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USE OF TERBACIL, ATRAZINE AND OTHER HERBICIDES IN BUSH ROSE PRODUCTION

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Summary In an attempt to assess alternatives to simazine it was compared with four other herbicides, terbacil, atrazine, propachlor and aziprotryne. All gave satisfactory weed control except the last two which failed to control cruciferous weeds.

INTRODUCTION

Simazine has been widely adopted in commerce for the control of weeds in roses but it has no contact action on seedlings, and will not control perennial weeds. The object of this experiment was to compare simazine with four other herbicides applied at the same time and under similar conditions. The herbicides used were propachlor, aziprotryne, atrazine and terbacil. Atrazine was known to control some germinated seedlings. Terbacil controls Agropyron repens and some other perennial weeds in addition to the annual weeds present in this experiment. To obtain information on the stage of weed susceptibility, atrazine was applied at a weed height of 2 in. and 4 in. in addition to its pre-emergence application.

METHOD AND MATERIALS

The experiment was carried out at Shardlow Hall, Shardlow, Derby during 1970 and 1971. The soil is a sandy loam overlaying river gravel. During the winter of 1969-70, 25 tons of farmyard manure was applied to the site. The herbicide programme adopted was as follows:

1	After planting the rootstocks	24. 4. 70.
2	After budding	4. 8. 70.
3	After heading back	11. 3. 71.

Eight treatments were applied as follows:

A	Atrazine	1.5 lb per acre	
B	Atrazine	1.5 lb per acre	(when weed was 2 in. high)
C	Atrazine	1.5 lb per acre	(when weed was 4 in. high)
D	Aziprotryne	2.0 lb per acre	
E	Propachlor	3.9 lb per acre	
F	Simazine	1.5 lb per acre	
G	Terbacil	1.6 lb per acre	
H	Terbacil	2.4 lb per acre	

It will be seen that treatments B and C were delayed. Atrazine was applied at the same rate as the normal treatment, the main difference being that the weed on plot B was allowed to grow till it averaged approximately 2 in. high and on plot C a similar weed growth was allowed, but delayed even further till the weed was approximately 4 in. high.

Three rootstocks were used:- Rosa multiflora, Rosa canina var. inermis, Rosa dumetorum var. laxa. One cultivar, Ama, was common to all treatments and rootstocks.

The layout was single plots, each 15 ft x 11 ft, containing 4 rows of 20 plants in each row. The results are based on record made on the 2 middle rows of each plot.

RESULTS

Year 1 (1970)

Observations were made on the rootstocks during the first year. Terbacil caused vein clearing in R. multiflora, which was more obvious at the higher rate of application (treatment H). Other rootstocks showed no symptoms. The delayed atrazine treatments B and C caused severe leaf scorch and leaf fall in R. multiflora and slight chlorotic areas in R. canina var. inermis and R. dumetorum var. laxa. All symptoms of damage had disappeared by the end of the season.

Year 2 (1971) Maiden Year

The percentage "blow outs" i.e. the shoot from the bud breaking off, which occurred during 1971 were recorded and are shown in Table 1.

Table 1

Percentage "Blow Outs"

Rosa dumetorum var. laxa	0.0
Rosa canina var. inermis	2.6
Rosa multiflora	7.6

The number of "blow outs" were not apparently affected by the herbicide treatments. There did, however, seem to be a marked link between number of "blow outs" and the rootstock used and this is relevant in table 2 below.

Table 2

Treatments	R. multiflora		R. canina var. inermis		R. dumetorum var. laxa	
	Survival %	Mean Weight Oz	Survival %	Mean Weight Oz	Survival %	Mean Weight Oz
A	82.5	3.5	95.0	11.9	100.0	12.3
B	92.5	9.6	89.5	12.2	9[illegible].5	12.7
C	95.0	[illegible].7	100.0	11.2	97.5	10.1
D	67.0	10.4	80.0	11.6	100.0	11.2
E	72.5	10.7	85.0	12.4	100.0	12.5
F	87.0	13.7	87.5	13.1	100.0	11.6
G	75.0	11.2	[illegible]7.5	11.6	100.0	11.0
H	85.0	10.1	92.5	10.2	100.0	11.1

Table 3

Percentage bushes in each grade, 15 October 1971

Treat-ments	R. multiflora				R. canina var. inermis				R. dumetorum var. laxa			
	I	II	III	Fail	I	II	III	Fail	I	II	III	Fail
A	57.5	20.0	15.0	17.5	77.5	7.5	10.0	5.0	67.5	25.0	7.5	0
B	62.5	15.0	15.0	7.5	67.5	15.0	5.0	12.5	67.5	20.0	5.0	7.5
C	62.5	20.0	12.5	5.0	77.5	17.5	5.0	0	70.0	15.0	2.5	2.5
D	57.5	0	10.0	32.5	55.0	15.0	10.0	20.0	87.5	12.5	0	0
E	50.0	10.0	12.5	27.5	70.0	7.5	7.5	15.0	75.0	22.5	2.5	0
F	72.5	10.0	5.0	12.5	75.0	12.5	0	12.5	72.5	25.0	2.5	0
G	60.0	7.5	7.5	25.0	77.5	10.0	0	12.5	70.0	22.5	7.5	0
H	67.5	12.5	5.0	15.0	82.5	2.5	7.5	7.5	90.0	10.0	0	0

Grade I 3 or more shoots at least 15 in. long.
Grade II 2 to 3 shoots at least 15 in. long.
Grade III others
Fail "Blow outs" etc.

DISCUSSION

There was no marked difference in weight of bushes which could be attributed to the treatments applied; the difference which is more pronounced on R. multiflora is partly accounted for by the higher rate of losses due to blown-out shoots during 1971. There was, however, evidence of terbacil and atrazine damage occurring on the cultivar budded on to R. multiflora. This took the form of severe chlorosis and vein clearing where terbacil was used at the highest rate (treatment H). Severe bronzing occurred where atrazine application was delayed (treatments B and C).

Weed control was satisfactory throughout, except for the cruciferous weeds and Poa annua, which grew on areas D and E, where aziprotryne and propachlor were used. Atrazine in each of the treatments A, B and C was an effective contact herbicide. Small weeds were more easily killed than the more mature seedlings.

Caution

Terbacil is a persistent material. It does not appear to affect the growth of roses but, successional crops of barley, ryegrass, lettuce and Acer plantanoides have been severely damaged or killed by soil residues of terbacil, more than a year after the last application.

In view of a common practice among rose growers to include this crop among others in a farm rotation, extreme caution should be exercised when deciding on a herbicide programme.

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WEED CONTROL FOR CONTAINER-GROWN ORNAMENTALS

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Summary Dichlobenil impregnated discs did little to control weeds. Herbicides sprays were more effective than applications of granules. Spraying with simazine, diuron and chloroxuron gave the best weed control. Pronamide and trifluralin had little effect. Mulching with peat to a depth of one inch was unsuccessful in controlling weeds one year but gave a considerable reduction in 1972. A peat mulch incorporating simazine was successful although high rates of simazine were necessary where liverwort (**Marchantia polymorpha**) was involved.

Overhead irrigation compared with sub-irrigation encouraged weed growth, particularly liverwort.

Propachlor granules applied in sand were not successful in controlling weeds but simazine or lenacil granules similarly applied were much more effective.

Senecio greyi was damaged or killed by directed sprays of simazine 1.5 lb a.i./ac or higher. 1.25 lb a.i./ac simazine in a mulch or mixed with sand was safe.

INTRODUCTION

Hand weedings is expensive and frequently involves handling individual containers. Where the containers are standing on sub-irrigated sand beds, removal for weeding interferes with water uptake capillarity.

Residual herbicides could eliminate hand weeding but the high organic content of the growing medium, the wide range of ornamental plants grown and the different watering systems utilised, all contribute towards the problems encountered.

The investigations described aim to provide information on plant tolerance and to provide adequate weed control by chemical means. Ultimately, the nurseryman must try out the more promising treatments on his particular range of plants as no experimental programme can cover the thousands of different ornamental plants grown commercially. This account is a progress report of results to date.

METHODS AND MATERIALS

The plants in the experiment at Efford Experimental Horticultural Station are growing in a peat/sand substrate.

Efford I 1971

Subjects: Ilex aquifolium, x Cupressocyparis leylandii and Pyracantha atalantioides

Treatments

1. Control
2. peat mulch 1 in. depth
3. 1 in. peat + 7½% dichlobenil granules 4 lb a.i./ac
4. 1 in. peat + 50% simazine at 25 lb a.i./ac
5. 1 in. peat + 50% simazine at 50 lb a.i./ac
6. discs impregnated with dichlobenil 3 lb a.i./ac

The herbicides were mixed with fine sand to achieve even distribution within the peat mulch. The containers were standing on sub-irrigated sand beds.

Efford II 1972

Subjects: Berberis x stenophylla, Deutzia scabra, Choisya ternata, Thuja occidentalis, Pyracantha coccinea, x Cupressocyparis leylandii.

Treatments

1. Control
2. peat mulch 1 in. depth
3. 1 in. peat + 50% simazine at 1.25 lb a.i./ac
4. 1 in. peat + 50% simazine at 5.0 lb a.i./ac
5. 1 in. peat + 50% simazine at 10.0 lb a.i./ac
6. 1 in. peat + 50% simazine at 20.0 lb a.i./ac
7. 1 in. peat + 2% simazine granules at 1.25 lb a.i./ac
8. 2% simazine granules 1.25 lb a.i./ac mixed with sand and sprinkled on surface of substrate.

Two watering systems were employed; sub-irrigation and overhead irrigation.

Efford III 1972

Subject: Ilex 2 yr. old potted-on in April 1972

Treatments

1. Control
2. peat mulch 1 in. depth
   Spray treatments at rate of 100 gal/ac
3. 50% chloroxuron at 2.1 lb a.i./ac
4. 80% diuron at 2.0 lb a.i./ac
5. 50% pronamide at 1.25 lb a.i./ac
6. 50% simazine at 1.56 lb a.i./ac
7. trifluralin at 1.00 lb a.i./ac
8. 80% lenacil at 1.66 lb a.i./ac
9. 1 in. peat + 50% simazine at 20.0 lb a.i./ac. Granules mixed with sand and sprinkled on surface of substrate
10. 7½% dichlobenil at 7.5 lb a.i./ac
11. 5% propachlor at 8.0 lb a.i./ac
12. 2% simazine at 2.0 lb a.i./ac
13. 2% lenacil at 2.0 lb a.i./ac

The containers were standing on a sand bed irrigated by seephose tube.

Efford IV 1972

Subject: Senecio greyi

Treatments

1. 1 in. peat + 50% simazine at 1.25 lb a.i./ac
2. 1 in. peat + 50% simazine at 5.0 lb a.i./ac
3. 1 in. peat + 50% simazine at 10.0 lb a.i./ac
4. 1 in. peat + 50% simazine at 20.0 lb a.i./ac
5. spray treatment 50% simazine at 1.5 lb a.i./ac
6. 1 in. peat + 2% simazine granules at 1.25 lb a.i./ac
7. 2% simazine granules mixed with sand and sprinkled on surface of substrate at 1.25 lb a.i./ac

Standing on sand bed sub-irrigated.

Bagshot I 1972

Trials were also carried out by John Waterer, Sons and Crips Ltd at the Nurseries, Bagshot, Surrey.

Subject: Ligustrum ovalifolium 'Aureum', Chamaecyparis lawsoniana 'Grayswood Gold', Prunus 'Kanzan', Rhododendron 'Pink Pearl', Ilex sp., Azalea No. 117, Cornus alba 'Elegantissima', Forsythia sp., Rose 'Speks Yellow', Hibiscus syriacus 'Woodbridge', x Cupressocyparis leylandii, Spiraea x arguta, Philadelphus 'Belle Etoile' and Deutzia 'Mont Rose'

Treatments

1. peat mulch 1 in. depth
2. 1 in. peat + 2% granules lenacil, at 1.25 lb a.i./ac
3. 1 in. peat + $7\frac{1}{2}$% granules dichlobenil at 5.2 lb a.i./ac
4. 1 in. peat + 5% granules trifluralin at 1.0 lb a.i./ac
5. 1 in. peat + 5% granules propachlor at 4.0 lb a.i./ac
6. 1 in. peat + 2% granules simazine at 1.25 lb a.i./ac

The plants were growing in loamless composts and in order to make room for the herbicide mulches, about $\frac{3}{4}$ in. of the original compost had to be removed. Watering was achieved by overhead irrigation.

RESULTS

Efford I 1971

Neither simazine nor dichlobenil harmed the plants. Weed control was complete with the mulches containing herbicide. A mulch of untreated peat did not control weeds. Dichlobenil impregnated discs gave practically no control. Weeds grew up through the discs as well as around the edge.

The subjects were planted out at the completion of the experiment and all grew well showing no adverse effects.

Efford II 1972

Eleven weeks after treatment no plant was showing signs of being affected by herbicide.

With the exception of liverwort (Marchantia polymorpha) the weed population was low but generally speaking, there were more in the overhead watered plots. The watering system had an even larger effect on the presence of liverwort. It was absent on the sub-irrigated plots.

Table 1

Overhead irrigation - percentage substrate surface covered by liverwort 12 weeks after treatment

Treatment (lb a.i./ac)	Liverwort % cover
Control	54.5
1 in. peat mulch	36.5
Peat mulch + simazine w.p.	
1.25	20.7
5.00	18.7
10.00	5.6
20.00	0.6
Peat mulch + granules	
1.25	26.7
Granules + sand	
1.25	19.6

Efford III 1972

No damage to the holly plants was evident.

Table 2

Main weeds present and scale of weed control

Treatment	*Salix* sp.	*Cardamine hirsuta*	*Senecio vulgaris*	Weed Control (0-10)
Control	+	+	+	0
1 in. peat		+	+	5
chloroxuron		s	s	9
diuron				10
pronamide	+	+	+	3
simazine				10
trifluralin	+	+	+	2
lenacil	+			8
peat + simazine				10
Granules + sand				
dichlobenil	+	+		7
propachlor	+	+	+	1
simazine			+	8
lenacil		+		8

s one tiny seedling of each species

Eleven weeds after treatment, simazine 1.56 lb a.i./ac, peat mulch + simazine 20.0 lb a.i./ac, and diuron 2.0 lb a.i./ac were completely free from weeds. The chloroxuron treatment was nearly as good but two tiny seedlings had appeared.

Efford IV 1972

No weeds were present eleven weeks after the treatments had been applied.

Senecio greyi was not apparently damage by 1.25 lb a.i./ac simazine applied as a wettable powder in a peat mulch, granules in a peat mulch or as granules in sand.

1.5 lb a.i./ac simazine as a directed spray caused severe mottling of the foliage. With 5.0 lb a.i./ac simazine slight mottling occurred but at 10.0 lb and 20.0 lb a.i./ac severe mottling and death was caused.

Bagshot I 1972

Of the fourteen subjects in the trial only one was showing signs of damage ten weeks after the treatments had been applied. Chamaecyparis lawsoniana 'Grayswood Gold' was seriously damaged by lenacil and propachlor granules and the plants with the simazine mulch also began to lose their colour.

As with some of the Efford plants, a layer of surface compost had to be removed to make room for the mulches and overhead irrigation was used. It is possible that the herbicides moved more rapidly into the active root zone than would otherwise have been the case.

DISCUSSION

The high rates of simazine employed in 1971 were used due to the high absorptive properties of peat but the results of the work in 1972, suggest that much lower rates will suffice. Dichlobenil discs did not prove satisfactory but it must be remembered that watering was achieved by sub-irrigation. Only rain would wet the discs.

The system of watering plays an important role in the development and control of weed seedlings. Liverwort in particular is more plentiful and vigorous where overhead irrigation is employed. Such a watering method encourages the development of liverwort on path edges and this growth provides a source of contamination. Wind-bourne seeds such as those of Salix spp. Senecio vulgaris, Epilobium spp. and Chamaenerion angustifolium frequently settle on container grown plants. Cardamine hirsuta is another very common weed. Covering the substrate surface with a plastic disc which fits around the plant stem is said to prevent weed seeds reaching the substrate. Water moves towards the plant stem and one can imagine situations where the water can also carry seed resting on the surface of the disc. Weeds growing in the sand on which the containers are standing are a source of seed. The safety of paraquat and another herbicide to control such weeds is being investigated at Efford. Some growers have used paraquat without harm to the container-grown plants. The surface of a peat mulch tends to dry out when not watered overhead and this can restrict weed germination and development.

When loamless composts or sterilised loam is employed, the major sources of weed seeds are standing ground and the surrounding area. Ephemeral weeds create a continuous problem but where wind-bourne seeds form the major worry, careful timing of herbicide application might be very important.

Liverwort is affected by simazine application but in trials in this country and abroad, chloroxuron is very effective. If overall sprays of chloroxuron are employed some plants e.g. Buddleia may be injured. Overhead irrigation can be used to wash the foliage afterwards.

Generally speaking, the granular formulations of herbicides used in these trials have not been as effective as the spray treatments. However, the summer has been dry and overhead irrigation was used in only one of the Efford trials. When applied direct to the surface of the substrate, the granules were mixed with about twenty-five times their volume of sand. To aid thorough mixing with peat, the granules were mixed with about one hundred volumes of sand.

Methods of commercial application must be considered and spraying has a distinct advantage, particularly when the containers are standing pot-thick. Alternatively, where potting machines are employed, it should be possible to fix nozzles with adjustable outputs at the end of the production line.

If applications are required later in the season, efficient spraying will be more difficult due to the cover being provided by the cultivated plant. Under these circumstances herbicide mulches can be considered but space should be left at potting time.

The trials will be extended. To date, the most promising materials appear to be simazine, diuron and chloroxuron, but further information is required on the range of plants that can be safely treated and on the effective period of the materials used.

Acknowledgements

The interest and co-operation shown by John Waterer, Sons and Crips is much appreciated. My thanks are also due to Miss M Scott and other members of staff at Efford Experimental Horticultural Station who have carried out the trials.

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THE EFFECT OF ENVIRONMENTAL FACTORS ON THE PERFORMANCE OF GLYPHOSATE AGAINST AGROPYRON REPENS

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Summary The effect of the post-spraying environment on the control of *Agropyron repens* by a new post-emergence herbicide, glyphosate, was investigated in 1) controlled environment cabinets where light, temperature and humidity were varied while other factors were held constant, 2) the glasshouse where there was some degree of control and 3) outside where there was no control of the aerial environment. Plants grown from single node rhizome fragments were sprayed at the 3-4 tiller stage with 0.05, 0.2 and 0.8 kg/ha of glyphosate and 6 weeks later shoot weight and number, rhizome weight, total nodes and sprouted nodes were recorded. Regrowth was assessed following replanting after a further 6 weeks. 0.8 kg/ha was lethal in all environments while the effectiveness of the other doses depended on the environment. Visible symptoms appeared first in the high light, temperature and humidity environments. Light level did not have a clear cut effect on ultimate survival, but low temperature and high humidity appeared to enhance glyphosate toxicity. Outside other environmental factors including wind and rain may influence herbicide performance.

INTRODUCTION

Glyphosate is a new broad spectrum post-emergence herbicide which is readily translocated in perennating organs and shows great promise for the control of *Agropyron repens* (Baird *et al*., 1971). Environmental conditions influence the activity of several foliage-applied herbicides used to control *A. repens*, e.g. the ultimate effect of paraquat is greater at 6°C than at 16°C (Caseley, 1970). Consequently it was considered pertinent to investigate the effectiveness of glyphosate against *A. repens* under contrasting environmental conditions, as this herbicide has potential in many agricultural and horticultural situations and is likely to be used throughout the year.

The object of the work reported here was to examine the effect of the post-application environment on glyphosate performance in controlled environment cabinets where light, temperature and humidity were varied while other factors were held constant; in the glasshouse, where there was some degree of control; and outside where there was no control of the aerial environment.

METHOD AND MATERIALS

Single node 2.5 cm rhizome fragments of *Agropyron repens* L. (Beauv.) clone 31 (WRO collection) were planted in a sandy loam soil from the WRO farm and grown in a glasshouse until they reached the 3-4 tiller stage. The glasshouse controls were set to give 16°C ± 5. The temperature rarely fell below this, but in warm weather often exceeded 21°C. Humidity ranged between 40-80% rh.

Uniform plants were selected and transferred outside and to Saxcil controlled environment cabinets set up to provide conditions approaching those found in the glasshouses. After 24 h aclimatization, the cabinets were gradually adjusted to give the conditions shown in Fig. 1 which fall within the range of daily means recorded at Begbroke. Daylength was set at 16 hours throughout the experiments and temperature was constant day and night except in the experiment where temperature was a variable when the night temperatures were 5°C below the day temperatures shown in Fig. 1. The amount of water in the air is expressed as %rh, but in the experiments where light and temperature were variables the %rh was adjusted to give a constant vapour pressure deficit (VPD)

$$VPD = (SVP_T - SVP_T \times \frac{rh}{100})$$

where SVP is saturated vapour pressure, rh is relative humidity and T is temperature. The glasshouse and outside environment wet and dry bulb temperatures and light intensity were integrated hourly and the weekly means are shown in Fig. 2. The half hourly rain records were taken from a Dyne's tilting rain gauge and those for the weekly means from a Standard Meteorological Office gauge. The run of wind was taken with a Standard Meteorological Office anemometer producing integrated output hourly.

Plants were transferred to and from the spray room in a closed box and returned to the cabinet immediately after application of the herbicide, to minimise the time the plants were out of their designated environments. The glyphosate was applied at 0.05, 0.2 and 0.8 kg/ha to the foliage with a laboratory pot sprayer set to deliver 352 l/ha at 2.11 kg/cm² pressure. To ensure that only the foliage was treated with herbicide the compost surface was covered with peat before spraying and the latter removed subsequently. Approximately 6 weeks after application of the herbicide the plants were harvested and the following assessments made:- 1) type of symptoms; 2) number of shoots; 3) fresh weight of shoots; 4) fresh weight of rhizomes; 5) total number of nodes; 6) number of sprouted nodes. The rhizomes were then replanted in fresh soil and grown in the glasshouse for a further 6 weeks when regrowth was assessed.

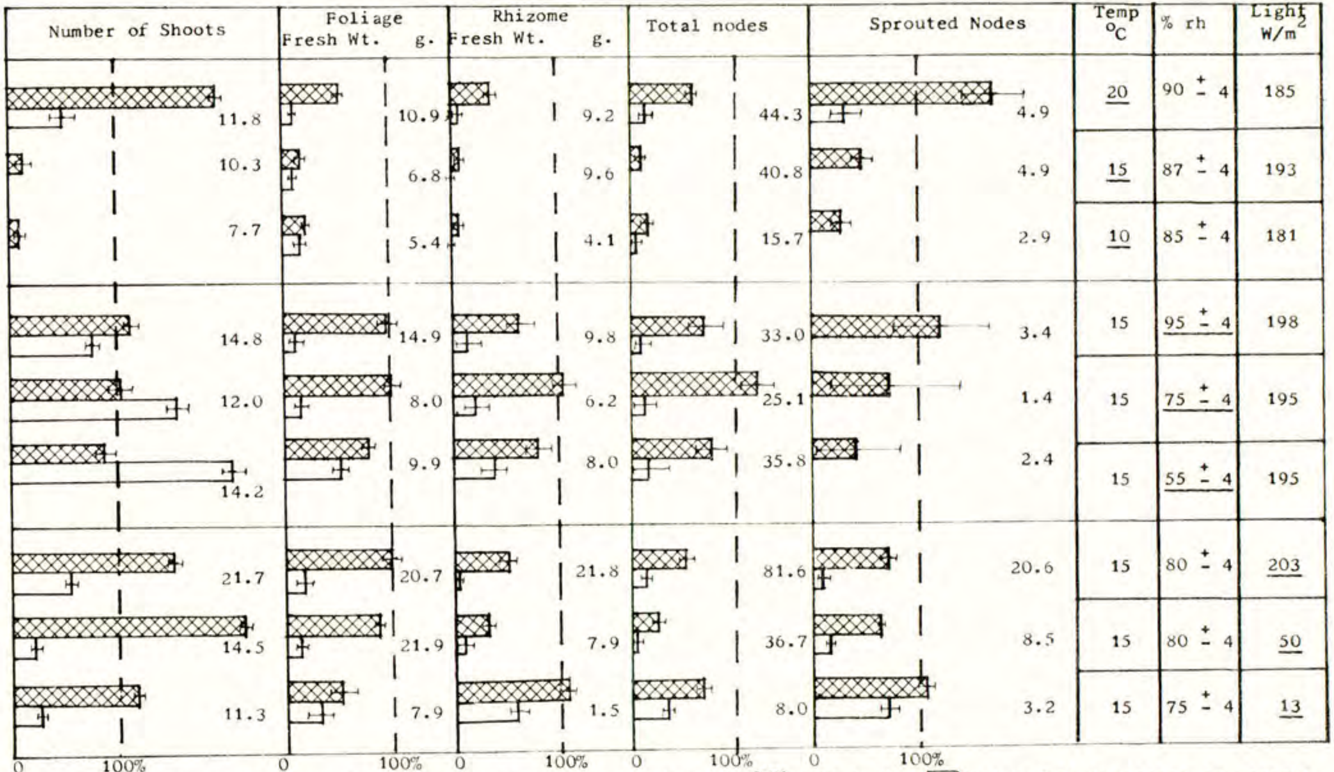
The plants in each experiment were set up in 2 randomised blocks each containing 2 replicate pots per treatment.

At the time of conducting the experiments where temperature was a variable the available formulation of glyphosate was MON 0468 (the monodimethylamine salt of N-(phosphonomethyl) glycine) and this was applied with the recommended 1% MON 0011 wetter for all doses. In the other experiments MON 1139 (the isopropyl-amine salt of N-(phosphonomethyl) glycine) with incorporated wetter was employed. This formulation was used alone in the experiment with humidity as a variable and with 0.1% Tergitol NPX added to each dose in the experiment with light level as a variable.

RESULTS

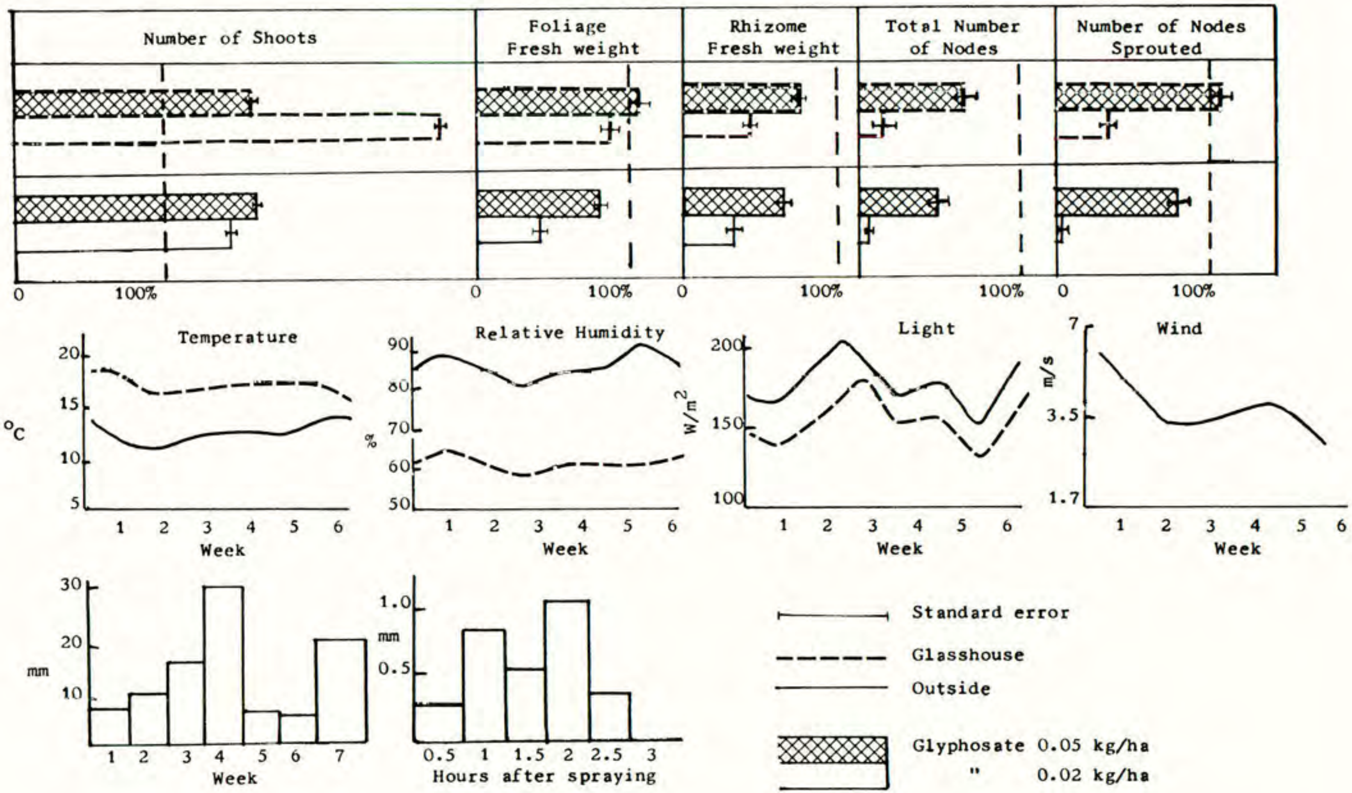
Figure 1 summarises 3 experiments conducted in controlled environment cabinets and in order to make a direct comparison between environments the results have been expressed as percent of controls. The 0.8 kg/ha dose was omitted as it was lethal in all environments within 6 weeks except at the low light level (13 W/m²) where there was a little rhizome growth and one out of four plants had two sprouted nodes, but these died during the regrowth period. In control plants shoot and rhizome production was greatest at 200 W/m² where the ratio of shoot to rhizome weight was 1:1, while at 13 W/m² it was 5:1. This is in agreement with Williams (1970) who found shading in the field reduced rhizome weight more than shoot weight. Although only a small quantity of rhizome was produced in the controls at the low light level there was a trend towards less reduction of rhizome weight and total number of nodes following treatment with 0.05 and 0.2 kg/ha of glyphosate compared with the higher

Fig. 1 The effect of light, temperature and humidity on the performance of glyphosate against *A. repens* 6 weeks after treatment (controlled environment cabinets)



The horizontal bars are means of 4 plants treated with glyphosate (▩ 0.05 kg/ha, □ 0.2 kg/ha) expressed as percent of controls (12 plants) with ⊢⊣ representing the standard error. The numbers on the right of each horizontal bar are the control means for each environment, the variable environmental parameter in each experiment is underlined.

Fig. 2 The performance of glyphosate on *A. repens* 6 weeks after treatment in glasshouse and outside environment



The horizontal bars are the means of 4 plants for treatments expressed as percent of controls (12 plants) and the standard error for each mean shown as horizontal line within the base.

light levels.

The trend with temperature is more readily discernible and as the temperature was raised the performance of glyphosate fell. This trend was still evident at the time of the regrowth assessment, e.g. the plants treated with 0.05 kg/ha glyphosate from the 20/15°C environment had a mean of 14 shoots while of those from the 10/5°C cabinet, two were dead and two had one small shoot each. The trend with humidity is less clear cut, but at the 0.2 kg/ha dose number of shoots and foliage and rhizome fresh weights were depressed most at high humidity.

The glasshouse and outside data are from an experiment sprayed on 23/5/72 and harvested between 4 and 5/7/72; regrowth after re-planting was assessed 17/8/72. The glasshouse plants were the most vigorous and tended to recover from the treatments better than the outside plants e.g. at the regrowth assessment they had a mean of 15 shoots following treatment with 0.2 kg/ha glyphosate compared with a mean of 5 shoots on the outside plants.

In all environments the 0.8 kg/ha dose stopped growth and the plants died slowly. At the lower doses cessation of growth of the existing shoots was often accompanied by prolific sprouting even from nodes on aerial shoots. The leaves were diminutive, misshapen and sometimes partially chlorotic. In the environments conducive to activity of glyphosate these shoots made little growth and died while in conditions favouring regrowth successive leaves were increasingly normal and new shoots eventually resembled those of the controls.

DISCUSSION

In each of the cabinet experiments the formulation of glyphosate was changed and the pre-spraying environment of the plants was different due to seasonal affects in the glasshouse. Thus comparisons can be safely made between levels of the same parameter, but caution should be exercised in comparing levels of control between the three experiments and in comparing the relative importance of light, temperature and humidity. In Fig. 1 and 2 the control values for the parameters recorded in each environment have been included to assist in the assessment of the relative importance of the effect of environment on the plant alone compared with the plant plus glyphosate.

In general the results indicate that glyphosate activity is influenced by all the environmental parameters investigated.

The least conclusive factor was light. At the low level visible cessation of growth and yellowing of the foliage appeared in about 10 days compared with 6 days at the high light level. The data in Fig. 1 show that at 13 W/m^2, shoot number and weight were depressed to about the same extent as at the higher light levels, bearing in mind the smaller size of the plant. In contrast the reduction of rhizome weight and number of nodes was poor compared to the higher light levels especially when the size of the control rhizomes are considered.

It would appear that low light levels lead to a delay in the manifestation of visible damage in the foliage and in toxic acitivty in the rhizome. The latter could possibly be attributed to the fact that there was little movement of photosynthates from the foliage to the rhizome. At the regrowth assessment, after 6 weeks in the glasshouse, the high and low light level plants had mean shoot numbers of 2.7 and 2.3 respectively at the 0.2 kg/ha dose. Thus in this experiment an initial delay in toxicity at the low light level did not affect the performance of glyphosate at the final assessment.

In the experiment where humidity was a variable the 0.05 kg/ha dose had very little effect on any of the parameters and this may possibly be attributed to the fact that additional wetter was not included in this experiment. At the 0.2 kg/ha dose shoot number and weight, and to a lesser extent rhizome weight, are depressed most at the high humidity. Enhanced glyphosate activity in this environment may well be associated with a fully hydrated cuticle and slow drying of spray droplets facilitating uptake. At the regrowth assessment the low humidity plants had twice the mean number of shoots as those from the high humidity (30 and 15 respectively).

Baird and Begeman (1972) mention that MON 0468 was less effective at 32°C than at 16°C which is in accord with the results presented here. Possible factors contributing to the reduced activity of glyphosate at the high temperature include more rapid drying of the spray droplet resulting in reduced uptake, vigorous growth of the plant leading to dilution of the herbicide within the plant and high levels of biochemical activity leading to rapid detoxification.

Bearing in mind the trends in glyphosate activity established in the controlled environment cabinets (low temperature and high humidity improve performance) it is interesting to examine the glasshouse and outside results shown in Fig. 2.

In neither environment was light level likely to be a limiting factor. The temperature outside was about 4°C lower than in the glasshouse and this factor could have contributed to the higher activity of glyphosate outside. The humidity outside was high especially immediately after spraying due to a very light rain (about 1 mm in the first hour). Although Baird and Begeman (1972) found rainfall within 8 hours reduced glyphosate activity, the amount presumably has to be sufficient to wash off the chemical. The quantities that fell following herbicide application in this experiment (Fig. 2) could have enhanced hydration of the cuticle and distribution of the herbicide over the plant thus improving uptake. A further outside environmental factor which may have influenced these results was wind. Gusts of up to 7.6 m/s (17 m.p.h.) were recorded at a nearby meteorological station just before and after spraying. As the plants, until 48 hours before, had been grown in the glasshouse the foliage was soft and was consequently partially flattened and had to be supported with wire during spraying. It might be expected that this would damage the plant surface and this combined with the subsequent light rain would improve uptake. The glasshouse plants on the other hand were not exposed to wind damage and light rain. Furthermore they remained in the environment in which they were raised and were not subjected to the stress of changing environments which would probably improve their chances of recovery.

It would appear that the trends in herbicide performance in relation to environmental factors established in controlled environment cabinets can be useful in interpreting glasshouse and outside results. However, the tentativeness of this discussion indicates the lack of information in this area and further studies are in progress at WRO to clarify some aspects with special attention to variation of environmental factors around the time of spraying.

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ARTEFACTS IN CONTROLLED ENVIRONMENT STUDIES

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Summary Experiments have been carried out in controlled environment cabinets with ioxynil and bromoxynil salts and esters and three weed species. In the case of the salts in particular, it has been found that efficacy is very greatly reduced in the cabinets compared with greenhouse or outdoor environments. Investigations have been carried out to determine the reason for this reduction in efficacy, which appears to be connected largely with the turbulent air flow system used to control cabinet temperature. A similar effect was produced in the greenhouse by using a fan to blow air over the plants at approximately 1.5 m sec^{-1}. Some improvement was obtained by frequently re-wetting the leaves of sprayed plants in the cabinets, using a hand atomiser.

INTRODUCTION

Studies on the effect of environment on the activity of ioxynil and bromoxynil were initiated in 1967 (Savory, 1968) with greenhouse and outdoor pot experiments. These have subsequently been continued and expanded to include experiments in controlled environment cabinets. In the course of this work it has gradually become apparent that important discrepancies were occurring between results of controlled environment experiments on the one hand, and results from greenhouse, outdoor pot and field experiments on the other. Over 20 experiments have been conducted during the past 15 months to discover the reason for these discrepancies, and these are described in this paper.

MATERIALS AND METHODS

1. Plant Material

The species used were *Tripleurospermum maritimum* ssp. *inodorum* (scentless mayweed), *Polygonum lapathifolium* (pale persicaria) and *Stellaria media* (chickweed). Seedlings were pricked out 3 per 9 cm clay pot, and sprayed at the 8 leaf, 4 leaf and 14 leaf + side-shoots stages respectively. There were 5 or 6 replicate pots per treatment in experiments involving several herbicide rates, and 30 replicate pots in single-rate experiments. Fresh weights were recorded 10-14 days after spraying, and ED 90 values calculated from log dose/probability graphs.

2. Environments

(a) Four controlled environment cabinets were used, Fisons Type CM 94 PG. Temperature and relative humidity settings are specified in the Tables of results. A 16 hour photoperiod and 8 hour nyctoperiod, was used throughout. Cabinets were maintained at 400 vpm CO_2, and plants were stood on capillary-watering trays in the upper half of the cabinets.

(b) The cabinet environment was compared with greenhouse conditions in some experiments. Typical conditions are shown in Table 1; supplementary lighting was used from August to April to give a 16 hour photoperiod; temperature and radiation levels in summer would be higher and more variable.

Table 1

Mean greenhouse environmental conditions, Experiments 11 and 12

		Experiment 11	Experiment 12
Radiation (cals cm^{-2} hr^{-1})	A*	10.2	9.4
	B	-	-
Dry bulb temperature (°C)	A	21.1	19.8
	B	12.7	13.1
Relative humidity (%)	A	60	59
	B	81	73

* A = photoperiod (16 hours), B = nyctoperiod (8 hours). This notation will be used throughout.

(c) Experimental treatments were used in some cases (see Results). Briefly, these were (i) re-wetting of foliage post-spraying, effected with a hand atomiser; (ii) provision of wind in the greenhouse, effected by placing a 30 cm fan near the plants. This gave a wind speed of 1.5 m sec^{-1} measured by a Sheppard sensitive anemometer, very similar to the value recorded by the same instrument placed near the middle of a Fison's cabinet; (iii) addition of infra-red radiation to the spectrum in the cabinets, effected by putting a tungsten bulb in the growing chamber. Radiation levels (Table 2) were measured with a Kipp solarimeter; estimates of radiation in the visible range were obtained by replacing the outer dome of the solarimeter with a hemispherical flask containing about 2 l distilled water to absorb the infra-red radiation. This method proved satisfactory for 1-2 hours, until the water warmed up.

Table 2

Visible and total radiation in greenhouse and controlled environment cabinets (cals cm^{-2} hr^{-1})

Source of Radiation	Total Radiation	Estimated radiation in visible range
Greenhouse (lamps only)	7.6	2.8
Fison's Cabinet	7.2	6.8
Fison's Cabinet plus tungsten bulb	22.6	8.6

3. Chemicals

Solutions of ioxynil-Na and bromoxynil-K salts, and emulsions of ioxynil and bromoxynil octanoates, were applied at 20 gal/acre spray volume by a laboratory sprayer, and plants returned to their environments within 30 minutes of spraying.

RESULTS

Table 3

Mayweed: Preliminary experiments (Nos. 5-8) in environmental cabinets; effect of regimes on efficacy of ioxynil and bromoxynil

Regime				ED 90 (oz/acre)			
Temperature (°C)		Rel. Humidity (%)		Ioxynil Na salt	Bromoxynil K salt	Ioxynil octanoate	Bromoxynil octanoate
A*	B	A	B				
25	20	60	60	>48	>48	24	3
25	20	90	90	4	22	6	1.5
15	12	90	90	40	24	40	3

* A = photoperiod, B = nyctoperiod in all tables (see Methods)

Table 4

Mayweed: Effect of supplementary treatments on efficacy of bromoxynil salt (Experiment Nos. 9-13) and octanoate (Experiment No. 14)

Location	Supplementary treatment	ED 90 (oz/acre) Expt 9	Expt 10	Expt 11	Expt 12	Expt 13	Expt 14
1. Environmental cabinets:	i) None	>32	>32	>32	>32	>32	6
	ii) 'B' humidity = 95%			12		10	3
Temperature A=20°, B=15°	iii) Tungsten lamp			>32			
Rel. humidity A=70%, B=70%	iv) Low light (approx. 40% of normal)				30		
	v) Rewetting twice each day	10	20				
except where specified	vi) Rewetting hourly each day				5		
2. Greenhouse (for conditions see Table 1)	i) None	2	3	2	6	3	2
	ii) Wind from fan				16	16	4

Table 5

Mayweed: Effect of variations in relative humidity in environmental cabinets on efficacy of bromoxynil salt (Experiment Nos. 15 and 17)

Regime				ED 90 (oz/acre)	
Temperature (°C)		Relative Humidity (%)		Experiment 15	Experiment 17
A	B	A	B		
20	15	65	65	32	>48
20	15	65	95	12	>48
20	15	80	95	12	38
20	15	95	95	16	8

Table 6

Pale persicaria and chickweed: Efficacy of bromoxynil and ioxynil salts (respectively) in environmental cabinets and greenhouse (Experiment Nos. 25 and 26)

Regime				ED 90 (oz/acre)	
Temperature (°C)		Relative Humidity (%)		Pale Persicaria Bromoxynil K-salt (Expt 25)	Chickweed Ioxynil Na-salt (Expt 26)
A	B	A	B		
1. Cabinets					
20	15	60	80	>24	≫32
20	15	60	95	20	>32
20	15	90	95	5	>32
2. Greenhouse					
i) No supplementary treatment				2.5	8
ii) Plus wind from fan				6	22

DISCUSSION

Originally, it had been hoped to identify the major climatic variables affecting the efficacy of ioxynil and bromoxynil formulations by means of multiple regression analysis of series of outdoor pot experiments (Savory, 1968; and unpublished data), and then to examine interactions more closely in controlled environments. It soon became clear, however, that many results obtained in environmental cabinets were quite unrealistic compared with those from outdoor pot experiments and normal field usage. In Table 3, only the results for bromoxynil octanoate, and for ioxynil under warm, humid conditions, are at all credible.

It was therefore decided to compare the results to be obtained for mayweed/bromoxynil salt in the cabinets with greenhouse results in the same experiments, using plants from a single batch on each occasion, and all sprayed at the same time. The only variables would be the environments in which the plants were placed after spraying. Results are shown in Table 4 (some have been omitted for the sake of simplicity). The standard regime for the cabinets was chosen to be as close as possible to average greenhouse conditions in temperature and humidity (cf. Table 1), but nevertheless in five experiments the greenhouse ED 90 for bromoxynil salt fell between 2 and 6 oz/acre, while in the cabinets 32 oz/acre did not cause 90% reduction in fresh weight. Neither reduction of light intensity nor the addition of infra-red radiation to the spectrum affected efficacy appreciably in the cabinets. Increasing the humidity in the nyctoperiod, or rewetting the leaves of the sprayed plants both increased efficacy considerably, though not to greenhouse levels unless the rewetting was done hourly.

One factor that cannot be altered in the cabinets, without losing control of temperature and humidity, is the turbulent cross-flow of air. Therefore we attempted to provide similar conditions in the greenhouse by means of a fan adjusted to give roughly the same wind speed over the plants - a wind speed sufficient to cause noticeable shaking of the plants. Though the method was crude, it was surprisingly effective, reducing efficacy on every occasion by a factor of about 2-3 (cf. Table 6 for results with pale persicaria and chickweed also). Bromoxynil octanoate in one experiment showed the same trends as the salt, but to a very much smaller degree: this agrees with outdoor results.

We went on to see whether, by maintaining a high 'night' humidity, we could obtain a realistic result and at the same time determine the effect of varying the 'day' humidity (known from previous work to be an important variable in outdoor experiments). Two repeat experiments (Table 5) gave almost opposite results with mayweed, and the prospects looked equally unhopeful for pale persicaria and chickweed (Table 6).

Detailed results of a number of other experiments have been omitted due to lack of space, but two points should be mentioned. Firstly, several factorial experiments in which the position of the shelf (with its load of capillary-watered plants) within the cabinets was altered and CO_2 was supplied or withheld, did not yield results significantly different from those with the standard method. Secondly, it had been noted that, with the airflow from left to right across the cabinets, the plants in the right-hand side used more water than those on the left. Over nine experiments with mayweed, it was found that about 30% more water was needed to replenish the right-hand capillary trays than for the left-hand trays, and similar results have been obtained for the other two species. This led us to set up experiments in which all 30 pots in a cabinet were sprayed with a single herbicide dose: when the correct dose was achieved, there was a very marked decrease in susceptibility at the right-hand side, with smaller decreases along the front and back edges. Photographs of these positional differences are available. Similarly, in the greenhouse the plants subjected to the effect of the fan used more water than those without the fan - in this case nearly twice as much. These increases in water use cannot be ascribed solely to decreased plant mortality, as they were recorded within three days of spraying, before the onset of any phytotoxic symptoms.

CONCLUSIONS

Experiments with bromoxynil and ioxynil have shown that it is impossible to simulate normal field and outdoor pot results in cabinets with high airflow rates, particularly when using aqueous salt formulations, except possibly by rewetting the leaves frequently after spraying: this point requires further investigation. The artificially high resistance of plants in the cabinets to these herbicides does not appear to be connected with CO_2 levels, light quality or intensity, or position of the shelf within the cabinets. However, there is a marked lateral variability in susceptibility within the cabinets which appears to be connected with wind speed and transpiration rates. Analogous results have been consistently obtained in the greenhouse, using a fan to produce an artificial airflow. It will be of interest to measure stomatal apertures under cabinet and greenhouse conditions, and to test other herbicides in these cabinets.

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SOME INCREASES IN EFFICACY OF FOLIAGE APPLIED HERBICIDAL SALTS DUE TO ADDITION OF AMMONIUM IONS

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Summary In pot experiments several ammonium salts were synergists when added to foliage applied water soluble herbicides. Certain rates of ammonium sulphate and nitrate increased picloram phytotoxicity in dwarf bean (*Phaseolus vulgaris* L.). Ammonium nitrate enhanced the effects of MCPA salt in willow (*Salix fragilis* L.) and poplar (X *populus gelrica* Ait.) and increased the contact activity of mecoprop salt on privet (*Ligustrum ovalifolium* Hassk.) and *Rhododendron ponticum* L. Some rates of ammonium nitrate, sulphate, citrate and chloride were synergistic when applied in mixture with picloram to guava (*Psidium guajava* L.) Ammonium sulphate was the most active of these additives. Mixtures of ammonium nitrate with esters of MCPA or mecoprop were not synergistic. The mode of action of the additives is uncertain but their effects are probably not due to changes in the pH of spray solutions or to enhancement of herbicide movement through the epidermis.

INTRODUCTION

Increased phytotoxicity following the addition of ammonium ions to foliage applied herbicide sprays has been reported on several occasions, for example with DNOC (Crafts and Reiber, 1945), endothal (Tischler *et al.*, 1951), dinitrophenols (Simon, 1953), 2,4-D (Al'tergot, 1962; Fullilove, 1968) and 2,4,5-T (Brady, 1970). The present paper described experiments designed to investigate these interactions further and to evaluate the effects of ammonium salts and some other nitrogenous compounds on certain other herbicides, particularly those used for controlling trees and shrubs. The work is part of a wider research project in which several possible methods of increasing herbicidal activity in woody species are being examined.

METHOD AND MATERIALS

(a) Experiments with dwarf bean

Preliminary trials with dwarf bean used a technique which has been described previously (Turner, 1972). Briefly, solutions of picloram salt, an additive and mixtures of both compounds were sprayed onto the unifoliate leaves of 2-week old plants whose first trifoliate leaves were just starting to unfold. The soil surface and young growth above the unifoliate leaves were shielded from the spray. Plants were kept in a greenhouse for 14-16 days, when the end result of herbicide uptake and translocation was assessed by weighing new growth. Experiments of this type were carried out with ammonium nitrate, ammonium sulphate, ammonium thiocyanate and also urea. The last compound was tested because of its reported effect on ion penetration through cuticles (Yamada *et al.*, 1965). Ammonium thiocyanate was included in view of its known properties as an "activator" with aminotriazole (Amchem Products, Inc., 1959).

(b) Experiments with woody species

Pot-grown plants of privet (Ligustrum ovalifolium Hassk.), poplar (X Populus gelrica Ait.), willow (Salix fragilis L.), guava (Psidium guajava L.) and Rhododendron ponticum L. were used. The temperate species were planted during the winter and were sprayed in summer when the plants were in full leaf and were 0.5-0.9 m tall. Willow and poplar were grown from cuttings while privet and Rhododendron were transplanted from a nursery. Guava plants were raised from seed in the greenhouse, transplanted to 15 cm pots and sprayed at 6 months from germination when 0.2-0.3 m tall.

Many experiments were of a factorial type, usually with 2-3 levels of herbicide, 4-6 levels of an additive and 4-8 replications. In one trial with privet 3-way mixtures of picloram, ammonium nitrate and tributyl phosphate were examined. The latter compound is known to have synergistic effects in mixture with picloram salt (Turner, 1972). Spray solutions were applied with a large cabinet sprayer, at volume rates of 148-352 l/ha. The doses of herbicide used were intended to injure but not kill the test plants. Analytical quality ammonium salt additives were used. A wetting agent (0.25% v/v Agral 90) was added to all spray solutions. The soil beneath woody species was covered with dry powdered peat during spraying to prevent root uptake and the plants were kept under cover for 24 h after treatment. The peat layer was then removed and the foliage was washed in a strong stream of water. During this process the soil was shielded from herbicides with a sheet of plastic film

Picloram and ammonium nitrate were introduced into the vascular tissue of guava plants using a method devised by Little and Blackman (1963) and employed previously for other studies with this species (Turner and Loader, 1971).

Leaf injury was assessed either by estimating the area of living leaf as a percentage of the area present on untreated controls or, at the conclusion of experiments, by weighing the leaf present on treated and control plants. In guava new growth following picloram treatment which was easily distinguishable from older foliage present at spraying, was removed and weighed at the conclusion of experiments. Regrowth produced by the temperate species was weighed in the season following treatment.

For simplicity, statistical analysis of data expressed in terms of percentages has been carried out using the original untransformed values.

RESULTS

(a) Experiments with dwarf bean

The results of four experiments each with one additive are summarised in Table 1. The nitrogen compounds had no appreciable effects when applied alone at 0.05 or 0.25 kg/ha: weights of regrowth following these treatments are not presented.

(b) Experiments with woody species

The effects of ammonium nitrate and urea on picloram activity were examined in experiments with privet and guava. With privet, 1 kg/ha picloram had no visible effect either alone or with the additives. In guava, urea slightly reduced the effects of picloram. However in this species mixtures of ammonium nitrate with picloram salt were synergistic (Table 2), phytotoxicity being significantly increased by 1-20 kg/ha of the additive. In the absence of picloram ammonium nitrate was inactive at rates of up to 20 kg/ha.

Table 1

Effects of 4 additives on phytotoxicity of picloram to dwarf bean. Weights of regrowth at 15-18 days as % of untreated control

	No picloram			Picloram 0.5 g/ha (as K-salt)					
Rate of additive, kg/ha	1.0	2.5	S.E.	0	.05	.25	1.0	2.5	S.E.
Ammonium nitrate	87	87	± 8.4	14	17	8	4	5	± 2.8
Ammonium sulphate	89	93	± 5.3	21	8	9	8	20	± 5.8
Ammonium thiocyanate	16	7	± 6.7	35	35	27	9	3	± 6.4
Urea	102	89	± 7.7	9	6	6	6	5	± 1.3

Table 2

Effect of ammonium nitrate-picloram mixtures on guava

Treatment (kg/ha a.i.)		Mean weight of new growth (g)
Picloram (as K-salt)	Ammonium nitrate	at 35 days
0.5	0	9.2
0.5	1	3.7
0.5	2.5	1.4
0.5	5	2.2
0.5	10	0.9
0.5	20	0.5
		SE ± 1.22

Table 3

Effect of ammonium nitrate-MCPA mixtures on willow and poplar

Treatment (kg/ha)		Willow		Poplar	
Amm. nitrate	MCPA as salt(S) or ester (E)	% leaf injury at 13 days	Mean wt. (g) of regrowth at 11 months*	% leaf injury at 27 days	Mean wt. (g) of regrowth at 11 months*
0	0	5	57 (5)	11	19 (5)
5	0	8	55 (5)	9	19 (5)
10	0	8	60 (5)	13	16 (5)
20	0	21	62 (5)	16	19 (5)
0	1S	80	3 (2)	25	5 (5)
5	1S	92	0 (0)	100	0 (0)
10	1S	92	0 (0)	100	0 (0)
20	1S	92	0 (1)	98	0 (0)
0	1E	65	2 (2)	93	0 (0)
5	1E	84	1 (1)	97	0 (0)
10	1E	83	0 (0)	92	0 (0)
20	1E	77	3 (4)	96	0 (0)
		SE ± 3.9	± 1.1	± 3.2	± 1.2

* Numbers of living plants out of 5 in parenthesis

Following this result, mixtures of ammonium nitrate with salts or esters of other growth regulator herbicides were tested. Added ammonium nitrate considerably increased the contact effects of mecoprop salt on privet but had no effect on regrowth. Mixtures with a mecoprop ester were antagonistic. Similar results were obtained with Rhododendron. However, mixtures of MCPA salt with ammonium nitrate applied to willow and poplar were synergistic, as assessed both by leaf injury following treatment and by regrowth in the following season (Table 3).

The effects of other ammonium salts and nitrates on picloram activity were examined in experiments with guava. Sodium nitrate was inactive while mixtures with calcium nitrate were obviously antagonistic. However several ammonium salts were synergistic (Table 4). In this experiment rates of additive were designed to supply ammonium ions equivalent to 2.5 kg/ha or 10 kg/ha ammonium nitrate. The lower rates were usually more effective, the most marked interaction being with ammonium sulphate. These effects were probably not due to changes in the pH of the spray solution which were small except in the case of ammonium citrate (Table 4). No additive had any effect in the absence of picloram.

A factorial experiment with guava tested 5 levels each of picloram and ammonium sulphate. Almost no new growth was present when the experiment was terminated at 53 days. Table 5 shows weights of living leaf at this time.

Table 4

Effect of ammonium salt-picloram mixtures on guava

Additive treatments (kg/ha)	Picloram 0.5 kg/ha		Picloram 1 kg/ha	
	pH of sol-ution	Mean wt. (g) of new growth at 58 days	pH of sol-ution	Mean wt. (g) of new growth at 58 days
No additive	5.9	10.6	6.2	8.8
Amm. nitrate 2.5	6.0	6.9	6.1	2.4
" " 10	5.7	7.5	5.9	4.4
Amm. sulphate 2.5	6.1	1.1	5.7	2.9
" " 10	5.8	2.3	5.6	3.7
Amm. chloride 2.5	5.9	10.3	5.5	3.4
" " 10	5.7	8.4	5.5	3.5
Amm. citrate 2.5	6.8	3.3	6.7	3.7
" " 10	6.7	6.7	6.5	3.0

S.E. new growth weights (all comparisons) $\pm$ 1.54

Table 5

Effect of ammonium sulphate-picloram mixtures on guava
Weights of living leaf at 53 days

Picloram, kg/ha (as K-salt)	Ammonium sulphate kg/ha Nil	4.1	8.2	12.4	16.5	Mean
Nil	56.0	53.5	55.1	53.9	54.2	54.2
0.75	22.0	11.5	13.1	10.7	12.3	13.9
1.50	17.2	7.1	6.0	8.8	15.5	9.1
2.25	11.9	11.4	5.7	2.2	1.7	6.6
3.00	14.5	4.1	4.4	2.1	0.3	5.1
			S.E. $\pm$ 3.12			$\pm$ 1.40

Some effects of 3-way mixtures of picloram salt, emulsified tributyl phosphate and ammonium nitrate are shown in Table 6. There was no relationship between contact effects and weights of leaves at 10 months. Picloram alone or with either additive separately was inactive but some mixtures of all three chemicals significantly reduced leaf weights.

The results of introducing picloram salt and ammonium nitrate into the vascular tissues of guava are not given in detail. 4 μg of picloram injected into the midrib of a young but fully expanded leaf reduced new growth by about 35%. When 20 μg or 80 μg ammonium nitrate was introduced with picloram phytotoxicity was unchanged.

Some effects of separate and mixed spray applications of picloram and ammonium sulphate are given in Table 7. All picloram treatments were applied simultaneously and all plants were washed 24 h later. This washing was additional to washing after pretreatment with ammonium sulphate (Treatment 2).

Table 6

Effects of ammonium nitrate-tributyl phosphate-picloram mixtures on privet

Additive treatment (kg/ha)		No picloram		Picloram 2 kg/ha	
Ammonium nitrate	Tributyl phosphate	% leaf injury (1 day)	Leaf weight (g) (10 months)	% leaf injury (1 day)	Leaf weight (g) (10 months)
0	0	0	93	0	86
2.5	0	0	103	0	103
5	0	0	95	0	91
0	2.5	18	96	10	98
2.5	2.5	24	100	14	51
5	2.5	24	100	15	66
0	5	43	109	40	93
2.5	5	46	107	44	73
5	5	51	113	37	41

S.E. leaf weights at 10 months (all comparisons) ± 8.9
S.E. % leaf injury at 1 day (all comparisons) ± 2.7

Table 7

Effects of ammonium sulphate and picloram on guava

Ammonium sulphate treatment	Mean wt. (g) of new growth at 69 days: Picloram 0.5 kg/ha	Picloram 2 kg/ha
1. No ammonium sulphate	7.5	2.3
2. 5 kg/ha 24 h before picloram, foliage washed 1 h before applying picloram	1.4	0.0
3. 5 kg/ha 24 h before picloram, foliage not washed as in (2)	0.5	0.2
4. 5 kg/ha in mixed spray with picloram	1.1	0.5
5. 5 kg/ha 24 h after picloram, after washing foliage	2.7	1.3

S.E. (all comparisons) ± 0.90

DISCUSSION

From the present studies and from previous work it appears that ammonium salts may increase the phytotoxic effects of several types of water soluble herbicide. In the present study not all mixtures with water soluble herbicides were synergistic but none were antagonistic, even where large doses of ammonium salts were added. The 20 kg/ha doses of ammonium salts applied in some experiments involved w/v concentrations of about 20%. By contrast with other synergists such as tributyl phosphate (Turner, 1972) there appears to be little risk of reducing herbicidal activity through overdosage. Further trials with other herbicides and a wider range of species seem warranted. As potential additives most ammonium salts are cheap, very soluble in water and of low mammalian toxicity.

Interactions between picloram and ammonium salts do not appear to have been reported previously. These were often very marked, for example in one experiment only 1 kg/ha ammonium nitrate reduced the regrowth of picloram treated guava plants by over 60% (Table 2). The use of this herbicide is at present limited by its cost and persistence in soil: increased activity obtained by using additives such as ammonium sulphate may reduce the dosage necessary for effective weed control and so enable picloram to be used more widely.

In the present experiments mixtures of ammonium nitrate with MCPA or mecoprop esters were not synergistic (Table 3). However other workers have increased the phytotoxicity of growth regulator esters by adding ammonium salts (Al'tergot, 1962; Brady, 1970). These apparently contradictory effects cannot be explained but there is an obvious similarity between the present work and previous studies with organophosphorus additives (Turner, 1972). Both types of additive may be synergistic with salts of growth regulator herbicides but have not been found to interact in this way with ester formulations. It is hoped to carry out further experiments with a wider range of mixtures of ammonium salts and herbicidal esters.

Ammonium sulphate and citrate were more active than ammonium nitrate and chloride in mixture with 0.5 kg/ha picloram. With 1 kg/ha picloram all ammonium salts had approximately similar effects (Table 4). The foliar uptake of a weak organic acid such as picloram usually increases at low pH (Sargent and Blackman, 1962) but in the present study none of the additives appreciably increased the acidity of spray solutions. Ammonium citrate had an opposite effect. In this connection, Orgell and Weintraub (1957) have shown that in addition to ammonium ions several anions may increase 2,4-D responses in bean plants. As in the present study, sulphate ions were particularly effective.

The interaction of ammonium salts with picloram was only slightly affected by the relative proportions of the two compounds: in guava (Table 2) there were only small differences in the effects of mixtures containing 1-20 kg/ha ammonium nitrate. However a small dose of picloram with a large amount of additive was sometimes less phytotoxic than the same picloram treatment with a lower rate of an ammonium salt (Tables 4-5). The 3-way interaction between picloram, tributyl phosphate and ammonium nitrate is of particular interest. The mode of action of the additives is unknown but perhaps the enhanced contact activity of tributyl phosphate in the presence of ammonium nitrate may in turn have increased the rate of picloram uptake. On the other hand the additives may have interacted with picloram independently: possibly tributyl phosphate promoted foliar uptake while ammonium nitrate increased movement from the site of penetration. When picloram and ammonium sulphate were applied separately their interaction was little affected (Table 7). In particular the effects of treatment with 0.5 kg/ha picloram were significantly increased when washed plants were sprayed with ammonium sulphate 24 h after applying the herbicide. It appears therefore that the site of the interaction was within the plants rather than at leaf surfaces and that synergism was not primarily a result of enhanced herbicide uptake through the epidermis. As there was no interaction when picloram and an ammonium salt were injected into vascular tissue it is possible that ammonium salts may increase herbicide movement through the mesophyll.

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THE EFFECTS OF SPRAY PROPERTIES ON THE PLACEMENT AND ACTIVITY OF HERBICIDES: A RESEARCH PROGRAMME

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Summary Techniques being used at the N.I.A.E. in a research programme aimed at providing data for the design of new spray forming equipment are described. The work includes studies of methods of forming sprays with controlled properties, and the behaviour of drops entering a crop canopy and impacting on plant surfaces. Experiments being carried out jointly with the Weed Research Organization on the effects of deposits on herbicidal activity are also mentioned.

INTRODUCTION

The improvement of application techniques and machinery depends on a full understanding of the processes involved in herbicide spraying from the formation of the drops to the eventual uptake of the active ingredient and its subsequent effect on the plant. With the majority of commercial nozzles sprays are formed by the random break up of sheets of liquid. This results in sprays of a heterogeneous nature which are virtually impossible to define in terms relevant to their performance in the field.

Work at the N.I.A.E. is directed towards the production of sprays with controlled properties suitable for any given crop and weed situation, with the eventual objective of providing design data for a new type of spraying machine which will enable spraying to be carried out in a logical manner.

PROGRAMME OF WORK

In Fig. 1 the different items of work have been shown. The initial objective is to determine the spray characteristics required for particular crop and weed situations through a study of the way deposits are formed on plants, and the effects of the deposits on herbicidal activity. The latter work is being carried out jointly with the W.R.O.

At the same time work on methods of producing sprays with controlled properties is being carried out. This enables equipment to be developed for use in the laboratory experiments, and at a later stage, for use in the evaluation of results under field conditions. Any particular requirements of the spray liquid in terms of its physical properties will have to be taken into consideration when formulating new herbicides. It is therefore essential to maintain close co-operation with the chemical industry.

BIOLOGICAL REQUIREMENTS

Several herbicides and weeds are being used to examine the extent to which the form of a deposit on a plant, as distinct from the total amount of active ingredient present, affects herbicidal activity. Experiments are carried out during eight months of the year using plants grown in trays under partially controlled conditions in a glasshouse. When the plants are at the required stage of development the trays are removed to the laboratory and sprayed using a spinning disc in a cabinet (Byass and Charlton 1968). A conveyor in the cabinet enables the time the plants are exposed to the spray to be varied, and different types of deposits are obtained by the use of a range of drop sizes.

Fluorescent dyes are used to determine the application rate by washing off the spray collected in petri-dishes and measuring the level of fluorescence. The amount of spray retained by the plants is determined in a similar way, and by relating the amount to the plan areas of the plants an estimate can be made of the amount of spray retained by plants returned to the glasshouse for later assessment of herbicidal activity.

The results of the first series of experiments on the application of barban to Avena fatua have shown that at low application rates the form of a deposit can affect herbicidal activity, the deposits formed with the smallest drop size being the most effective.

EFFECTS OF SPRAY PROPERTIES ON RETENTION

Considerable work has been carried out elsewhere on the structure of plant surfaces and their wettability in relation to the physical properties of spray liquids (Holloway 1969, 1970). Properties of the spray such as impact velocity, trajectory and airflow have rarely been considered in any detail.

In order to examine the effect of these properties on retention, a continuous stream of uniform drops is required. For this purpose a vibrating needle drop generator has been constructed. A needle is attached to the end of a flexible blade which can be kept vibrating at its natural frequency and at a constant amplitude. The depth to which the needle enters a drop of liquid on the end of a capillary tube determines the size of drop produced. The velocity at which the drops impact on a plant surface can be varied by projecting the drops into an air-flow. Preliminary work with aqueous sprays and grass weeds has shown that when drops impact at terminal velocity they are often only retained if below about 300 µm diameter.

A high speed cine camera is used to examine the behaviour of drops at impact. Early trials with drops of 1 mm diameter impacting at terminal velocity on barley showed that with aqueous sprays the drops were not retained on the plants but tended to either run down the stems and leaves and then become detached, or to break up into smaller drops.

In addition to determining the amount of spray retained on a plant surface, fluorescent dyes are used to examine the area covered by a deposit. This is accomplished by photographing the deposit under ultra-violet light and analysing the negative with an image analysing computer. If more information is required about the form of a deposit this will be obtained by the use of an automatic thin layer chromatogram scanner.

MOVEMENT OF SPRAY TO THE TARGET

A study of the movement of spray in the field from its source to the target is limited by restrictions on the techniques which can be used outside the laboratory, and is dependant on the atmospheric conditions available when the crop is at any required stage of development. For these reasons the work will be carried out in a wind tunnel.

Before natural wind conditions could be reproduced in the wind tunnel it was necessary to obtain data on wind conditions in and above a cereal crop. Between 1 m and 10 m from ground level this was obtained by using cup anemometers, and below 1 m by the use of a hot-wire anemometer with its output displayed by a galvanometer in a chart recorder.

In order to introduce the correct turbulence in the wind tunnel information was required on the diffusion of drops in the field. This was obtained by releasing drops from the top of a 34 mm diameter vertical tube with its outlet at crop height and 0.5 m from ground level. The drops were produced by a spinning disc positioned below the ground so that when they were emitted from the tube they had no appreciable vertical velocity. A fluorescent dye was added to the spray solution and the diffusion pattern determined by washing off the spray deposited on lengths of polyvinyl chloride sleeving attached to frames 1m and 2 m downwind.

When work on the wind tunnel has been completed it will be possible to examine the movement of drops in a wide range of wind conditions, and to include the effects of using additional air to assist penetration into the crop. For this work plants will be grown in trays in a glasshouse as previously described.

FORMATION OF SPRAYS

In investigating the effects of spray properties on the placement of a herbicide it is necessary to have a means of producing sprays with controlled properties. The formation of such sprays is therefore an important part of the study.

Initially the effects of formulation on the break up of liquids by spinning discs is being examined with the purpose of producing sprays with narrow drop size spectra. Information on drop size, velocity and trajectory is obtained direct from photographic plates by the use of short duration twin flash spark units. Any particular properties of a liquid required for the production of the sprays will be examined in terms of possible effects on retention and biological requirements.

PRESENT POSITION

The techniques needed for this study are now all available, although some setting up of field conditions in the wind tunnel has still to be done. This paper outlines the approach and indicates the methods to be used. It also illustrates, by reference to some preliminary results, the sort of data which is expected from such an investigation.

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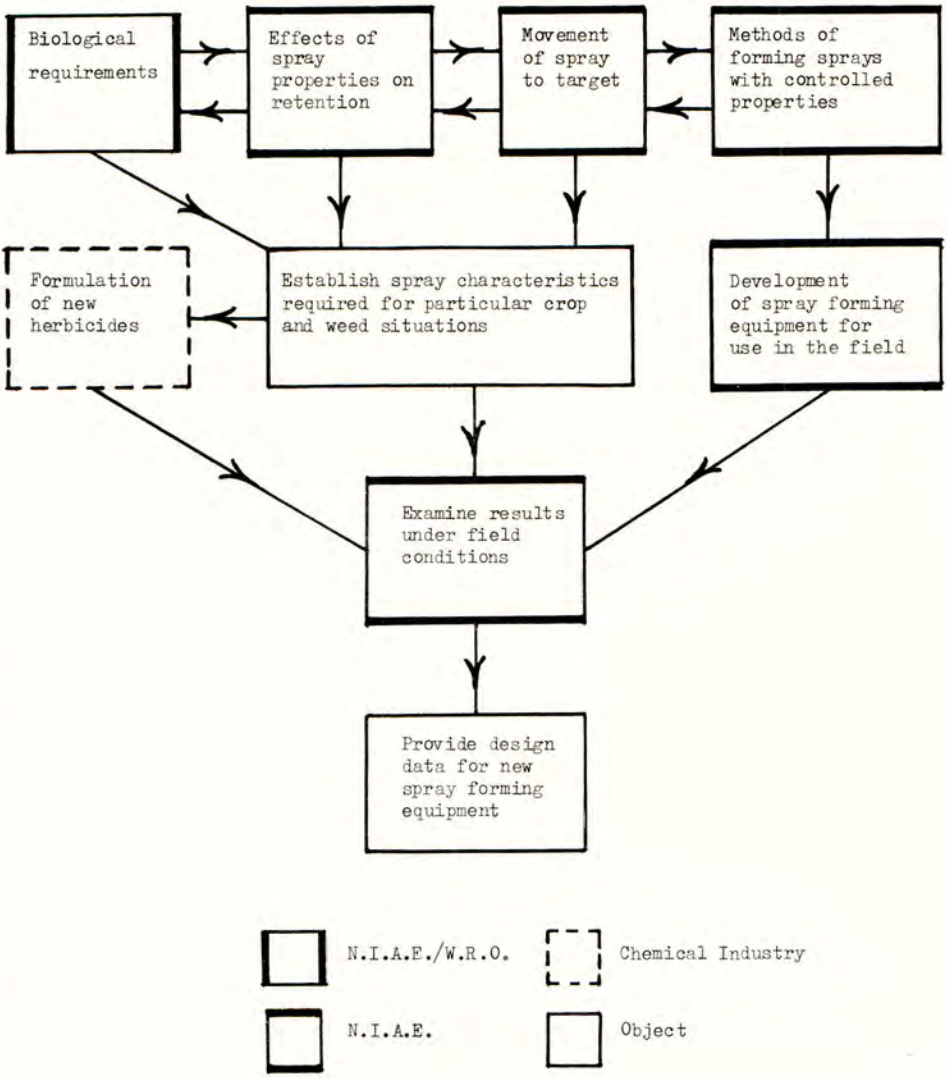
Figure 1. Programme of work



TRIALS IN CEREALS WITH BENTAZON*) (3-ISOPROPYL-1H-2,1,3-BENZOTHIADIAZIN-4(3H)-ONE 2,2-DIOXIDE) IN COMBINATION WITH HORMONES (BAS 3580 H AND BAS 3960 H)

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Summary Both BAS 3580 H and BAS 3960 H are highly selective in cereal. The most important broad-leaved weeds (*Chrysanthemum s.*, *Cirsium spp.*, *Galium ap.*, *Matricaria spp.*, *Raphanus r.* and *Sinapis arv.*) are controlled with 4 kg of each product per ha. Application may take place at any time between the development of the third cereal leaf and the end of tillering.

Neither the malting quality of spring barley nor the baking quality of winter wheat is reduced by BAS 3580 H. Trials with BAS 3960 H are at present in progress.

INTRODUCTION

Herbicides used in modern weed control must be selective as well as effective. They should not have any negative effect on the internal or external crop quality. The following paper discusses the effect of BAS 3580 H and BAS 3960 H on weeds, crop quality and yield.

METHOD AND MATERIALS

The following products were used in the trials:

BAS 3580 H: 26 % 3-Isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide

+ 34 % Dichlorprop

BAS 3960 H: 25 % 3-Isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide

+ 37.5 % Mecoprop

The control product was a normal commercial herbicide:

Code number: 2630 H: 60 g Ioxynil
+ 360 g 2,4-DP/l.

*) Proposed common name

The products were applied in spring between the third leaf stage and the end of tillering. The furthest stage reached by the weeds was the D-6 leaf or large rosette stage.

The trials were carried out on plots 20-25 m^2 in area, with 4 replications. An adapted van der Weij applicator was used in the logarithmic trials, where the plots were 2 x 20 m^2 in area. The herbicidal activity and crop compatibility were evaluated according to the EWRC scale. Trials were carried out in Austria, Belgium, Czechoslovakia, Denmark, Finland, France, Germany (Federal Republic), Great Britain, Italy, The Netherlands, Poland, Switzerland, and Yugoslavia.

The cereal samples were dried until the moisture content did not exceed 14 %, and all weed seeds and broken grains (< 1.75 mm) were removed. The grain size, the thousand grain weight and the hectolitre weight were determined by the method employed by Pelshenke et al. Malt analysis was used to determine the malting quality of spring barley and the rapid mix test (11) to determine the baking quality of wheat.

RESULTS

Crop compatibility Logarithmic spraying trials were carried out with both products and showed that the herbicides were very selective. Even when the maximum application rate was exceeded fourfold, slight damage to plants (chlorotic patches on the leaves and growth inhibition) was extremely rare (< 1 %) and was quickly overcome in the normal course of growth. Particular emphasis should be laid on the good compatibility obtained in oats and rye, which are normally very sensitive.

Herbicidal efficacy Numerous trials carried out in Germany (Federal Republic) and Europe show that BAS 3580 H and BAS 3960 H have a very broad spectrum of herbicidal activity against broad-leaved weeds. Good results were obtained with both 3 and 4 kg/ha (see Table 1). Observation of the range, however, shows that good results cannot be guaranteed with 3 kg/ha, particularly in cool weather, as was the case in 1970, or when more resistant weeds (Lamium spp., Galeopsis tetr.) are found in large numbers. The two compounds are nevertheless just as effective as the control product, or even slightly superior to it even in cool weather. If temperatures are higher (as, for example, in 1971) BAS 3580 H is slightly more effective than BAS 3960 H as is shown by the range obtained.

Table 1

Herbicidal efficiency in % of BAS 3580 H and BAS 3960 H in comparison to a commercial product containing Ioxynil + 2,4-DP (Mean of all cereal varieties)

Product	kg/ha	n	1970	n	1971
BAS 3580 H	3	38	90 (62-98)	62	89 (84-96)
	4	82	94 (82-98)	114	96 (89-98)
BAS 3960 H	3	-	-	23	91 (82-95)
	4	12	96 (90-98)	25	95 (96-98)
2630 H	4	56	92 (80-98)	56	93 (89-97)

( ) = scattering range
n = number of trials

Effect on individual weed species Table 2 makes clear the different susceptibilities of various species and the difference in activity between BAS 3580 H and BAS 3960 H.

A clear advantage is the good activity against weeds such as Chrysanthemum segetum, Galium aparine, Matricaria spp. and Stellaria media, which are normally difficult to control. Galium aparine in particular, which is increasing in numbers and interfering with mowing, is brought under complete control. BAS 3580 H is more effective against Lamium spp., Papaver spp., Polygonum spp. and Veronica spp., while BAS 3960 H is slightly more effective against Galeopsis tetr. and Viola arv.. BAS 3580 H has a wider overall spectrum, especially when the Polygonum spp. are included.

Table 2

Herbicidal spectrum of BAS 3580 H compared with that of BAS 3960 H, % efficiency

Weed species	BAS 3580 H 4 kg/ha	BAS 3960 H 4 kg/ha
Anagallis arvensis	98 (5)	100 (5)
Arabidopsis thaliana	88 (2)	96 (2)
Atriplex patula	99 (2)	100 (1)
Capsella bursa pastoris	86 (14)	77 (10)
Chenopodium album	85 (23)	87 (13)
Chrysanthemum segetum	96 (19)	96 (5)
Cirsium arvense	91 (2)	85 (1)
Fumaria spp.	100 (4)	100 (2)
Galeopsis tetrahit	56 (19)	87 (4)
Galinsoga parviflora	96 (1)	95 (3)
Galium aparine	98 (35)	94 (10)
Lapsana communis	100 (3)	97 (3)
Lamium spp.	74 (9)	34 (8)
Matricaria spp.	97 (39)	97 (31)
Myosotis arvensis	93 (12)	89 (3)
Papaver spp.	92 (8)	85 (4)
Polygonum aviculare	85 (13)	67 (18)
Polygonum convolvulus	96 (25)	79 (9)
Polygonum persicaria	93 (14)	94 (11)
Ranunculus arvensis	98 (3)	100 (3)
Raphanus raphanistrum	99 (4)	98 (4)
Sinapis arvensis	100 (4)	99 (10)
Solanum nigrum	95 (1)	100 (1)
Sonchus arvensis	100 (1)	100 (1)
Stellaria media	95 (96)	97 (37)
Thlaspi arvensis	100 (2)	100 (2)
Veronica hederifolia	79 (13)	69 (10)
Veronica spp.	83 (20)	49 (7)
Viola arvensis	60 (26)	69 (11)

( ) = number of trials

Effect on yield Tables 3 and 4 show the yields obtained in 1970 and 1971. Yields of spring cereals were higher than those of winter cereals in 1970, while the position was completely reversed in 1971. This situation is explained by the generally cool and wet weather in spring 1970. Treatment of winter cereal was delayed, so that competition from weeds lasted longer and control was slower and less successful. When the spring cereal was treated the weather conditions were normal for the time of year.

In 1971 the weather was for the most part warm and dry, and weed control was very good. The small increase in the yield of spring cereals is explained by the reduced competition from weeds - with the exception of oats, which is usually grown on moist soil. The positive results emphasise the high selectivity of the two products, which proved just as effective as the control product.

Table 3

Yields obtained in 1970 after treatment with BAS 3580 H compared with a herbicide containing Ioxynil+2,4-DP (Control = 100)

	n	BAS 3580 H 3 kg/ha	BAS 3580 H 4 kg/ha	2630 H 4 kg/ha
winter barley	5	101 (95-110)	102 (91-115)	103 (98-118)
winter rye	2	92 (85-99)	98 (95-102)	101 (97-104)
winter wheat	12	104 (98-118)	104 (94-118)	103 (96-119)
spring wheat	5	107 (102-113)	103 (99-110)	102 (100-103)
spring barley	6	104 (96-118)	104 (97-111)	100 (96-103)
oats	6	106 (97-112)	108 (103-113)	106 (97-110)

( ) = scattering range

Table 4

Yields obtained in 1971 after treatment with BAS 3580 H and BAS 3960 H in comparison to that obtained with a herbicide containing Ioxynil + 2,4-DP (Control = 100)

	n	BAS 3580 H 3 kg/ha	BAS 3580 H 4 kg/ha	BAS 3960 H 3 kg/ha	BAS 3960 H 4 kg/ha	2630 H 4 kg/ha
winter barley	19	111 (92-115)	113 (95-126)	-	-	111 (98-119)
winter rye	9	109 (95-117)	114 (98-122)	100 (92-100)	-	109 (95-116)
winter wheat	15	107 (100-115)	107 (102-112)	105 (96-108)	109 (96-111)	107 (96-116)
spring wheat	10	101 (97-105)	105 (98-108)	103 (100-106)	102 (102-108)	102 (100-108)
spring barley	11	101 (94-105)	104 (101-110)	99 (98-102)	100 (99-102)	102 (100-105)
oats	13	108 (99-112)	106 (97-115)	101 (89-112)	99 (92-106)	105 (92-109)

( ) = scattering range

Effect on quality A knowledge of the effect of herbicides on the external and internal quality is particularly important in fruit destined for human consumption. The results of some investigations carried out with BAS 3580 H are given here. To prevent a reduction in quality due to weeds, the trials were carried out in cereal crops which were practically weed-free.

External quality Treatment with BAS 3580 H had practically no effect on grain size, thousand grain weight and hectolitre weight of spring barley and winter wheat.

Internal quality No adverse effects on the malting quality of barley or the baking quality of winter wheat treated with BAS 3580 H were detected (4).

Trials with BAS 3960 H are at present in progress.

DISCUSSION

Both BAS 3580 H and BAS 3960 H have proved highly selective in all varieties of cereals. The good crop compatibility is clearly reflected in the positive effect on the yield. Both products have a broad range of activity against broad-leaved weeds in cereal (grasses, with the exception of tropical weeds, are not controlled). Among the weeds controlled are important species such as *Galium aparine*, *Matricaria spp.*, *Polygonum spp.* and *Stellaria media*. BAS 3960 H appears to be more effective in cool weather and BAS 3580 H in warm weather.

Neither the malting quality of spring barley nor the baking quality of winter wheat is affected negatively. Such an effect is not to be expected as trials with radio-active material have shown that the new active ingredient is nearly always transported basipetally, leaving no residue in the grain (10).

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THE DECAY OF RESIDUES OF VEGETATION, AND OF PURE CELLULOSE TREATED WITH AMINOTRIAZOLE AND PARAQUAT

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Summary Aminotriazole and paraquat applied to barley stubble in the field did not delay significantly the normally slow process of stubble decay in the field. Stubble sprayed in the field and incubated under constant temperature and humidity on the soil surface, behaved similarly. In model experiments when pure cellulose was sprayed with high concentrations of the two herbicides inhibitory effects could occur; occasionally decay was stimulated. When the soil alone was treated with the two herbicides, aminotriazole but not paraquat had an effect on cellulose decomposition. It is concluded that both herbicides may have a potential to delay the decomposition of the cellulosic fraction of plant material but the present experiment failed to show any serious effect on barley stubble sprayed in the field.

INTRODUCTION

Numerous aspects of the use of herbicides in minimum cultivation systems have been studied in great detail. However, little is known of the effect of herbicides on the decay of the stubble of cereals and residues of grass swards treated with herbicides to control weeds and other vegetation prior to re-sowing. Research on this topic may be desirable because reports of laboratory experiments show that moulds and other micro-organisms degrading cellulose are inhibited by some doses of certain herbicides. Disappearance of stubble in the field is brought about to a large extent by micro-organisms decomposing the cellulose and lignin components. This may be preceded by, or occur simultaneously with, activities of animals, either feeding directly on the surface, or pulling the stubble residues down into the soil, for instance by earthworms. In addition, wind, rain, alternate freezing and thawing may all assist in the dispersal of stubble. Under normal conditions cereal stubble decomposes very slowly. If a herbicide was to delay this slow process further, certain disadvantages would occur such as: 1) impedance of seed drills when sowing without prior cultivation; 2) the potential transfer of traces of herbicides from the dead residues to the young crop (Jeater and McIlvenny, 1965); 3) the overwintering on stubble of plant pathogens such as Ophiobolus graminis, (Jeater and McIlvenny, 1965; Wilkinson and Lucas, 1969; Moore and Thurston, 1970).

Wilkinson and Lucas (1969) showed that the presence of the paraquat formulation 'Gramoxone W' in plant residues affects the ability of some fungi to compete with each other when utilizing dead plant residues. The authors suggest that this might influence the rate at which these substrates are subsequently decomposed. Szegi (1970) and Giardina, Tomati and Pietrosanti (1970) demonstrated the inhibition of cellulolytic activity by paraquat, though often only transient. Grossbard (1971) showed that young ryegrass (Lolium perenne, L. S.23) treated with paraquat decayed more slowly than grass killed by heat, a treatment chosen to simulate the effect of paraquat. She also reported that ^{14}C labelled rye leaves sprayed with paraquat decomposed less rapidly than did controls (Grossbard, 1971).

The purpose of the investigations to be described was to establish whether aminotriazole or paraquat have any effect on the decay of plant residues; these two chemicals were selected because of their widespread use in controlling weeds in stubble in sward destruction prior to reseeding, and in minimum cultivation techniques. Four different situations were examined: 1) barley (Hordeum vulgare. Pers. cv. Impala) stubble left to decay in the field after spraying with the two herbicides; 2) barley stubble sprayed in the field but incubated in a controlled environment, optimal for tissue decomposition; 3) ^{14}C-labelled leaves of rye (Secale cereale L.) sprayed with the two herbicides and incubated on the surface of soil; 4) the decay of pure cellulose, in the form of calico strips and powdered cotton wool, incubated under controlled conditions.

METHOD AND MATERIALS

1) Stubble in the field

Randomized plots, 9.3 x 1.3 m, of barley stubble in five blocks were sprayed on 7 October 1970 with 4.5 kg/ha aminotriazole as 'Weedazol-TL' and with 560 g/ha paraquat as 'Gramoxone W'. The plots were divided into four sub-plots and on 9 November 1970, 11 January 1971 and 28 April 1971 all the stubble from a different sub-plot was collected and the total dry weight determined. Leaves and stems were separated, sub-samples of stems were cut to 5 cm length, and six replicates of 100 stems were weighed. The dry weight of stems at each sampling time was expressed as a percentage of the initial weight in November 1970, the loss in weight being used as a measure of decomposition.

A second parameter of the decay of stubble was oxygen uptake by leaves and stems, using a Gilson respirometer. Respiration reflects the activity of the microflora involved in the decay of stubble in the field. Stems from five blocks and leaf material from three blocks was tested. The leaves and stems were cut finely, 0.1 g leaves or 0.5 g stems were placed in Warburg flasks together with 0.5 ml water and oxygen uptake was measured over a 4.5 h period. As a third parameter changes in the tensile strength of the stems were measured, but only at the first sampling because of the labour involved and the great variability of the data obtained. Twenty sections of stem 3.2 x 50 mm from each plot were cut and tested by a machine based on the sliding weight principle. Breaking loads were measured and calculated as tensile strength (g/mm^2) and then expressed as % of that for stems from control plots.

2) Plant residues incubated under controlled conditions

a) Barley stubble. Decomposition studies in the field, especially if based on loss in weight, are difficult because stubble residues can be dispersed by a variety of factors not associated with genuine decay. In order to obtain more precise data the material collected at the first sampling was also incubated at constant temperature and high humidity, both on a soil surface and buried in soil. Fine mesh 'Terylene' bags were filled with approx. 2 g of leaves or 4 g of stems and weighed, placed on the surface of soil in metal boxes, watered, the whole box re-weighed and placed inside a polythene bag, which was sealed and incubated at 23°C. The soil in the boxes was collected from the plots from which the samples were taken. Further samples were buried at a standard depth in separate boxes. Each box contained four bags of which two were removed after 12 weeks incubation and the other two after 30 weeks. During incubation the bags were turned at intervals of two weeks and the moisture content maintained by adding water to adjust to the initial weight.

b) ^{14}C-labelled rye leaves. Fragments of uniformly labelled cereal rye were placed on the surface of soil and sprayed with aminotriazole as 'Weedazol-TL' at 11 kg/ha and paraquat as 'Gramoxone W' at 1.7 kg/ha. Gradual decomposition during incubation was observed visually by autoradiography (Grossbard, 1972).

3) Cellulose decomposition

The effects of the two herbicides were tested in the laboratory on strips of unbleached boiled calico and powdered acid-treated cotton wool. These materials were sprayed with aminotriazole as 'Weedazol-TL' at 8860 ppm or paraquat as 'Gramaxone W' at 1330 or 2660 ppm. On the basis of the area of calico strip exposed to spray these concentrations correspond approximately to 11 kg/ha aminotriazole and 1.7 or 3.4 kg/ha paraquat, these doses being about 3-4 times greater than some field applications. Most of the work was done with paraquat. Thereafter the treated cellulose was placed on the surface of, or buried in untreated soil in plastic boxes, or unsprayed materials were buried in soil treated with 500 ppm of the herbicides. For burial the calico was attached to plastic cotton reels; the cotton wool was placed in 'Terylene' bags for both buried and surface incubation. The boxes containing both calico and cotton wool were inserted into polythene bags, inflated with air and incubated at 23°C. Aeration and adjustment of the soil moisture content were carried out every two weeks. Weight loss determinations (D.M.) were made mainly on the cotton wool in bags; on calico strips only when incubated on the surface. Results are expressed as % loss of the weight before incubation. The extent of colonization by micro-organisms was assessed by visual observation, mostly on the calico strips.

RESULTS

1) Stubble in the field

a) Total weight of straw

At the first sampling the weights from paraquat-treated plots were lower than those of the controls, suggesting a slight stimulation of decomposition (Table 1), otherwise there was no indication of any major effect.

Table 1

The effect of aminotriazole and paraquat on weight of straw remaining on plots, as % of control

Sampling date	Aminotriazole	Paraquat	± S.E.
9.11.70	98	83	7.1
11.1.71	92	95	7.5
28.4.71	96	97	13.9

b) Individual stems

Loss in weight per 100 stems was somewhat greater on herbicide-treated plots than on controls, suggesting that there was no delaying effect on tissue decay (Table 2). Likewise oxygen uptake was not affected (Table 3). The results of the tensile strength measurements, available for one sampling only show no significant differences from control (Table 4).

Table 2

The effect of aminotriazole and paraquat on loss in weight of stems of barley stubble left to decay in the field
% loss in weight when compared with material sampled on 9.11.70

	Control	Aminotriazole	Paraquat
Sampling date	Weight loss	Weight loss	Weight loss
11.1.71	13	20	19
28.4.71	18	24	25

± S.E. of means = 2.8

Table 3

The effect of aminotriazole and paraquat on O_2 uptake of leaves and stems of barley stubble left to decay in the field, as % of control

Material	Sampling date	Aminotriazole	Paraquat	± S.E.
Leaf	9.11.70	113	99.7	5.3
	11.1.71	108	115.0	12.7
	28.4.71	106	100.0	5.9
Stem	9.11.70	98	96.8	4.7
	11.1.71	95	90.8	4.2
	28.4.71	99	96.0	6.5

Table 4

The effect of aminotriazole and paraquat on the tensile strength of barley stems decaying in the field

Treatment	% Control
Aminotriazole	102.8
Paraquat	100.6
± S.E.	9.6
L.S.D.	31.4

c) Leaves

Measurements of oxygen uptake gave no indication of any inhibitory effect from the herbicide treatment (Table 3). There was some suggestion of minor stimulations.

2) <u>Plant residues incubated under controlled conditions</u>

a) Barley stubble

When barley stubble was incubated on the soil surface the results were similar to those obtained in the field (Table 5). The only significant effect ($P < 0.05$)

Table 5

The effect of aminotriazole and paraquat on the decay of barley stubble sprayed in the field and incubated under controlled conditions

Parameters	Weeks of Incubation	Plant Material	Control	Amino-Triazole	Paraquat	± S.E.	L.S.D. P(0.05)
			Unburied				
Loss in weight as % Initial weight	12	Stems	32	35	38	2.9	9
		Leaf	31	30	35	2.2	7
	30	Stems	48	44	47	3.1	10
		Leaf	28	35	35	5.0	16
Oxygen uptake µl O_2/g/h	12	Stems	292	333	312	33.9	111
		Leaf	387	420	348	44.8	146
	30	Stems	96	87	60	11.8	39
		Leaf	244	351	284	24.4	80
			Buried				
Loss in weight as % Initial weight	12	Stems	35	30	26	4.7	15
	30	Stems	53	50	45	5.6	18
Oxygen uptake µl O_2/g/h	12	Stems	366	321	327	24.7	81
	30	Stems	169	262	309	48.0	157

was a stimulation of oxygen uptake from aminotriazole treatment when determined after 30 weeks incubation. The only suggestion of an inhibitory effect was on the respiration of stem material treated with paraquat where inhibition was nearly significant after 30 weeks. This was counterbalanced by a stimulation of oxygen uptake by the same material when buried. There were no other significant effects from any treatment at either time with the buried stems.

b) ^{14}C-labelled rye leaves

Visual observations of decay are based on changes in the density of the autoradiographic images with time of incubation as a criterion for the loss of carbon constituents. Both the paraquat- and aminotriazole-treated leaves appeared to decay somewhat slower than the controls but the overall effect was small and transient.

3) Cellulose decomposition

In some instances direct treatment of cellulose materials with high concentrations of paraquat led to a reduced rate of decay (Fig. 1 and Table 6). There was

Table 6

The effect of aminotriazole and paraquat on the decay of sprayed calico strips and powdered cotton wool incubated for four weeks either on the

Results are expressed as loss in weight as % of weight before incubation, followed by the appropriate S.E.

	Conc. ppm	Calico on Soil Surface	Cotton Wool on Soil Surface	Cotton Wool Buried in Soil
Control	0	25.8 ± 2.8	4.5 ± 0.29	6.4 ± 0.25
Aminotriazole	8860	29.6 ± 2.5	1.4 ± 0.25	2.0 ± 0.22
Paraquat	1330	10.7 ± 2.5	3.6 ± 0.25	4.1 ± 0.22

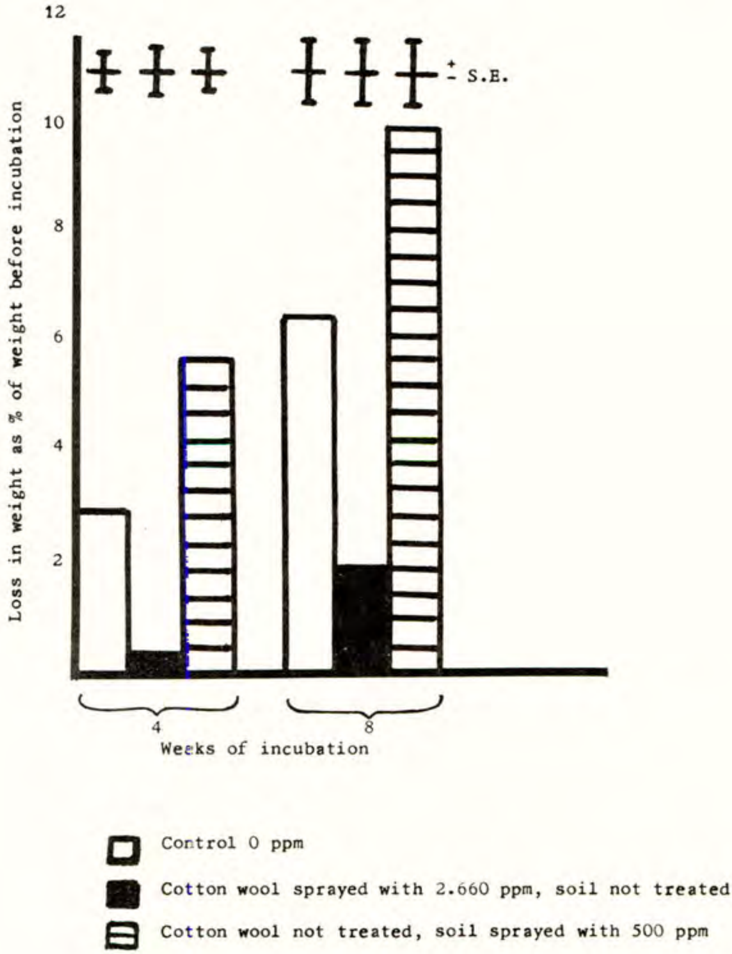
some recovery from this effect with the passage of time. In contrast burial of untreated cotton wool in soil treated with paraquat led to enhanced decay and the effect persisted. The rate of decay of cotton wool powder was very slow but sufficient for the inhibitory effect of treatment with a high concentration of aminotriazole to show up, whether left on the soil surface or buried (Table 6). Visual observations suggested less microbial colonization - and of a different composition - had occurred when calico strips and cotton wool treated with paraquat were placed on the surface or buried in untreated soil; and when unsprayed calico strips were buried in soil treated with 500 ppm of aminotriazole. On the other hand calico treated with aminotriazole on the surface of untreated soil or untreated strips buried in soil sprayed with paraquat showed a similar pattern of colonization to the controls.

DISCUSSION

The experiments with barley stubble both in the field and under controlled incubation conditions do not indicate any appreciable inhibition of decay resulting from treatment with aminotriazole or paraquat. They do not substantiate the suggestion by Wilkinson & Lucas (1969) that treatment with a formulation of paraquat may affect the subsequent decomposition of plant material. However, laboratory experiments with model cellulosic substrates indicate that certain combinations of treatment of either the cellulose or the soil with high concentrations of these herbicides can lead to a slowing-up and changes in microbial colonization and decay. This suggests that vigilance must be maintained to detect any circumstances in which treatment with these or other herbicides might delay decay of plant material to the disadvantage of agricultural practice.

Figure 1

The effect of paraquat on the decay of cotton wool powder buried in soil



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WEED CONTROL IN WINTER WHEAT IN EASTERN WASHINGTON[1]

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Summary Eleven herbicide treatments were applied to replicated plots in winter wheat fields in eastern Washington. These experiments were located on three soil types and the study period was from 1967-1971. Bromoxynil, diuron, linuron, terbutryne, and bromoxynil plus MCPA were applied following emergence of the wheat in the autumn. The 2,4-D and 2,4-D plus dicamba were applied to tillered wheat in the spring.

Weed control varied due to herbicide and weed species. *Bromus tectorum* was not controlled. Most broadleaf weeds were effectively controlled by one or more of the herbicides.

Wheat yields varied due to soil type and year. Bromoxynil, while less effective on some weed species, was the most selective herbicide. Diuron, linuron, and terbutryne frequently reduced yields on soils with less than 1.5% organic matter. The autumn applied bromoxynil plus MCPA occasionally reduced yields at two of the three locations. The occasional yield reduction from spring applied 2,4-D and 2,4-D plus dicamba varied with year and location.

INTRODUCTION

Winter wheat is produced on more than one million ha annually in eastern Washington. Sixty percent is grown on land in a summer fallow-wheat rotation because of low (17-40 cm) annual rainfall. About ten percent is irrigated and the remainder is grown in annual cropped areas receiving 45-60 cm of annual precipitation. Elevation ranges from 150 m to 900 m above sea level. Rainfall increases with elevation.

Annual weeds are an economic problem in the production of winter wheat and frequently reduce grain yield by competing with the crop. Rydrych and Muzik (1968), Swan (1971), and Swan and Furtick (1962). Since 1945 2,4-D has been widely used for selective weed control in winter wheat. In recent years, several new selective herbicides have been tested and are now recommended for annual broadleaf weed control in winter wheat. Swan (1969).

Objectives of this study were to test seven herbicides, alone or in combination, for safe and effective weed control in winter wheat under varying environmental conditions.

[1]Scientific Paper No. 3934. College of Agriculture Research Center, Washington State University, Pullman, Project Number 1888.

METHODS AND MATERIALS

Experiments were conducted in the eastern Washington wheat growing area from 1967 through 1971 on cooperating growers' fields. Since crop tolerance was the primary objective, fields most free of weeds were chosen. At irrigated sites, winter wheat was in rotation with legumes and row crops. A summer fallow followed by winter wheat rotation was used in the areas with less than 45 cm annual precipitation and a winter wheat, pea or lentil, summer fallow rotation was employed in areas averaging more than 45 cm. Most of the herbicides were tested at the effective rate and twice the effective rate.

Winter wheat was sown in October and the herbicides (except 2,4-D) were applied in November. At this time wheat was in the two to three leaf stage of growth and the weeds were less than 4 cm in diameter. The 2,4-D and 2,4-D plus dicamba were applied in March or April when the wheat averaged four tillers and twelve leaves. Most weed species averaged 15 cm in diameter and were occasionally bolting. The control plots were hand weeded and soil samples (14 cm in depth) were taken when the experiments were established.

The experimental design was a randomized complete block with four replications. Plots were either 2 m by 6 m or 3 m by 6 m. Herbicide effect on weeds was determined by visually estimating the percentage control in comparison with the unweeded controls. An area 0.8 m by 5 m was harvested from the centre of each plot in July or August with a plot size combine. Duncan's Multiple Range Test was used to define significant differences between means.

RESULTS AND DISCUSSION

Most annual weeds in eastern Washington wheat fields germinate in the autumn, winter, or early spring. Salsola kali is an exception. This species germinates in the late spring or early summer. A weed with this phenology is difficult to control with autumn applied herbicides.

Weed Control

Percentage weed control varied due to herbicide and weed species (Table 1). None of the herbicides controlled Bromus tectorum. However, on occasion, diuron, linuron, and terbutryne have given some control of this species[1]. The autumn applied herbicides did not control Salsola kali. In contrast, the spring applied treatments were effective. Montia perfoliata and Lamium amplexicaule were resistant to 2,4-D. Terbutryne was ineffective on Descurainia sophia and bromoxynil did not control Anthemis cotula. However, most weed species were effectively controlled by the treatments.

Wheat Yields

The data are from selected fields which best represented the three soil types.

Wheat yields varied due to soil type and year (Table 2). Results from each soil type are discussed separately.

Sandy Loam to Loam Soil

Wheat yields in 1967 were from a grower's field in the non-irrigated Horse Heaven Hills area. The 1968-1971 experiments were located in an irrigated district near Pasco.

[1] Unpublished weed control research reports. Washington State University

Table 1

Mean weed control from herbicides applied to winter wheat in eastern Washington[a]

Weed	Bromoxynil 0.6[b]	Diuron 1.1	Linuron 0.6	Terbutryne 1.1[c]	Bromoxynil plus MCPA 0.4 + 0.4	2,4-D 1.1	2,4-D plus dicamba 0.8 + 0.1
	Herbicide and rate (kg/ha)						
Bromus tectorum	0	0	0	0	0	0	0
Salsola kali	0	0	0	0	--	80	100
Montia perfoliata	100	100	90	100	90	0	10
Holosteum umbellatum	50	45	95	95	70	50	65
Papaver argemone	100	100	100	100	--	100	100
Camelina microcarpa	85	100	95	90	100	80	90
Descurainia sophia	95	100	100	15	100	100	100
Sisymbrium altissimum	70	100	100	80	65	100	100
Thlaspi arvense	90	80	85	85	95	95	100
Amsinckia species	100	100	100	100	--	100	100
Lithospermum arvense	90	100	95	95	95	60	70
Lamium amplexicaule	70	95	100	100	85	20	25
Galium aparine	80	80	100	100	100	60	60
Anthemis cotula	0	90	70	60	20	70	90
Lactuca serriola	80	100	100	100	90	100	100

[a]Compiled from all experiments 1967-1971

[b]0.4 kg/ha in 1968, 1969, and 1970

[c]1.6 kg/ha in 1970 and 1971

Table 2 (i)

Effect of herbicides, applied to three soil types, on wheat yield[a] in eastern Washington

Soil: Sandy loam to loam (sprinkler irrigated)
Sand - 56% Organic matter - 0.8%
Clay - 7% Cation exchange capacity - 8 meq/100 g
Annual precipitation - 20 cm plus 56 cm from irrigation

Treatment	Rate kg/ha	Year 1967[b]	1968	1969	1970	1971
Hand weeded control	--	100 ab (1176)	100 a (8850)	100 ab (1310)	100 ab (6889)	100 a (10053)
Bromoxynil	0.6[c]	105 a	100 a	102 a	101 ab	100 a
Diuron	1.1	86 a-c	82 f	0 g	102 a	100 a
Diuron	2.2	69 cd	3 g	0 g	--	--
Linuron	0.6	103 a	93 b-d	90 d	98 a-d	100 a
Linuron	1.1	75 b-d	88 de	0 g	--	--
Terbutryne	1.1[d]	105 a	90 c-e	103 a	96 b-e	96 a
Terbutryne	2.2	104 a	94 bc	94 cd	--	--
Bromoxynil plus MCPA	0.4 0.4	--	96 ab	101 ab	95 c-e	99 a
Bromoxynil plus MCPA	0.8 0.8	--	86 e	90 de	86 f	97 a
2,4-D (LVE)	1.1	88 a-c	85 ef	95 bc	99 a-d	97 a
2,4-D (LVE) plus dicamba	0.8 0.1	98 ab	89 c-e	90 d	100 a-c	--
Unweeded control	--	109 a	99 a	99 ab	93 e	100 a
Weed population/m^2		*Salsola kali* (1)	*Descurainia sophia* (1)	No weeds	*Descurainia sophia* (1)	*Descurainia sophia* (1)/3 m^2

[a] Based on percent of hand weeded control. Numbers in parentheses are yield in kg/ha. Percentages within a column sharing the same letter are not significantly different at the 5% level.

[b] Non-irrigated

[c] 0.4 kg/ha in 1968, 1969, and 1970

[d] 1.6 kg/ha in 1970 and 1971

Table 2 (ii)

Effect of herbicides, applied to three soil types, on wheat yield[a] in eastern Washington

Soil: Loam to silt loam
Sand - 34% Organic matter - 1.2%
Clay - 11% Cation exchange capacity - 13 meq/100 g
Annual precipitation - 25 cm

Treatment	Rate kg/ha	1967	1968	Year 1969	1970	1971
Hand weeded control	--	100 a (2668)	100 a (2164)	100 a (1969)	100 bc (2607)	100 a (2809)
Bromoxynil	0.6[b]	91 a	95 a	101 a	100 ab	101 a
Diuron	1.1	93 a	90 a	101 a	91 f	96 a
Diuron	2.2	91 a	77 a	97 ab	--	--
Linuron	0.6	91 a	89 a	97 ab	100 a-c	102 a
Linuron	1.1	91 a	99 a	95 ab	--	--
Terbutryne	1.1[c]	97 a	98 a	100 a	98 d	95 a
Terbutryne	2.2	97 a	110 a	99 a	--	--
Bromoxynil plus MCPA	0.4 0.4	--	87 a	87 cd	92 f	96 a
Bromoxynil plus MCPA	0.8 0.8	--	106 a	82 de	87 g	84 b
2,4-D (LVE)	1.1	91 a	83 a	91 bc	102 a	99 a
2,4-D (LVE) plus dicamba	0.8 0.1	95 a	94 a	78 ef	95 e	--
Unweeded control	--	86 a	92 a	100 a	100 bc	101 a
Weed population/m^2		No weeds	No weeds	*Bromus tectorum* (1)	*Sisymbrium altissimum* (5)	No weeds

[a] Based on percent of hand weeded control. Numbers in parentheses are yield in kg/ha. Percentages within a column sharing the same letter are not significantly different at the 5% level.

[b] 0.4 kg/ha in 1968, 1969, and 1970

[c] 1.6 kg/ha in 1970 and 1971

Table 2 (iii)

Effect of herbicides, applied to three soil types, on wheat yield[a] in eastern Washington

Soil: Silt loam
Sand - 18% Organic matter - 4.2%
Clay - 24% Cation exchange capacity - 22 meq/100 g
Annual precipitation - 53 cm

Treatment	Rate kg/ha	1967	1968	Year 1969	1970	1971[d]
Hand weeded control	--	100 a (6377)	100 e (6014)	100 a (4764)	100 a (5127)	--
Bromoxynil	0.6[b]	99 a	109 bc	94 de	101 a	--
Diuron	1.1	100 a	106 cd	98 a-c	98 ab	--
Diuron	2.2	94 a	105 d	99 a	--	--
Linuron	0.6	100 a	105 d	96 b-d	100 a	--
Linuron	1.1	94 a	107 cd	101 a	--	--
Terbutryne	1.1[c]	98 a	104 d	95 c-e	98 ab	--
Terbutryne	2.2	102 a	107 d	99 a	--	--
Bromoxynil plus MCPA	0.4 0.4	--	114 a	100 a	99 ab	--
Bromoxynil plus MCPA	0.8 0.8	--	112 ab	98 a-c	96 ab	--
2,4-D (LVE)	1.1	96 a	94 f	94 de	90 c	--
2,4-D (LVE) plus dicamba	0.8 0.1	98 a	85 h	93 de	91 b	--
Unweeded control	--	99 a	98 e	93 e	91 b	--
Weed population/m^2		*Camelina microcarpa* (4) *Lamium amplexicaule* (2)	*Lamium amplexicaule* (50) *Thlaspi arvense* (40)	*Lithospermum arvense* (10) *Anthemis cotula* (10)	*Lamium amplexicaule* (50)	*Lithospermum arvense* (50) *Lamium amplexicaule* (35) *Thlaspi arvense* (10)

[a] Based on percent of hand weeded control. Numbers in parentheses are yield in kg/ha. Percentages within a column sharing the same letter are not significantly different at the 5% level.

[b] 0.4 kg/ha in 1968, 1969, and 1970

[c] 1.6 kg/ha in 1970 and 1971

[d] Not harvested due to lodging

Considerable crop injury due to treatment occurred in 1968. This was not evident until late April following initiation of sprinkler irrigation. Apparently the winter (December through March) precipitation of 6.4 cm did not leach the herbicides but, when additional water was applied, the chemicals moved into the crop root zone.

Greatest wheat kill occurred in 1969. This crop injury, in contrast to 1968, was evident in March prior to initiation of sprinkler irrigation. Winter precipitation totalled 14.6 cm. This was sufficient to leach the herbicides and the less selective ones killed the crop. Moreover, wheat yields were very low due to the experiment inadvertently not being fertilized. In 1971 there were no significant yield differences.

The injury frequency from diuron, linuron, and terbutryne is such that these chemicals cannot be recommended for this soil type and conditions. The autumn applied bromoxynil plus MCPA, especially at the double rate, frequently reduced crop yield.

One *Descurainia sophia* plant per m^2 apparently reduced crop yield in 1969. No yield reductions due to weeds was measured for the other years.

Loam to Silt Loam Soil

These experiments were located in the Ritzville and Lind areas. In general, there was less crop injury in degree and frequency than occurred on the sandy loam to loam soil. This was probably due to several factors including more clay and organic matter and less total water. Nevertheless, the injury frequency (one year out of five) was such that diuron, linuron, and terbutryne cannot be recommended for this area. Likewise, the autumn applied bromoxynil plus MCPA frequently reduced wheat yields under these conditions.

No yield reductions were measured due to weed competition in studies conducted in this area.

Silt Loam Soil

These experiments were located on the annual cropped Palouse soils near Pullman. No yield differences were measured in 1967. In 1968, as the result of hoeing, the hand weeded control had a high incidence of eye-spot disease (*Cercosporella herpotrichoides*) resulting in a yield reduction. The weeding operation and resultant heaping of soil at the base of wheat stems is well known in the Pacific Northwest to increase eye-spot disease.

Bromoxynil gave only partial control of *Lamium amplexicaule* in 1968 and no control of *Anthemis cotula* in 1969. As a result, plots treated with this herbicide yielded significantly less for these two years. The effective rate of diuron, linuron, and terbutryne showed good selectivity on this soil type under these conditions. Moreover, bromoxynil plus MCPA, in contrast to the other locations did not reduce crop yield. The weed populations in 1968, 1969, and 1970 significantly reduced crop yield due to competition.

Weed control and crop yield in herbicide treated winter wheat plots varied according to year, weed species, and chemical. Bromoxynil, while less effective on some weed species than other herbicides, was the most selective for all locations. Linuron and terbutryne were more selective than diuron. Autumn applied bromoxynil plus MCPA reduced wheat yields at two locations. However, this combination is more selective when applied in the spring[1]. The application of 2,4-D or 2,4-D plus dicamba sometimes brought about a yield reduction.

[1]Unpublished weed control research reports. Washington State University

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A STUDY OF THE GROWTH OF AGROPYRON REPENS (L) BEAUV. DURING AND AFTER THE GROWTH OF SPRING BARLEY AS INFLUENCED BY THE PRESENCE OF UNDERSOWN CROPS

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Summary A. repens was planted into spring barley; alone, undersown with ryegrass or red clover, or oversown, at the point of barley ear emergence, with white mustard, Sinapis alba or a range of varieties of rape, Brassica napus and Brassica campestris. Crop growth was measured and the growth of A. repens was recorded.

In 1970 the presence of Italian ryegrass reduced the amount of A. repens rhizome formed during the year by over 70% but reduced the yield of barley by over 25%. The other crops, in both seasons, and the perennial ryegrass which was undersown in 1971 had negligible effect on barley yield but were less effective in suppressing A. repens growth. Reduction of 20-40% of A. repens growth were recorded with these other crops.

Establishment of the brassica crops from seed oversown at the time of barley ear emergence was good in both years. White mustard and an early maturing variety of oil seed rape (Brassica campestris) were not successful due to poor growth and a high incidence of premature flowering and mortality.

The more strongly vegetative varieties of rape made very good growth and would tolerate low doses of dalapon which could augment the suppression of A. repens. The possibilities for developing this technique are discussed.

INTRODUCTION

Earlier work (Cussans, 1968, 1970) showed that, when barley and A. repens were grown in competition, the barley had more effect on growth of A. repens than vice versa. The effect of competition from barley was to reduce the growth of new A. repens rhizome and to delay the onset of that growth. It would, therefore, appear that, by the end of the growing season, a substantial majority of the A. repens present in a cereal stubble will have been produced after cereal harvest or during the period when the crop was ripe but not harvested.

Since A. repens is so much influenced by competition, it seemed likely that this summer and autumn growth of new rhizome could be reduced by the presence of an undersown forage crop.

Ideally, such a crop would have to be sufficiently rapid in its growth to effect a useful reduction in A. repens growth but not so vigorous as to reduce cereal yield. It seemed that these two requirements could be antagonistic. Another possibility would be a crop having some suppressive effect and some tolerance of a herbicide which would augment the effect of competition. Some brassica crops fulfilled this latter requirement but could not be undersown at the time of sowing the cereal crop.

Against this background, the two experiments described here were set up to examine the effects on A. repens growth of ryegrass and red clover undersown conventionally in March and of some brassica crops oversown much later in the season. The seed of these crops was broadcast at about the time of barley ear emergence, in June.

METHOD AND MATERIALS

The experiments were carried out on a sandy loam soil at Begbrcke Hill Farm. In each case a randomised block design was used, with four replicates. After initial cultivation and application of fertilizer, 15 cm rhizome pieces of A. repens, selected for uniform diameter and appearance, were planted. Sixteen rhizome sections were planted into each assessment area. These plots were 0.91 m x 0.91 m and were surrounded by planted discard areas and further discard areas planted to crop but not A. repens. The planting technique has been described more fully elsewhere (Cussans 1968). The dry weight of rhizome planted on each assessment plot was approximately 4.0 g in 1970 and approximately 4.5 g in 1971. After planting the A. repens rhizome, barley var. Impala was planted on all plots. After that, the seed of ryegrass and clover was broadcast on the appropriate plots and harrowed in. The whole area was then flat rolled.

The dates of crop planting were 26th March 1970 and 1st April 1971.

The oversown crops were sown on the 11th June 1970 and 21st June 1971. The barley was at the sheath burst stage on each occasion and the seed was broadcast when the tall foliage was dry. Seed rates of the brassicae were varied according to the sample weight so as to give comparable seed numbers sown per unit area.

Crop varieties and seed rates are tabulated below.

Table 1

Treatments	1970	1971
All	Barley, Impala 157 kg/ha	Barley, Impala 146 kg/ha
1.	No other crop	
2.	Italian ryegrass. S.22 20 kg/ha	Perennial ryegrass. S.24 20 kg/ha
3.	Broad red clover 8 kg/ha	Broad red clover 8 kg/ha
4.	White mustard 23 kg/ha	Fodder rape, var. Emerald 7.2 kg/ha
5.	Oilseed rape var. Nilla (Brassica napus) 10.5 kg/ha	Oilseed rape var. Echo (Brassica campestris) 4.1 kg/ha
6.	Oilseed rape var. Rigo (Brassica napus) 10.5 kg/ha	Oilseed rape var. Victor (Brassica napus) 9 kg/ha

Within each treatment the assessment plots were randomised for four dates of assessment in 1970 and two dates in 1971. These dates were, in 1970: 29th June, 11th August, 12th October and 7th December and, in 1971; 16th August and 6th December. At each date of assessment the plants of Agropyron repens were recovered, washed, and separated into; aerial parts, the original planting material, new rhizome and shoot bases. One assessment took place at barley maturity, when the crop was removed and threshed with a small plot thresher for determination of grain and straw yield.

Dry weights of the undersown crops were determined at each assessment and, at the last assessment, the dry weight of "other vegetation" was also recorded. This latter mainly comprised volunteer barley plants with a few weed plants, mainly *Stellaria media* and *Senecio vulgaria*.

The autumn weather during both years of these experiments was relatively dry and sunny. The calculated soil moisture deficit on 31st May was, in 1970, 55.9 mm, and in 1971, 26.9 mm. The moisture availability in the top 30 cm of the soils concerned was estimated to be 38 mm.

The monthly precipitation totals for the months of June to October are tabulated below. The 1971 data refer only to natural rainfall but in 1970 25 mm of irrigation water was applied on the 24th June.

Table 2

Total monthly precipitation mm

	1970	1971
June	53.1	118.7
July	44.2	58.8
August	42.8	84.9
September	34.1	17.2
October	17.5	62.0

RESULTS

The effect of undersown crops on barley yield

Table 3

Yield of barley t/ha at 85% Dry Matter

Treatments	1970	1971
No undersown crop	3.80	3.05
Undersown ryegrass	2.82	2.76
Undersown clover	4.00	2.73
Oversown Brassicae (see Table 1)	3.87	3.01
	4.19	2.94
	4.52	2.86
S.E.	0.244	0.135

Table 3 shows that, in 1970 the presence of undersown Italian ryegrass reduced barley yield by over 25%. The other crops tended to increase barley yield, and the increase reached a statistically significant level in the case of one variety of oilseed rape. In 1971 none of the yield differences reached statistical significance and yield of barley on plots undersown with perennial ryegrass was no lower than that on the clover plots.

Establishment and growth of other crops and other vegetation

1970 Experiment

On the 29th June the plant population of all the undersown crops was adequate. Seedlings of ryegrass were not counted but the population was dense, and estimated as at least 250 plants/m^2. 116 plants of Red Clover/m^2 were recorded and the populations for White Mustard and the two varieties of oilseed rape were 61, 109 and 80 plants/m^2 respectively. Populations of oilseed rape and clover remained relatively static but populations of White Mustard fell continuously to 26/m^2 in December.

Table 4 gives details of the dry weights of aerial parts of the undersown crops expressed as grams per assessment plot (0.91 m x 0.91 m).

Table 4

Total dry weight above ground of undersown crops g/plot

	29th June	11th August		12th October		7th December	
Italian ryegrass	93.4	176.6	±38.0	199	±23	164	±16
Red Clover	4.1	22.3	±4.0	111	±24	117	± 9
White Mustard	-	6.4	± 1.5	63	± 7	72	±13
O.S. Rape Nilla	-	13.8	± 3.3	79	±11	84	± 7
O.S. Rape Rigo	-	11.2	± 2.9	78	± 8	89	±14

Table 4 shows the rapid early growth of ryegrass in 1970, relative to the growth of other crops and in absolute terms. The dry matter yield on the 11th August was approximately 2.0 t/ha. After sampling on the 11th August some of the ryegrass foliage was tipped by the combine harvester so later yield assessments are less meaningful. However, growth rate of this species fell off after 11th August and a decline in dry weight was recorded between October and December, possibly due to senescence of some of the older leaves.

Red clover grew more slowly to a maximum of 117 gm/plot or approximately 1.4 t/ha of dry matter by early December.

Of the oversown brassicae the two varieties of oilseed rape behaved similarly but differed markedly from White Mustard. The rape varieties formed a complete foliage canopy and remained almost completely vegetative and about 15-20 cm high until the final assessment. White Mustard reacted to oversowing by a high incidence of premature flowering. Many plants flowered and died whilst only 10-12 cm high, thus accounting for the mortality referred to earlier. The remaining plants flowered more or less normally but the overall foliage canopy was more broken and uneven.

Thus although final yields of the brassicae as shown in Table 4 were similar, with yields of White Mustard only marginally lower, the growth form was different.

The dry weight of all other vegetation was assessed on the last two dates and data are given in Table 5. This was almost entirely volunteer barley but with some occasional plants of Stellaria media and Senecio vulgaris.

Table 5

Dry weight above ground of all "Other Vegetation" g/plot

	12th October		7th December	
No undersown crop	34.2	± 8.7	34.1	±14.3
Italian ryegrass	0.9	± 0.8	0.3	± 0.3
Red Clover	20.1	±11.6	5.3	± 1.8
White Mustard	8.6	± 1.2	6.5	± 1.7
O.S. Rape Nilla	10.7	± 4.9	5.8	± 1.5
O.S. Rape Rigo	8.2	± 3.0	10.6	± 2.7

Table 5 shows that the presence of undersown crops, notably Italian ryegrass, reduced the growth of volunteer barley plants. Dry weight per unit area of volunteer barley and weeds was not very great and did not appear to increase between October and December. The barley plants were showing some frost scorch and some mortality by the time of the December assessment.

1971 experiment

Seedling emergence of ryegrass was again adequate, a mean of 264 seedlings/m^2 being recorded on the 16th August. Establishment of red clover was adequate but poorer than in 1970, 54 seedlings/m^2 were recorded on the 16th August. Establishment of the brassicae was also rather poorer than in 1970; 52 plants/m^2 of the fodder rape "Emerald" were recorded in August, falling to 35 plants/m^2 in December. 69 plants/m^2 of the Brassica napus Oil Seed Rape "Victor" were counted in August and 51 plants/m^2 in December. The population of the Brassica campestris Oil Seed Rape "Echo" was 33 plants/m^2 in August falling to 13/m^2 in December. This variety reacted in the same way as the white mustard in 1970, with a high incidence of premature flowering and it seems possible that initial establishment was greater than that recorded on the 16th August.

Table 6 gives the dry weights of the aerial parts of these undersown crops.

Early growth of all crops was very much poorer in 1971 and only red clover reached a comparable yield by the time of the December assessment. With the exception of the "Echo" variety of rape all crops did appear vigorous and provided a full foliage canopy.

On the 7th December the dry weight of volunteer barley plants, and the sparse growth of broad-leaved weeds was assessed. There was much less growth of volunteer barley in the autumn of 1971 than in 1970 and the effect of undersown crops on this growth was less marked. However, in 1971 as in 1970 the growth of volunteer barley was least on the plots undersown to ryegrass.

Table 6

Dry weight above ground of undersown crops, volunteer barley and other weeds g/plot

	Undersown crops 16th August		Undersown crops 7th December		Volunteer barley etc. 7th December
Not undersown					14.60
Perennial ryegrass	16.91	±2.44	101.8	±17.02	2.85
Red Clover	3.03	±0.41	110.7	±18.98	5.50
Fodder rape	0.68	±0.24	46.4	± 9.87	8.06
O.S. Rape "Echo"	0.25	±0.07	21.7	± 6.55	9.30
O.S. Rape "Victor"	1.66	±0.33	47.3	±10.89	10.50
					±4.95

Growth of Agropyron repens

1970 experiment

Fig. 1

Total Dry wt. of *A. repens*/plot

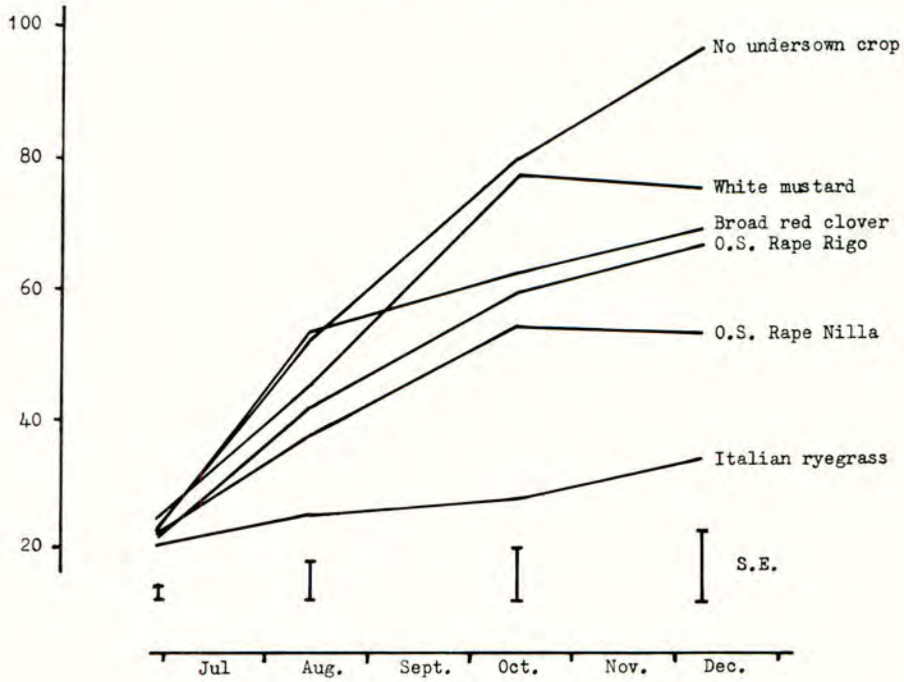

Figure 1 shows the total dry weight of all structures of A. repens recovered at four dates.

There was little difference in total dry weight of A. repens between the various treatments at the time of the first assessment but increasing differences thereafter. Growth of A. repens was poorest on the plots undersown to Italian ryegrass and, by the time of the final assessment on the 7th December, the mean dry weight of A. repens on these plots (30 g) was less than one third of that on the control plots (97 g).

The plots undersown to red clover or oversown to Oilseed rape also showed a reduction in total dry weight of A. repens at the last two assessments but this was of a lower order; total dry weight being about two thirds of that on the control plots. No reduction in A. repens growth was recorded on the plots oversown to white mustard at the first three assessments but total dry weight was lower at the time of the final assessment on the 7th December.

Fig. 2

Dry wt. of new rhizome of A. repens/plot

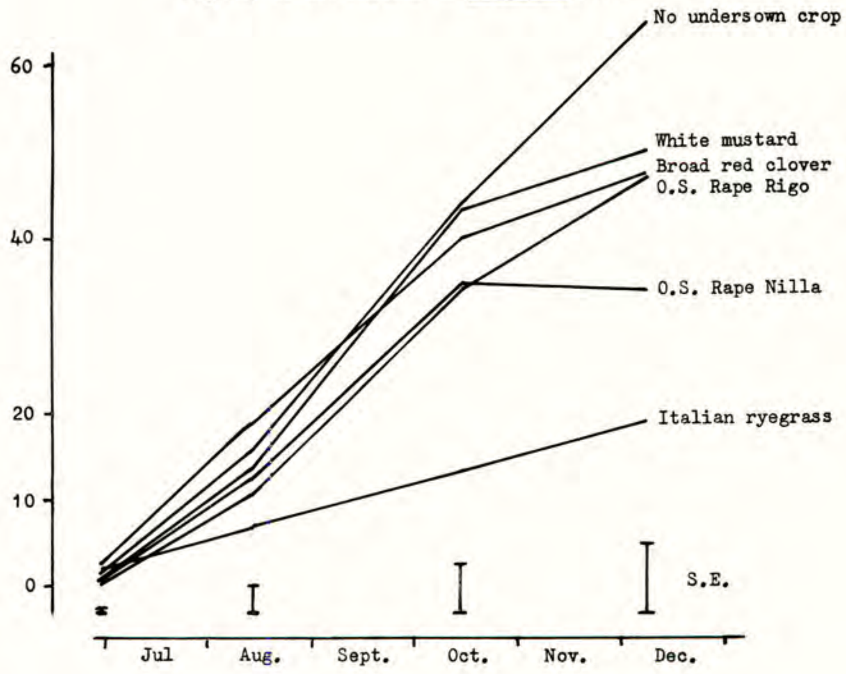

Figure 2 shows the dry weight of A. repens rhizome produced during the course of the experiment.

The data on rhizome growth show similar trends to the total dry weights shown in Figure 1 although the differences appeared later in the season on all plots except those undersown to Italian ryegrass. On all plots, considerably more rhizome was produced than the 4.0 g which was planted in March.

1971 experiment

Table 7 gives data for the total dry weight and new rhizome dry weight of A. repens on two dates of assessment; 16th August and 6th December.

Table 7

A. repens total dry weight and dry weight of new rhizome g/plot

	16th August		6th December	
	Total dry weight	New rhizome	Total dry weight	New rhizome
No undersown crop	38.6	10.7	103.0	65.7
Undersown perennial ryegrass	30.8	8.9	65.9	42.7
Undersown red clover	43.5	11.9	85.7	52.7
Oversown Fodder Rape "Emerald"	37.2	11.6	74.0	47.8
Oilseed Rape "Echo"	35.7	8.7	108.9	69.2
Oilseed Rape "Victor"	38.2	11.4	66.6	39.8
S.E.	5.25	2.06	6.79	5.41

One of the oversown crops, the oilseed rape B. campestris "Echo" did not reduce growth of A. repens at the time of the final assessment. The other varieties, of Brassica napus, resulted in a 30-40% reduction of A. repens growth recorded at the final date of assessment. This is similar to the effect of two different Brassica napus varieties in 1970. The plots undersown to perennial ryegrass had a comparable growth of A. repens to the B. napus plots. The effect of undersown ryegrass on A. repens growth was, therefore, much less in 1971 than in 1970.

Undersown red clover also had rather less influence on A. repens in the 1971 experiment than in 1970. Rhizome dry weight on the 6th December was reduced by about 20% compared to the control plots.

The dry weight of rhizome recorded in early December on the control plots, with no undersown crop, was similar in both experiments. In 1970, from a planted rhizome weight of 4.0 g, 65.0 g of rhizome had been produced by the 7th December. In 1971, from a planted rhizome weight of 4.5 g, 65.7 g of rhizome had been produced by the 6th December.

DISCUSSION

All of the undersown or oversown crops tested in these experiments had a considerable influence on the growth of A. repens although the latter was well established before the brassicae were oversown. The relative competitive abilities of A. repens and the undersown crops must have been levelled out to some extent by the fact that a high proportion of the aerial shoots of A. repens was removed by the combine harvester. In contrast, the brassica crops were untouched and comparatively small proportions of the shoots of ryegrass and clover were cut.

It was hardly surprising that the most effective reduction in A. repens growth was caused by the vigorous growth of Italian ryegrass in the first experiment. However, even this treatment allowed some build up of A. repens rhizome and, of course, the yield of barley was very seriously affected.

All the other undersown crops, although having no deleterious effect on crop yield, allowed a very considerable build up of A. repens rhizome. It would appear from these experiments, therefore, that the suppression of A. repens by undersown ryegrass and clover, although useful, was hardly sufficient to justify the risk of yield loss. Dyke (1970, 1972) at Rothamsted, however, did record much more encouraging results. In these experiments the growth of A. repens on plots undersown with ryegrass and clover was less than half of that recorded on the normal barley plots. It would seem that there is further scope for study of this aspect of undersowing.

In contrast to the long established practice of undersowing ryegrass and clover, oversowing of brassica crops is rather novel. The establishment of the more vegetative types of Brassica napus rape was very good in these experiments. There was no interference with the barley crop, in the experiments reported here, although it would be desirable to determine the degree of risk to both barley and rape during an exceptionally wet and delayed harvest. The oversown rape crops were no more efficient than undersown red clover in suppressing rhizome growth of A. repens. Rape does, however, have the advantage of being tolerant of low doses of dalapon. Growth of rape in these experiments was satisfactory despite the fact that no fertilizer was applied after the normal spring application.

Another series of experiments is in progress to examine the possibilities of this technique and it does seem possible that oversown rape treated with dalapon could provide the basis of a cheap suppression of the couch grasses and volunteer cereals coupled with a valuable green crop.

Acknowledgements

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THE USE OF CYANAZINE MIXTURES FOR WEED CONTROL IN CEREALS

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Summary Extensive field trials have been carried out in the U.K. on wheat, barley and oats using mixtures of cyanazine* (2-(4-chloro-6-ethylamino-s-triazin-2-ylamino)-2-methyl propionitrile) and phenoxy-alkanoic acid herbicides. Applications were made between the 3 leaf and mid-tillering stage of crop growth with the weeds at the seedling to early 4 leaf stages. A wide spectrum of broad leaved weeds was controlled by all mixtures, with cyanazine/2,4-DP being especially effective against all common Polygonum spp. However in Scottish trials, the cyanazine/MCPA mixture proved particularly effective against Polygonum aviculare, and was generally more effective than cyanazine/2,4-DP against Galeopsis tetrahit. There were no obvious signs of crop damage and in many instances yields were higher than those obtained from the standard treatments.

INTRODUCTION

The widespread use of growth regulator herbicides in cereals has drawn attention to those weed species inadequately controlled by these compounds. During its early development cyanazine was shown to be particularly active against many of these weeds which occur in cereals and are "difficult to kill". Chapman (1968) reported the foliar activity of cyanazine and accordingly it was decided to investigate the possible use of the compound in cereals. The earliest work in 1969 was with the material alone but there were obvious advantages from using reduced rates fortified with phenoxyalkanoic acid herbicides. By the end of 1970 the possible range of commercial ratios had been selected and it is the evaluation of these which is reported on in this paper.

METHOD AND MATERIALS

Thirty-eight replicated trials, together with forty-six farmer applied trials were carried out in the U.K. during the past two years.

Replicated trials were of a randomised block design with four replicates. Plot sizes were 3.2m. x 32.0m. Treatments were applied using a hydraulically operated sprayer mounted on a Land Rover, at a volume of 280 l/ha at 2.1 kg/cm^2. Applications were made between the three leaf to mid-tillering growth stage of the crop with weeds varying from seedling to early 4 leaf stage.

Weed control was assessed by quadrat counts, by the E.W.R.C. scale and by an overall percentage cover broken down into individual weed species.

Crop effects were assessed visually and recorded in the E.W.R.C. Scale.

* proposed common name + now with Richardsons Belfast

Table 1

Winter Cereals % Weed Control

	Wheat Overall	Wheat Stellaria Media	Wheat Convolvulus Arvensis	Wheat Sinapis Arvensis	Wheat Polygonum Persicaria	Barley Overall	Barley Stellaria Media	Barley Veronica Persica	Barley Matricaria Spp
T1 - mid tillering									
Untreated control (Weeds/quadrat)	0(80.5)	0(61.9)	0(5.6)	0(9.5)	0(2.5)	0(97.0)	0(82.8)	0(9.0)	0(7.5)
Commercial standard	79.0	88.1	0	100	100	80.2	90.6	50	89.3
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	85.2	94.4	0	100	48	98.5	98.0	100	100
Cyanazine/MCPA 0.28 + 0.7 kg ai/ha	84.8	95.2	0	100	100	93.7	95.8	100	89.3
T2 - late tillering									
Untreated control (Weeds/quadrat)	0(77.5)	0(61.9)	0(5.6)	0(6.8)	0(2.0)	0(97.0)	0(82.8)	0(7.5)	0(5.8)
Commercial standard	89.3	94.5	50.0	100	100	70.7	69.6	0	100
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	80.9	90.0	13.0	100	60	21.0	78.2	20.0	86.2
Cyanazine/MCPA 0.28 + 1.4 kg ai/ha	89.3	94.5	7.0	100	100	52.8	19.0	36.0	31.1

Yields from all replicated trials were taken from a 60 sq. m. area per plot using a modified Claas combine and weights corrected to 15% moisture.

Two different formulations of cyanazine were tested, a 50% W.P. and a 50% w/v suspension concentrate. The appropriate hormone weedkiller for the weeds present was included for comparative purposes.

Treatments evaluated were as follows -

Cyanazine + 2,4-DP	0.28 + 1.4 kg. a.i./ha.
" + "	0.28 + 1.7 kg. a.i./ha.
" + "	0.28 + 2.1 kg. a.i./ha.
" + "	0.37 + 1.4 kg. a.i./ha.
" + MCPA	0.28 + 1.0 kg. a.i./ha.
" + "	0.28 + 1.7 kg. a.i./ha.
" + "	0.37 + 1.7 kg. a.i./ha.

2,4-DP = 2-(2,4-dichlorophenoxy) propionic acid
MCPA = 4-chloro-2-methylphenoxyacetic acid

RESULTS

In winter cereal trials conducted in England a commercially acceptable level of weed control (better than 85%) was obtained from all mixtures when applied at the mid-tillering stage of the crop. Assessments made between 40-50 days after application showed that most over-wintering weeds were controlled. In one wheat trial later emergence of <u>Convolvulus arvensis</u> caused a problem. However the commercial standards used also showed an unsatisfactory control of this weed. (Table 1)

The mild winter of 1970/1971, gave rise to well established weed populations early in the year and the delayed T1 application gave poorer weed control than normal. No crop damage was recorded although in wheat, the cyanazine/2,4-DP mixtures showed slight temporary leaf chlorosis. (Table 2)

<u>Table 2</u>

<u>Winter Cereals 1971 Mean Crop Damage</u>

	Winter Barley		Winter Wheat	
	Site 1	Site 2	Site 1	Site 2
T1 - mid tillering				
Untreated control	1.0	1.0	1.0	1.2
Commercial standard	1.8	1.0	1.2	1.4
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	1.2	1.0	1.5	1.7
Cyanazine/MCPA 0.28 + 0.7 kg ai/ha	1.0	1.0	1.0	1.6
T2 - late tillering				
Untreated control	1.0	1.5	1.0	1.5
Commercial standard	1.5	1.0	1.5	1.4
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	1.2	1.0	1.5	1.9
Cyanazine/MCPA 0.28 + 1.4 kg ai/ha	1.3	1.0	1.0	1.4

E.W.R.C. Scale 1-9

No significant differences in yields were seen in either wheat or barley at either application timing. (Table 3)

Table 3

Winter Cereal Yields expressed as % of Control

	Winter Barley		Winter Wheat	
	Trial 1	Trial 2	Trial 1	Trial 2
T1 - mid tillering				
Untreated control	100	100	100	100
Commercial standard	120	99	88	110
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	110	99	92	114
Cyanazine/MCPA 0.28 + 0.7 kg ai/ha	117	98	94	118
T2 - late tillering				
Untreated control	100	100	100	100
Commercial standard	106	97	106	98
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	104	99	95	108
Cyanazine/MCPA 0.28 + 1.4 kg ai/ha	108	99	104	102

In spring cereals, applications made at the 3-4 leaf stage of the crop showed that all mixtures has performed well with little difference between cyanazine/2,4-DP and cyanazine/MCPA. In Scottish trials however, the latter were slightly superior when applied at the higher dose, especially where Galeopsis tetrahit was dominant. The low dose of the cyanazine/2,4-DP was particularly effective against the Polygonum spp. in England.

In the case of Chrysanthemum segetum, the mixture of cyanazine/2,4-DP checked this weed when applied at the 3-4 leaf stage of the crop and later applications gave a 45% to 50% reduction in population.

Trials in 1971 on spring barley showed that a high overall level of weed control was achieved by both mixtures at both timings. Species acceptably controlled (better than 85% reduction in population) included Stellaria media, Galeopsis tetrahit, Convolvulus arvensis, Matricaria spp., Polygonum persicaria, Chenopodium album, Spergula arvensis and Raphanus raphanistrum, however Polygonum aviculare was only checked by the mixtures in the English trials. Scottish trials on spring oats in 1971 showed that both 2,4-DP and MCPA mixtures gave a better than 90% control of weeds, with the high dose of cyanazine/2,4-DP being slightly more effective.(Table 4)

Table 4

1971 Scotland - Spring Cereals
Detransformed means for overall weed cover as % of control

Treatment \ Time		T1		T2
Control (weeds per sq.m.)			100 (571)	
Cyanazine/24DP	0.28 + 2.1 kg ai/ha	9.5		8.9
	0.37 + 2.1 " "	8.5		5.7
Cyanazine/MCPA	0.28 + 1.4 " "	9.6		12.0
	0.37 + 1.4 " "	8.3		7.1
Commercial standard			13.0	
L.S. Ratio between treatment means			1.9	

Trials in 1972 on spring barley and oats have shown that both 2,4-DP and MCPA mixtures applied between the 3 leaf and 5 leaf stage of the crop have again given excellent weed control. The cyanazine/MCPA mixtures have performed as well as the cyanazine/2,4-DP mixtures and in Scottish trials have been superior where *Galeopsis tetrahit* and particularly *Polygonum aviculare* have been present.

Table 5

Control of Polygonum aviculare from Scottish trials 1972 (Barley)
% of untreated control based on counts

Treatment \ Site		1*	7*	10*
Cyanazine/24DP	0.28 + 1.4 kg ai/ha	12.5	31.4	37.3
	0.37 + 1.4 " "	15.1	23.2	27.1
Cyanazine/MCPA	0.28 + 1.7 " "	8.0	6.6	5.1
	0.37 + 1.7 " "	3.3	2.1	6.2
Untreated (Mean Nos of weeds/sq.m./plot)		100 (60)	100 (173)	100 (413)

* Only trials which had sufficient population for analysis.

As in 1971 the current cyanazine mixtures have not given commercially acceptable control of Chrysanthemum segetum. However initial testing of an experimental formulation containing cyanazine, CMPP and 2-4D produced a high level of *Chrysanthemum segetum* control with no serious crop effects.

In a single trial on spring wheat in England excessive rainfall (6.35 mm) immediately after first application date caused an unacceptable level of weed control.

Table 6

Mean overall % weed control 7-8 weeks after treatment
1972 - Scotland - Spring Cereals
B = Barley   O = Oat

Treatment \ Site	B 1	B 2	B 3	B 4	B 6	B 7	B 8	B 9	B 10	O 12	O 14
Cyanazine/2,4-DP 0.28 + 1.4 kg ai/ha	96.8	96.9	99.1	96.3	90.6	81.8	98.1	94.5	80.8	97.4	94.6
Cyanazine/2,4-DP 0.37 + 1.5 kg ai/ha	96.4	97.5	99.0	96.4	92.7	87.4	98.2	97.3	86.7	98.2	93.3
Cyanazine/MCPA 0.28 + 1.7 kg ai/ha	97.6	97.0	98.5	96.0	97.1	97.1	97.2	97.4	96.7	98.5	94.6
Cyanazine/MCPA 0.37 + 1.7 kg ai/ha	99.0	98.8	99.4	94.2	99.0	98.6	97.1	98.5	96.3	98.4	95.1
Commercial standard	90.0	93.6	94.6	88.5	93.1	95.9	92.0	97.2	98.1	89.9	69.0
Untreated	0	0	0	0	0	0	0	0	0	0	0
(Mean Nos. of weeds/sq.m./plot)	(309)	(206)	(232)	(568)	(239)	(360)	(229)	(148)	(879)	(191)	(505)

Detransformed treatment means for weed cover as % of untreated control
1972 - Scotland - Spring Cereals

Treatment \ Site	B 1	B 2	B 3	B 4	B 6	B 7	B 8	B 9	B 10	O 12	O 14
Cyanazine/2,4-DP 0.28 + 1.4 kg ai/ha	3.2	3.1	0.9	3.7	9.4	18.2	1.9	5.5	19.2	2.6	5.4
Cyanazine"2,4-DP 0.37 + 1.4 kg ai/ha	3.6	2.5	1.0	3.6	7.3	12.6	1.8	2.7	13.3	1.8	6.7
Cyanazine/MCPA 0.28 + 1.7 kg ai/ha	2.4	3.0	1.5	4.0	2.9	2.9	2.8	2.6	3.3	1.5	5.4
Cyanazine/MCPA 0.37 + 1.7 kg ai/ha	1.0	1.2	0.6	5.8	1.0	1.4	2.9	1.5	3.7	1.6	4.9
Commercial standard	10.0	6.4	5.4	11.5	6.9	4.1	8.0	2.8	1.9	10.1	31.0
Untreated	100	100	100	100	100	100	100	100	100	100	100
(Mean Nos. of weeds/sq.m./plot)	(309)	(206)	(232)	(568)	(239)	(360)	(229)	(148)	(879)	(191)	(505)
Greatest value significantly less than control ($p < 0.05$)	44.8	41.9	42.9	70.4	53.9	48.2	52.2	44.4	59.2	53.0	64.8
Least significant ratio between ($p < 0.05$)	2.64	2.85	2.77	1.53	2.10	2.41	2.19	2.66	1.88	2.15	1.69

Table 7

Mean overall % weed control 61 days (T2) and 68 days (T1) after treatment
1972 - England - Spring Cereals

Treatment \ Time	Wheat T1	Wheat T2	Barley T1	Barley T2
Cyanazine/2,4-DP 0.28 + 1.7 kg ai/ha	68.1	89.4	80.7	94.9
" /2,4-DP 0.28 + 2.1 kg ai/ha	56.6	86.1	96.8	94.5
Cyanazine/MCPA 0.28 + 1.0 kg ai/ha	55.9	80.7	79.3	86.9
Commercial standard	30.7	60.9	-	-
Commercial standard	-	-	73.3	77.1
Untreated control (Mean % weed cover)	0 (96.5)	0 (95.0)	0 (21.7)	0 (27.4)

Detransformed treatment means for % cover of broadleaved weeds
61 days (T2) and 68 days (T1) after treatment
1972 - England - Spring Cereals

Treatment \ Time	Wheat T1	Wheat T2	Barley T1	Barley T2
Cyanazine/2,4-DP 0.28 + 1.7 kg ai/ha	30.8	10.1	4.2	1.4
" /2,4-DP 0.28 + 2.1 kg ai/ha	41.9	13.2	0.7	1.5
Cyanazine/MCPA 0.28 + 1.0 kg ai/ha	42.6	18.3	4.5	3.6
Commercial standard	66.9	31.5	-	
Commercial standard	-		5.8	6.1
Untreated control (Mean% weed cover)	100 (96.5)	100 (95.0)	100 (21.7)	100 (27.4)
Least significant ratio between treatments ($P < 0.05$)	1.65		2.46	

Table 8

Weeds controlled with more than 85% reduction by Cyanazine/2,4-DP and Cyanazine/MCPA mixtures in the UK

Aethusa cynapium	Polygonum aviculare
Atriplex patula	Polygonum convolvulus
Anagallis arvensis	Polygonum persicaria
Capsella bursa-pastoris	Polygonum lapathifolium
Chenopodium album	Raphanus raphanistrum
Convolvulus arvensis	Sinapis arvensis
Fumaria officinalis	Silene album
Galeopsis tetrahit	Solanum nigrum
Lamium purpureum	Spergula arvensis
Lamium amplexicaule	Stellaria media
Lepidium draba	Thlaspi arvensis
Linaria vulgaris	Urtica urens
Matricaria spp.	Veronica spp.
Myosotis arvensis	Viola arvensis
Papaver rhoeas	

Any crop effects that were noted in the 1971 and 1972 trials were slight and disappeared a few days after treatment. In variety trials the mixtures were tested on 9 varieties of spring oats, 20 varieties of spring wheat and 24 varieties of spring barley. Mixtures of 2,4-DP with 0.56 kg cyanazine i.e. twice the rate likely to be used in practice caused no effect on any of the wheat, oat or barley varieties tested except that slightly smaller ears were noted in varieties Sultan, Clermont and Felda. These observations on crop safety were supported by a series of log trials alongside the replicated trials.

In Scottish trials both cyanazine mixtures gave yield increases, the most consistant being the cyanazine/2,4-DP applied at 2-4 leaf stage of the crop. Yields generally showed an increase over the untreated controls in the English trials except at one site where marginally depressed yields were obtained when treatments were made at the 5 leaf stage of the crop. (Table 9)

Table 9

1971 Cereal Yields - Scotland
expressed as % of control

Treatment \ Time	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Barley T1	Barley T2	Oats T1	Oats T2
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	109	103	108	101	114	106	113	112	102	122	93	91	98	106	97	96	117	121
Cyanazine/2,4-DP 0.37 + 2.1 kg ai/ha	108	105	108	108	117	112	113	113	116	115	97	101	97	103	104	97	117	117
Cyanazine/MCPA 0.28 + 0.7 kg ai/ha	106	-	102	-	112	-	113	-	104	-	98	-	95	-	100	-	-	-
Cyanazine/MCPA 0.28 + 1.4 kg ai/ha	-	94	-	104	-	112	-	113	-	106	-	101	-	98	-	104	119	117
Cyanazine/MCPA 0.37 + 0.7 kg ai/ha	104	-	109	-	116	-	112	-	110	-	96	-	97	-	98	-	-	-
Cyanazine/MCPA 0.37 + 1.4 kg ai/ha	-	100	-	107	-	104	-	115	-	110	-	103	-	98	-	97	121	119
Commercial standard	-	104	-	117	-	109	-	111	-	109	-	104	-	103	-	101	-	119

1972 Cereal Yields (Barley) - Scotland
expressed as % of control

Treatment \ Site	2*	4*	7*	3*	9*
Cyanazine/2,4-DP 0.28 + 1.4 kg ai/ha	103.6	115.6	110.6	121.2	104.7
Cyanazine/2,4-DP 0.37 + 1.4 kg ai/ha	105.5	113.8	108.0	121.7	105.5
Cyanazine/MCPA 0.28 + 1.7 kg ai/ha	97.6	112.7	107.0	116.7	106.4
Cyanazine/MCPA 0.37 + 1.7 kg ai/ha	101.6	112.6	106.4	114.7	105.6
Commercial standard	102.7	111.5	110.6	115.3	109.8
Untreated	100.0	100.0	100.0	100.0	100.0
(kg/ha)	(5382)	(6576)	(5058)	(5767)	(4886)
LSD between treatments P = 0.05	6.2	3.7	5.6	4.7	7.7
Range outside which means are significantly different controls	93.9-106.1	96.9-103.6	94.5-105.5	95.7-104.3	92.4-107.6

(* Only yield results available at time paper was prepared)

Table 9 Cont.

1971 Spring Cereal Yields - England expressed as % of control

Treatment \ Time	Barley		Barley		Barley		Barley		Barley		Barley		Barley	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	104	103	101	108	90	70	110	108	126	100	109	87	95	99
Cyanazine/MCPA 0.28 + 0.7 kg ai/ha	104	-	106	-	94	-	106	-	117	-	118	-	86	-
Cyanazine/MCPA 0.28 + 1.4 kg ai/ha	-	100	-	108	-	93	-	109	-	122	-	92	-	89
Commercial standard	108	99	104	119	99	98	107	106	134	132	88	86	117	93

1972 Spring Cereal Yields - England expressed as % of control

Treatment \ Time	Wheat			Barley		
	T1	T2	Mean	T1	T2	Mean
Cyanazine/2,4-DP 0.28 + 1.7 kg ai/ha	102	103	103	101	98	99
Cyanazine/2,4-DP 0.28 + 2.1 kg ai/ha	107	105	106	106	97	101
Cyanazine/MCPA 0.28 + 1.0 kg ai/ha	110	110	110	99	103	101
Commercial standard	99	97	98	-	-	-
Commercial standard	-	-	-	103	90	96
Untreated control	100	100	100	100	100	100
(Mean control yield kg)	(33.8)	(34.3)				

DISCUSSION

One of the most striking symptoms to be observed was the nature of the effect on susceptible weeds. After a preliminary period when only some marginal scorch could be seen there was a rapid onset of chlorosis followed by the complete collapse of the weeds. The appearance of the weed debris being reminiscent of the best results of DNOC leaving a very clean bottom to the crop unlikely to encourage parasitic fungi. This cleanliness of the stubble was a feature of all the farmer applied trials and was commented on favourably at harvest time.

The T1 application result (Table 1) tends to indicate that on most soils the root action of the cyanazine component of the mixture (0.28 kg/ha) is small, and that most activity arises from foliar absorption. The collapse of large overwintered chickweed is a further indication of this.

The results on Polygonom aviculare in Scottish trials may be explained by the higher dose of MCPA in the mixture being applied where heavy infestation of this weed occurred. This situation did not arise on English sites.

The highest levels of weed control were obtained when the cyanazine mixtures were applied at the 3-4 leaf stage of crop growth. Later applications tended to give slightly less effective overall weed control possibly because certain weeds were less susceptible as they became more mature.

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AN ASSESSMENT OF THE PRACTICE AND POTENTIAL FOR THE JOINT APPLICATION OF SOLUTION FERTILISERS AND HERBICIDES IN THE U.K

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Summary Results from a number of trials into the joint application of herbicides with solution fertilisers are reviewed together with some comments from commercial farmer experience. The scope for increased use of such mixtures in the future is discussed with the relevant limitations.

INTRODUCTION

The continued reduction in the farm labour force means that at busy times of the year there are considerable advantages and economies to the farmer in adopting a bulk handling system for fertilisers. Solution fertilisers, being easily transferred by pumping, are proving attractive as an alternative to handling bagged fertiliser. Bulk solution fertiliser systems are, therefore, being increasingly integrated into farming practice in the U.K. Moreover solution fertilisers are more flexible than their solid counterparts when it comes to the addition of herbicides as this may be possible on the farm but is seldom practicable with solids because of long production runs.

Solution fertilisers, which are more commonly referred to as liquid fertilisers, are aqueous solutions of ammonium nitrate, ammonium phosphates, ammonium polyphosphates, urea and potassium chloride. Concentrations are normally limited, for solubility reasons, to 24-28 units per cwt. or approximately 9 gallons. Typical grades are :-

Table 1

Nutrient content of solution fertilisers

N	P_2O_5	K_2O
26.0	0	0
14.0	6.0	8.0
7.0	7.0	10.0
9.0	9.0	9.0
4.0	10.0	10.0

Apart from the obvious advantages in being able to complete two farming operations at the same time, a reduction in the labour requirement may make all the difference between completing and not completing work in a difficult season. In addition, soil compaction is reduced through the elimination of one set of wheelings. The timely application of adequate fertiliser will also ensure vigorous crop growth which may also increase the herbicidal effect through increased crop competition.

It is important always to appreciate that this technique of joint application is a compromise. Before any field work is started physical compatibility tests must be made. The results may be conveniently grouped in the following categories :-

(a) Compatible

(b) Compatible with good agitation

(c) Incompatible

In the field, the choice of jet will also have a major effect on the results.

REVIEW

The opportunities for the joint application of herbicides with solution fertilisers may be classified according to their timing and method of application related to the crop. Thus there may be the possibilities of applying a solution fertiliser/herbicide treatment at the following times :-

(a) Before ploughing on to the previous crop stubble.

(b) Pre-planting or drilling, often as a soil incorporated treatment.

(c) As an overall spray, pre-emergence, of a drilled crop.

(d) Post-emergence of the crop but as a directed treatment.

(e) Post-emergence of the crop as an overall top dressing.

Not all these possibilities will prove reasonable since the normal limitations of timing for the weed or fertiliser scorch together with the sowing or planting delays dictated by the herbicide or fertiliser will apply.

(a) Pre-ploughing.

Here the scope for the combined application of solution fertilisers seems limited by two factors. Firstly by the fact that autumn applied nitrogen will largely be leached away during a normal winter and secondly by the normal planting delay required with herbicides. No reports of farmers using such treatments pre-ploughing are known in the U.K.

(i) Aminotriazole

At the recommended rate the commercial formulation of aminotriazole is physically compatible with some high and low nitrogen compounds. It would, therefore, seem possible to consider autumn application with 4-10-10 or 6.6-20-0 to control perennial grasses and certain broadleaved weeds, plough after three weeks and drill with winter wheat or oats. Similarly in the spring a joint treatment with, for example, 14-6-8 could be followed by spring wheat or oats, kale or maize. Ploughing in the spring may mean that the frost mould is lost but it would seem possible to apply an aminotriazole treatment combined with 9-9-9 or 7-7-10 solution fertiliser. There is clearly a need for a critical appraisal and some farmer experience. With the improved fertilisers now available application as a fine spray through a chemical jet would seem to be advisable. Information is needed on the effects, if any, of scorch on the uptake and efficiency of the herbicide.

(ii) Dalapon

The opportunity for combined dalapon/solution fertiliser treatment in the autumn seems ruled out by the normal sowing delay for the herbicide. However, a spring application in the appropriate compound fertiliser and ploughing after twenty days could be followed by carrots, sugarbeet, rape or kale. Dalapon as a commercial formulation appears physically compatible with many solution fertilisers but again there is a need for information on the herbicidal efficiency of such treatments. Since there is no complication of the crop being present, the use of a chemical jet seems appropriate to achieve maximum retention on the grass foliage.

(iii) TCA

Although TCA is soluble to a limited degree in several solution fertilisers it is not sufficiently so for autumn application at the rates required for perennial grass weed control. Application of low rates of TCA in solution fertilisers before ploughing therefore does not seem to be possible or of any particular value.

(b) Pre-planting or pre-drilling.

There is considerable scope for the joint application of herbicides with solution fertilisers. With the continued expansion of the solution fertiliser market and the possible introduction of new herbicides this technique may be used on an increasing scale in the future. Since no crop is present the important aspects are those of physical and chemical compatibility coupled with the normal limitations in timing and rates of herbicide.

(i) Atrazine

Commercially available w.p. formulations of atrazine appear to be physically compatible with most solution fertiliser grades provided good agitation is maintained to minimise any settling out. Although practical experience is lacking with this treatment there seems to be a good case for the application of atrazine at 2 - 8 lb commercial product/acre with a high nitrogen compound 2-3 weeks pre-drilling of maize and incorporated in the seed bed in the normal fashion.

(ii) Diallate

The commercial formulation of diallate is compatible with many grades of solution fertilisers provided adequate agitation is given. Pre-mixing the concentrate in an equal volume of water before mixing with the solution fertiliser is desirable. Immediate incorporation (or within one hour) into the soil is advised and it is obviously necessary to make sure that the high output of modern solution fertiliser applicators does not get too far ahead of the harrows. Joint application of diallate with solution fertilisers has been practiced on an extensive commercial scale for many years before the sugarbeet crop with satisfactory results even though the depth of incorporation for the herbicide is not ideal for the fertiliser. Application before red beet and brassicas in the appropriate fertiliser also seems viable. One replicated trial (Chafer 1967) pre-drilling of oil-seed rape on wild oat free land examined the application of both triallate and diallate as a joint application in 10 cwt of 14-6-8 or 20 gallons of water per acre.

Table 2

Yield of Oil Seed Rape - cwt/ac

Treatment	10 cwt 14-6-8	10 cwt 14-6-8 with triallate as a joint spray	10 cwt 14-6-8 Then triallate in 20 g.p.a.	10 cwt 14-6-8 with diallate as a joint spray	10 cwt 14-6-8. Then diallate in 20 gpa
	17.0	15.9	15.5	17.3	17.3
			L.S.D.	1.1 cwt	
			C. of V.	4.2%	

In this trial there were no significant differences in yield between a conventional application in water or as a joint solution fertiliser treatment.

(iii) EPTC

EPTC as the commercially available e.c. is compatible with several grades of solution fertilisers provided agitation is maintained during the mixing and spraying operation. It is therefore possible to apply EPTC with the grades 7-7-10 or 9-9-9 before the potato crop and since the chemical is incorporated to a depth of 6 - 7 in. efficient use of both broadcast fertiliser and chemical seems possible. Only a limited acreage has been treated in the U.K. using this technique but results were satisfactory. Again it is important to make sure that the application of fertiliser and chemical does not get too far ahead of the incorpcrating implement.

(iv) Paraquat

Although the commercial formulation of paraquat is physically compatible with some grades of solution fertilisers in practice there has been some variability with the results where a joint application has been attempted. This is probably due to some effects in herbicidal activity through the inclusion of the fertiliser. However it seems desirable always to apply the solution fertiliser/paraquat mixtures through a chemical jet since it is known that a fine spray increases the activity of this herbicide. In the field only average results have been obtained where joint application has been made through low pressure fertiliser jets.

(v) Propham

This herbicide is commonly available commercially as the 50% w.p. but more recently e.c. formulations have been introduced. As a wettable powder, propham has been mixed and applied commercially on several hundreds of acres of sugarbeet as a joint treatment a few days before drilling. In general this has given satisfactory results, especially on medium-heavy soils, but the importance of maintaining agitation and uniform dispersion of the herbicide was confirmed by one report of crop damage in Norfolk through uneven application of the chemical on light land. It is likely that the e.c. formulation will mix more readily with solution fertilisers but again this needs confirming. Application of propham with solution fertiliser before peas has not been reported and this may be because of the limited response to broadcast fertiliser or the practice of ploughing this down.

(vi) Pyrazon

The commercial 80% w.p. formulation of pyrazon will form a uniform dispersion through some solution fertiliser grades provided agitation is maintained. Satisfactory results have been obtained in practice but only on a limited acreage where pyrazon has been applied through fertiliser jets with 15 cwt 7-7-10 per acre and incorporated pre-drilling of sugarbeet. Again care is needed to ensure that the correct rate of herbicide/fertiliser spray mixture is applied.

(vii) TCA

Although the use of TCA with solution fertilisers to control perennial grass weeds as a pre-ploughing technique is impracticable, it is possible to use this technique to control wild oats before drilling of sugarbeet. Satisfactory results have been obtained applying $7\frac{1}{2}$ lb TCA in 15 cwt 7-7-10 or 7 cwt 14-6-8 per acre a few days before drilling sugarbeet. It is also possible to apply $7\frac{1}{2}$ lb TCA with 14-6-8 at 7 - 9 cwts per acre 14 days before drilling kale or oilseed rape. No reports are known where low rates of TCA have been applied with 2.3-6-12 before peas but again this is possible from the compatibility aspect.

(viii) Triallate

A considerable acreage of cereals is treated annually with a joint application of the commercially available formulation of triallate in solution fertilisers. Triallate is compatible with many solution fertiliser grades provided agitation is maintained. Where the solution fertiliser has a high phosphate content some slight cloudiness has been noted in laboratory tests. However, provided the herbicide is pre-mixed with an equal volume of water and the mixture is applied as soon as possible satisfactory results are obtained. As with diallate prompt incorporation is important. The recommendation that the herbicide should be incorporated within the top 1 in. of soil does not seem a serious limitation perhaps because of the small responses of cereals to phosphate and potash on many soils. No reports from farmers of triallate being used before carrots and peas or beans are known. One replicated trial (Chafer 1967) in spring barley compared an application of triallate with 5 cwts 14-6-8 or in 20 g.p.a. Both treatments gave a similar control of *Avena fatua*, assessed by counts of *A. fatua* panicles in early August. Yield increases were also obtained.

Table 3

Yields of spring barley and counts of A. fatua panicles for different application methods of triallate

Treatment	5 cwt 14-6-8	5 cwt 14-6-8 with triallate as a joint spray	5 cwt 14-6-8 Then triallate/ 20 g.p.a.
A. fatua/plot	36,000	187	176
Yield cwt/ac	19.8	26.0	25.9
		L.S.D. 1.1 cwt	
		C. of V. 3.9%	

(ix) Trifluralin

This herbicide as the commercially available e.c. appears compatible with many grades of solution fertilisers. A limited acreage has been treated with joint applications of trifluralin and 7-7-10 with satisfactory results. There would seem to be scope for increased usage. Again prompt incorporation is important, this is probably more so than whether or not trifluralin is applied with solution fertilisers. Again there is a need to ensure that the high work rate of the solution fertiliser applicator does not run ahead of the incorporating implements. In some areas there is a preference for somewhat deeper incorporation of fertiliser than the 2 in. advised for trifluralin and this might limit the adoption of this technique.

(c) Overall spray, pre-emergence of drilled crops.

Here the use of joint treatments of liquid fertilisers with herbicides presupposes that the crop is being grown on reasonably fertile soils as the response to surface applied fertiliser will not be high. There seems little or no experience of this technique with surface applied residual herbicides in the U.K.

However, it would seem possible to apply for example pyrazon or lenacil with solution fertilisers pre-emergence of sugarbeet. Similarly atrazine pre-emergence of maize and simazine in field beans are possibilities. More information is needed on the effects, if any, on crop germination from such combinations and the influence of different jets on coverage and residual activity. Are chemical jets essential or will the coarser spray pattern from fertiliser nozzles suffice particularly where high rates of fertiliser are applied?

(d) Directed spray post-emergence of the crop.

Most of the comments made in Section (c) apply except that at the present time solution fertilisers are seldom applied as an inter-row directed spray being more commonly "dribbled" between row crops. Currently there seems little scope for the application of herbicides with dribbled fertiliser.

(e) Post-emergence of the crop as an overall treatment.

The overall application of herbicides with solution fertilisers, most commonly 26% nitrogen, is the most obvious use for joint applications.

(i) Barban

It is known that some growers have attempted a joint application of nitrogen fertiliser and barban. This seems ill advised because of the different application criteria for the fertiliser and the herbicide.

(ii) Chlormequat

Increased crop scorch usually results from joint applications of chlormequat with solution fertilisers and some caution is needed with such mixtures particularly if applied when the first joint can be felt at the base of wheat tillers. Crop damage has resulted from the joint application of mixtures of chlormequat and solution fertiliser with certain herbicides under dry conditions. This mixture should be avoided because of the risks of excessive shortening of the crop.

(iii) Cereal Herbicides

This subject has already been reported on at a previous Conference (Townsend 1968) and at that time attention was drawn to the fact that little critical evidence was available and that there was a need for further research. Since that time further detailed trials have been completed in winter wheat, spring barley, permanent grass and on a ryegrass ley. Two trials in winter wheat (NAAS 1969) showed that the addition of dichlorprop/MCPA to 26% nitrogen solution increased the level of crop scorch two to threefold. Yields were not affected at one site but were 1 cwt/ac lower at the other. A further trial in winter wheat (ADAS 1970) showed the inclusion of dichlorprop/MCPA with 26% nitrogen solution to have little effect on straw length, 1000 grain weight, tillers and plants per metre of row or flag leaf area. However, yields were 5.4 cwt/acre lower when the herbicide was included with the solution fertiliser and crop scorch was also doubled. It is interesting to note that applying this herbicide conventionally in 15 g.p.a. of water also reduced yields by 4.5 cwt/acre. Further trials at Rothamsted Experimental Station (Freeman 1970) showed that the inclusion of increasing amounts of herbicide increased the level of crop scorch on winter wheat, spring barley and permanent grass but that this soon grew out and there was little evidence that it had a permanent effect or lessened yields. Applied as a fine spray there was some evidence that the herbicide was more effective when applied in the solution fertiliser than in water. Trials at Rothamsted (Freeman & Penny 1971) in wheat again showed that the inclusion of the herbicide increased crop scorch which increased with increasing amounts of fertiliser and herbicide. Slightly better weed control resulted from the combined application and the inclusion of the herbicide caused irregular effects on yield. In spring barley scorch from the solution fertiliser increased with increasing amounts of herbicide which had a greater effect than increasing the rates of fertiliser. The herbicide decreased yields slightly in eight out of nine comparisons presumably because of the severe scorching effect. On permanent grass and S24 perennial ryegrass similar effects were produced, scorch increasing with increasing rates of herbicide and solution fertiliser. Weed control was satisfactory however and there was little effect on yield.

(iv) Metoxuron

Some trials with mixtures of metoxuron and liquid fertilisers were reported at the last conference (Griffiths and Ummel 1970). The general conclusion was that the inclusion of metoxuron did not increase the extent of leaf scorch or influence the control of blackgrass. Limited practical experience since then has shown that increased crop scorch can result from a joint application but that satisfactory control of blackgrass results. In a further trial (Chafer 1970) in winter wheat crop scorch was not caused perhaps because rain fell within 2 hours of application. Using solution fertiliser jets a slightly lower control of both wild oats and blackgrass resulted probably because of the reduced contact effect from the coarser spray.

Table 4

Control of wild oats and blackgrass with metoxuron applied in N26% or water

Treatment	Jet	Wild oat tillers/plot	Blackgrass heads/ quadrat
N26% 65 units/ ac	LF	3600	75.6
N26% 65 units and 4 lb metoxuron/ac	LF	512	8.8
N.26% 65 units/ac Then 4 lb metoxuron in 23 g.p.a.	Chemical	133	0

DISCUSSION

There are considerable practical advantages in being able to apply both fertiliser and herbicide as a joint treatment. This practice is being adopted by many farmers to apply cereal herbicides as a reasonably effective compromise particularly in difficult spraying seasons. Whilst the weed control results where cereal herbicides are applied through fertiliser jets generally tend to be slightly less than conventional treatments, solution fertiliser being flexible readily lend themselves to this technique often with satisfactory results. Crop scorch from overall application post-emergence of a cereal may be increased but this does not arise with soil incorporated joint applications and it is here that the major growth of this technique is to be expected.

There is still a need for more information on this farming compromise particularly since results are influenced by different herbicide formulations, solution fertiliser types and also the application equipment. However with solution fertilisers the opportunity is often available to the grower to maximise the use of an essentially flexible system yet still bearing in mind certain limiting factors.

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LATE SPRAYING OF WINTER WHEAT

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Summary A series of experiments carried out by N.A.A.S. with 4 chemicals applied at 2 rates and 2 growth stages of winter wheat is reported. Some chemicals applied at both growth stages depressed yield from 0.6 cwt/ac to 5.3 cwt/ac depending on dose and locality.

INTRODUCTION

A series of experiments was undertaken by N.A.A.S. to study the effect on grain yield of spraying winter wheat at two growth stages. Sites were chosen where weed populations were very low so that the direct effect of herbicides on the wheat could be assessed. This paper summaries the results of 5 experiments over the years 1968 to 1971 carried out in the West Midland region and 3 experiments carried out in 1970 and 1971 in the South West region on winter wheat.

METHOD AND MATERIALS

The chemicals shown on Table 1 were applied at two growth stages, growth stage 5 (G.S.5) when the wheat was fully tillered and growth stage 7 (G.S.7) when the majority of plants were showing the second node at base of stem. Two rates of chemical were applied, a single dose and a double dose to measure the effect of overlap. In the West Midland series the chemicals were applied at both growth stages but in the South West the double rate was confined to growth stage 7. In the South West, Joss Cambier was used for all three experiments whilst in the West Midlands Cappelle Desprez was used for four years and Maris Ranger in 1971. The herbicides were applied by Landrover sprayer in the South West experiments and by a Dorman "Wheel-a-way" sprayer in the West Midlands, at 25 psi in 20 gal/ac.

Table 1
Chemicals and doses used

	Chemical	Dose oz. a.i./ac West Midland	South West
1	MCPA	20	12
2	MCPA	40	24
3	Dichlorprop	36	24
4	Dichlorprop	72	48
5	Ioxynil 4 + Dichlorprop 24 + MCPA 8		
6	Ioxynil 8 + Dichlorprop 48 + MCPA 16		
7	2,3,6-TBA 2 + Dicamba 1½ + MCPA 8 + Mecoprop 12		
8	2,3,6-TBA 4 + Dicamba 3 + MCPA 16 + Mecoprop 24		

RESULTS

West Midlands

The summary of the mean yields over the 5 years is given in Table 2.

This shows a mean yield depression from all sprays of 1.3 cwt/ac at G.S.5 and 1.9 cwt/ac at G.S.7; in only two treatments applied at G.S.5 were yields increased above the unsprayed control. Of the sprays used only dichlorprop and ioxynil at the double rate significantly depressed yield at both growth stages, similarly the TBA/dicamba mixture at double the recommended rate significantly depressed yield at G.S.7. In fact the double dose of TBA/dicamba mixture produced the highest yield increase when applied at G.S.5 and the greatest depression when applied at G.S.7. The mean yield effect of the two rates applied at the two growth stages is shown in Table 3.

Table 2
Yields of grain : cwt/ac at 85% dry matter (West Midlands)

Chemical	Applied at G.S.5		G.S.7	Mean
Single rate		(±0.71)		(±0.50)
MCPA	46.9		46.9	46.9
Dichlorprop	46.1		46.8	46.5
Ioxynil + dichlorprop + MCPA	48.6		46.8	47.7
2,3,6-TBA + dicamba + MCPA + Mecoprop	48.1		46.6	47.4
Double rate				
MCPA	46.2		48.0	47.1
Dichlorprop	45.1		45.5	45.3
Ioxynil + dichlorprop + MCPA	45.4		45.0	45.2
2,3,6-TBA + dicamba + MCPA + Mecoprop	48.8		44.6	46.7
Mean of sprayed treatments	46.9	(±0.25)	46.3	
Unsprayed control		48.2		

Table 3
Yield effect (cwt/ac) at 2 growth stages (West Midlands)
(mean of 4 herbicides)

Growth stage and dose	Yield effect (±0.62)	95% Confidence interval
G.S.5 (single)	- 0.8	- 2.0 to + 0.4
G.S.7 (single)	- 1.4	- 2.6 to - 0.3
G.S.5 (double)	- 1.8	- 3.0 to - 0.6
G.S.7 (double)	- 2.4	- 3.6 to - 1.2

This shows a yield depression in the range 0.8 cwt/ac to 2.4 cwt/ac; the 95% confidence intervals are also shown in table 3.

South West

The mean yields for the three years are given in Table 4, which shows a mean yield depression of all sprays in the range 0.6 cwt/ac at G.S.5 to 4.3 cwt/ac at G.S.7.

Table 4
Yields of grain : cwt/ac at 85% dry matter (South West)

Chemical	Applied at G.S.5		G.S.7	Mean
Single rate		(±0.76)		(±0.54)
MCPA	45.2		43.0	44.1
Dichlorprop	45.2		45.7	45.4
Ioxynil + dichlorprop + MCPA	45.8		41.3	43.5
2,3,6-TBA + dicamba + MCPA + mecoprop	44.6		40.1	42.3
Double rate				
MCPA			43.6	
Dichlorprop			43.6	
Ioxynil + dichlorprop + MCPA			43.1	
2,3,6-TBA + dicamba + MCPA + mecoprop			31.9	
Mean of sprayed treatments	45.2		41.5	
Unsprayed control		45.8		

All treatments, except the ioxynil mixture applied at G.S.5, depressed yields. Five treatments significantly depressed yields when applied at G.S.7 and these were MCPA, ioxynil and TBA/dicamba (single dose) and ioxynil and TBA/dicamba (double dose). The greatest yield depression occurred with TBA/dicamba applied at G.S.7 at both rates - this ranged from 5.7 cwt/ac with the single dose to 13.9 cwt/ac at the double dose.

Table 5
Yield effect (cwt/ac) at 2 growth stages (South West)
(mean of 4 herbicides)

Growth stage and dose	Yield effect (±0.54)	95% Confidence interval
G.S.5 (single)	- 0.6	- 1.68 to + 0.48
G.S.7 (single)	- 3.3	- 4.38 to - 2.22
G.S.7 (double)	- 5.3	- 6.38 to - 4.22

The effect of the chemicals applied at the two growth stages on the mean yield is shown in Table 5. The yield depressions fall in the range 0.6 cwt/ac to 5.3 cwt/ac, and the 95% confidence intervals are shown.

DISCUSSION

Experiments conducted in the period 1943 to 1947 by Blackman and Roberts (1950) showed an average improvement in the yield of cereals, as a result of controlling weeds with herbicide sprays, greater than 20 per cent. A study carried out by Evans (1966) on the effect of commercial treatments in experiments published in the period 1958 to 1964 indicated that yield response to spraying was generally quite small. A survey carried out by N.A.A.S. (Evans 1969) between 1965 and 1967 on the comparison of yields of cereals on sprayed and unsprayed plots at 297 sites on commercial farms indicated that farmers would have lost no or very little yield by withholding spraying for a year.

The experiments reported here indicate that yield depressions, in the order of 0.7 cwt/ac, can occur when a range of herbicides are applied to winter wheat at the correct dose and growth stage. When chemicals are applied incorrectly, either at too late a stage of growth of the crop or by overlapping spray boom, the yield depression can be considerable. This is borne out by Evans (1969) who found in the survey that 37% of the fields were sprayed incorrectly - either at the incorrect dose or the spray was applied at too late a stage of growth of the crop. In the West Midland experiments doubling the dose depressed the mean yield of the 4 chemicals by 1.0 cwt/ac at both growth stages and similarly delaying the application from G.S.5 to G.S.7 at both doses the yield was depressed by 0.6 cwt/ac. With a different variety (Joss Cambier) the South West experiments showed that delaying spraying from G.S.5 to G.S.7, at the normal rate of herbicide, produced a mean yield depression of 2.7 cwt/ac. The larger yield depression in the South West experiments is due partly to a consistent yield depression after using the double rate of TBA/dicamba mixture at both growth stages. At one site in 1970 the yield depressions with this chemical was 9.5 cwt/ac at G.S.5 and 25.3 cwt/ac at G.S.7.

In the West Midland series it was consistently observed that dichlorprop caused crop scorch and increased lodging. The yield depression of this chemical was in the range of 1.4 cwt/ac to 3.1 cwt/ac for both growth stages and doses.

Farmers can no longer guarantee a yield increase from spraying winter wheat in the Western side of England and there must be other reasons for spraying. These must include for example - ease of harvesting and drying, and less weed seeds in corn samples.

Acknowledgements

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CONTROL OF ANNUAL BROAD-LEAVED WEEDS IN WINTER WHEAT WITH HERBICIDES USED PRIMARILY AGAINST ALOPECURUS MYOSUROIDES AND AVENA FATUA

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Summary Low weed populations severely limited the scope and precision of the comparisons. There were a number of cases where commercial claims were at variance with the data, both positively and negatively. Post-emergence application of soil acting materials tended to be superior to pre-emergence.

INTRODUCTION

A range of herbicides was evaluated for the control of A. myosuroides and A. fatua by the Crop Husbandry Department of A.D.A.S. Eastern Region between 1969 and 1972 (North and Livingston, 1970; Baldwin and Livingston, 1972 and Proctor and Livingston, 1972). At a large proportion of the sites populations of annual broad-leaved weeds were too low for meaningful effects of treatments to be determined. Several treatments were included at too few sites to make their inclusion here worthwhile.

METHODS AND MATERIALS

Details of sites and treatments are given in the papers referred to. Counts of annual broad-leaved weeds were made as late in spring as possible; normally just before or at the early jointing stage of the wheat.

KEY to sites:- * 1969-70 A.m. experiments; ** 1971/72 A. myosuroides experiments;

ƒ 1969/70 A. fatua experiments; ƒƒ 1971/72 A. fatua experiments.

RESULTS

See Tables 1 and 2

Table 1

Population of Main Annual Broad-Leaved Weeds/m^2

Site	All species	Galium aparine	Stellaria media	Polygonum convolvulus	Polygonum aviculare	Sinapis arvensis	Veronica spp
1 *	14.3	-	3.9	5.5	-	-	1.3
2 *	41.9	0.6	5.0	-	1.6	-	30.0
3 *	13.1	2.1	-	9.2	-	0.2	-
4 *	3.9	-	0.4	0.4	-	0.8	0.2
5 *	0.6	-	-	-	-	0.4	-
6 *	17.6	4.1	11.6	-	0.2	1.2	0.6
7 *	47.6	3.1	-	-	-	0.6	37.0
8 *	19.6	-	0.8	-	-	-	18.0
1 †	28.2	0.6	5.1	0.8	4.1	3.5	1.0
2 †	27.2	-	-	1.0	3.3	-	8.0
3 †	87.4	4.7	14.3	29.2	18.6	-	9.4
4 †	33.9	7.6	-	0.6	7.4	-	4.5
1 **	20.5	0.6	1.0	-	1.8	0.9	11.4
3 **	44.1	-	-	-	-	8.6	9.2
4 **	39.6	-	24.5	-	0.2	1.3	11.6
4 #	84.0	-	-	-	-	-	-
6 #	16.7	-	3.3	-	1.0	4.7	6.9
7 #	38.8	2.4	0.6	11.3	20.2	2.9	1.2

Weed populations were not assessed on seven unlisted sites as populations were far too low for meaningful interpretations to be made of treatment effects.

Table 2

Mean % control of main species

Treatment	P convolvulus	G. aparine	Stellaria media	Veronica spp.	S arvensis	P. aviculare
Tri-allate gr. pre -emergence	-	-	-	59	18	-
Terbutryne pre-emergence	64	24	35	60	-	55
Barban post-emergence	2	36	12	20	45	40
Methabenzthiazuron pre-emergence	26	35	77	57	-	49
Nitrofen pre-emergence	84	61	20	89	-	49
Metoxuron pre-emergence	7	51	27	15	-	56
Metoxuron post-emergence	77	67	93	58	95	96
Metoxuron late-post emergence	75	90	100	75	96	100
Chlortoluron pre-emergence	79	34	78	25	83	82
Chlortoluron post-emergence	74	55	95	59	86	90
Dichlobenil/fluometuron post-emergence	64	29	89	34	-	97
Cyanazine post-emergence	80	43	100	93	83	89
Brompyrazone + isononuron post-emergence	85	49	93	60	-	98
701. (a substituted urea) post-emergence	50	41	90	81	-	70
Lenacil + ioxynil post-emergence	48	73	79	53	-	89

DISCUSSION

Populations of individual species, other than Veronica, were low compared to the annual grass weeds. Veronica spp however are probably of little economic importance in cereals so far as effects on yield and ease of harvesting are concerned.

It is of note that, even allowing for the small size of the sample, the relative frequencies of species did not match well with those of a recent survey, (ANON, 1968), in which Stellaria was of much greater importance irrespective of soil type.

Experience has shown that, in making their choice, farmers take careful account of the claimed efficiency of the annual grass weed herbicides against annual broad-leaved species, especially in the case of A.myosuroides herbicides. These data will be found to suggest several wide divergencies from commercial claims but almost equally in over and under estimates of efficiency. This is no doubt largely due to the comparatively limited data yet accumulated.

The pre-emergence application of metoxuron and chlortoluron tended to be appreciably less effective than post-emergence treatments in their control of annual broad-leaved weeds; the late metoxuron application giving particularly good control.

Of the pre-emergence treatments nitrofen and chlortoluron seemed particularly effective against P. convolvulus. Though the former did quite well against G. aparine and Veronica it was less satisfactory against S. media on which methabenzthiazuron was promising. Chlortoluron had good effect on P. aviculare.

Of the post-emergence treatments cyanazine was notably effective except against G.aparine while the dichlobenil/fluometuron treatment, of those materials currently marketed, was amongst the less active though giving rather better control of P.convolvulus than claimed.

Although barban was the least effective material some activity against broad-leaved weeds has also been reported elsewhere (ANON 1971).

Tri-allate seemed to have some effect but was included at too few centres for any worth while appraisal to be possible.

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