing effect on the crop and caused extensive yellowing of the leaf edges and killed some plants. Endothal/propham failed to control Chenopodium album.

Nitrofen gave excellent control of all the weeds present except Stellaria media, Capsella bursa pastoris, Senecio vulgaris and Sonchus oleraceus. Table 2 shows that the post emergence nitrofen treatment (P) was the only treatment where the "order of merit" based on visual assessment of weed control (made on September 15) did not agree with the "order of merit" based on actual yield of roots. This may have been caused by the distortion in the crop plants which took place immediately after the application of the herbicide. This does not agree with the findings of Tyson and Bartlett (1964) whose results indicated that post emergence application of nitrofen (1 lb/ac) and chlorpropham (0.5 lb/ac) at any stage of crop growth from emergence to the 3-4 true leaf stage did not cause any reduction in yield.

Trial 3 (1967)

Herbicides and Cultivations Trial

This trial was laid down in 5 randomised blocks. There were ten treatments, each 50 yd X 2 yd. The seed was precision sown to a 12-inch stand. Table 3 gives treatments, yield and D.M. content of bulbs and tops.

The outstanding result from this trial was the almost complete failure of nitrofen to control Chenopodium album and to a lesser extent Polygonum persicaria, in both the post and pre-emergence applications. This may be explained by the fact rather dry soil conditions at sowing time. In 1966 the soil was damp at the time of sowing and applying the herbicide.

Table 2

Trial treatments, no. roots and weeds, yield of roots and visual assessment of Weed control - 1966 (b).

	Treatment: Herbicide	lb/ac	Cultivation	Roots. 1000/ac	Roots. tons/ac	Weeds 1000/ac	Visual assessment of weed control 15/9/66 order of merit.	Order of merit based on yield
A.	Paraquat	0.875	-	37	29.9	18	8	7
B.	As A + F		-	35	30.9	11	6	4
C.	As A + I		-	38	30.3	14	7	6
D.	As A +		2 steerage hoeings	36	31.8	8	5	3
E.	Control on stale seedbed		-	-	-	-	-	-
F.	Dimexan + Chlorbufam + Cycluron	8.375 0.463 0.313	- - -	30	21.8	41	13	13
I.	Endothal + Propham	2.28 1.71	- -	31	23.1	43	12	12
J.	As F +		2 steerage hoeings	30	29.1	15	10	8
K.	As I +		2 steerage hoeings	31	25.9	15	9	11
L.	Hand weeding, singling +		2 steerage hoeings	37	32.0	5	2	2
M.	Control on fresh Seedbed		-	30	17.1	55	14	14
N.	- - -		2 steerage hoeings	30	27.0	19	11	9
O.	Nitrofen	3	-	31	30.6	10	4	5
P.	Nitrofen	1.2	-	29	26.1	7	3	10.
S.	Nitrofen (band sprayed)	1.05	+ 2 steerage hoeings	29	34.0	3	1	1
	S.E.			±1.0	±0.93	±3.0	-	-

Table 3

Trial treatments, no. roots/ac, yield of roots and tops/ac and D.M. of roots and tops - 1967.

Treatment			Bulbs.			Tops	
Herbicide	lb/ac	Cultivations	1000/ac	tons/ac	% D.M.	tons/ac	% D.M.
A. Paraquat	0.875	-	19	26.8	8.9	3.1	12.0
B. As A +		2 Steerage hoeings	18	29.8	8.8	3.3	11.8
C. Hand weeding, singling		+ 2 steerage hoeings	28	36.6	8.7	4.1	12.1
D Multi-pre sowing tillings (3)		+ 2 steerage hoeings	23	32.4	8.6	3.9	12.0
E. Control on fresh seedbed		-	21	11.4	9.5	2.4	12.3
F. Nitrofen + Chlorpropham (post emergence)	1.2 0.5	- -	21	25.7	9.2	3.2	12.3
G. Nitrofen	3.0	-	24	22.8	9.2	3.3	12.5
H. Nitrofen + Chlorpropham	3.0 0.5	- -	21	19.3	9.3	2.7	12.2
I. Nitrofen post emergence	1.2		23	26.5	8.9	3.3	12.0
J. Nitrofen band sprayed	1.05	+ 2 steerage hoeings	24	33.4	8.7	3.6	12.0
		S.E.	±0.2	±1.36	±0.19	±0.11	±0.20
		Sig. of F- Test	[illegible]	***	N.S.	[illegible]	N.S.

The effect of steerage hoeing both on the appearance of the crop and the subsequent yield was noticeable in the B treatment. Indeed it might be argued that the success of the I treatment was attributable to the steerage hoeing in view of the failure of the G treatment.

The pre-sowing tillings and the post emergence steerage hoeings of the D treatment gave excellent weed control. However, as the weather conditions decide whether pre-sowing tillings can be done or not, it may not be advisable to rely on this technique. As might be expected hand weeding gave the best weed control and the greatest yield of roots per acre, but perhaps at an uneconomically high cost.

1968.

In 1968 there were two herbicide trials laid down.

(a) Age of Seedbed (Paraquat)

(b) Herbicides and Cultivations.

(a) Age of Seedbed Trial.

Results.

In this trial the seedbeds were prepared on different dates and all the treatments were sown on the same date, in order to eliminate the effect of different sowing dates. Two levels of herbicide application were used. The trial was laid down in 5 randomised blocks. There were 10 treatments each 50 yd X 2 yd. The seed was precision sown to an 8-inch stand in 18 inch rows. Table 4 gives the treatments and the influence of seedbed age at time of sowing and spraying on various yield measurements (averaged over two rates of herbicide application)

Table 4
Trial treatments plant population and yield of roots and tops/ac - 1968 (a)

	Herbicide	lb/ac	Age of seedbed (weeks)	Roots 1000/ac	Roots tons/ac	Tops tons/ac
A.	Paraquat	0.75	7	24	23.7	2.8
B.	Paraquat	1.125				
C.	Paraquat	0.75	6	25	27.0	3.1
D.	Paraquat	1.125				
E.	Paraquat	0.75	5	27	28.9	3.5
F.	Paraquat	1.125				
G.	Paraquat	0.75	4	31	30.4	3.7
H.	Paraquat	1.125				
I.	Paraquat	0.75	3	30	30.4	3.6
J.	Paraquat	1.125				
		S.E.	-	±.640.	±0.591	±0.122

The difference in the number of roots per acre can be explained by the condition of the seedbed at sowing time. The older seedbeds were hard and "caked" and this caused bad plant establishment.

(b) Herbicide and Cultivations Trial.

Results.

This trial was laid down in 5 randomised blocks and it contained 10 treatments, each 50 yd X 2 yd, with 4 rows 18 inches apart in each.

Treatment application and sowing

The A and B plots were tilled and finally rolled on April 12th.

The D and B plots each received one run of a spring tined harrow on the following dates: April 12, 19, 26, May 10, 17 and 24. On May 30th they were harrowed with a light harrow and rolled. All were precision sown (except C which was sown thickly) at 8 inches apart with the variety Bangholn on May 31st. The herbicides were applied to the A,B,H and I plots on June 1st and to the J plots on June 15th (first true leaf about 0.75 in. across) The B,F,C,G and H plots were steerage hoed on June 18th and July 2nd. The C plots were singled to 8 inches apart on June 22nd.

Table 5

Treatments, number of bulbs and weight of bulbs and tops/ac - 1968 (b).

Treatment.	Bulbs (no.) 1000/ac	Bulbs (tons)	Tops (tons)
A. 0.875 lb paraquat/ac	29	14.9	2.6
B. 0.875 lb paraquat + 2 steerage hoeings	26	16.7	2.8
C. Hand weeded and singled + 2 steerage hoeings	41	31.2	4.0
D. 7, weekly pre-sowing tillings	29	7.4	1.9
E. Control on fresh seedbed	26	4.8	1.4
F. Precision sown and hand weeded	31	29.4	3.4
G. As D + 2 steerage hoeings	31	17.8	3.2
H. 1.05 lb. nitrofen band-sprayed + 2 steerage hoeings	30	18.9	3.8
I. 3 lb. nitrofen/ac pre-emergence	26	7.5	2.1
J. 1.2 lb. nitrofen/ac post-emergence	24	8.0	2.1
S.E.	± 1.7	± 2.32	± 0.34.
Sig. of F. Test	***	***	***

All the treatments gave very poor yields except C and F. The higher plant population of C may account for the better yield from this treatment. Both paraquat treatments were poor possibly due to the caked condition of the seedbed at the time of sowing. Again the steerage hoeing improved the yield in every case, as may be judged from the superior yield from treatment B as against treatment A and from treatment G as against treatment D. The nitrofen applications failed to control the weeds present and the multi-weekly pre-sowing tillings were totally inadequate.

DISCUSSION

Of the herbicides tested, none proved equal to mechanical and hand weeding, except for one isolated treatment, in the year 1966. In that year the singling and weeding was done under unfavourable soil and weather conditions and this may be the explanation for the result. The additional yield obtained from the hand weeding and singling treatments should be sufficient to pay for the extra cost involved.

All the pre-emergence herbicides were unsatisfactory from the point of view of selectivity. Paraquat applied on a stale seedbed was the most reliable treatment next to hand labour, but, the results suggest that the seedbed should not be more than 3 weeks old and should not be prepared before May 1st.

Although studies were not made on the effects of insect pests on the different treatments both Phyllotreta spp. (Turnip flea beetle) Eriosischia brassicae (Cabbage root fly) and Eriosischia floralis (Turnip root fly) were recorded in almost all of the trials. These pests could be a source of serious consequence where the crop is sown to a stand or where there is the additional danger of phytotoxicity.

The experiments demonstrate that the herbicides available during the years 1965-68 were not generally satisfactory for swedes. Nevertheless, this crop is highly sensitive to weed competition and it is to be hoped that the herbicides of the future will be more effective than those available at present.

In order to achieve effective weed control from the stale seedbed technique, the sowing of the crop must be postponed till the last days in May. This late sowing and the lower plant population which results from the stale seedbed, reduces the yield of roots per acre by 5 tons. (Leonard 1968). Therefore until effective herbicides become available expensive hand weeding and singling (3/- per 100 yard row) may prove more economic than using the herbicides available at present.

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Proc. 10th Brit. Weed Control Conf. (1970)

WEED CONTROL IN TABLE SWEDES

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Summary Experiments over three seasons compared various herbicides for crop tolerance and weed control efficiency. Haloxydine proved too phytotoxic for the swede crop and sulfallate plus chlorpropham checked initial growth and reduced final yield. Treatment with aziprotryne gave effective weed control and did not affect final yield, but marked yellowing of the foliage of emerging seedlings suggested that crop tolerance needs further examination. Trifluralin although giving excellent weed control produced an unacceptable proportion of malformed roots for use in table swedes. Propachlor and nitrofen were the least phytotoxic of the herbicides tested although neither gave effective control of a number of important weed species.

INTRODUCTION

Investigations into cultural methods for the production of high yields of swede turnips of the desired size for household use have been carried out at S.H.R.I. for a number of years. The experiments reported in this paper cover three years' examination of possible herbicides for the crop.

METHODS AND MATERIALS

The experiments were sited on sandy clay loam soils with the following physical analyses:-

%	Sand	Silt	Clay	Loss on ignition
1966	64.1	17.7	13.9	8.66
1967	57.6	23.4	14.3	9.44
1969	60.5	19.3	16.1	8.24

Randomised block layouts were used with 3-5 replications of each treatment. Plot size was 20 ft by 8 ft in 1966, 20 ft by 6 ft in 1967 and 10 ft by 6 ft in 1969. The crops were drilled on the flat in rows 2 ft apart and singled to approximately 6 in. apart in the row. In 1966 the cultivar CHO was used, but this was replaced by Danestone in the other two experiments. Herbicide applications were made by Oxford Precision Sprayer in a water volume of 65 gal/ac. Weed counts were taken on 2 x 1 yd^2 quadrats/plot and weeds were removed by hand from all plots before there was any visible evidence of competition with the crop. Crops were scored for vigour on a 10 - 0 scale (10 = normal healthy crop, 0 = no crop). At harvest the roots were graded for size and shape. Roots in the grade 4-6 in. diameter were considered most suitable for household use (table size). All herbicide rates are quoted as lb or oz a.i./ac.

RESULTS

1966

Treatments and dosages are shown in Table I.

Table I

1966 harvest results

Treatment	Dose lb/ac.	Yield of table size roots tons/ac.	No. of marketable roots of table size/plot
Untreated	-	14.7	64.8
Nitrofen pre-em.	3.0	14.7	65.6
Nitrofen post-em.	3.0	13.7	62.8
Sulfallate + Chlorpropham	1.79 + 0.26	12.5	66.4
Propachlor	3.9	14.2	60.2
Trifluralin	1.0	15.5	51.4
LSD 5%		1.4	9.1
LSD 1%		1.9	12.4
Coeff. of variation %		7.6	11.1

The trifluralin was sprayed and incorporated to 1 in. depth by rotovation one week before sowing. The other herbicides were applied two days after sowing, apart from the post-emergence application of nitrofen which was made 10 days after crop emergence.

Nitrofen applied at either stage failed to control chickweed and these plots were handweeded at the same time as the untreated control plots (27 July). Trifluralin gave the most effective control, with propachlor and sulfallate + chlorpropham only slightly less effective. All three treatments were handweeded on 23 August. *Fumaria officinalis* proved resistant to propachlor and *Stellaria media* was only partially controlled. Trifluralin had no effect on *Capsella bursa-pastoris* and *Senecio vulgaris*; plots treated with sulfallate plus chlorpropham carried a proportion of each of these species. Both propachlor and sulfallate plus chlorpropham checked the growth of crop seedlings slightly and this effect remained visible until singling. No differences could be seen thereafter. However, sulfallate plus chlorpropham significantly reduced the final yield of roots of table size compared with the untreated control (Table I). Propachlor, nitrofen and trifluralin had no adverse effect on total yield, but it was found on lifting that a significant proportion of roots from plots treated with trifluralin were malformed. The affected roots ranged from those which were slightly misshapen to those which were completely hourglass-shaped. The proportion of roots affected averaged 15% but ranged from 3% to 28% on different replications. None of the other treatments affected the number of marketable roots harvested.

1967

Propachlor was applied three days after sowing at 2.6, 3.9 and 5.2 lb/ac. Poa annua and Myosotis arvensis were well controlled, but the herbicide failed to control Fumaria officinalis or Polygonum species at any dosage. Although all dosages of propachlor substantially reduced the population of Stellaria media not even the highest was able to eliminate it. All the herbicide plots were handweeded on the same day there being very little visible difference between herbicide treatments in density of weed stand.

There were no visible adverse effects on germination or growth attributable to treatment with propachlor. The results at harvest (Table II) showed no significant differences in total yield of roots, yield of table size (4-6 in. diameter) or yield of tops.

Table II

1967 harvest results

Treatment Propachlor lb/ac.	Total yield of roots tons/ac.	Total yield of tops tons/ac.	Yield of table size roots tons/ac.
0	30.5	5.9	20.5
2.6	34.2	7.2	19.6
3.9	32.1	6.3	29.0
5.2	32.5	6.9	1.0
LSD 5%	NS	NS	NS
Coeff. of variation %	9.1	14.4	15.1

1969

Treatments and dosages are shown in Table III.

Table III

1969 crop records

Treatments	Crop vigour 10-0 18/7/69	Pre-singling stand count/ 2 yd row 23/7/69	Total wt. tons/ac. (roots)	% defective roots of table size
Untreated	10.0	114.8	10.5	5.8
Propachlor	9.8	127.8	10.6	1.6
Nitrofen	9.8	106.0	11.6	1.6
Aziprotryne	8.5	125.0	10.7	3.3
Haloxydine 4 oz.	8.8	121.0	10.2	14.6
Haloxydine 8 oz.	5.3	91.3	9.1	19.3
LSD 5%	1.9	NS	1.0	11.3
1%	2.6	-	1.4	15.7
0.1%	3.6	-	2.0	21.7
Coeff. of variation %	14.3	24.4	6.5	97.8

The herbicides were all applied 6 days before crop emergence. At this time the first weed seedlings were just coming through the ground. Nitrofen and propachlor gave insufficient control of several of the weed species present. Aziprotryne and the lower dose of haloxydine were very satisfactory overall while the double dose of haloxydine was outstanding. The evidence suggested however, that Matricaria species may be relatively resistant to this herbicide. All weeds were removed by hand four weeks after treatment.

The crop emerged evenly on all plots, but various degrees of yellowing of the foliage were present on plots treated with aziprotryne and haloxydine. This was eventually outgrown in the case of aziprotryne and the lower dose of haloxydine but a proportion of seedlings on plots treated with the higher dose of haloxydine died and the vigour of the survivors was significantly affected (Table III). Subsequently, plots treated with either dose of haloxydine produced a proportion of plants with multiple heads, as a result of the death of the initial growing points. Otherwise growth was apparently normal until the plants were harvested. When the roots were examined for market grading, it was found, however, that the multiheaded plants showed internal rotting. The area of diseased tissue was immediately below the crown of the plant, suggesting that the disease organism had entered the plant via the dead tissue of the initial growing point. The main organisms identified were pectolytic Erwinia spp., normally associated with potato blackleg disease. The higher rate of haloxydine significantly reduced the total yield of roots. Although the percentage of roots of table size was unaffected by treatments, the actual number of marketable roots in this grade on plots treated with haloxydine was reduced by the presence of the diseased multi-headed plants. Aziprotryne, propachlor and nitrofen had no adverse effect on the yield or quality of roots.

DISCUSSION

Nitrofen, although the safest of the herbicides used in these trials, has never been satisfactory in certain areas because of its failure to control Stellaria media. Propachlor was the least phytotoxic of the newer alternatives but its weed spectrum and persistence were not as good as those of some of the other herbicides. Increasing the dosage did not give a worthwhile improvement where resistant weeds were present. Trifluralin has usually given the best overall performance on the local weed flora (Lawson, 1968) and there are promising reports on its use in fodder swedes in other papers in this session. However, the root malformations obtained in our experiment, although of little importance in a fodder crop would be unacceptable in a table swede crop. Similar effects have been reported in radishes (Tyson & Smith, 1966). Possibly the incidence of these malformations may be associated with the depth and efficiency of incorporation of the herbicide. Haloxydine and sulfallate plus chlorpropham checked crop growth and affected yield but aziprotryne merits further examination.

The need to avoid adverse effects in the size, shape or quality of table swedes makes the search for new herbicides more difficult than with the purely fodder crop. The results of these trials suggest that until further information is available on the phytotoxicity of more effective herbicides, weed control programmes for table swede crops should be based on nitrofen and propachlor, supplemented where necessary by cultivation to remove resistant weeds.

Acknowledgments

Thanks are due to the commercial firms who supplied samples of the herbicides used in these experiments and to M. Perombelon who identified the fungal disease affecting the multiheaded roots.

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TRIALS IN SCOTLAND AND NORTHERN ENGLAND WITH TRIFLURALIN FOR THE CONTROL OF ANNUAL WEEDS IN SWEDES

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Summary In 1969 twelve one acre grower trials, plus a limited marketing of 1,000 acres, was carried out with trifluralin at 1 lb/acre on swedes in N. England and Scotland. Weed control proved to be satisfactory and a mean increase in yield of 15% over tractor hoed control was recorded from the five sites which were harvested. Full marketing was carried out in 1970 and weed control assessments at seventeen sites showed an overall weed control of 72% compared with the unweeded control. Incorporation with springtine harrows, as well as with rotary cultivators, gave satisfactory results even when the swedes were grown as ridge crops. The combination of trifluralin and TCA gave better control of A.repens than did TCA used alone. The results indicate that supplementary hoeing may be required in addition to the use of trifluralin.

INTRODUCTION

Small plot replicated trials on swedes were carried out in Scotland, in 1965, and have been briefly reported (Tyson and Smith 1966). These trials indicated that trifluralin at 1 or 2 lb/ac gave commercially acceptable weed control with no depression of crop yield, although at some sites 2 lb/ac caused slight damage. Nitrofen, both pre- and post-emergence, was evaluated in parallel with trifluralin at that time. The economics of the swede crop in 1965 were such that only the cheapest treatment - nitrofen at 1 lb/ac post-emergence was considered acceptable. Although the difficulty in incorporating trifluralin into a ridged crop was a disadvantage, good results with trifluralin in the United Kingdom, on drilled and transplanted brassica crops, plus the fact that nitrofen applied post-emergence on swedes did not always give completely satisfactory weed control, prompted further work. Grower trials, plus a limited marketing of 1,000 acres in 1969 was followed in 1970 by a full marketing of 20,000 acres.

METHOD AND MATERIALS

Trifluralin was used as Treflan an emulsifiable concentrate containing 48% a.i. at a rate of 1 lb a.i./ac.

Site details are given in Table 1 for 1969 trials and in Table 2 for the 1970 trials. Space did not permit the inclusion in Table 2 of the following data for the 1970 trials.

Site 6; TCA 15 lb/ac was applied both alone and in combination with trifluralin

Site 7; as for Site 6 except that incorporation of the TCA and trifluralin was with heavy harrows followed two days later by rotary cultivation.

Site 8; as for Site 7 except that the first incorporation was with spike toothed harrows followed eight hours later by rotary cultivation

Site 9; TCA 30 lb/ac was applied both alone and in combination with trifluralin

Site 10; Trifluralin was used at 0.5 lb/ac

Site 12; Trifluralin was used at 0.5 lb/ac plus TCA 15 lb/ac which was applied alone and in combination with trifluralin

Soil type was a medium loam for all sites except sites 5, 6 and 17 where it was a sandy loam and sites 2 and 3 where it was a heavy loam. The applications at sites 1-5 were supervised by one of the authors.

The weed assessments in 1970 were made by taking 20 x 1 ft^2 quadrats and the crop assessments at sites 1-5 by counting 7 x 15 ft of row per treatment.

Harvest data in 1969 was obtained by lifting 5 x 30 ft of row per treatment. The swedes were "topped and tailed" and the marketable roots were weighed.

All dosage rates in these experiments are quoted as lb a.i./ac.

Table 1

Site Details for 1969

Site No:	Location	Method of incorp.	Growing system	Crop cultivar	Dates of appln.	drilling	harvest
1	Northumberland	rotary cult.	ridge	Victory	6.5.69	6.5.69	20.10.69
2	Berwicks.	rotary cult.	ridge	Peerless	28.4.69	29.4.69	21.10.69
3	Roxburghs.	rotary cult.	ridge	Benefactor	2.5.69	27.5.69	21.10.69
4	Roxburghs.	rotary cult.	ridge	Wilhelmsburger	28.4.69	28.4.69	22.10.69
5	Roxburghs.	rotary cult.	flat	Wilhelmsburger	2.5.69	5.5.69	22.10.69

All the sites were 3 acres in size and the application of trifluralin at 1 lb/ac was made by the same contractor using a combined sprayer/rotary cultivator with an application rate of 20 gal/ac. At sites 1 and 4 TCA at 20 lb/ac was also applied both alone and in combination with trifluralin.

Table 2

Site Details for 1970

Site No.	Location	Method of incorp.	Acres treat.	Growing system	Crop cultivar	Dates of appln.	drilling	assess.
1	Cumberland	spike harrow and rotary cultivation	1	ridge	Wilhelmsburger	11.5.70	12.5.70	22.6.70
2	Cumberland	rotary cult.	1	ridge	Pentland Harvester	11.5.70	12.5.70	22.6.70
3	Cumberland	rotary cult.	3	ridge*	Wilhelmsburger	15.5.70	16.5.70	22.6.70
4	Cumberland	rotary cult.	1	ridge*	W.Cumbs 1	18.5.70	19.5.70	23.6.70
5	Cumberland	springtine harrow	8	ridge*	W.Cumbs 1	26.5.70	27.5.70	23.6.70
6	Roxburghs.	springtine harrow	7	flat*	Wilhelmsburger	5.5.70	7.5.70	27.7.70
7	Roxburghs.	heavy harrow rotary cult.	3	ridge*	Yellow turnip	13.5.70	14.5.70	27.7.70
8	Berwicks.	spike harrow springtine harrow	20	ridge*	Crofter	12.5.70	14.5.70	27.7.70
9	Fife	springtine harrow	20	flat*	Wilhelmsburger	30.4.70	7.5.70	28.7.70
10	Fife	springtine harrow	1	semi-* ridge	Wilhelmsburger	15.4.70	17.4.70	28.7.70
11	Kincards.	rotary cult.	3	ridge	Angus Champion	13.5.70	14.5.70	29.7.70
12	Angus	rotary cult.	3	ridge	Victory	6.5.70	8.5.70	29.7.70
13	Aberdeen.	discs	2	semi-ridge	Peerless	6.5.70	7.5.70	30.7.70
14	Moray.	rotary cult.	1	semi-* ridge	Yellow turnip	6.5.70	7.5.70	30.7.70
15	Inverness.	rotary cult.	9	semi-* ridge	Monkwood	11.5.70	12.5.70	30.7.70
16	Inverness.	discs	5	ridge	Epicure	2.5.70	4.5.70	30.7.70
17	Ayrshire	rotary cult.	6	ridge*	McGills Green Top	12.5.70	13.5.70	3.8.70

* precision drilled at 6 in. or greater spacing

RESULTS

Weed control data for the 1970 sites are summarised in Table 3, crop establishment data for 1970 in Table 4 and yield data for 1969 sites in Table 5.

Table 3

Weed control for trifluralin 1 lb/ac as % of untreated from 17 sites in 1970

	Susceptible weeds						Moderat. susc.	Resistant Weeds					
	Stellaria media	Polygonum aviculare	Chenopodium album	Polygonum persicaria	Galeopsis tetrahit	Fumaria officinalis	Spergula arvensis	Matricaria spp.	Capsella bursa-pastoris	Sinapis alba	Raphanus raphanistrum	Agropyron repens	Overall % weed control (excluding A.repens)
Mean % dominance of untreated	22.6	17.7	14.6	13.2	5.5	3.5	1.5	16.4	2.5	1.3	1.0		
Site No:													
1.		91	100	75								67	87
2.	100		92	75				78					88
3.			75	83								33	78
4.	92	100	100		100	100				0		0	94
5.		100	100	82				67					87
6.	100		71	69		86			50				72
7.		78	65	60		56	40	38					59
8.		59	72	71		100			82	50			70
9.	69							46	70				56
10.		70	72			100		20					69
11.	83	88		100	77			56				0	82
12.	63	88	71	80	75		70	11	0				60
13.	70		88				100	50	25			60	66
14.		81	80	71	85			33		0			66
15.	100	76	92			100	33	7				33	67
16.	62	90		84	69	71	50					0	74
17.	70	67		56	100					11	0	37	50
Mean % control	81	82	83	76	84	88	57	41	45	15	0	29	72

At sites 6,7,8,9 and 12 trifluralin was applied as a tank mix with TCA which was used to give control of A.repens. At sites 9 and 12 the TCA alone and in combinations with trifluralin gave 100% control of A.repens but at sites 6,7 and 8 the control was improved by the use of the mixture. The extent of this improved control cannot be ascertained as there was no untreated area. A.repens also occurred at eight sites where TCA was not used and the mean control achieved by trifluralin alone was 29%. Further work would be needed to demonstrate any synergism between trifluralin and TCA as regards control of A.repens.

Table 4

Crop establishment counts from 1970 trial sites nos. 1-5 taken 14 weeks after application

Site No:	Additional treatment to plots: Control	Trifluralin	No. of swede plants/90 ft of row Control	Trifluralin	Overall % weed control by Trifluralin
1.	tractor hoeing and singling	tractor hoeing and singling	52	117	87
2.	tractor hoeing and singling	tractor hoeing and singling	74	138	88
3.	unweeded*	unweeded*	59	118	78
4.	unweeded*	unweeded*	75	119	94
5.	unweeded*	unweeded*	60	113	87

* precision drilled at 7 in. spacing

Table 5

Weed control and yield data from the 1969 trials

Site No.	Additional treatment to plots: Control	Trifluralin	Yield of swedes (lb/150 ft of row) Control	Triflur.	Overall % weed control by Trifluralin	Dominant weeds
1.	tractor hoeing and singling	singling	510	516	67	P.persicaria Matricaria sp.
2.	tractor hoeing and singling	singling	508	613	88	C.album
3.	tractor hoeing and singling	singling	425	508	84	C.album
4.	tractor hoeing and singling	singling	375	413	79	P.persicaria
5.	tractor hoeing	unweeded	174	247	93	C.album
			Mean increase 15.3%			

DISCUSSION

In the 1970 trials trifluralin 1 lb/ac gave an overall annual weed control of 72% when compared with unweeded control treatments. Adequate commercial weed control (70% +) was achieved only at 9 of the 17 sites. Table 3 shows that the poorer results were at sites 6-17 which were assessed 11-15 weeks after application, whereas the better results at sites 1-5 were assessed 4-6 weeks after application. These results suggest that for a long season crop like swedes some supplementary tractor hoeing may be required in addition to the use of trifluralin.

The poor results at sites 9, 13, 14, 15 and 17 can also be partly explained by the presence of resistant weeds, particularly Matricaria spp.

At sites 10 and 12 trifluralin was used at 0.5 lb/ac, this rate was probably insufficient for good weed control, particularly at site 12 where there were resistant weeds present.

At eight sites the incorporation of the trifluralin was carried out by rotary cultivation and at two sites by discing. Good weed control and therefore satisfactory incorporation was achieved at other sites by the use of springtine harrows and at one site by the use of spiked harrows followed by springtine harrows.

Of the 1970 trials only sites 6 and 9 were drilled on the flat and sites 10, 13 14 and 15 were drilled on a semi- or very low ridge. Weed control did not appear to be affected by the growing system although the authors did notice that at other sites the control of F.officinalis was better on the ridge than on the flat.

Unfortunately crop counts were not taken at the same time as the weed counts. However, the data in Table 5 for sites 1 and 2 taken fourteen weeks after application does demonstrate how the use of trifluralin plus tractor hoeing and singling increased crop establishment over the controls which were only tractor hoed and singled.

At eleven sites in 1970 the swedes were drilled at a 6 in. or greater, spacing. This spacing, plus the use of trifluralin, could largely eliminate the need for hand hoeing and would enable swedes to be grown on the flat rather than on the ridge. Row width could then be reduced from the present average of 28 in, down to 18 or 20 in. thus effecting a saving on growing costs as well as increasing yield.

The acreage of swedes and fodder turnips grown in the United Kingdom has been declining for many years although the rate of decline, since 1968, shows signs of slowing down. This slowing down may, or may not, have been due to the usage of herbicides but the Authors consider that trifluralin can help to satisfy the present need for a herbicide in the swede crop. The use of trifluralin will give the crop a good start in a weed-free enviroment and by giving reliable control of difficult to hoe weeds such as S.media and P.aviculare will make supplementary hoeing, if required, much easier to carry out.

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Proc. 10th Br. Weed Control Conf. 1970

THE TOLERANCE OF CARROTS AND PARSNIPS TO POST-EMERGENCE APPLICATIONS OF LINURON, PROMETRYNE AND DALAPON

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Summary Evidence is presented to show that linuron, prometryne and dalapon can be applied to carrots and parsnips from the cotyledon stage onwards without significant crop injury. Dalapon achieved an appreciable degree of couch grass control at doses up to 7.0 lb/ac without significantly reducing crop yield. This was shown to be a promising additional treatment to linuron and prometryne where couch is a problem. Linuron was shown to be one of the most persistent soil applied herbicides. It suffered a loss in activity of 80% in about six months under field conditions. Whilst it is likely to present problems in short term crop rotations, on this evidence there would be no appreciable carry over residue from one year to the next at least where doses do not exceed 2.0 lb/ac.

INTRODUCTION

Weed control in carrots and parsnips with soil-applied herbicides such as linuron and prometryne has been amply demonstrated experimentally by Roberts and Wilson (1964) and in Northern Ireland by Allott and Uprichard (1966) as well as by their continued commercial use. Whilst these herbicides control the majority of germinating annual weed seedlings, they are not effective against grass weeds, particularly perennial species such as *Agropyron repens* (couch grass). The occurrence of this weed in carrots in Northern Ireland stimulated the investigations which are described in this paper. The regular use of persistent soil-applied herbicides such as linuron also necessitates a consideration of their soil persistence which is briefly discussed.

METHOD AND MATERIALS

The experiments were conducted at Loughgall on light to medium loam soils. Specific soil descriptions are included with the results of each experiment. Herbicides were all applied in a water volume of 50 gal/ac. All herbicide doses refer to lb a.i./ac. Standard herbicide formulations were used throughout. The total marketable yields of carrots and parsnips were recorded. Yield results for 1966, the first year of this series of experiments, are presented in terms of lb/plot. For subsequent years the yields from the herbicide treatments are presented as ratios of the yields of the hand weeded controls. Weed control was assessed by scores on a scale from 0-5 where 0 = weeds absent and 5 = weeds dominant. Statistical significance is indicated, where appropriate, by the standard error of the difference between two treatment means. Persistence was investigated by applying herbicides in the spring at 2.0 lb/ac and sowing lettuce at monthly intervals thereafter. Crop tolerance was then assessed by scores taken five weeks after each sowing using a 0-5 scale where 0 = no effect, 5 = plant death.

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RESULTS

Experiment 1 (Carrots cv Chantenay Red Core)

This experiment was conducted as an initial investigation into the tolerance of carrots to post-emergence treatments of dalapon alone and in association with linuron and prometryne. The soil contained a total sand fraction of 71.1%, silt 8.8%, clay 11.3% and organic matter as measured by loss on ignition 6.2%. Mean yields of roots (table 1) show that treatments 5 and 14 significantly reduced yield compared to other treatments and the hand weeded control and that treatment 8 gave an appreciably lower yield than most other treatments. Yield reductions, however, were always associated with a poor weed control and could be attributed more to weed competition than to toxicity. The majority of herbicides increased yield compared to the hand weeded control.

Table 1

Effect of post-emergence herbicides on the yield of carrots (cv Chantenay Red Core)

Herbicide	Dose lb/ac	Mean yield lb/plot
1. hand weeded control	-	35.97
2. linuron (cotyledon stage)	1.0	42.70
3. linuron (cotyledon stage)	2.0	50.13
4. linuron (1st true leaf)	2.0	57.95
5. prometryne (cotyledon stage)	1.0	21.24
6. prometryne (cotyledon stage)	2.0	52.27
7. prometryne (1st true leaf)	2.0	55.53
8. dalapon (cotyledon stage)	3.5	33.38
9. dalapon (2nd true leaf)	3.5	43.89
10. dalapon (2nd true leaf)	3.5	41.62
+ dalapon (5th true leaf)	3.5	
11. linuron +	1.0	55.77
dalapon (2nd true leaf)	3.5	
12. prometryne +	1.0	60.54
dalapon (2nd true leaf)	3.5	
13. dalapon (2nd true leaf)	7.0	41.54
14. dalapon (5th true leaf)	7.0	17.22
S.E. of a difference		± 2.290

d.f. error 26

Experiment 2 (Parsnips cv Offenham)

This experiment examined the tolerance of parsnips to post-emergence applications of dalapon, linuron, and prometryne. The soil had the same physical properties as Experiment 1. Herbicide treatments did not adversely affect crop yields (table 2). As in Experiment 1 the lowest crop yields coincided with the poorest weed control.

Table 2

Effect of post-emergence herbicides on the yield of parsnips (cv Offenham)

Herbicides	Dose lb/ac	Mean yield lb/plot
1. hand weeded control	-	25.68
2. linuron (1-2 true leaf)	0.75	36.93
3. linuron (1-2 true leaf)	1.00	37.30
4. linuron (3-4 true leaf)	0.75	41.39
5. linuron (3-4 true leaf)	1.00	46.25
6. prometryne (1-2 true leaf)	0.75	43.16
7. prometryne (1-2 true leaf)	1.00	39.59
8. prometryne (3-4 true leaf)	0.75	45.02
9. prometryne (3-4 true leaf)	1.00	44.73
10. linuron (3-4 true leaf)	0.75	31.60
+ dalapon (pencil thickness)	3.50	
11. linuron (3-4 true leaf)	0.75	45.39
+ dalapon (pencil thickness)	7.00	
12. prometryne (3-4 true leaf)	1.00	48.32
+ dalapon (pencil thickness)	3.50	
S.E. of a difference		± 7.598

d.f. error 22 Note: Dalapon in treatments 10 and 12 was applied twice at an interval of two weeks.

Experiments 3 and 4 (Carrots cv Chantenay Red Core, parsnips cv Offenham)

These experiments were designed to verify the tolerance of carrots and parsnips to post-emergence applications of dalapon and to examine the value of low doses of this herbicide for the control of couch grass (*Agropyron repens*).

The carrot experiment was conducted in the same soil but on an adjacent site to the previous year. The soil for the parsnip experiment contained 56.3% sand, 11.1% silt, 24.7% clay and 9.7% organic matter as measured by loss on ignition. The yield ratios (table 3) show that there were no differences between treatments but that all herbicides caused a yield reduction compared to the hand weeded control although, particularly in the case of parsnips, this effect was very marginal. Where herbicides were applied earlier than pencil thickness there was a trend towards a yield reduction in carrots but not in parsnips. The control of couch grass by dalapon was not outstanding but it was appreciably better than with prometryne or linuron. The degree of couch grass control was not influenced by the time of herbicide application.

Experiments 5 and 6 (Carrots cv Chantenay Red Core and parsnips cv Offenham)

These experiments were both conducted in a soil containing 53.3% sand, 11.6% silt, 27.0% clay and 12.1% organic matter as measured by loss on ignition. The ratios of crop yields to the hand weeded controls (table 4) show that there were no significant treatment differences.

Table 3

Yields of carrots (cv Chantenay Red Core) and parsnips (cv Offenham) expressed as ratios of the hand weeded controls following post-emergence applications of dalapon, prometryne and linuron

Herbicide	Dose lb/ac	Mean Yield as ratio of hand weeded control		Agropyron repens Score
		Carrot	Parsnip	(Carrot trial only)
1. dalapon	3.5	0.67	0.89	2.44
2. dalapon	3.5	0.74	0.97	1.67
+ dalapon (2 weeks later)	3.5			
3. dalapon	7.0	0.78	0.94	1.33
4. prometryne	1.0	0.80	0.89	4.08
5. linuron	1.0	0.71	0.95	3.78
S.E. of a difference		± 1.453	± 1.036	-
Time of herbicide application				
1. cotyledon stage		0.70	0.93	4.22
2. 2nd true leaf		0.68	0.88	4.67
3. pencil thickness		0.84	0.97	4.22
S.E. of a difference		± 1.126	± 0.804	-

d.f. error 28

Table 4

Yield of carrots (cv Chantenay Red Core) and parsnips (cv Offenham) expressed as ratios of the hand weeded controls following post-emergence applications of dalapon

Herbicide	Dose lb/ac	Mean Yield as ratio of hand weeded control	
		Carrots	Parsnips
dalapon	3.5	0.98	0.87
dalapon	3.5	0.86	0.82
+ dalapon 2 weeks later	3.5		
dalapon	7.0	0.89	0.77
S.E. of a difference		± 0.085	± 0.065
Time of herbicide application			
cotyledon stage		0.88	0.83
2nd true leaf stage		0.91	0.80
pencil thickness		0.95	0.83
S.E. of a difference		± 0.085	± 0.065

d.f. error 16

Experiment 7

This experiment examined the relative soil persistence of six soil-applied herbicides. From Fig. 1 it is evident that within 22 weeks of the herbicide applications there had been a loss of 80% in the activity of simazine and atrazine, whilst a loss of 80% in the activity of linuron and terbacil occurred after 23 weeks, after 19 weeks with lenacil and after only 12 weeks with prometryne.

DISCUSSION

The current recommendations for the post-emergence treatment of carrots with dalapon (British Crop Protection Council 1968) for the control of perennial grasses involve herbicide application when the crop root has reached pencil thickness. Earlier applications could be advantageous, however, in weedy situations if the crop is sufficiently tolerant. As the results show dalapon can be applied to carrots and parsnips from the cotyledon stage onwards without significantly affecting yields at doses up to 7.0 lb/ac. Such an early application, however, whilst suppressing the couch grass sufficiently to allow the crops to become established may not provide an adequately prolonged control and a second treatment at pencil thickness may be necessary. Whilst these herbicides failed to increase yields significantly it is probable that with a heavy infestation of couch grass they could have this effect.

When the persistence of several soil-applied herbicides was examined under field conditions it was evident that terbacil and linuron were the most persistent followed by atrazine, simazine, lenacil and prometryne. All these herbicides, however, suffered an 80% loss in activity within six months of application. On this evidence, therefore, it is unlikely that herbicides that are in common use will persist sufficiently to damage a succeeding crop in the growing season after spraying. As herbicide persistence is likely to vary with climatic and soil conditions care must be exercised, however, in the choice of herbicides, the time interval between spraying and sowing the following crop and in crop rotation, particularly where a short term crop rotation is contemplated.

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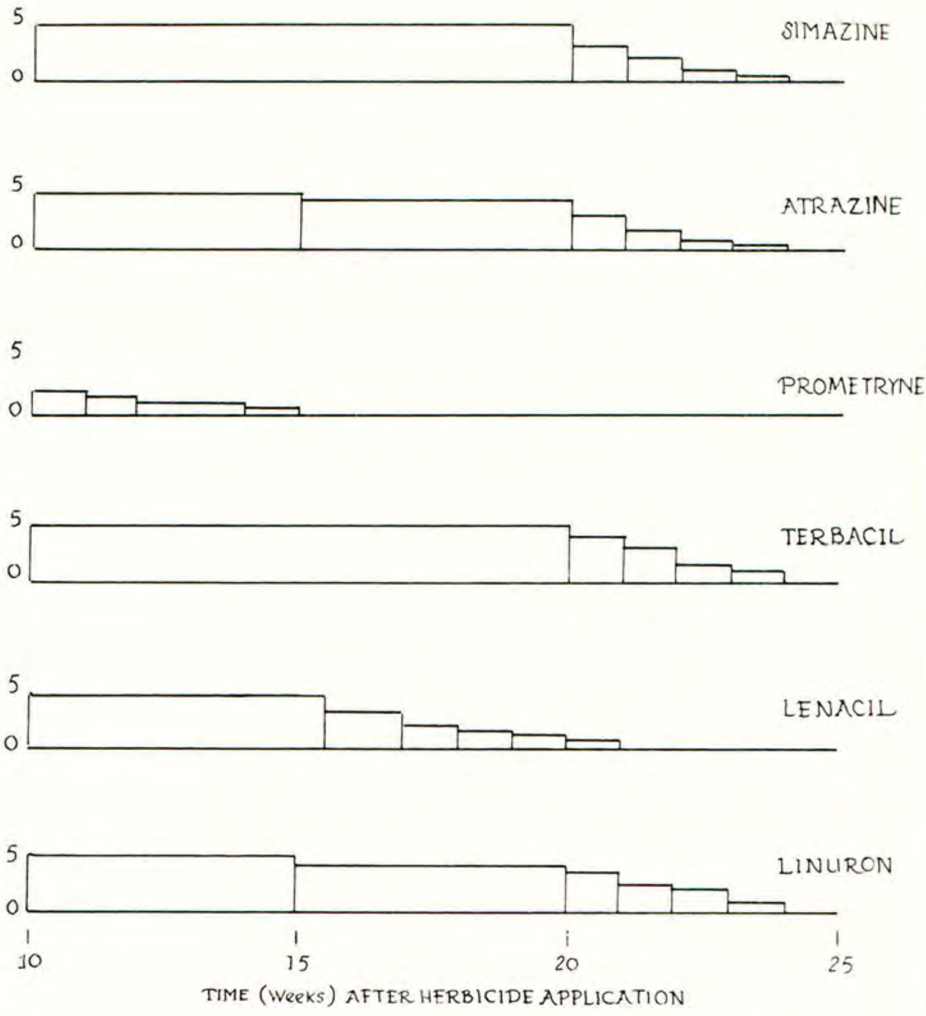
Fig. 1



HERBICIDE PERSISTENCY IN A SOIL CONTAINING 20.0% COARSE SAND, 35.5% FINE SAND, 12.9% SILT, 24.4% CLAY AND 8.9% LOSS ON IGNITION, ASSESSED BY SCORES ON LETTUCE SOWN AT MONTHLY INTERVALS AFTER HERBICIDE TREATMENTS.

Proc. 10th Br. Weed Control Conf. 1970

CHLORBROMURON AS A HERBICIDE FOR CARROTS, PARSNIPS AND CELERY

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Summary Results of 18 trials are reported in which carrots, parsnips and celery showed a high degree of tolerance to chlorbromuron. Split applications with half the required dose applied pre-emergence and the second half applied post-emergence gave better control of weeds than a single pre-emergence application on mineral soils, and post-emergence applications were superior on organic soils. The dose required for good weed control varied with soil type: 0.5 + 0.5 lb/ac on very light soils, 0.75 + 0.75 lb/ac on light soils, 1.5 + 1.5 lb/ac on medium soils and 1.5 lb/ac applied post-emergence on organic soils. At these doses chlorbromuron gave good control of many annual weeds.

INTRODUCTION

Chlorbromuron was first reported by Green et al (1966) and results of trials with chlorbromuron as a herbicide for potatoes were reported by Smith and Marks (1968). The results of these trials showed that this herbicide gave control of a wide range of annual weeds when applied before or after weed emergence.

Preliminary trials in 1966 revealed the tolerance of carrots to pre- or post-emergence applications of chlorbromuron. Trials were continued in the following three years to establish dose rates and application timing.

Pre-emergence applications using doses already established as giving good weed control were used on mineral soils. In addition the use of two applications of reduced doses before and after crop and weed emergence were investigated. It was thought that a split application technique would reduce weed competition at emergence and prolong the control of susceptible weeds beyond that given by a single pre-emergence application.

On organic soils it had been shown previously in trials on potatoes that chlorbromuron had a limited residual life and in the carrot trials carried out on organic soils split applications were not used.

In 1969 trials with chlorbromuron were extended to include parsnips and celery using the same rates of use as those being used on carrots.

METHOD AND MATERIALS

A 50% wettable powder formulation of chlorbromuron was used in all trials. Linuron was used at recommended rates as a comparative standard in all except one trial. All doses are given as lb a.i./ac. Untreated plots which were not weeded were included in all trials.

All trials were of a randomised block design with two or four replicates and a plot size of 12-24 yd^2 depending on the row widths and spatial arrangement of the crop. Treatments were applied with a precision plot sprayer or knapsack sprayer using 25-50 gal water/ac.

Assessments of weed control were made after the pre-emergence applications counting individual weed species in 6-10 1 ft^2 quadrats per plot and about four weeks after the post-emergence applications using the proposed EWRC Scoring System which is briefly as follows:

Score	Activity in % Control
1	100
2	97.5
3	95
4	90
5	85
6	75
7	65
8	33
9	0

Crop vigour scores were made at the same time as weed assessments using the same scale where the percentage represents the degree of vigour of the crop in each treatment compared with that in the untreated plots. In this scale a crop vigour score of 4 represents the limit of acceptability. Where possible yield assessments were made by hand lifting sample areas from each plot. The lifted crop was trimmed as in commercial practice before weighting.

RESULTS

The results of the trials in carrots, parsnips and celery are given in Tables 1-3. Weed control and crop vigour results are the means of the scores made four weeks after the application of the post-emergence treatments. Where yield assessments were made the yields for each treatment is expressed as a percentage of that from the untreated plots.

Table 1

Weed control, crop tolerance and yield results with chlorbromuron in carrots

Trial Reference	Soil Type	Dose lb a.i./ac	Growth Stage at Application: Crop	Growth Stage at Application: Weeds	Weed Control Score	Crop Vigour Score	Yield as % of Untreated
1/67	Sandy loam	2.0	Pre-em.	Pre-em.	4	1	156
		0.75+0.75	Pre + 5 lf.	Pre + 8 lf.	3	1	150
		1.0+1.0	"	"	2	1	138
		2.0+2.0	"	"	1	1	146
		linuron	"	"	2	1	140
							S.E.± 10.9
1/68	Coarse sandy loam	1.0	Pre-em.	Pre-em.	5	3	
		0.5+0.5	Pre + 2 lf.	Pre + 4 lf.	3	2	
		1.0+1.0	"	"	2	4	
		linuron	"	"	2	3	
1/69	Sandy loam	1.5	Pre-em.	Pre-em.	4	1	117
		0.75+0.75	Pre + 2 lf.	Pre + 4 lf.	3	1	114
		1.0+1.0	"	"	3	2	119
		1.5+1.5	"	"	2	1	123
		linuron	"	"	2	2	116
							S.E.± 15.0
2/69	Loamy coarse sand	1.0	Pre-em.	Pre-em.	5	2	221
		0.5+0.5	Pre + 1 lf.	Pre + 1 lf.	4	2	194
		0.75+0.75	"	"	4	3	249
		1.0+1.0	"	"	4	4	221
		linuron	"	"	4	3	200
							S.E.± 26.4
3/69	Peat	1.5	4 lf.	8 lf.	4	2	218
		3.0	"	"	3	2	225
		linuron	"	"	3	2	215
							S.E.± 18.3
4/69	Sandy loam	1.5	Pre-em.	Pre-em.	8	1	
		0.75+0.75	Pre + 4 lf.	Pre + 8 lf.	6	1	
		1.0+1.0	"	"	4	1	
		1.5+1.5	"	"	3	1	
		linuron	"	"	3	1	
14/69	Peat	0.75	1 lf.	2-3 in.	4	1	
		1.0	"	"	3	1	
		1.5	"	"	2	1	

Table 2

Weed control, crop tolerance and yield results with chlorbromuron in parsnips

Trial Reference	Soil Type	Dose lb a.i./ac	Growth Stage at Application Crop	Growth Stage at Application Weeds	Weed Control Score	Crop Vigour Score	Yield as % of Untreated
5/69	Sandy loam	1.5	Pre-em.	Pre-em.	3	1	102
		0.75+0.75	Pre + 2 lf.	Pre + 4 lf.	3	2	97
		1.0+1.0	"	"	2	2	99
		1.5+1.5	"	"	2	2	87
		linuron	"	"	2	2	91
							S.E.± 10.2
6/69	Peat	1.5	Pre-em.	Pre-em.	2	1	139
		3.0	"	"	2	1	131
		1.5	2 lf.	3 lf.	2	2	201
		3.0	"	"	2	2	215
		linuron	"	"	4	1	175
							S.E.± 35.7
7/69	Coarse sandy loam	1.5	Pre-em.	Pre-em.	4	1	
		0.75+0.75	Pre + 2 lf.	Pre + 3 lf.	2	1	
		linuron	Pre-em.	Pre-em.	2	1	
8/69	Clay loam	1.5	Pre-em.	Pre-em.	8	1	120
		0.75+0.75	Pre + 4 lf.	Pre + 6 lf.	5	1	112
		1.0+1.0	"	"	5	1	112
		1.5+1.5	"	"	4	1	112
		linuron	"	"	6	1	108
							S.E.± 9.8
15/69	Loamy coarse sand	1.5	Pre-em.	Pre-em.	2	1	
		0.75+0.75	Pre + 2 lf.	Pre + 1½ lf.	2	2	
		linuron	"	"	1	1	
16/69	Peat	1.5	Pre-em.	1½ in.	2	1	149
		3.0	"	"	2	1	134
		linuron	"	"	3	1	146
		1.5	2-3 lf.	3-4 in.	2	2	205
		3.0	"	"	2	2	220
		linuron	"	"	4	1	179
							S.E.± 36.4

Table 3

Weed control, crop tolerance and yield results with chlorbromuron in celery

Trial Reference	Soil Type	Dose lb a.i./ac	Growth Stage at Application Crop	Weeds	Weed Control Score	Crop Vigour Score	Yield as % of Untreated
9/69	Peat	1.0	3-4 lf.	12 in.	5	2	103
		1.5	"	"	3	2	114
		3.0	"	"	2	3	108
		linuron	"	"	4	2	102
							S.E.± 5.7
10/69	Peat	1.0	4-5 lf.*	Pre-	8	1	89
		1.5	"	"	7	2	91
		3.0	"	"	6	3	102
		linuron	"	"	7	1	105
							S.E.± 11.3
11/69	Peaty loam	1.0	5-6 lf.	Pre-	7	2	135
		1.5	"	"	6	2	135
		3.0	"	"	4	3	148
		linuron	"	"	6	2	138
							S.E.± 9.8
12/69	Peaty loam	1.0	8 lf.*	1 lf.	1	2	100
		1.5	"	"	1	2	88
		3.0	"	"	1	2	83
		linuron	"	"	1	2	101
							S.E.± 6.1
13/69	Peat	1.0	4 lf.*	6 lf.	3	2	
		1.5	"	"	3	7	
		3.0	"	"	2	7	
		linuron	"	"	2	2	

* Treatments applied to established transplants.

It is apparent from the above tables that the optimum dose and timing of applications of chlorbromuron varies with soil type as follows:

Soil Type	Dose of chlorbromuron lb a.i./ac Pre-em.	Post-em.
Very light soils	0.5 +	0.5
Light soils	0.75 +	0.75
Medium and loamy soils	1.0 +	1.0
High organic soils		1.5

The susceptibility of individual weed species to the above doses of chlorbromuron is given in Table 4.

Table 4

Weed control with chlorbromuron

Weed Species	No. of Sites Occurring	EWRC Weed Score 1-4	5	6-7	8-9
Aethusa cynapium	2		1	1	
Alopecurus myosuroides	1			1	
Anagallis arvensis	2	2			
Capsella bursa-pastoris	3	3			
Chenopodium album	6	6			
Daucus carota	1				1
Galeopsis tetrahit	2	2			
Lamium purpureum	2	2			
Myosotis arvensis	1	1			
Poa annua	7	6	1		
Polygonum aviculare	7	5	2		
Polygonum convolvulus	4	1	3		
Polygonum persicaria	7	7			
Reseda lutea	2			2	
Senecio vulgaris	6	4		2	
Stellaria media	6	6			
Tripleurospermum maritimum spp. inodorum	6	5	1		
Urtica urens	7	7			
Veronica persica	5	4			1
Viola spp.	2	2			

DISCUSSION

Weed Control

As had been previously established in trials on potatoes by Smith and Marks (1968), the dose of chlorbromuron required to give satisfactory weed control increased with increasing clay and organic matter content in the soil. The results reported show that by using split applications on mineral soils with half the dose applied pre-emergence and half post-emergence, the extent and duration of weed control was improved compared with the same total amount of herbicide applied once pre-emergence. In all trials on mineral soils except 4/69 on carrots and 8/69 on parsnips, weed control was good using split application. In trial 4/69 the predominant weed was *Veronica spp.* which was at an advanced stage of growth (8 leaf) when the post-emergence application was made and in trial 8/69 the predominant weed was *Alopecurus myosuroides*, which was not well controlled by chlorbromuron.

On organic soils applications after weed emergence gave better weed control than pre-emergence treatments as indicated by the weed scores in trials 10/69 and 11/69 compared with other trials in Table 3. Although the weed scores from trials 6/69 and 16/69 on parsnips do not appear to corroborate this, the higher yields obtained from the post-emergence treatments in these trials do suggest more prolonged and therefore better weed control.

In all trials chlorbromuron gave a similar level of weed control to that obtained with linuron and controlled a wide range of weeds when applied as a split application or a single post-emergence application. *Myosotis arvensis* and *Polygonum aviculare* appeared to be better controlled with split applications of chlorbromuron than with a single post-emergence treatment. Post-emergence applications of chlorbromuron did, however, appear to have a more pronounced contact action than that of linuron giving a quick kill of emerged weeds. In commercial usage in 1970 post-emergence applications of chlorbromuron on *Urtica urens*, *Polygonum persicaria* and *Chenopodium album* up to 12 in. tall and *Senecio vulgaris*, *Tripleurospermum maritimum spp. inodorum* up to 6 in. high gave effective weed control.

Carrots appeared to be tolerant of double the dose required to give a good weed control when applied at the 1-5 leaf stage of the crop and showed a similar selectivity to that of linuron on a range of soil types. Although minor reductions in vigour were recorded these were not reflected in subsequent yields. In commercial usage post-emergence applications of chlorbromuron to carrots at the cotyledon stage have not caused phytoxicity to the crop. The following cultivars of carrots were treated in the trial reported: Early Nantes, Early Model, Vitalonga, Perfecta and Chantenay.

Trials carried out on the two major cultivars of parsnips, Cambridge Improved Marrow and Tender and True, indicated that this crop was also highly tolerant of chlorbromuron at doses of up to double those needed for satisfactory weed control. In only one instance, trial 5/69, was a slight deperession in yield noted although this depression was less than that obtained with the recommended dose of linuron and was not significant.

In celery a marked reduction in yield occurred in trial 12/69. In this trial the transplants were large (8 leaf) at the time of spraying and suffered a severe initial check which appeared to be outgrown 4 weeks after spraying as indicated in the vigour scores, but yields were depressed. In trials 9/69 and 10/69 which were the same cultivar (New Dwarf White) sprayed at an earlier stage, no crop check or yield depression was noted. The severe crop check in trial 13/69 is not explicable. However, in trial 11/69 on the same cultivars (Lathom) no check was observed and subsequent commercial applications on the variety have proved satisfactory.

CONCLUSION

The results of these trials show that chlorbromuron is selective in carrots and parsnips and gives a good control of many annual weeds. Commercial recommendations have been made for use in these crops where the contact action of chlorbromuron has proved very effective against large weeds. Further work is in progress on celery to establish recommendations.

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Proc. 10th Br. Weed Control Conf. 1970

AN EVALUATION OF METOXURON FOR THE CONTROL OF ANNUAL WEEDS IN CARROTS

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Summary Metoxuron was evaluated for pre- and post-emergence control of annual weeds in carrots. Post-emergence treatments appeared to be slightly more effective than pre-emergence. Dosage rates between 2.4 and 4.0 lb/ac, produced acceptable levels of weed control. Excellent control of *Matricaria* spp. was obtained with these dosage rates applied post-emergence on sand and organic soils respectively, and they proved to be effective for this purpose in commercial usage in 1970. *Veronica* spp. and *Polygonum aviculare* indicated a degree of resistance to this treatment. Maximum crop tolerance was obtained when application was made after the two-true leaf stage of growth.

INTRODUCTION

Metoxuron is manufactured by Sandoz Ltd., Basle, Switzerland. Evaluation of the commercial product (DOSANEX), containing 80% a.i., for the control of broad-leaved weeds in carrots in Europe is reported by Berg (1968). Trials were initiated in the United Kingdom by Farm Protection Ltd., in 1968 to evaluate the use of metoxuron for broad-leaved weed control in carrots. The following report describes trials carried out in 1968 and 1970.

METHOD AND MATERIALS

All experiments were sprayed using an Oxford Precision sprayer applying a spray volume of 40 gal/ac. Plot size was 45.5 ft x 6 ft = 1/160 acre and treatments were replicated four times. Five trials were carried out in 1968 and four trials in 1970.

Weed control and crop tolerance was assessed according to the following scale:-

% Weed Control	Weed/Crop Score	% Crop Tolerance
100	1	100
97.5 - 100	2	97.5 - 100
95 - 97.5	3	95 - 97.5
90 - 95	4	90 - 95
85 - 90	5	85 - 90
75 - 85	6	75 - 85
65 - 75	7	65 - 75
32.5 - 65	8	32.5 - 65
0 - 32.5	9	0 - 32.5

Trial Number	Location	Soil Type	Variety	Date Sown	Stage of growth at application: Pre-em.	Stage of growth at application: Post-em.
1968						
1	Notts	S.L.	Sharpes 210 Chant.	14/3	g	Cot.- 1 leaf
2	Norfolk	S.L.	Elsoms Supreme	15/3	g	Cot.- 1 leaf
3	Norfolk	L.S.	New Model	2/5	n.g	$2\frac{1}{2}$-$3\frac{1}{2}$ leaf
4	Yorks	G.S.	Elsoms Topik	6/5	n.g	2 -$2\frac{1}{2}$ leaf
5	Yorks	O.S.	Chantenay Supreme	17/5	n.g	2 -$2\frac{1}{2}$ leaf
1970						
1	Lancs	O.S.	Berlicum Type	6/6	-	1 - 2 leaf
2	Lancs	O	Nantes	3/7	-	Cot.- 1 leaf
3	Suffolk	L.S.	Chantenay	28/4	-	4 - 8 leaf
4	Suffolk	L.S.	Red Cored	30/4	-	6 - 8 leaf

S.L. = Sandy Loam
L.S. = Light Sand
G.S. = Gravel Sand
O.S. = Organic Sand

O. = Organic
g = germinated
n.g = not germinated
cot.= cotyledon

Linuron applied pre-emergence was used as a standard treatment. Pre-emergence treatments were assessed 30 - 36 days after treatment, and post-emergence treatments between 5 - 7 weeks after treatment.

All dosage rates mentioned are quoted as lb a.i./ac.

RESULTS

Weed Control - 1968 Trials

TABLE 1

Weed Control Scores - 1968 Trials.

Treatment	Dosage lb/ac.	Trial Number 1	2	3	4	5	2 (*A. fatua*)
Pre-emergence							
Metoxuron	1.2	6.3	7.7	-	-	-	4.5
"	1.6	4.9	7.0	-	6.3	7.4	4.3
"	2.4	4.1	4.8	1.0	4.6	8.1	4.3
"	3.2	-	-	-	4.5	6.3	-
"	4.0	3.0	4.3	2.2	-	-	-
"	4.8	-	-	-	3.6	4.5	-
"	6.4	-	-	1.0	-	-	-
Linuron	0.5	-	6.7	4.8	-	8.3	4.0
"	0.75	2.6	-	-	1.0	-	-

TABLE 1 continued

Weed Control Scores - 1968 Trials

Treatment	Dosage lb/ac.	Trial Number 1		2	3	4	5	2 (*A.fatua*)
Post-emergence								
Metoxuron	1.6	6.1	-*	3.6	5.0	8.6	-	6.8
"	2.4	4.5	8.4	-	3.8	8.5	4.9	-
"	3.2	-	-	4.3	1.0	8.5	4.3	4.6
"	4.0	3.6	4.5	-	1.0	-	3.2	-
"	4.8	-	-	2.8	-	8.4	-	3.0
"	6.4	-	-	2.8	1.0	8.2	1.0	3.0

* Sprayed late post-emergence when weeds 3-6 inches high.

Weed control was acceptable with 2.4 lb/ac metoxuron applied pre-emergence at all sites except at site 5, where a dense infestation of C. album was only partially controlled. Even the standard rate of linuron did not produce acceptable control at this site. (Table 1).

Metoxuron gave similar results at comparable dosages at sites 1,2 and 4. It was particularly effective at site 3 (a light sand) where the weed flora consisted mainly of Matricaria spp and P. persicaria.

At sites 1 and 2, P. convolvulus and P. aviculare showed intermediate susceptibility and this was confirmed at site 4 where the infestation of P. aviculare was dense. In this particular instance the performance of linuron was superior to all rates of metoxuron.

At most trial sites there was an indication that the activity of metoxuron was slightly greater when applied post-emergence. Generally, acceptable control was obtained with 2.4 lb/ac applied early post-emergence. At site 4, however, all rates of metoxuron applied post-emergence proved ineffective for the control of a dense infestation of P. aviculare, and inferior to pre-emergence treatments with metoxuron. The reverse occurred at site 5 where the main weed was C. album. This suggests that weeds vary in their sensitivity to metoxuron depending upon the time of treatment, but generally the post-emergence treatment is superior.

At site 2 all pre-emergence treatments, and post-emergence treatments above 3.2 lb/ac gave acceptable control of wild oats.

Weed Control - 1970 Trials

TABLE 2

Weed Control Scores - 1970 Trials

Treatment	Dosage lb/ac	Overall Weed Control Site 1	Site 2	Site 3	Site 4	Control of P.aviculare Site 3
Metoxuron	2.4	3.8	6.0	1.0	1.0	8.3
"	3.2	2.8	5.3	1.0	1.0	8.0
"	4.0	3.0	3.5	1.0	1.0	6.0
"	4.8	2.5	3.3	1.0	1.0	6.3
"	6.4	1.0	3.0	1.0	1.0	4.8

During 1970, only post-emergence treatments of metoxuron were evaluated at four sites; site 1 and 2 on organic soil and sites 3 and 4 on sandy soils.

No standard treatment was included in these trials, and the degree of weed control was assessed, approximately 30 days after treatments, according to the previously mentioned 1 to 9 scale.

Sites were selected where the dominant weeds were of the mayweed family, and application was made when all weeds were well established. Excellent control of Matricaria matricarioides, Tripleurospermum maritimum and Anthemis spp was obtained with 2.4 lb/ac on sandy soils and 4.0 lb/ac on organic soils (Table 2). Control of most other annual broad-leaved weeds, except P. aviculare and Veronica spp was good with 3.2 lb/ac. The resistance of P. aviculare to metoxuron was recorded at site 3. On organic soils, the residual activity of metoxuron appeared to last approximately two weeks, with seedling weeds becoming established after this time. The extent of this establishment was dependent upon the presence of sufficient soil moisture.

TABLE 3

Weed Infestation Levels

Weeds	Trial Number: 1968 Trials 1	2	3	4	5	1970 Trials 1	2	3	4	Average % weed control
C. album	+	+	+	+	+++	+	++		+++	***
Matricaria spp.	+++	+++	+++	+		+++		+++	++	***
P. aviculare	++	++		+++	+	+		+	+	*
P. persicaria			+++			+	+			***
P. convolvulus	++	+++	+		+					**
Lamium spp.						+	+++			***
G. tetrahit				+			+			***
C. segetum					+					**
Sonchus spp.		++					+			*
S. media		+++		++			++			***
Veronica spp.	+	++		+						*
C. bursa-pastoris	+									***
S. vulgaris		+		+			+	+		**
V. triclor	+	+								*
U. urens						+++				***
S. arvensis			+		+	+			++	***
L. arvensis									+	***

Degree of infestation: +++ Dense infestation > 5 plants/ft^2
+ Sparse infestation < 1 plant /ft^2

% control: *** 85 - 100%
(when 4.0 lb/ac. applied at seedling stage) ** 70 - 85%
* 70%

Crop Tolerance - 1968 Trials

TABLE 4

Crop Tolerance Scores - 1968 Trials

Treatments	Dosage lb/ac.	Trial Number 1		2	3	4	5
Pre-emergence							
Metoxuron	1.2	3.4		1.0	-	-	-
"	1.6	2.8		1.0	-	2.8	2.2
"	2.4	4.0		1.0	4.1	3.4	2.2
"	3.2	-		-	-	4.0	2.2
"	4.0	4.5		3.4	6.1	-	-
"	4.8	-		-	-	6.1	2.2
"	6.4	-		-	8.0	-	-
Linuron	0.5	-		3.0	3.8	-	1.0
"	0.75	4.6		-	-	4.2	-
Post-emergence							
Metoxuron	1.6	3.0	-*	2.8	3.8	2.4	-
"	2.4	2.8	3.4	-	3.8	2.8	4.1
"	3.2	-	-	3.8	3.4	3.2	4.1
"	4.0	4.2	2.8	-	4.9	-	4.0
"	4.8	-	-	6.5	-	3.2	-
"	6.4	-	-	7.6	5.0	3.4	4.5

* Sprayed late post-emergence when weeds 3-6 inches high.

Severe phytotoxicity was detected where metoxuron was applied pre-emergence at 4.0 lb/ac, and above at site 3 and 4 (Table 4). At both sites the soil was very light and porous. On the sandy loam soils (sites 1 and 2) the tolerance to metoxuron was acceptable at dosage rates below 4.0 lb/ac, although some chlorosis was recorded at site 1. On organic soil (site 5) crop tolerance was much greater.

Generally the tolerance of carrots to pre- and post-emergence applications of metoxuron was similar. Phytotoxicity and crop thinning was most severe at dosage rates above 4.0 lb/ac applied post-emergence and was unacceptable at sites 2 and 3. Phytotoxicity at site 2 was severe at 4.8 and 6.4 lb/ac because of the association of application at the cotyledon stage of growth and light soil. This is confirmed at site 1 (a similar soil type to site 2) where later application when carrots had developed 6 true leaves caused negligible phytotoxicity at 4.0 lb/ac.

Although the post-emergence treatments appear to have caused a depression in crop vigour at site 5 in comparison with the pre-emergence treatments, this depression was caused by weed competition prior to spraying and was not the result of phytotoxicity.

Crop Tolerance - 1970 Trials

TABLE 5

Crop Tolerance Scores - 1970 Trials

Treatment	Dosage lb/ac.	Site 1	Site 2	Site 3
Metoxuron	2.4	2.3	1.8	3.3
"	3.2	2.5	2.5	3.5
"	4.0	2.3	3.3	4.0
"	4.8	3.3	2.8	3.8
"	6.4	3.3	3.3	4.3

Slight phytotoxicity was detected where 4.0 lb/ac was applied at site 3, which was a very light (blow) sand, otherwise the tolerance of carrots was found to be very satisfactory (Table 5). No assessments were made at site 4, because weed competition prior to treatment had severely depressed the growth of the carrots.

The tolerance of a large number of carrot varieties was examined at two sites in 1970, and there appeared to be no difference in tolerance to 6.4 lb and 8.0 lb/ac. applied at the 2-6 leaf stage of growth.

Yield Data - 1968 Trials

TABLE 6

Treatment	Dosage lb/ac.	Relative Yield – Trial Number: 1		2	5
Pre-emergence					
Metoxuron	1.2	119		76	-
"	1.6	121		97	222
"	2.4	127		104	221
"	3.2	-		-	229
"	4.0	104		104	-
"	4.8	-		-	221
Linuron	0.5	-		100	100
"	0.75	100		-	-
Post-emergence					
Metoxuron	1.6	116	-*	111	-
"	2.4	124	110	-	210
"	3.2	-	-	115	218
"	4.0	110	126	-	229
"	4.8	-	-	79	-
"	6.4	-	-	69	-
LSD P = 0.05		22.1		26.4	29.5

* Late post-emergence.

Yields from plots treated with metoxuron are quoted as a percentage of the yield from plots treated with linuron at each site. A sample area of 30 feet of single row was harvested in each plot.

The majority of the treatments with metoxuron produced superior yields to linuron treatments, and a large yield response was obtained at site 5 because the pre-emergence treatment with linuron did not control the dense infestation of C. album. The phytotoxicity detected by visual assessment of the post-emergence treatments 4.8 and 6.4 lb/ac, at site 2, is supported by the yield depression recorded for these treatments. Pre-emergence treatment with 1.2 and 1.6 lb/ac metoxuron did not produce acceptable weed control at site 2 and this is confirmed by yield data. Supplementary hand weeding was necessary in some plots, but this was not done until the weed population had terminated its main effect upon crop yield.

DISCUSSION

Metoxuron between 2.4 and 4.0 lb/ac was found to produce acceptable control of most annual broad-leaved weeds in carrots when applied either pre- or post-emergence. The higher dosage rate was necessary on organic soils. Post-emergence treatments proved to be highly effective for the control of Matricaria spp., Tripleurospermum maritimum and Anthemis spp., and was confirmed by numerous commercial sprayings during 1970.

Phytotoxicity was detected where dosage rates of 4.0 lb/ac and over were applied pre-emergence or at the cotyledon stage of growth on light sandy soils. The same dosage rate, however, applied after the carrots had produced two true leaves was not found to produce phytotoxicity.

ACKNOWLEDGMENTS

The authors wish to thank all members of staff who have assisted in the field trials and preparation of this report, together with the farmers who kindly co-operated.

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EVALUATION OF HERBICIDES IN CARROTS AND CELERY

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Summary Trials were carried out in carrots and celery on fen peat at Lullymore in 1967 and on Houghton muck at the Experimental Muck Farm, Michigan State University in 1968. The major weed species at the Lullymore site were Senecio vulgaris, Stellaria media, Chenopodium album and Poa annua. Portulaca oleraceae and Stellaria media were the principal weed species on the site at Michigan. At both sites the most effective weed control in carrots was obtained with pre-emergence plus post-emergence applications of linuron at 1.0 lb + 1.0 lb/ac, prometryne at 1.0 lb + 1.0 lb/ac or linuron at 1.0 lb + prometryne at 1.0 lb/ac.

In celery, two post-planting applications of linuron at 1.0 lb/ac or prometryne at 1.0 lb/ac controlled all weed species effectively and twice normal doses of these herbicides applied at Michigan had no adverse effect on the crop. Chlorbromuron applied at 2.0 lb/ac at Michigan and at 1.5 lb/ac at Lullymore gave good weed control.

INTRODUCTION

In Ireland there is an increasing awareness of the suitability of peat soil for the production of carrots, celery and other crops. However, more frequent weed flushes, accompanied by the remarkably rapid weed growth compared to mineral soil, particularly during the summer months, makes chemical weed control more necessary. Normally cultivation is not of great benefit because of the ease with which re-rooting can occur on peat soil.

The highly adsorbtive characteristics of peat soils, resulting in problems with soil acting herbicides, are well known. High doses of herbicide are required for good weed control. With the expansion in the acreage of carrots and celery being produced on peat soil there is an urgent need for a safe, effective weed control programme for these crops.

METHOD AND MATERIALS

Trials were sited on fen peat at Lullymore in 1967 and on Houghton muck at Michigan State University Experimental Muck Farm in 1968. The site at Lullymore had a pH of 5.0, a cation exchange capacity of 225 me/100 g and a 94% organic matter content.

At Michigan soil pH was approximately 6.4. The organic matter content varied from 80 - 89% and the cation exchange capacity was 182 me/100 g. A randomised block design was used in both trials. Treatments were replicated four times in the carrot trial and three times in the celery trial. Herbicides were applied at both sites with a pressure retaining sprayer, using a volume of 40 gal/ac at Lullymore and 36 gal/ac at Michigan. All doses are given as lb/ac a.i. In all trials assessments of weed growth and crop damage were made at least twice during the growing season. Weed density was assessed by counts from three ft^2 quadrats thrown at random in each plot.

RESULTS

Carrot trial, Lullymore, 1967

Pre-emergence herbicides were applied one day before the crop emerged. Post-emergence herbicides were applied at the two true leaf stage of the crop. At this time weeds in the untreated plots were in the 1 - 2 leaf stage but eight weeks after emergence the crop was totally eliminated due to weed competition (Table 1).

All treatments except linuron at 1.0 lb + 1.0 lb/ac, linuron at 1.0 lb + methiuron at 2.0 lb/ac and linuron at 1.0 lb + prometryne at 1.0 lb/ac caused crop injury. Linuron at 2.0 lb/ac applied post-emergence, methiuron at 4.0 lb/ac post-emergence and methiuron at 2.0 lb + 2.0 lb/ac were the most injurious. In plots treated with linuron at 2.0 lb/ac the crop recovered rapidly. Injury caused by methiuron at 2.0 lb + 2.0 lb/ac and methiuron at 4.0 lb/ac persisted for 11 weeks but yields were not significantly reduced with either treatment.

Table 1

Effects of treatments on crop and weeds. Carrot (c.v. Regulus, drilled May 10 1967)

Treatments	Time of application 1* lb/ac	2* lb/ac	Assessments August 24 Crop	Weeds	Yield tons/ac	% weed kill Poa annua	Chenopodium album
Linuron	1.0	1.0	9.0	9.8	15.5	71	86
Prometryne	1.0	1.0	8.3	8.5	16.9	0	97
Linuron + prometryne	1.0	1.0	8.8	8.7	19.1	50	91
Linuron + methiuron	1.0	2.0	9.0	8.7	19.1	69	99
Methiuron	2.0	2.0	7.8	9.5	18.8	85	94
Linuron		2.0	9.3	9.3	21.3	56	98
Methiuron		4.0	7.3	9.8	18.6	67	96
Untreated			0.0	0.0		0	0
S.E. of treatment mean (df=21)					5.4		
Weeds/10ft^2 in control plots						15	16

1* - applied one day prior to emergence, 2* - applied at the 2 true leaf stage

Rating scales: Crop : 0(complete kill) - 10 (no damage)

Weeds : 0(dense cover of weeds) - 10 (no weeds)

Plots sprayed pre-emergence were weed-free when post-emergence herbicides were applied. In untreated plots the principal weeds, Poa annua and Chenopodium album were in the 1 - 2 leaf stage. Of the post-emergence sprays linuron at 2.0 lb/ac showed the most rapid contact action, giving complete weed kill and weed emergence did not recur for 11 weeks. The activity of methiuron 4.0 lb was slower but compared favourably with other treatments eventually. Linuron at 1.0 lb + 1.0 lb/ac and linuron at 1.0 lb + prometryne at 1.0 lb/ac gave good weed control but prometryne at 1.0 lb + 1.0 lb/ac gave poor control of Poa annua. All treatments gave good control of Chenopodium album.

Carrot trial. Michigan, 1968

All herbicides applied in this trial showed excellent crop selectivity and there was no significant difference in yield between any treatment. Pre-emergence treatments were applied five day after sowing to a weed-free soil. Linuron at 1.0 lb/ac and prometryne at 1.0 lb/ac gave effective weed control. Chlorbromuron at 1.0 lb/ac provided satisfactory weed control but weeds emerged one week after application of nitrofen at 6.0 lb/ac.

Post emergence herbicides were applied three weeks after pre-emergence application. Heavy rainfall which occurred immediately prior to post-emergence treatment encouraged weed growth throughout the whole experiment. All treatments except chloroxuron at 3.0 lb/ac provided excellent initial weed control. Liquid and powder formulations of nitrofen showed poor residual activi - weeds emerged three weeks after application of this herbicide at 6.0 lb/ac. Application of linuron at 1.0 lb + prometryne at 1.0 lb/ac, linuron at 1.0 lb + 1.0 lb/ac and prometryne at 1.0 lb + 1.0 lb/ac gave the most effective control. Satisfactory control was provided by chlorbromuron at 1.0 lb + 1.0 lb/ac and linuron at 1.0 lb + chlorbromuron at 1.0 lb/ac. Results are given in Table 2.

Table 2

Effect of herbicide treatments on crop and weed growth. Carrots 1968

Treatment	Time of application 1* lb/ac	2* lb/ac	Yield ton/ac	Assessments Crop	Weeds	No. weeds /yd2
Linuron	1.0	1.0	12.7	8.3	9.3	4
Linuron + nitrofen (liquid)	1.0	6.0	15.6	9.5	9.0	13
Linuron + chloroxuron	1.0	3.0	13.9	9.0	7.0	16
Linuron + chlorbromuron	1.0	1.0	12.0	8.3	9.3	8
Linuron + prometryne	1.0	1.0	12.1	8.5	9.0	2
Chlorbromuron	1.0	1.0	13.7	8.8	9.0	6
Prometryne	1.0	1.0	13.0	8.5	9.0	4
Nitrofen (powder)	6.0	6.0	16.1	8.5	8.5	20
S.E. of treatment mean (df=21)			2.4			

1* - pre-emergence application. 2* - application at the 2 leaf stage.
Rating scale as in Table 1.

Celery herbicide trial, Lullymore 1967

Single applications of herbicides were applied two weeks after planting when the celery (c.v. Lathom Blanching) was established and before weeds had germinated. Split applications were applied two weeks after planting and two weeks later. Weeds were in the 2 - 3 true leaf stage four weeks after the crop was planted. All herbicides were selective except methiuron 2.0 lb/ac, which caused complete crop kill (Table 3). Untreated plots were handweeded once only, five weeks after planting. Weed competition, which occurred in these plots prior to and after weeding, caused a considerable reduction in crop yield compared to those treated with herbicides.

The principal weed species in the trial were Poa annua and Stellaria media. Senecio vulgaris and Chenopodium album were also present in fewer numbers. Prometryne at 1.0 lb + 1.0 lb/ac was the most effective treatment against Stellaria media. Poa annua showed some resistance to linuron at 0.5 lb + 0.5 lb/ac. Of all the treatments applied, linuron at 1.0 lb + 1.0 lb/ac and prometryne at 1.0 lb + 1.0 lb/ac gave the best overall weed control.

Celery herbicide trial, Michigan 1968

No weeds were present when pre-emergence herbicides were applied. The crop (c.v. Utah 527) was highly tolerant to all treatments. Single post-planting applications of linuron at 2.0 lb, prometryne at 2.0 lb, chlorbromuron at 2.0 lb and nitrofen at 6.0 lb/ac gave excellent weed control for six weeks. Chlorbromuron at 1.0 lb and linuron at 1.0 lb/ac gave good weed control, but the residual effects of these treatments lasted only four weeks. Prometryne at 1.0 lb/ac was satisfactory but only gave short lived weed control. Chloroxuron at 6.0 lb/ac gave poor results and weeds were more advanced compared to other treatments when the second post-planting sprays were being applied.

Of the repeated post-planting applications, linuron at 1.0 lb and 2.0 lb, prometryne at 2.0 lb and chlorbromuron at 2.0 lb/ac gave the best weed control and plots were weed free for 6 weeks after application. Nitrofen at 6.0 lb/ac caused severe defoliation and scorch of weeds. Prometryne at 1.0 lb and chloroxuron at 6.0 lb/ac gave satisfactory control and the few weeds which survived these treatments were never vigorous enough to cause competition. Although chlorbromuron at 1.0 lb/ac did not kill weeds outright, it checked them sufficiently to prevent any adverse effects to the crop. Results are given in Table 4.

Table 3

Effects of herbicides on crop and weeds. Celery (c.v. Lathom Blanching, planted June 9 1967)

Treatment	Time of application 1* lb/ac	2* lb/ac	Yield ton/ac	Assessments 8 August Crop	Weeds	No. of P. annua/15ft^2	Wt. of S. media/15ft^2 (g)
Linuron	1.0	1.0	53.9	9.0	9.3	13	297
Prometryne	1.0	1.0	54.5	9.8	9.3	10	84
Linuron	0.5	0.5	51.3	9.3	8.3	18	336
Linuron	2.0		46.1	9.5	6.8	5	213
Prometryne	3.0		54.6	10.0	8.8	9	412
Methiuron	2.0	2.0	00.0	0.0	10.0	12	409
Chlorbromuron	1.5	1.5	55.3	9.5	8.5	11	366
Control			24.5	8.3	9.5	4	847
S.E. of treatment mean (df=21)			3.6			2.9	72.4

1* - applied two weeks after planting. *2 - applied four weeks after planting.
Rating scale as in Table 1.

Table 4

Effects of herbicide treatment on crop and weeds. Celery (c.v. Utah 527, planted May 14 1968)

Treatment	Time of application 1* lb/ac	2* lb/ac	Yield ton/ac	No. of weed/yd^2 July 26	September 5
Handweeding			23.5	-	16
Nitrofen	6.0	6.0	28.3	5	11
Chloroxuron	6.0	6.0	29.3	6	7
Chlorbromuron	1.0	1.0	25.3	11	9
Chlorbromuron	2.0	2.0	29.8	-	10
Prometryne	1.0	1.0	27.6	4	6
Prometryne	2.0	2.0	27.9	-	7
Linuron	1.0	1.0	25.3	-	11
Linuron	2.0	2.0	28.2	-	6
S.E. of treatment mean (df=23)			2.7		

1* - applied 2 weeks after planting. 2* - applied 6 weeks after planting.

DISCUSSION

The results of this series of experiments show that carrots and celery were reasonably tolerant to most of the chemicals applied. Higher doses were necessary for good weed control on peat as compared to mineral soil, but yields of neither crop were significantly reduced with twice normal applications of linuron or prometryne - results which are in agreement with those of Allott and Uprichard 1966.

Linuron at all doses gave good weed control in carrots. There was little difference in effectiveness between a post-emergence application of linuron at 2.0 lb/ac and a pre- plus post-emergence application of this herbicide at 1.0 + 1.0 lb/ac, but the latter treatment was slightly more selective.

Carrots were slightly less tolerant to prometryne than linuron in the Lullymore trials. Prometryne gave satisfactory control of a wide spectrum of weed species at both sites. Only Poa annua showed resistance to this herbicide. Chlorbromuron at 1.0 lb/ac also gave good weed control and showed good selectivity. Methiuron gave very effective weed control but although carrot yield was not reduced the check in growth following application suggests that the margin of safety with this herbicide is not great. Pre- and post-emergence application of nitrofen at 6.0 lb/ac gave good initial weed control but the residual activity was poor and Stellaria media was completely resistant.

The most effective of the combined pre-and post-emergence treatments were linuron at 1.0 lb + 1.0 lb/ac and linuron at 1.0 lb + prometryne at 1.0 lb/ac. Linuron at 1.0 lb + chlorbromuron at 1.0 lb/ac or methiuron at 2.0 lb/ac also gave satisfactory control. Where linuron at 1.0 lb/ac was followed by nitrofen at 6.0 lb/ac or chloroxuron at 3.0 lb/ac poor weed control resulted.

None of the herbicides had any adverse effect on celery except methiuron which caused complete crop kill. At Lullymore, linuron and prometryne gave the most promising results. The 1.0 lb/ac dose of both these herbicides applied two weeks after planting and repeated two weeks later gave more prolonged weed control than single, twice normal applications applied two weeks after planting. Prometryne at 1.0 lb + 1.0 lb/ac gave better control of Stellaria media than the linuron treatments. Chlorbromuron also gave satisfactory weed control.

At Michigan, linuron, prometryne and chlorbromuron gave good control of all annual weeds present. Chlorbromuron at 2.0 lb/ac provided slightly less residual activity than linuron or prometryne but was more persistent than chloroxuron at 6.0 lb/ac. Nitrofen showed good contact effects except on Stellaria media but the residual activity of this material was relatively short lived.

Acknowledgements

Grateful thanks are due to Mr. J. Courtney for technical assistance at Lullymore and Daniel Hess for technical assistance at M.S.U. Sincere thanks are also due to Mr. J. C. Cassidy, Kinsealy and Dr. Alan Putnam, M.S.U. for their advice in planning and carrying out these trials.

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POST-EMERGENCE HERBICIDES FOR ONIONS

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Summary As part of a weed control programme for onions, trials were carried out in New Zealand during 1968-70 to develop safe post-emergence treatments to follow early applications of residual chemicals already in use.

Applications were made to the crop at several growth stages. Methabenzthiazuron at 24 oz/ac did not affect vigour. Aziprotryne at 24 oz/ac, ioxynil at 8 oz/ac and linuron, prometryne and terbutryne each at 6 oz/ac caused an initial slight check from which the crops quickly recovered. Differences in yield between these treatments were slight and generally not significant.

INTRODUCTION

Reliable weed control can be obtained in onion seedbeds with propachlor, chlorbufam/pyrazon, paraquat and diquat. At best, such treatments are fairly short-lived and there has been a need for other chemicals to provide continued weed control after crop emergence. The work reported here has confirmed the safety of several new treatments which have since been recommended to growers (Cox, 1970).

METHODS AND MATERIALS

Details of the five trials reported are given in Table 1.

The trials were situated on silt loam soils at Levin and at Bulls and used the cultivars Pukekohe Long Keeper and Rangitikei Red, respectively. Plots were twenty foot long and contained 4 or 6 rows drilled at 15 or 12 in. spacing in six replicates with the exceptions of Expt. Y503 which consisted of single row plots and Expt. Y547 which contained three replicates. In Expt. Y677 the plots were split after the early spray treatments so that repeat treatment applications could be made to sub-plots at the bulbing stage.

Some information was gained on weed control (see Table 2) but the experiments were primarily intended to investigate crop tolerance. They were weeded before significant competition occurred and then maintained weed-free as far as possible.

A propane-powered sprayer was used to apply chemicals at 30 gal/ac or, in Expt. Y547, at 20 gal/ac.

Table 1

Details of treatments

Expt. No. Location	Y503 Levin	Y547 Levin	Y677 Levin	Y702 Bulls	Y701 Bulls
Date sown	14/2/68	22/11/68	15/9/69	15/9/69	15/9/69
No. of days from sowing (a) to spraying (b)	41 74	53	63 95	43	64
Growth stage (a) at spraying (b)	3 true leaf 4 true leaf	3½ true leaf	3 true leaf bulbing	1½ true leaf	3 true leaf
Chemical doses, oz/ac a.i.					
Linuron	6, 9,12	6	6	6	6
Methabenzthiazuron		24,48*	24,36	24,36	24,36
Prometryne	6, 9,12	6	6	6	6
Terbutryne		6,12	6	6	6
Aziprotryne			24,36	24,36	24,36
Cypromid	8,12,16	12,24			
Ioxynil octanoate		8,12,16	8,12	8,12	8,12

*This treatment unreliable due to spraying trouble

Table 2

Susceptibility of the most common weed species in Expts. Y677, Y701, Y702 to treatments applied (i) just before and (ii) after emergence

S = susceptible I = intermediate effect R = resistant

Treatment	Dose (oz/ac)	*Fumaria muralis* (i)	*Fumaria muralis* (ii)	*Polygonum persicaria* (ii)	*Chenopodium album* (i)	*Chenopodium album* (ii)	*Amaranthus retroflexus* (i)	*Amaranthus retroflexus* (ii)	*Coronopus didymus* (ii)
Linuron	6	R	R	I	I	S	I	S	I
Methabenz-thiazuron	24	-	I	I	R	S	I	I	I
Methabenz-thiazuron	36	-	-	S	I	S	S	-	S
Prometryne	6	-	S	I	R	I	R	I	I
Terbutryne	6	-	S	I	I	S	R	I	S
Aziprotryne	24	-	I	R	I	S	R	I	R
Aziprotryne	36	-	S	I	S	S	R	I	R
Ioxynil	8	-	S	S	I	S	R	I	S
Ioxynil	12	-	S	S	I	S	R	I	S

Crop injury was assessed from vigour scores and yields of mature bulbs.

RESULTS

Expt. Y503. This experiment was carried out late in the season when slower growing conditions prevailed. Detailed leaf measurements made two weeks after treatment failed to show any consistent differences in growth. Observations made two months after the 3 true leaf spraying and one month after the 4 true leaf spraying showed effects as follows:-

	3 true leaf spraying	4 true leaf spraying
Linuron	Slight growth check at 12 oz/ac	No effect noted
Prometryne	Slight growth check at 12 oz/ac	Slight leaf scorch at 9 and 12 oz/ac
Cypromid	Slight growth check at 8, 12 and 16 oz/ac	No effect noted

At the 4 true leaf stage spraying damage caused by prometryne treatments occurred mainly on the surfaces of the less erect leaves.

Expt. Y547. Damage symptoms began to appear one week after treatment with the yellowing and straggled effect of ioxynil at 16 oz/ac. Later assessments are summarised in Table 3. The effects of terbutryne, cypromid and ioxynil treatments were evident. Scorch caused by the lower doses of terbutryne (6 oz/ac) and ioxynil (8 oz/ac) largely disappeared during the following two weeks.

An accurate yield assessment was not possible as an attack of downy mildew (*Perenospora destructor*) spread through the crop but it was clear that cypromid at 24 oz/ac had severely reduced yields.

Table 3

Expt. Y547. Treatment effects assessed (a) 9 and (b) 21 days after spraying, in order of severity

Means of 3 scores, range 10=full vigour to 3=severe damage (0=plants killed)

Treatment, dose(oz/ac)		(a) Score	Comment	(b) Score	Comment
Untreated		10.0		10.0	
Methabenzthiazuron	24	10.0		10.0	
*(Methabenzthiazuron	48	9.7		9.7)	
Linuron	6	8.7	Slight tip scorch	9.7	
Prometryne	6	8.0	" " "	9.3	
Terbutryne	6	7.7	Tip scorch	9.3	
Ioxynil	8	7.0	Slight scorch chlorosis	8.7	Some tip scorch
Cypromid	12	6.0	Tip scorch	8.7	Tip scorch
Terbutryne	12	5.7	Leaf scorch	8.0	Tip scorch
Ioxynil	12	5.7)	Scorch, chlorotic	7.3)	Tip scorch chlorotic
Ioxynil	16	3.7)	straggling	6.7)	straggling
Cypromid	24	3.0	Severe scorch	6.0	Tip scorch

*This treatment unreliable due to spraying troubles.

Expts. Y677, Y701, Y702. Similar chemical treatments were applied but at various growth stages of the crop (Table 1). The effects caused were minor and transient. Crop vigour after spraying was most closely observed in Expt. Y677 and the amount of damage which developed at the onion 3 true leaf stage and, again, at bulbing stage 4½ weeks later is shown in Table 4.

Table 4

Expt. Y677. Treatment effects assessed after spraying in order of severity

Means of 6 scores, range 10 (full vigour) to 7 (some damage) (see text)

9 days after spraying at 3 true leaves Treatment, dose (oz/ac)	Score	12 days after repeat spraying at bulbing Treatment, dose (oz/ac)	Score
Control	9.8	Control	9.3
Methabenzthiazuron 24	9.5	Methabenzthiazuron 24	9.1
Prometryne 6	9.3	Prometryne 6; linuron 6	9.0
Terbutryne 6; aziprotryne 24, 36	8.8	Aziprotryne 24	8.8
Linuron 6; methabenzthiazuron 36	8.6	Ioxynil 8; methabenzthiazuron 36	8.6
Ioxynil 8	7.6	Aziprotryne 36; terbutryne 6	8.5
Ioxynil 12	7.0	Ioxynil 12	7.6

Damage symptoms shown by all chemicals except ioxynil followed a similar pattern ranging in severity from chlorosis to slight scorch mainly of the leaf tips. Ioxynil caused a characteristic straggling of the onions with some chlorosis of the younger leaves. On a theoretical scoring scale ranging from 0 (death) to 10 (full vigour) readings above 6 were obtained. Final plant populations were recorded at maturity and statistical analysis of the figures obtained from all three trials (coefficients of variation ranging from 9.3 to 13.6%) indicated that no treatment caused plant mortality.

Yields are given in Table 5. Within experiments there were no statistical differences between chemical treatments. The tendency for chemical treatments to give higher yields than controls (Expt. Y677, Y701) reflects the difficulties experienced in effectively hand weeding the crop.

DISCUSSION

These trials were primarily concerned with crop tolerance. After treatments which had caused an unacceptable level of foliar damage (Expt. Y547) were eliminated there remained several which caused little effect when applied early post-emergence or at bulbing (Expts. Y677, Y701, Y702). The straggled appearance of the crop following ioxynil treatments did not persist and was less marked at the later growth stage.

Yields from four trials confirmed that methabenzthiazuron at 24 oz/ac, aziprotryne at 24 oz/ac and ioxynil at 8 oz/ac may be recommended for post-emergence application to onions. Aziprotryne had less foliar activity

Table 5

Expts. Y677, Y701, Y702 Onion yields (tons/ac)

Treatment	Dose (oz/ac)	1- t.l. Expt. Y702	3-3½ t.l. Expt.Y701	3 t.l. Expt.Y677	3 t.l. repeated at bulbing Expt.Y677
Linuron	6	10.2a*	12.2ab	18.2a	16.2a
Methabenz-thiazuron	24	11.0a	12.0ab	17.7ab	17.0a
Methabenz-thiazuron	36	10.9a	12.7a	16.5ab	16.2a
Prometryne	6	12.0a	11.8ab	16.5ab	16.7a
Terbutryne	6	12.3a	10.9bc	17.4ab	15.8a
Aziprotryne	24	10.6a	11.7ab	17.2ab	17.7a
Aziprotryne	36	12.7a	12.7a	17.7a	16.1a
Ioxynil	8	10.7a	12.4ab	17.5ab	16.9a
Ioxynil	12	11.1a	11.9ab	17.5ab	17.1a
Control		11.6a	9.5c	14.9b	12.7b
C.V.%		18.9	10.9	12.6	9.0

*Duncan's test for significance. Figures in the same column without a letter in common differ at P = 0.05

than methabenzthiazuron and may be useful when weeds are small. Ioxynil will probably be of greatest value later in the season against larger weeds. Linuron and prometryne, already in commercial use, are sufficiently selective at 6 oz/ac; terbutryne may provide a useful alternative.

All of the chemicals used in these trials are broad-leaved weedkillers and will be of little use where a severe grass weed problem occurs. Such weeds as Echinochloa crus-galli and Digitaria sanguinalis are of increasing importance in onion growing areas and future herbicide testing should take account of this problem.

An indication of the importance of efficient chemical weed control in onions is provided by the fact that the best efforts to produce weed-free controls still resulted in yields lower than herbicide treatments in three of the trials.

Acknowledgments

Thanks are expressed to Miss R.M. Kerr and Miss L.M. Thomas for technical assistance, to Biometrics Section of the Department of Agriculture for statistical analyses and to the growers in Bulls who co-operated.

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