Proc. 11th Br. Weed Control Conf. 1972

A PRELIMINARY INVESTIGATION ON CONTROL OF WATER HYACINTH BY SPIDER MITES

A.H. Pieterse

Department of Agricultural Research, Royal Tropical Institute,
Amsterdam, The Netherlands

Summary The reproductive potential of twelve spider mite species, belonging to three different genera, on water hyacinth was studied. All species, with the probable exception of Oligonychus gossypii, were able to reproduce on water hyacinth. Highest reproduction rates were obtained with Tetranychus tumidus, Oligonychus sylvestris Tetranychus neocaledonicus and Tetranychus macfarlani. If the population was sufficiently large, spider mites seriously damaged water hyacinth leaves. The present work suggests that spider mites may be used as an aid in reducing Eichhornia crassipes in certain areas.

INTRODUCTION

Spider mites (Tetranychidae Donnadieu), a family of plant sucking mites, are serious pests of various plant species. In the genus Tetranychus the time for development from egg to adult averages eight days at 26°C, if conditions are favourable. An adult female lays her eggs for approximately 20 days, at an average rate of 8-10 eggs a day. Infested leaves first show white spots, and after that dry out if the mite population is sufficiently dense. Many spider mite species are polyphagous, but not all host plants are optimal for reproduction. Moreover, food preferences of different species may vary, as has been illustrated by van de Bund and Helle (1960). These authors observed that, unlike Tetranychus cinnabarinus, Tetranychus urticae does not build up large populations on carnation. Beans, on the other hand, are optimal host plants for both species.

It was reported by Cooreman (1959) that Tetranychus urticae, the two-spotted spider mite, develops extremely well on the water hyacinth (Eichhornia crassipes). In Cooreman's paper pictures are shown of water hyacinth leaves which are seriously injured by two-spotted spider mite infestation.

Without denying the potential dangers to crop plants of using spider mites in practice, it appeared useful to study the reproductive potential of some other spider mite species on water hyacinth with regard to possible control of the weed.

MATERIALS AND METHODS

Twelve spider mite species, belonging to three different genera, were kindly supplied by the Centre O.R.S.T.O.M., Tananarive, Madagascar, and the Laboratory of Applied Entomology of the University of Amsterdam. Tetranychus urticae was included in the present work for purposes of comparison. Most strains had been in culture in the laboratory during several years. Details of their origin are shown in Table 1.

The experiments were carried out on whole water hyacinth plants with 4 to 5 leaves of about equal size, additional leaves being removed. The plants were placed in trays containing cotton wool saturated with water. The cotton wool ensured isolation between the leaves. It was not possible to work with detached water hyacinth leaves placed in water, because, such leaves withered within two days. Fifteen adult females were placed on a leaf and the number of adult females on the leaf was counted after 14 days. There were at least 10 replicates for each test. Testing was done under constant light, at 25° - 27° C and 70% r.h.

A preliminary experiment in the greenhouse was conducted to study the effect of spider mites on the growth of water hyacinth grown in trays (40x55x10 cm) filled with water. This test was started with one water hyacinth plant infested with the species *Tretanychus neocaledonicus*. Another, similar plant was cultured in a different tray of the same size. Each tray was placed under a cage of perspex and gauze to ensure isolation.

RESULTS

All species, with the probable exception of *Oligonychus gossypii*, were able to reproduce on water hyacinth leaves. However, the rate of reproduction varied considerably; results are presented in Table 1.

Table 1

Data on origin of the different spider mite species and average numbers of adult females after 14 days

Species	Collected at	Year of collection	Average numbers adult females after 14 days
Eutetranychus banksi McGregor	Florida, U.S.A.	1967	112
" sambiranensis Gut.	Madagascar	1970	73
" bessardi Gut.	Madagascar	1968	110
Oligonychus gossypii Zacher	Madagascar	1969	11
" sylvestris Gut.	Madagascar	1969	227
Tetranychus cinnabarinus Boisduval	Aalsmeer The Netherlands	1967	89
" macfarlani Gut.	Mauritius	1970	212
" neocaledonicus André	Madagascar	1969	214
" pacificus McGregor	California, U.S.A.	1965	143
" urticae Koch	Voorne The Netherlands	1961	163
" tchadi Gut.	Bebedjia, Tchad	1970	66
" tumidus Banks	Kentucky, U.S.A.	1968	229

The highest number of adult females after 14 days were obtained with respectively *Tetranychus tumidus*, *Oligonychus sylvestris*, *Tetranychus neocaledonicus* and *Tetranychus macfarlani*. The reproduction of *Tetranychus cinnabarinus*, *Tetranychus tchadi* and *Tetranychus sambiranensis* proved to be very slow while the number of adult females of *Oligonychus gossypii* even decreased. The reproduction rates of *Eutetranychus banksi*, *Eutetranychus bessardi*, *Tetranychus pacificus* and *Tetranychus urticae* were more or less intermediate to the reproduction rates of the fast and slow reproducing groups.

The fast-growing species seriously affected the water hyacinth leaves. After 14 days the leaves turned yellowish. In experiments initiated with 30 females of a fast-growing species, instead of with 15 females, the leaves died within 14 days.

In order to check whether spider mites are able to slow down water hyacinth growth, a preliminary experiment was carried out in the greenhouse. A plant having 7 leaves, which was infested with 40 adult females of the species *Tetranychus neocaledonicus* per leaf, produced only 2 new plants with a total of 15 leaves. The control plant produced 6 new plants with a total of 41 leaves.

DISCUSSION

The preliminary results of the present investigation show that several mite species are able to feed on water hyacinth. In addition, it has been demonstrated that some species can seriously damage water hyacinth leaves and slow down the growth of the weed. Attention should be drawn to the fact that mass rearing of spider mites does not entail many expenses. Astronomic numbers can be obtained in a very short time with modest facilities. Whether, in fact, spider mites can be used as a means of biological control of water hyacinth needs detailed investigations in situ. As many crop plants are sensitive to spider mites, primarily hyacinth infested waters at a great distance from agricultural districts could be considered. An example might be the Brokopondo Lake in Surinam which is surrounded by a mixed, natural vegetation.

Most probably, spider mites will not be able to eradicate dense stands of water hyacinth. This implies that, if usable, it would be for slowing down growth, which could result in preventing the development of a dense water hyacinth mat.

Acknowledgements

The author wishes to thank Mr. J. Gutierrez of the Centre O.R.S.T.O.M. in Tananarive, Madagascar, and Dr. W. Helle, of the Laboratory of Applied Entomology of the University of Amsterdam, for supplying the mite species. Thanks are also due to Miss J.F. Abbenes for her help in conducting the experiments.

References

COOREMAN, J. (1959) *Tetranychus telarius* (Linné) (Acari, Tetranychidae) parasite de la jacinthe d'eau (*Eichhornia crassipes* Mart.). *Bull. Agric. Congo de Belge*, *50*, 395-401.

BUND, C.F. VAN DE and HELLE, W. (1960) Investigations on the *Tetranychus urticae* complex in North-West Europe. *Ent. exp. & appl.* *3*, 142-156.

Proc. 11th Br. Weed Control Conf. (1972)

PRE- AND POST-EMERGENCE CONTROL OF CONVOLVULUS ARVENSIS WITH RP 17623

J. G. Davison
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary The herbicide 2-tertiobutyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-(4H)-1,3,4-oxadiazoline-5-one (RP 17623) was applied to *Convolvulus arvensis* in 5 field experiments. In one, 4.5 kg/ha pre-emergence was less effective than chlorthiamid at 11 kg/ha but in a second experiment 4 kg/ha was equal to 10 kg/ha chlorthiamid in the first year and better in the second. RP 17623 was more effective post-emergence than pre-emergence. In 3 experiments RP 17623 and 2,4-D were applied at 2.5 kg/ha post-emergence. Although RP 17623 gave complete initial kill it resulted in more regrowth than 2,4-D in both the year of treatment and the following year.

INTRODUCTION

The herbicide 2-tertiobutyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-(4H)-1,3,4-oxadiazoline-5-one (RP 17623) aroused interest when it was announed that it controlled *Convolvulus arvensis* (Burgaud *et al*, 1969) and that vines, which are very susceptible to growth-regulator herbicides, were unaffected by a concentration of 5 ppm in the nutrient solution applied to plants growing in sand (Julliard and Ancel, 1969). Further information (Burgaud *et al*, 1970) indicated it was more effective post-emergence than pre-emergence, especially when the treatments were repeated over a number of years.

The object of the experiments reported here was to determine the susceptibility of *Convolvulus arvensis* to RP 17623 in Britain. Five experiments are described. In two, pre- and post-emergence treatments were compared with chlorthiamid. In the remaining three, post-emergence treatments were compared with 2,4-D.

METHOD AND MATERIALS

The two experiments in which RP 17623 was applied both pre- and post-emergence and compared with chlorthiamid were carried out at Begbroke Hill on single plants that had been planted in 1968. The *Convolvulus arvensis* (bindweed) covered an area of 3 x 3 m and the area treated was 4 x 4 m. Alleys between plots were cultivated in autumn and spring and in the spring chlorthiamid was incorporated by rotary cultivation to prevent unwanted spread of bindweed. In Expt.1, RP 17623 was applied at 3 doses, 1.1, 2.2 and 4.5 kg/ha on three dates in 1970, on 24 April when the first bindweed shoots were just emerging, on 29 May at 60% ground cover and on 27 July when there was up to 100% ground cover and the plants flowering. Chlorthiamid was applied at 11, 22 and 45 kg/ha at the first date. There was no further application of these herbicides. Bindweed response was assessed at intervals over the following 29 months. In Expt.2, RP 17623 was applied at 4 and 8 kg/ha on 29 April 1971 just as the first shoots were emerging, and at 2, 4 and 8 kg/ha on 1 June 1971 when there was 80-90% ground cover and individual shoots were up to 40 cm long but there were no flower buds. Chlorthiamid at 10 kg/ha was also applied on 29 April. The treatments were repeated in 1972 on the 21 April and 22 June, when the flower buds were just visible.

Table 1
Expt 1   Amount of bindweed - as percentage ground cover

Treatment dose (kg/ha)	Date applied 1970	1970				1971					1972	
		May	June	July	Sept	May	June	July	Aug	Sept	May	June
RP 17623												
1.1)		1	18	39	43	40	84	100	30	38	43	95
2.2)	24 April	0	6	25	22	20	65	97	73	20	20	80
4.5)		0	9	22	28	18	60	90	80	42	25	83
1.1)		5	1	18	28	22	58	100	75	33	28	88
2.2)	29 May	6	1	4	16	8	53	70	67	28	14	73
4.5)		6	1	1	2	2	8	27	38	23	5	43
1.1)		4	18	44	12	17	65	100	83	43	32	93
2.2)	27 July	4	19	42	3	7	48	95	62	22	9	65
4.5)		7	27	53	0	1	11	60	60	30	3	30
Chlorthiamid												
11)		0	0	0	1	2	5	24	27	21	11	52
22)	24 April	0	0	0	2	0	1	4	7	5	2	13
45)		0	0	0	0	0	0	0	1	1	1	5
Control		6	18	48	45	32	85	100	70	35	28	88

The three experiments in which RP 17623 was applied post-emergence only and compared with 2,4-D were started in 1971. Both herbicides were applied at 2.5 kg/ha. The experiments were carried out in commercial apple orchards that had received a standard commercial pre-emergence weed control programme based on simazine. In Expt.3 (Suffolk), treatments were applied on 11 June just before flowering started. In Expt.4 (Kent), RP 17623 was applied on 26th May, when the shoots were up to 30 cm long, and on 7 July when the plants were flowering. The 2,4-D was applied on 26 May. In Expt.5 (Essex) RP 17623 was applied on 11 June, when shoots were up to 40 cm long and bearing flower buds, and on 14 July when 2,4-D was also applied at which time the bindweed was in full bloom.

There were 3 replicates in each experiment except Expt.2 in which there was only 2. Plot size in Expts.3-5 was from 9 x 2.7 m to 13 x 5 m according to tree spacing. Each plot contained two trees and bindweed assessments were confined to the area between. RP 17623 and 2,4-D were applied as sprays at 250 l/ha using a floodjet at 0.5 kg/cm^2 or 550 to 750 l/ha with fanjets at 0.7 - 1.4 kg/cm^2. Chlorthiamid was applied as 7.5% w/w granules. In Expt.1, a 40% e.c. of RP17623 was used, in the other four experiments a 25% e.c. was used. The 2,4-D used was a 32% diethanolamine salt.

In all experiments assessments have been confined to estimations of percentage ground cover of bindweed. This has been done at approximately monthly intervals during the growing season.

RESULTS

The percentage ground cover figures in Table 1 show that in Expt.1, RP 17623 applied at 1.1kg/ha in late April had no effect on the bindweed, and that at 2.2 and 4.5 kg/ha there was approximately 50% control. The post-emergence application in May gave rapid shoot kill but by July there was regrowth, the amount being inversley proportional to the dose applied. Chlorthiamid was much more effective giving complete control. The effect of chlorthiamid at 11 kg/ha persisted into the second season after treatment. The only RP 17623 treatment to have an appreciable effect in the year after treatment was 4.5 kg/ha applied in May or July.

In Expt.2 the bindweed had been established a year longer and this accounts for the greater ground cover figures for the controls in Table 2. Chlorthiamid was less effective than in Expt.1 and similar to RP 17623 at 4 kg/ha pre-ermegence. Increasing the pre-emergence dose from 4 to 8 kg/ha reduced by half the amount of bindweed in August. All post-emergence treatments gave complete shoot kill, but regrowth soon developed. There was better control with the higher doses and the August results indicate that doubling the dose halved the amount of regrowth. In addition the post-emergence treatments were twice as effective as the pre-emergence treatments. In the second year of treatment RP 17623 gave better control than chlorthiamid even though the latter gave the same control as in the first year. The June 1972 assessment shows that the 1971 post-emergence treatments resulted in an appreciable reduction in growth one year after treatment.

The results from Expts. 3-5 in Table 3 show that RP 17623 gave good initial kill with variable amounts of regrowth in the season of treatment. There was less regrowth with 2,4-D than with RP 17623 applied at the same date. In the two experiments in which RP 17623 was applied at two dates there was less regrowth with the later application. The July 1972 assessment shows that one year after treatment there was more regrowth with RP 17623 than with 2,4-D, even in Expt.5 where there was little difference in shoot kill in the previous season.

Care was taken to avoid the branches and leaves of the trees in Expts.3-5 but some trunk bases were inadvertently sprayed. No crop injury symptoms were observed

Table 2

Expt 2 Amount of bindweed - as percentage ground cover

Treatment dose (kg/ha)	1971 May	June	July	Aug	Sept	Oct	1972 May	June	July	Aug
RP 17623										
a) pre-emergence										
4	0	1	14	24	14	3	0	0	3	0
8	0	0	10	13	9	3	0	0	1	<1
b) post-emergence										
2	30	85	11	28	20	5	2	20	3	5
4	35	88	5	15	8	5	1	3	1	<1
8	42	93	6	7	1	3	0	2	1	0
Chlorthiamid										
pre-emergence										
10	7	3	17	27	11	4	2	3	10	20
Control	37	88	100	95	65	28	38	85	98	92

Table 3

Expts 3-5 Amount of bindweed - as percentage ground cover

Expt No.	Treatment	Application date ('71)	Initial cover	1971 July	1971 Aug	1971 Sept	1971 Oct	1972 May	1972 June	1972 July
3	RP 17623	11 June	85	1	6	11	11	-	50	73
	2,4-D	11 June	93	<1	1	1	2	-	3	6
	Control	-	93	100	15*	5*	15	-	88	93
4	RP 17623	26 May	47	2	23	38	40	2	12	73
	RP 17623	7 July	47	(65)	0	1	5	1	4	33
	2,4-D	26 May	58	2	3	7	13	3	5	17
	Control	-	55	72**	80	92	63	7	37	90
5	RP 17623	11 June	22	6	2	2	5	-	8	32
	RP 17623	14 July	15	(58)	0	1	2	-	5	20
	2,4-D	14 July	23	(66)	4	1	0	-	1	2
	Control	-	20	63	25*	23	25	-	36	75

( ) % initial ground cover for second application date

* control plots sprayed with paraquat plus diquat after previous assessment

** control plots cut after previous assessment either in the year of treatment or in the following year.

DISCUSSION

The results from the pre-ermegence applications at Begbroke Hill indicate the need for a dose of at least 4 kg/ha for control comparable to that which can be achieved with chlorthiamid at 10 kg/ha. The limited evidence presented does suggest that repeating the treatments can lead to an improved control with RP 17623 as claimed by Burgaud *et al* (1970).

The post-emergence treatments although tending to be more effective than pre-emergence treatments were clearly no better and often less good than 2,4-D thus agreeing with the results of Agulhon *et al* (1972), Fort (1971) and Touzza and Lhérault (1971).

Regrowth in the season after treatment is influenced by factors such as the duration of shoot control in the previous season and the direct and indirect effects on the root system and the persistence of the herbicide in the soil. Although there has been some indication in the present work that bindweed shoots which emerge where RP 17623 has been applied may subsequently be killed by the treatment there is no indication that at 4 kg/ha there is sufficient persistence to give control in the following season as suggested by Burgaud *et al* (1970). Where shoot kill in the previous season was similar with RP 17623 and 2,4-D the reduction in regrowth with the latter is presumably due to translocation killing part of the root system.

The promising results that have been achieved with RP 17623 indicate that it could provide effective control of bindweed providing the dose is high enough. As such it may fulfil a need, especially where 2,4-D cannot be used because of risk to the crop.

Acknowledgements

The co-operation of the growers in whose crops these experiments were conducted and the help of May and Baker Ltd. and Shellstar Ltd. who supplied the herbicides are gratefully acknowledged. Thanks are also due to Miss J.P.Crabtree for assistance in the experimental work.

References

AGULHON, R., GAGNE, R., PAYAN, J.J., ROZIER, J.P. and LAURENT, J.C. (1972) Difficulties encountered in controlling perennial weeds in vineyards in the South of France. *C.r. 6^e Conf. Com. franc. mauv. Herbes (COLUMA)*. 735-45.

AMPHOUX, M., AGULHON, R. AND VERGNES, A. (1969) [Control of some perennial weeds in southern vineyards.] *C.r. 5^e Conf. Com. franc. mauv. Herbes (COLUMA)*, 924-38.

BURGAUD, L., DELORAINE, J., DESMORAS, J., GUILLOT, M., PETRINKO, P. AND RIOTTOT, M. (1969) Activity and selectivity in the greenhouse and in the field of a new herbicide: 2-tert. butyl-4(2,4-dichloro-5-isopropyloxyphenyl)- Δ_2-1,3,4-oxadiazoline-5-one. *Proc. 3rd.Symp. on New Herbicides, Versailles*, 201-36.

BURGAUD, L., DELORAINE, J., GUILLOT, M. and RIOTTOT, M. (1970) The control of *Convolvulus arvensis* and *Calystegia sepium* in orchards and vineyards with 2-tertiobutyl-4-(2,4-dichloro-5-isopropyloxphenyl)-(4H)-1,3,4-oxadiazoline-5-one. *Proc. 10th Br.Weed Control Conf.*, 745-51.

FORT, G. (1971) [Weed control in vineyards in Savoy.] *C.r. 6^e Conf. Com. franc.*

mauv. Herbes (COLUMA), 686-93.

JULLIARD, B. and ANCEL, J. (1969) [First evaluations of the inherent phytotoxicity of some hericides for vines.] C.r. 5^{e} Conf. Com. franc. mauv. Herbes (COLUMA)

TOUZZA, G. and LHERAULT, P. (1971) [Experimentation with herbicides in vineyards under Mediterranean climatic conditions.] C.r. 6^{e} Conf. Com.franc. mauv. Herbes(COLUMA), 705-14.

Proc. 11th Br.Weed Control Conf. (1972)

THE RESPONSE OF 21 PERENNIAL WEED SPECIES TO GLYPHOSATE

J. G. Davison
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary In a series of 34 trials glyphosate was applied to 21 species of perennial weed. Treatments were applied at high volume (600-3000 l/ha) and low pressure (0.3 to 0.6 kg/cm^2). Seven to 9 weeks after applying 1 kg/ha there was excellent control of Dactylis glomerata, Mercurialis perennis, Poa pratensis, Ranunculus repens, Rumex obtusifolius, Taraxacum officinale and Potentilla anserina. At 2 kg/ha there was excellent control of Agropyron repens, Cirsium arvense, Epilobium hirsutum, Heracleum sphondylium, Potentilla reptans and Rubus fruticosus when assessed 7 to 17 weeks after treatment. Results with Convolvulus arvensis have been rather variable; 6 to 11 weeks after treatment 2 kg/ha was less effective than 2,4-D at 2.5 kg/ha but 4 kg/ha was similar. Even at 4 kg/ha it was ineffective when applied too early. Urtica dioica has been defoliated at 2 kg/ha. Appreciable regrowth occurred at only one site out of five after 9 weeks. Results are less clear with other species although Equisetum arvense appears to be more resistant than most.

INTRODUCTION

Soil-acting herbicides are widely used for the control of weeds under apple and pear trees in Britain, but they have to be supplemented with post-emergence herbicides such as aminotriazole, the growth-regulators and paraquat for the control of certain annual and perennial weeds. The announcements that the new herbicide glyphosate controls a wide range of monocotyledonous and dicotyledonous weeds, is not injurious to trees when applied to their basal bark and has no soil activity (Baird et al, 1971; Monsanto, 1971) indicate its potential usefulness in British Orchards.

A series of 34 trials is reported in which glyphosate was applied to 21 perennial species. The results are encouraging in showing that glyphosate is effective against many weeds although the slow response shown by some species indicates that with an interval of only 6 weeks between application and the last assessment the full effect may not have developed. These results must therefore be taken to indicate the general usefulness of glyphosate rather than to show the specific response of certain species.

METHODS AND MATERIALS

Glyphosate was applied at 34 sites at doses from 0.5 to 8 kg/ha as the isopropylamino salt using the formulation MON 2139 which contains a wetter. At 27 of the sites a standard herbicide or herbicide mixture was also applied. Those used were aminotriazole (activated) at 5 kg/ha, 2,4-D at 2.5 kg/ha and mecoprop at 2.5 kg/ha or a mixture of aminotriazole with either 2,4-D or mecoprop. The treatments were applied between 25 April and 11 July 1972. Volume rate was from 600 to 3000 l/ha. Table 1 gives details of the weeds sprayed, application date, stage of development, height of weed, treatments applied and volume rate. Treatments were applied with a knapsack sprayer at a pressure of 0.3 to 0.6 kg/cm^2. Plot size was variable but usually not less than 3 x 1 m. At each site treatments were randomised but not replicated.

Table 1

Site Details

Site	Species	Treated	Stage ⊠ growth	Height (cm)	Glyphosate dose (kg/ha) 0.5	1	2	4	8	Standard ø	Vol (1/ha)
1	Agropyron repens	3/6	V	60	x	x	x	x	-	AD	800
2	"	6/6	V	50	x	x	x	-	-	A	1000
3	Armoracia rusticana	25/6	V	50	-	x	x	x	-	AM	3000
4	Calystegia sepium	4/7	V	30*	-	x	x	x	x	D	900
5	Cirsium arvense	3/6	V	40	-	x	x	x	x	AD	300
6	Convolvulus arvensis	24/5	V	5	-	x	x	x	-	-	1000
7	"	6/6	V	4	x	x	x	-	-	A	1000
8	"	7/6	V	10	x	x	x	-	-	D	1000
9	"	13/6	V	15	-	x	x	x	-	A	600
10	"	5/7	F	30	-	x	x	x	x	C	900
11	"	11/7	F	30	-	x	x	x	-	D	900
12	Dactylis glomerata	13/6	F	80	-	x	x	x	-	AM	2000
13	Epilobium hirsutum	13/6	V	90	-	x	x	x	-	D	600
14	Equisetum arvense	3/6	V	25	-	x	x	x	x	AD	300
15	Heracleum sphondylium	3/6	V	30	x	x	x	x	-	AD	800
16	"	4/7	V	75	-	x	x	x	-	-	900
17	Malva sylvestris	24/5	V	60	-	x	x	x	-	-	1000
18	Malva neglecta	24/5	V	20	-	x	x	x	-	-	1000
19	Mercurialis perenne	9/5	F	75	-	x	x	x	-	D	1200
20	Poa pratensis	13/6	F	50	-	x	x	x	-	AM	2000

for key to symbols see foot of next page

Table 1 (Contd)

Site Details

Site	Species	Treated	Stage$^{\boxtimes}$ Growth	Height (cm)	Glyphosate dose (kg/ha) 0.5	1	2	4	8	Standard$^{\phi}$	Vol. (1/ha)
21	Potentilla anserina	3/5	V	7	-	x	x	-	-	-	1200**
22	"	4/7	F	12	-	x	x	x	-	-	900
23	Potentilla reptans	25/4	V	6	-	x	x	x	-	A	800
24	"	6/6	V	25	x	x	x	-	-	A	1000
25	Ranunculus repens	13/6	F	50	-	x	x	x	-	AM	2000
26	Rubus fruticosus	25/4	V	15	-	x	x	x	-	A	800
27	Rumex obtusifoluis	13/6	F	100	-	x	x	x	-	AM	2000
28	Taraxacum officinale	4/7	F	15	-	x	x	x	-	-	900
29	Tussilago farfara	3/6	V	30	-	x	x	x	x	AD	800
30	Urtica dioica	9/5	V	75	-	x	x	x	-	D	1200
31	"	3/6	V	100	-	x	x	x	x	AD	800
32	"	13/6	F	120	-	x	x	x	x	AM	2000
33	"	25/6	F	50	-	x	x	x	-	AM	3000
34	"	25/6	F	100	-	x	x	x	-	AM	3000

x = treatment applied
- = no treatment

ϕ = Stage of growth
V = vegetable
F = flowering

* = length of shoots
** = 600 l/ha for 1 kg/ha

ϕ Standard treatments

A = aminotriazole 5 kg/ha
C = mecoprop 2.5 kg/ha
D = 2,4-D 2.5 kg/ha
AD = A + D
AM = A + M

Apart from sites 14 and 29 which were in fallow, all other sites were in undisturbed soil. The majority were in the strips under apple trees that had previously received a soil acting herbicide but a few were on headlands.

Assessments were made at approximately monthly intervals. On each occasion a score was given for the volume of healthy green foliage. These scores are presented in Table 2 as a percentage of the untreated controls.

RESULTS

The results in Table 2 are from assessments taken from 6 to 17 weeks after treatment. In general the weeds responded slowly. Most sites were not seen until 3 to 6 weeks after treatment when it was evident that there had been no growth since treatment but frequently there was incomplete kill of the sprayed foliage at this stage. Later, especially with the broad-leaved species, higher doses resulted in defoliation and die-back of shoots. Where regrowth occurred with doses of 0.5 and 1 kg/ha it was either normal or normal except for having smaller leaves. Where there had been a severe check to growth or complete kill, regrowth usually consisted of masses of miniature shoots with tiny leaves. Except for Urtica dioica, which was chlorotic, regrowth was normal in colour.

A single assessment does not always give an adequate indication of weed response but the intermediate assessments help clarify some of the results presented in Table 2 as do the factors presented in Table 1. For instance, there was 90% control of Agropyron repens 8 weeks after treatment with 0.5 kg/ha at site 1, thereafter recovery was rapid. With Cirsium arvense (site 5) kill of sprayed shoots was complete at doses above 1 kg/ha; all regrowth appeared normal. The variable results with Convolvulus arvensis appear to indicate the need for a dose in excess of 2 kg/ha and that application should be delayed until the weed is well emerged. The poor initial response of Equisetum arvense at site 14 may be due to inadequate retention. The weed was covered in dew when sprayed and this caused considerable run-off of spray, nevertheless under the same conditions aminotriazole plus 2,4-D gave good results. Six weeks after treatment there was almost complete defoliation of Malva sylvestris at site 17 with 2 kg/ha while at 4 kg/ha only the stem bases appeared to be alive but seven weeks later plants on all treatments were flowering. The initial response of Malva neglecta at site 18 was similar, but the subsequent germination and development of seedlings masked the long term response of the treated plants. Potentilla anserina at site 21 was severely checked for 8 weeks before recovering completely as shown in Table 2. A previous treatment with aminotriazole that resulted in the weed being chlorotic when sprayed may have influenced these results. The Urtica dioica at site 33 had been cut down earlier in the season and was growing vigorously when it was sprayed, at the other sites growth was less active, this may account for the greater regrowth at site 33 at 2 kg/ha. Defoliation of U.dioica occurred slowly, taking up to 8 weeks with 2 and 4 kg/ha. Stem death occurred at 4 kg/ha but at 2 kg/ha only the tips were killed. The response to 1kg/ha was more rapid where growth was active (site 33), the apical leaves became chlorotic and a few very small leaves were produced before growth ceased.

At some sites the basal trunk of apple trees was inadvertently sprayed but no symptoms were detected on the crop.

DISCUSSION

The results presented show glyphosate to be active against a wide range of perennial weeds. Although no deliberate attempt was made to establish crop tolerance the absence of symptoms on trees whose basal bark was sprayed is encouraging. The development of seedling weeds shortly after application and the recolonization of some plots by creeping weeds help to confirm the lack of soil activity.

Table 2
Healthy foliage as percentage of untreated control

Site	Species	Interval (weeks)	Glyphosate (kg/ha)					Standard
			0.5	1	2	4	8	
1	Agropyron repens	12	100	2	1	1	-	2
2	"	11	9	15	0	-	-	5
3	Armoracia rusticana	9	-	75	50	15	-	30
4	Calystegia sepium	7	-	60	10	0	0	3
5	Cirsium arvense	10	-	8	3	1	1	8
6	Convolvulus arvensis	13	-	100	100	100	-	-
7	"	11	100	100	60	-	-	100
8	"	11	100	30	15	-	-	2
9	"	9	-	7	3	2	-	1
10	"	7	-	30	4	2	1	6
11	"	6	-	100	40	7	-	0
12	Dactylis glomerata	9	-	0	0	0	-	0
13	Epilobium hirsutum	9	-	10	2	0	-	0
14	Equisetum arvense	11	-	100	100	70	50	10
15	Heracleum sphondylium	12	100	5	1	0	-	0
16	"	7	-	7	2	1	-	-
17	Malva sylvestris	13	-	70	30	50	-	-
18	Malva neglecta	6	-	10	0	2	-	-
19	Mercurialis perennis	10	-	0	4	0	-	0
20	Poa pratensis	9	-	0	0	0	-	0
21	Potentilla anserina	16	-	100	100	-	-	-
22	"	7	-	0	0	0	-	-
23	Potentilla reptans	17	-	10	1	1	-	30
24	"	11	30	3	1	-	-	1
25	Ranunculus repens	9	-	0	0	0	-	2
26	Rubus fruticosus	17	-	8	1	3	-	1
27	Rumex obtusifolius	9	-	2	1	0	-	0
28	Taraxacum officinale	7	-	0	0	0	-	-
29	Tussilago farfara	11	-	7	12	2	1	1
30	Urtica dioica	10	-	20	4	1	-	40
31	"	11	-	20	3	2	1	40
32	"	9	-	20	2	1	1	2
33	"	9	-	50	40	6	-	0
34	"	9	-	100	10	1	-	5

- = no treatment

In considering these results it is important that for each site the interval between application and final assessment is taken into account. It has been shown that at some sites good initial response has not been maintained but it is also possible that a slow initial response may lead ultimately to more effective long-term control. Of the two species treated at several sites, Convolvulus arvensis and Urtica dioica, the variable response of the former is in agreement with other reports (Monsanto, 1971) and highlights the need for careful interpretation of results for other weeds occurring at fewer sites. Nevertheless, glyphosate at 1kg/ha has given excellent control of Dactylis glomerata, Mercurialis perennis, Poa pratensis, Ranunculus repens, Rumex obtusifolius, Taraxacum officinale and Potentilla anserina over a period of 7 to 9 weeks. At 2 kg/ha there has been excellent control of Agropyron repens, Cirsium arvense, Elilobium hirsutum, Heracleum sphondylium, Pontentilla reptans and Rubus fruticosus over a period of 7 to 17 weeks.

It has been suggested that the optimum volume rate is between 200 and 300 l/ha (Monsanto, 1971) and it has been shown that with Agropyron repens increasing the volume to 1000 l/ha while retaining a fixed ratio of active ingredient to wetter decreases effectiveness (Baird and Begeman, 1972). In the present work volumes of 600 l/ha to 3000 l/ha were used and on several occasions run-off occurred (for instance with Equisetum arvense at site 14). The necessity for low volume application requires further investigation since it is often safer in practice to apply high volume sprays under fruit trees. Two other aspects require detailed investigation. First, the importance of weed size or stage of growth, has already been mentioned in the context of Convolvulus arvensis but additionally there is the seasonal factor which will be important with overwintering weeds. Second, there is the interaction between glyphosate and other herbicides. Baird et al (1971) have demonstrated antagonism between glyphosate and several other herbicides including soil-acting herbicides. With terbacil there was antagonism with a tank mix but not when the terbacil was applied separately an hour after the glyphosate. Results with simazine have been inconclusive. Fruit growers are accustomed to applying mixtures of herbicides and situations can be envisaged in which glyphosate would be mixed with another herbicide. Information is needed on this and other aspects to enable full exploitation of this new and promising herbicide.

Acknowledgements

The co-operation of the growers who provided facilities for trials and the help of Monsanto Ltd. who supplied the glyphosate is gratefully acknowledged. Thanks are also due to Miss J.P.Crabtree and Miss R.M.Kerr for assistance in the experimental work.

References

BAIRD, D.D. and BEGEMAN, G.F. (1972) Post emergence characterization of a new quackgrass herbicide. Proc. 26th N.East Weed Sci.Soc., 100-106.

BAIRD, D.D., UPCHURCH, R.P., HOMESLEY, W.B. and FRANZ, J.E. (1971) Introduction of a new broad spectrum post-emergence herbicide class with unility for herbaceous perennial weed control. Proc. 26th No. cent Weed Control Conf., 64-68.

MONSANTO EUROPE, (1971) MON - 1139 Post-emergence herbicide. Publication Monsanto Europe S.A. pp 9.

Proc. 11th Br. Weed Control Conf. 1972

THE EFFECT OF STAGE OF FROND DEVELOPMENT ON THE ABSORPTION AND TRANSLOCATON OF ASULAM IN BRACKEN

P. Veerasekaran & R.C. Kirkwood
Department of Biology, University of Strathclyde, Glasgow C.1.

Summary In *vitro* experiments with field bracken and *in vivo* experiments using potted plants have shown that the stage of frond development affected the efficiency of absorption and translocation of ^{14}C-asulam. Absorption decreased with the stage of development of the frond indicating the importance of the cuticle barrier as the frond ages. In the early stages of frond development, radiolabel was predominant in the frond tips, while in mature plants radioactivity became concentrated in regions of meristematic activity in the rhizome viz, apices and frond buds. These results suggest that the optimum time of application occured after the fronds were completely unfurled, a stage at which assimilate movement favours basipetal translocation of the herbicide to the rhizome.

INTRODUCTION

It has been established as a result of recent experiments (Holroyd and Parker, 1970) that asulam, applied during summer months, gives excellent control of bracken (*Pteridium aquilinum* (L) kuhn). Investigators have suggested that the stage of frond development at the time of herbicide application may influence the extent to which it moves to and damages the rhizome apices and frond buds (Conway and Forrest, 1961; Hodgson, 1964; Volger, 1969). If the translocation of asulam is closely associated with assimilate movement, then changes in the pattern of assimilate movement in the developing frond may influence the efficiency of movement of foliage-applied asulam. The experiments reported were designed to assess; (1) the absorption and translocation of ^{14}C-asulam applied in *vitro* to pinnae, excised from field grown bracken at intervals from June to September, and (2) the rate and extent of absorption and translocation of ^{14}C-asulam applied in *vivo* to fronds of pot grown bracken at different growth stages.

METHOD AND MATERIALS

1. In vitro treatment of isolated pinnae from field-grown bracken.

Bracken fronds were collected each month from June to September during 1971 growing season from the Carrick Hills, Ayr. On each occasion the pinnules were excised from the mid-region of the 2nd, 3rd, and 4th pair of pinnae. The rachis of the detached pinnule was inserted into an agar block which acted as a "sink" and during the treatment period these pinnule/agar block systems were kept in moist trays in a growth cabinet maintained at 20 ± 0.5°C temp. and 80 ± 1% r.h. ^{14}C-asulam (methyl-4-aminobenzene sulphonyl carbamate) with a specific activity of 2.28mCi/mM was formulated as the sodium salt and applied as 4 x 2µl droplets to the 5th and 6th pair of pinnule segments (a radioactive dose of 0.16µCi per pinnule). After treatment periods of 24, 48 and 72 h the systems were dismantled and surface residues removed by washing the pinnules in water. The portion of ^{14}C-asulam retained in the cuticular wax was removed by washing with chloroform for 30 s. The amount of ^{14}C-asulam absorbed by the pinnules was estimated by combusting the dried tissue followed by liquid scintillation counting (Kalberer and Rutschmann, 1961; MacDonald, 1961). The $^{14}CO_2$ evolved was absorbed in 14% methoxyethanol - ethanolamine solution and a 1 ml aliquot transferred to a dioxan-based scintillation liquid (Bray, 1962) for radioassay using a Packard Tricarb Model 3375 Scintillation Counter.

2. In vivo treatment of green house grown pot plants

Bracken plants were established during the summer of 1971 and maintained in the green house at 20-25°C under high humidity conditions. Eight fronds were selected at each of the following stages:

Stage 1. 1st pair of pinnae fully expanded - 28 days after emergence
Stage 2. 2nd pair of pinnae fully expanded - 40 days after emergence
Stage 3. Fronds fully expanded including small pinnae at the frond apex - 67 days after emergence.
Stage 4. Fronds matured with the lower pair of pinnae showing signs of senescence - 103 days after emergence.

Asulam having a specific activity of 2.28 m Ci/mM, was formulated as 2000 ppm sodium salt solution, containing 0.05% ethylan C.P. Each frond received a total of 100 µl solution containing 0.5 µl radioactivity. Fifty 2 µl droplets were applied to the first and second pairs of pinnae, one 2 µl droplet being placed on each of the six basal pairs of pinnules. The remaining 2 x 2 µl droplets were applied to each rachis of the basal pinnae. In addition the remaining pinnules of the first and second pairs of pinnae received 300 µl of 5000 ppm unlabelled asulam. At the first stage only the first pair of pinnae were treated.. The treated plants were carefully transferred to a growth cabinet (20 ± 0.5°C and 80 ± 1% RH). Illumination was cycled to give 14 h light in each 24 h period.

The plants were harvested 15 to 30 days after treatment, 4 fronds being removed from each pot and washed free of soil. The treated pinnae were excised and surface residues of asulam removed by shaking the pinnae in 100 ml of water for 30 min. Radioactive residues retained in the cuticular wax were removed by washing with chloroform for 30 s. The remainder of the plant was divided into various regions, viz, untreated frond apex, basal rachis, rhizome, rhizome apices and frond buds. These tissues were dried at 60°C, ground in a mill and 100 mg of the material combusted for radioassay using oxygen combustion technique described previously.

The radioactive counts were expressed as percentages and prior to analysis of variance were converted to arcsines; thereafter significance was tested by Duncan's multiple range analysis ($P = 0.05$).

RESULTS

1. In vitro treatment of pinnae isolated from field bracken

Pinnules isolated from field bracken fronds at approximately monthly intervals during the season of 1971 were treated in vitro with ^{14}C-asulam. The uptake and distribution of radioactivity was assessed 24, 48 and 72 h after treatment and a consistent increase in absorption/translocation was observed according to the duration of the experiment. The results for the 48 h treatment period only, are presented in Table 1. Uptake has been calculated from the surface residue data and also by the summation of radioactivity calculated from the various regions. The results show that uptake declined significantly as the season progressed and according to the maturity of the pinnae from which the treated pinnules were isolated. The consistently low figure for 'uptake 2' as compared to 'uptake 1' suggests that some loss of radioactivity has taken place. Wax retention increased significantly at the later treatment dates and on several dates according to the maturity of the pinnae from which the treated pinnules had been isolated. Conversely, the level

Table 1

The uptake and distribution of radioactivity 48 h following ^{14}C-asulam treatment of pinnules isolated from pinnae of varying maturity during the growing season (1971) (mean of 4 replicates)

Date of treatment	Pinnae No.	Uptake (% applied)		Distribution of radioactivity (% of absorbed)		
		1	2	Wax	Treated pinnule	Translocation to agar blocks
19th June	* 2	32.43	29.74a	6.01f	93.56	0.43p
	3	36.02	27.37a	6.95f	92.82	0.23p
	4	33.75	27.15a	7.46g	92.27	0.24p
23rd July	* 2	31.01	21.66b	7.83g	90.66m	1.51q
	3	31.16	26.70c	9.00h	92.08	0.92q
	4	35.86	30.73a	5.57h	93.80	0.63q
25th August	* 2	28.71	21.48b	9.23h	90.26m	0.51q
	3	30.73	25.57c	9.91h	88.98m	1.11q
	4	31.08	26.02c	8.30h	91.27m	0.43q
20th September	* 2	21.96	11.43d	25.32i	73.49o	1.19q
	3	25.73	15.56e	18.01j	81.31n	0.68q
	4	25.42	16.76e	15.62k	83.86n	0.52q

* Oldest

1- uptake calculated as 100- surface residue

2- uptake calculated from radioassay of different regions

Duncan's Multiple Range Test; values having a common letter superscript are not significantly different at 5% level.

of radioactivity in the treated pinnule tissue significantly diminished with the progress of the season and on 23rd July and 20th September declined with frond maturity. The proportion of the absorbed dose translocated increased with time of season, a significant difference being observed between June and the other treatment dates. However, the levels transferred out of the treated pinnae into the agar block remained relatively low.

2. In vivo treatment of potted plots

Examination of the green house grown potted plants showed the following morphological symptoms at the end of the 30 day treatment. The fronds treated at the first growth stage showed a reduction in development. The frond tips gradually shrivelled and became quite chlorotic, the rachis turned brown especially in the meristematic region of the frond apex and further expansion of the pinnae was affected. At the second stage, chlorotic effects were less marked, though growth in height was restricted. Application of asulam at full frond and mature stages did not produce any distinct morphological changes in the applied frond, which remained green and active through out the treatment period. Observation of rhizome apices and frond buds, however showed that rhizome tips became hard and turned brown or black from white; while swelling occurred, growth in length was reduced; the frond buds became twisted and deformed. Marked splits were evident in the rhizome tips. These symptoms were less evident following treatment of the early growth stages.

The uptake and distribution of radioactivity, assessed 15 and 30 days following treatment is shown in Table 2. The results show that uptake, calculated from the plant radioassay data significantly decreased with the stage of growth at the time of treatment; higher levels of uptake generally being recorded after 30 days. Again the difference between 'uptake 2' as compared with 'uptake 1' suggest that some loss of radioactivity took place, particularly during the longer treatment period.

The distribution of radioactivity in the various regions of the plant has been expressed as a % of the absorbed dose. The level of cuticle wax retention significantly increased, particularly at stage 4, though there was no significant difference between 15 and 30 day treatment periods. Absorption by the pinnae diminished significantly with the stage of frond development as did acropetal movement into the untreated apical region of the treated fronds. On the other hand, basipetal translocation significantly increased with stage of growth, a proportionately higher level of activity being recorded in the buds and apices as compared with the rhizome per se. The increased translocation is reflected in the figures for the rachis. At the first stage most of the movement took place acropetally to the developing frond apex while some tracer moved downward to the rhizome. At the second stage acropetal and basipetal translocation was of equal importance; when the frond was completely unfurled, basipetal translocation was predominant.

DISCUSSION

It is well known that the efficiency of a foliage-applied translocated herbicide depends upon a variety of factors including the efficiency of absorption, translocation, adsorption at metabolically inactive sites and its biochemical action at metabolically active sites. In this investigation, the effect of absorption and translocation on stage of frond development has been studied using field and green house grown bracken.

There is evidence from field trials that the efficiency of foliage - applied asulam is influenced to some degree by the stage of frond development at the time of spraying (Martin, Williams, and Raymond, 1972). Similar, though 'narrower', seasonal trends have been reported for other foliage-applied compounds including aminotriazole, 4-chlorophenoxyacetic acid, aminotriazole and dicamba (Erskine, 1960, 1968; Kirkwood, 1962). The results presented here may explain some of the factors

Table 2

The effect of frond development on the uptake and distribution of radioactivity assessed 15-30 days following <u>in vivo</u> treatment with 0.5uCi of ^{14}C-asulam (mean of 4 replicates)

Stage of Growth	Treatment duration (days)	Uptake (% applied) 1	2	Wax	distribution of radioactivity(% of absorbed) Treated Pinnae	Acropetal frond apex	Basal rachis	rhizome	Basipetal rhizome buds	Total
1	15	31.10	23.51a	2.66h	72.66m	16.17q	2.06	2.54	3.72	6.26t
	30	43.65	29.11b	2.26h	77.34	14.22q	1.58	2.43	8.28	5.71t
2	15	21.93	14.61c	4.44i	72.26m	9.72r	4.45	3.57	5.55	9.12u
	30	30.11	17.23d	3.77i	71.18m	11.09r	3.71	3.99	6.18	10.17u
3	15	16.80	12.38e	6.40j	59.42n	1.76s	6.17	8.88	17.36	26.24v
	30	29.08	13.77f	5.93j	60.48n	2.15s	4.71	8.55	18.15	26.70v
4	15	12.32	7.05g	14.88k	51.56o	1.09s	5.18	14.02	16.26	30.28w
	30	22.05	7.70g	13.23k	45.80p	1.66s	4.94	14.46	17.60	32.06w

1. uptake calculated as 100- surface residue

2. uptake calcultaed from radioassay of various fractions of bracken frond

Duncan's Multiple Range Test; values having a common letter superscript are not significantly different at 5% level.

involved. In vitro and in vivo treatment of bracken with ^{14}C-asulam revealed that the efficiency of uptake of radioactivity was influenced by the stage of development of the treated pinnules, absorption diminishing with age. Changes in thickness, physical and chemical characteristics of the cuticle wax have been reported to take place during morphogenesis (Hull, 1970) and it is probable that these changes occur in the cuticle of the bracken frond. The increased proportion of the absorbed dose recorded in the cuticle wax of mature pinnae tend to verify this view.

There was evidence from both experiments that uptake decreased with time, the results of both experiments revealed a consistent difference between 'uptake 1' and 'uptake 2' recorded at 15 and 30 days. This could be explained by a photochemical degradation of surface residues rather than metabolism within the plant. There is evidence to suggest that the compound is not readily metabolised in the plant species investigated.

The translocation characteristics demonstrated in Table 2 illustrate the 'source to sink' concept originally suggested by Crafts (1961). Acropetal movement into the apical regions of the treated frond declined as the frond matured and basipetal movement down to rhizome increased. During the phase of bracken frond emergence and rapid expansion it would be expected that all the materials synthesised by the frond would be retained by the aerial portion and downward movement to roots or rhizome is minimum (Zimmerman, 1969). Thus when asulam is applied at stage 1 very little translocation to the rhizome is acheived though it increases thereafter as the frond expands. This pattern of movement has been reported for aminotriazole by Volger (1969). There is evidence that movement of carbohydrates from the rhizomes in the early stage of development rapidly depletes the rhizome of starch (cited Hodgson, 1964). When frond expansion is complete, the carbohydrate store in the rhizome is restored, indicating predominantly basipetal translocation at later stages, a maximum being reaching in the late summer. These findings suggest that maximum translocation of asulam to the rhizome takes place when basipetal movement of assimilates to the rhizome is rapid.

Further, the relatively high level of accumulation in the buds and apices suggests that asulam is transported in the phloem along with the assimilates to the regions of high metabolic activity. With the exception of stage 1, the proportion of radioactivity recorded in the basal rachis was relatively constant possibly indicating some fixation of asulam in the tissue pathways en route to the rhizome. It is also possible that any unmetabolised asulam remaining in the various regions, especially in the frond, would eventually be translocated to the rhizome and its associated buds. The radioactivity recorded in the frond apex at the first growth stage may be translocated downward once the frond has matured. This may not take place however, since morphologicalobservations have shown that when asulam is applied at stage 1 the frond tips become chlorotic and the stems completely darkened. Crafts (1961) showed that the extent of movement was correlated with the amount of chlorophyll in the treated leaf and that in Tradescantia amitrole did not move out of a chlorotic leaf.

To conclude, these experiements demonstrate the importance of stage of frond development on the efficiency of absorption and translocation of asulam - sodium salt formulation. The findings may, in part, explain some seasonal variation in effect of this compound previously observed in the field (Martin et al, 1972).

Acknowledgements

The authors express appreciation to May & Baker Ltd. for the Scholarship to one of us (P.V.), for the gift of ^{14}C-asulam and other chemicals, and for the helpful co-operation of Miss H. Cottrell and Dr. B. Savoury of the Plant Chemotherapy Division.

References

BRAY, G.A. (1960) A simple efficient scintillation technique for counting aqueous solution in a liquid Scintillation Counter. *Analyt. Biochem.* *I*, 279-85.

CONWAY, E. and FORREST, J.D. (1961) The effects of 4-chlorophenoxyacetic acid on the rhizomes of *Pteridium aquilinum* (L) Kuhn. *Weed Res.* *1*, 114-30.

CRAFTS, A.S. (1961) *Translocation in plants*. Holt, Rinehart & Winston, New York.

ERSKINE, D.S.C. (1960) An interim report on bracken control trials. *Proc. 5th Br. Weed Control Conf.*, 1960. 209-14.

ERSKINE, D.S.C. (1968) Experimental work in the chemical control of bracken 1958-1968. *Proc. 9th Br. Weed Control Conf.*, 1968. 488-92.

HODGSON, G.L. (1964) Chemical control of bracken. A.R.C. (W.R.O.) *Technical report*, *3*, 1964.

HOLROYD, J. and PARKER, C. (1970) Asulam for the control of bracken (*Pteridium aquilinum* (L) Kuhn). *Proc. 10th Br. Weed Control Conf.*, 1970, 371-76.

HULL, M.H. (1970) Leaf structure as related to absorption of pesticides and other compounds. *Residue Rev.*, *31*, 1-150.

KALBERER, F., and RUTSCHMANN, J. (1961) Eine Schnell methode sur bestimmung Von tritium, radiokoholenstoff und radioschwefel in belieiqem organischem probenmaterial mihels des flussigkeitz - scintillatons a Zahlers. *Hel-chim. Acta.* *44*, 7.

KIRKWOOD, R.C. (1962) The control of bracken. An interim report on further trials with amitrole, 4-CPA and 4-CPA/MCPA mixtures. *Proc. 6th Br. Weed Control Conf.* 1962, 401-6.

MacDONALD, A.M.G. (1961) The oxygen flask method. A review. *Analyst, Lond.*, *86*, 3-11.

MARTIN, D.J., WILLIAMS, G.H. and RAYMOND, J.C. (1972). *Proc. 11th Br. Weed Control Conf.* 1972 (in press).

VOLGER, C. (1969) *Pteridium aquilinum* and its control with aminotriazole. *Schr Reihe Forstl. Fak. Univ. Gottingen.*, *41*, 104.

ZIMMERMANN, M.H. (1960) Transport in phloem. *A. Rev. Pl. Physiol.*, *11*, 167-190.

Proc. 11th Br. Weed Control Conf. (1972)

REVIEW OF BRACKEN CONTROL EXPERIMENTS WITH ASULAM

D. Soper
May & Baker Ltd., Ongar Research Station, Essex

Summary This paper is essentially a progress report of replicated experiments and user trials laid down from 1970-72 to evaluate factors likely to influence the field activity of asulam on bracken, Pteridium aquilinum. The herbicide has been applied in June to September at doses ranging mainly from 2 to 4½ kg a.i. per ha. in both forestry and agricultural situations. Excellent control of bracken has been achieved, lasting two years after spraying, with 3.4 to 4.5 kg asulam per ha. applied within this period to expanded green fronds. Volumes of water in the low to medium range are optimal. The tolerance of conifers and hill flora, and some other ancillary investigations related to post-spraying management are still under study.

INTRODUCTION

Since the publication on the herbicidal activity of asulam on bracken (Holroyd et al. 1970), several series of experiments have been undertaken to investigate factors which could influence the field performance of the compound. These include time of treatment, dose, addition of wetter, application methods, and post-spray management. Observations have begun also, on grazing behaviour in treated areas and on the tolerance of hill flora and conifers to asulam.

METHOD AND MATERIALS

Field work was initiated in late Summer 1970, when four replicated trials were laid down to compare 2.2, 3.4 and 4.5 kg asulam per ha. applied to mature bracken fronds. The plots were 7.6m. square, duplicated, and volume rate was 336 l/ha. using the 'Colwood' small plot sprayer or knapsack sprayer (1 site - Laindon).

The majority of the experiments were laid down the following year and comprised three series. The first compared the same doses of asulam, but in addition the two lowest rates were applied with wetter, and dicamba was included at 4.5 kg/ha. At two forestry sites separate blocks were treated in July, August and September, but on three hill-land sites the August treatment was omitted. Plot size was 7.6m. by 9.1m. and the sprays were applied with the 'Colwood' at 364 l/ha. The second series was designed to test the effectiveness of the two highest rates of asulam (3.4 and 4.5 kg/ha.) using four types of spray machinery. High volume application with a hand-lance, delivering 1680 l/ha., was compared with 'Kestrel' hand and 'Motoblo' motorized knapsack sprayers, applying 336 and 168 l/ha. respectively, and with the 'Ulva' very low volume sprayer delivering the undiluted formulation at 11.2 l/ha. Plot size necessarily varied according to the equipment used and treatment took place at five sites between the end of June and early August. In the small-plot work there were two replicates, but in the third series of trials a simple unreplicated layout was adopted treating large areas of bracken with 4.5 kg asulam per ha. The farmer's or forester's own application machinery was used and 20 sites were sprayed throughout Great Britain mainly in the August to mid-September mature frond period. One additional site was treated from the air.

In 1972, because of the possible need to remove bracken soon after spraying to allow pasture improvement practices to begin or trees to grow, two replicated trials were laid down to determine the effect of post-spray cutting on the efficacy of asulam. A split split-plot layout has been adopted with the three doses used in the 1970 experiments, then the two application times June and July and finally the three management regimes, i.e., cutting 1, 2 and 4 weeks after treatment. There are three replicates and volume applied was 260 l/ha.

Pot experiments have been set up to determine the tolerance of selected hill flora to 2.2 to 9 kg asulam per ha. without wetter. The grasses Agrostis tenuis, Anthoxanthum odoratum, Deschampsia and Festuca spp., Molina caerulea and Nardus stricta, which were in flower at the time of treatment and the shrubs Calluna vulgaris and Vaccinium myrtillus were included. In collaboration with the Forestry Commission the tolerance of young conifers to applications of 1½ to 6 kg asulam per ha. is currently being examined. Three-year-old plants of Larix leptolepis, Picea abies, P. sitchensis, Pinus sylvestris, P. nigra, Pseudotsuga menziesii and Tsuga heterophylla have been treated in July and early September. Finally, a simple 2 plot unreplicated experiment has been laid down on a hill pasture to determine whether the attractiveness or acceptability of bracken to cattle is affected by asulam. Application was made at 4.5 kg a.i. per ha. on the 14th August, and observations on the grazing habits of the animals were made during daylight hours for 3 days after treatment and for the same period one month later.

In all this work 'Asulox', the 40% aqueous concentrate of asulam, as alkali metal salt, was used. All bracken assessments have been made using random quadrats, mainly $\frac{1}{2}m^2$, counting frond (i.e. stem) numbers.

RESULTS

Table 1 summarizes the results of the 1970 experiments giving information on the persistence of asulam for up to nearly two years after spraying. The 1971 replicated and user trials are summarized in Tables 2-5, all bracken counts being made about one year after treatment.

Only early results can be given from the 1972 work. In the hill-flora tolerance experiments, damage to Agrostis tenuis was severe at the higher rates, but the other grass species were much more tolerant; Calluna and Vaccinium were unharmed. Of the conifers treated, Tsuga heterophylla and Pinus nigra were susceptible to asulam but the other species were more resistant and exhibited no significant damage at 4.0 kg per ha., which was sufficient for bracken control. At both times of application and at both sites cutting the bracken has stimulated the rapid emergence of new fronds whether or not asulam had been applied one or two weeks earlier. In the grazing observation trial there is so far no indication that treated or untreated bracken is preferentially taken by cattle.

DISCUSSION

Bracken treated with asulam showed some sign of herbicidal damage in the year of application in the form of frond-tip chlorosis, but the effect of the chemical was mainly manifested by little regrowth of stem in the following year. In user trials carried out under a wide set of field conditions, 4.5 kg/ha. gave a mean 90-95% control of frond numbers after about twelve months (Table 4); the surviving fronds were much reduced in height and pinnule development and were frequently chlorotic.

TABLE 1

Effect of asulam on bracken 10-23 months after spraying

No. of fronds/$\frac{1}{2}m^2$, means of two replicates a = frond counts
b = $\sqrt{a + 0.5}$

Site location			Thurston		Thetford		Laindon		Triscombe	
Date of Treatment			3.9.70		3.9.70		18.9.70		19.8.70	8.7.71 *
Date of Assessment			14.7.71	3.8.72	14.7.71	14.7.72	23.7.71	2.8.72	8.7.71	10.8.72
Interval after spraying (months)			10	23	10	22	10	22	11	13
Asulam	2.24 kg/ha	a	0.4	0.6	0.4	4.6	2.6	2.8	29.0	0.4
		b	1.05	1.02	0.91	2.18	1.73	1.77	5.20	0.90
"	3.36 kg/ha	a	0	0.4	1.0	1.8	2.5	5.2	12.7	2.0
		b	0.71	0.85	1.12	1.38	1.67	2.32	3.43	1.30
"	4.48 kg/ha	a	0	0.1	0.5	0.6	2.0	2.4	20.7	0.5
		b	0.71	0.76	0.95	0.82	1.39	1.58	4.45	0.95
Unsprayed Control		a	4.0	6.9	19.2	28.0	33.7	23.7	57.4	39.9
		b	1.94	2.52	4.36	5.40	5.81	4.90	7.43	6.39
S.F. ± of treatment means (b)			0.122	0.116	0.143	0.446	0.196	0.171	0.385	0.197

* Resprayed (heavy drizzle on day of first treatment)

TABLE 2

Effect of timing, dose and wetter on the activity of asulam against bracken in forestry

No. of fronds/3m^2, mean of 2 replicates a = frond counts, $b = \sqrt{a + 0.5}$

Site		Thetford, Norfolk						Butley, Suffolk					
Date of Assessment		14.7.72						21.7.72					
Date of Treatment		19.7.71		9.8.71		13.9.71		20.7.71		11.8.71		14.9.71	
Herbicide	Dose kg/ha	a	b	a	b	a	b	a	b	a	b	a	b
Asulam	2.24	0	0.71	5.5	2.33	31	5.61	0.5	0.97	8	2.91	15	3.93
	3.36	1.5	1.40	2.0	1.58	27	5.23	1.0	1.14	4	2.11	3	1.85
	4.48	0	0.71	0	0.71	16	4.01	1.0	1.14	7.5	2.32	3.5	2.0
Asulam + 0.025% w/v 'Shellestol'	2.24	1.0	1.14	7.5	2.52	36.5	6.07	1.5	1.40	9.5	2.97	17	3.64
	3.36	0	0.71	6.0	2.52	30	5.51	1.5	1.29	6	2.55	2.5	1.67
Dicamba	4.48	32	5.51	0	0.71	6	2.48	19.5	4.47	1.0	1.14	6	2.55
Control		52.5	7.28	45	6.43	69	8.33	48	6.95	48.5	7.27	71	8.46
Standard Error ±			0.526		0.487		0.425		0.394		0.739		0.840

TABLE 3

Effect of timing, dose and wetter on the activity of asulam against bracken on Somerset hill land

No. of fronds/$3m^2$, mean of 2 replicates
a = frond counts
b = $\sqrt{a + 0.5}$

Herbicide	Dose Kg/ha												
Site		Triscombe				Broford				Hawkridge			
Date of Assessment		10.8.72				8.8.72				9.8.72			
Date of Treatment		27.7.71		8.9.71		28.7.71		8.9.71		28.7.71		7.9.71	
		a	b	a	b	a	b	a	b	a	b	a	b
Asulam	2.24	2.5	1.73	68.5	8.3	1.0	1.14	43.5	6.63	4.5	2.23	6.0	2.54
	3.36	2.5	1.73	55.5	7.48	0	0.71	49.5	7.06	2.5	1.53	8.0	2.91
	4.48	0.5	0.97	26.5	5.16	0	0.71	28.5	5.29	2.0	1.41	1.5	1.40
Asulam + 0.025% w/v 'Shellestol'	2.24	3.5	1.96	49.5	7.07	0	0.71	36	5.99	6.0	2.55	8.5	2.97
	3.36	1.0	1.14	33.5	5.83	1.5	1.40	33	5.77	4.5	1.89	6.6	2.64
Dicamba	4.48	103	10.16	18.5	4.36	52.5	7.14	52	7.23	103.5	10.12	63.5	6.86
Control		223	14.78	217	14.75	45.5	6.68	93.5	9.69	125.5	11.22	105	10.26
Standard Error ±			0.352		0.187		0.641		0.571		0.674		1.61

TABLE 4

Control of bracken with 4.5 kg asulam/ha. 11 to 12 months after treatment

21 user-applied unreplicated sites (13 pasture, 8 forestry)

Location	Description	Date of Treatment in 1971	Vol. of Applic. l/ha.	% Frond Cover at Treatment	Mean Frond Nos/m^2≠ in July/August 1972				% Control of Frond Nos.
					Treated	S.E.±	Untreated	S.E.±	
Iken, Suffolk	Heathland	20.7	448	95	0.6	0.32	21.7	1.82	97.2
Lydbury North, Salop	Perm. pasture	11.8	336	75	0.7	0.26	56.3	4.11	98.8
" "	Rough pasture	11.8	"	100	0.8	0.26	51.3	7.33	98.4
Alnwick, N'land	Lowland pasture	13.8	"	70	1.8	0.58	48.0	4.81	96.2
Minehead, Somerset	Moorland	15.8	224	90	1.0	0.44	44.0	5.42	97.7
Rendlesham, Suffolk	Conifer plantation	16.8	"	70	0.9	0.46	18.3	1.41	95.1
Tow Law, Durham	Hill pasture	18.8	336	80	2.1	0.49	53.0	4.12	96.0
Rendlesham, Suffolk	Conifer plantation	20.8	896	70	0.1	0.10	18.3	1.41	99.5
Bakewell, Derbys.	Moorland	24.8	448	90	2.1	0.62	55.7	6.46	96.2
Cannock Chase, Staffs	Pine plantation	27.8	336	100	1.0	0.37	36.7	3.92	97.3
Eskdalemuir, Dumfries	Spruce plantation	31.8	"	60	6.4	0.77	35.6	3.71	82.0
Thetford, Norfolk	Pine plantation	1.9	"	80	1.7	0.56	43.3	2.61	96.1
Snailbeach, Salop	Hill pasture	1.9	448	90	23.6	4.8	58.7	6.08	59.8
Kirkby Stephen, West'land	Perm. pasture	2.9	336	85	0.9	0.49	86.3	11.22	99.0
Lynton, Devon	Hill pasture	5.9	"	80	11.3	2.0	39.0	2.11	71.0
Strontoiller, Argyll	Hill pasture	7.9	"	90	1.0	-	29.9	-	97.7
Cannock Chase, Staffs	Pine plantation	8.9	168	100	0.8	0.44	36.0	3.06	97.8
Kilmelford, Argyll	Hill pasture	10.9	336	100	12.0	-	29.9	-	59.9
Euston, Norfolk	Cleared woodland	11.9	"	95	1.4	0.52	37.0	4.34	96.2
Delamere, Cheshire	Pine plantation	16.9	1,120	98	0.2	0.18	46.0	7.71	99.6
Bolton Abbey, Yorks	Moorland	18.9	56*	98	0.25	-	29.2	-	99.1

≠ ≮ 20 x $\frac{1}{2}m^2$ quadrats assessed on treated areas, ≮ 6 on controls.

* applied by fixed-wing aircraft.

TABLE 5

Effect of asulam at 3.36 and 4.48 kg/ha. using four application techniques

% control of frond numbers at stated intervals after spraying
(two replicates, 6 x $\frac{1}{2}m^2$ quadrats assessed/plot)

Site location				Presteigne	Forest of Dean		Butley	Thetford
Date of treatment				22.6.71	22.6.71	20.7.71	29.7.71	2. 8. 71
Bracken Growth Stage		Pinnae Frond Ht.		6 pairs 60-90 cm.	3 pairs 90-105 cm.	4 pairs 150-220cm	5 pairs 90-135cm	6 pairs 105-180 cm
Equipment		Vol. l/ha.	Dose kg/ha	13 months	13 months	12 months	12 months	11 months
HV		1680	3.36	86	96	94	99	80
Knap-sack	Hand(MV)	336	"	85	98	99	97	94
	Motor(LV)	168	"	95	93	97	100	98
HV		1680	4.48	-	100	100	100	97
Knap-sack	Hand(MV)	336	"	97	98	99	99	95
	Motor(LV)	168	"	95	100	98	100	98
Very low vol.		11.2	"	85	-	-	97	83
Control population, fronds/m^2 in July 1972				27	18	20	14	13

Persistence of herbicidal effect has been recorded so far over two seasons at three replicated sites (Table 1). Numbers of fronds have risen slightly on all plots during this period, but compared with the unsprayed areas even the 3.36 kg/ha. dose of asulam gave 90-95% control of frond numbers after one year which fell to only 80-85% control after two.

In some replicated trials 2.24 kg asulam/ha. has given a good result the following season, but this dose has generally been less reliable than the higher rates of 3.36 and 4.48 kg/ha.

The correct timing of application of asulam to bracken is a most important factor, and is probably more significant than dose. Best results were obtained when treatment was made in July and August, though at two sites (Table 5) spraying at the end of June was successful. Applications in the first fortnight of September in replicated trials (Tables 2 and 3) were less effective than those made earlier, except perhaps at the highest rate of 4.5 kg/ha. In the user trials this dose gave consistent results in August, but was not so consistent in September. Excluding very sheltered areas, bracken emergence was much later in 1972 than in the previous year and cold conditions can hasten senescence so that the weed often has quite a short season of frond growth. The central part of this June to September period is probably the optimum time of treatment in most areas of Great Britain, i.e. from the '3 to 4 pairs of pinnae' stage up to fully-expanded green frond.

In the replicated experiments reported in Tables 2 and 3, there appeared to be little difference between the bracken control obtained by treatments with and without wetter.

Good control of bracken has been achieved at all spray volumes, but there was a tendency for the high volume treatments to be less effective at the lower dose of 3.36 kg asulam/ha. and for the very low volume treatments to be variable probably because of the difficulty of seeing where the fine spray was going. Choice of equipment will obviously depend on practical considerations.

Only one site was treated from the air in 1971, but more have been sprayed this season in Scotland with the co-operation of local advisers.

Clearly the cutting of bracken soon after treatment with asulam cannot be recommended at present, but the long-term effect of this practice on herbicidal activity has yet to be observed. It is worth recording that at one replicated site (Broford, Table 3) limited treading and bruising of the fronds by horses post-spray did not result in unsatisfactory control being achieved the following season.

In forestry situations, asulam has safely 'released' young conifers from bracken cover, but direct treatment of Western hemlock and Corsican pine must be avoided. Because of the protection afforded by the bracken canopy, the damage to grasses seen in the pot experiments did not occur in the user trials where good swards have often been revealed the season after treatment.

Bracken is, of course, inherently toxic to livestock and its presence is a risk, especially when normal feed is lacking. From our records so far there is no reason to suppose that asulam-treated bracken is more (or less) acceptable to cattle than untreated fronds, but observations are continuing.

CONCLUSIONS

In practice the reliable rate of application for controlling bracken with asulam is from 3.36 to 4.48 kg/ha. applied low volume. For best results treatment must be made to an adequate pinna area in July/August, but before the plants begin to senesce in the autumn.

Acknowledgment

Thanks are due to my colleague Mr. R.W.E.Ball for the statistical analyses.

Reference

Holroyd, J., Parker, C., and Rowlands, A. (1970) Asulam for the control of bracken (Pteridium aquilinum) Proc. 10th Br. Weed Cont. Conf. pp. 371-6.

Proc. 11th Br. Weed Control Conf. (1972)

GROWTH OF AGROPYRON REPENS SEEDLINGS IN CEREALS AND FIELD BEANS

E. D. Williams
Rothamsted Experimental Station, Harpenden, Herts.

Summary Two experiments are described in which the growth of Agropyron repens seedlings was studied in field crops. In one A. repens seeds were sown singly in rows of winter wheat, spring wheat and spring barley with or without added nitrogen and in the other, sown thickly in plots of beans or barley undersown with ryegrass, clover or nothing.

Few seedlings established in the winter wheat when sown singly but in the spring cereals half the seeds sown produced seedlings and the amount of growth made depended greatly on when they emerged. Nitrogen increased the growth of seedlings more in spring wheat than in spring barley probably because spring barley itself responded more to nitrogen than did spring wheat making it compete more with the weed. By late August about 8% of the seedlings had rhizomes and these were ones that emerged early.

In the second experiment more seedlings survived and grew better in beans than in barley. Much rhizome was produced in beans but none in barley. Undersowing in both crops decreased weed growth, relatively more in beans than in barley, and clover was more suppressive than ryegrass.

INTRODUCTION

The agricultural importance of seed formation in the perennial grass weed, Agropyron repens (couch) will depend on the amount of seed produced, on its germination behaviour and on the growth and development of seedlings in field crops. Some information on the first aspect of the problem was obtained in 1969 (Williams & Attwood, 1971) when a survey showed that in many places the species produces a large number of viable seed. Information concerning seed germination, obtained mainly from laboratory and glasshouse studies, was reported previously (Williams, 1971) and such studies are now being extended into the field. Seedlings of couch which appear in field crops will be of practical consequence if they produce rhizomes, i.e. become perennial, when the crop is growing, or shortly afterwards, before post-harvest cultivations. Seeds contaminating crop seed could thus introduce the weed to clean areas, or diversify the population in already infested areas, thus increasing the difficulties of control. This report deals with two preliminary experiments on the growth of A. repens seedlings in field crops. In the first experiment seeds of A. repens were sown thinly in rows of cereals, simulating contamination of the cereal seed and in a second experiment the amount of growth made by the weed seedlings in barley and beans, undersown with ryegrass, clover or nothing was assessed.

METHOD AND MATERIALS

Experiment I.

This experiment had 4 randomised blocks of 3 plots and was sited on Rothamsted land which was fallow in 1970 and given 336 kg/ha of a compound fertiliser (0% N, 20% P_2O_5, 20% K_2O) in early autumn. Winter wheat (cv. Joss Cambier) was drilled on 1 October 1970 and spring wheat (cv. Kolibri) and barley(cv. Julia) on 26 February 1971 at normal seed rate into small plots 7.3 x 1.4 m (11 rows at 0.13 m). A. repens seeds, of 95% viability collected in 1970, were sown singly at 0.3 m intervals in the 7 centre rows of all plots. Half of each plot received 60 units of nitrogen as 'Nitrochalk' on 19 April (N_1) and the other half (N_0), none. The spring cereals were sprayed with ioxynil/mecoprop mixture on 20 May to control broad-leaved weeds.

In the spring cereals individual A. repens seedlings were ringed on 14, 19, 29 April, 6 and 20 May so that the time of emergence of all seedlings was known. The number of cereal plants in random ½ metre strips of row was counted on 29 April. Samples of cereals (from ½ m lengths of the 7 centre rows) and A. repens seedlings, usually 12, from within this area were taken on 9 May (from winter wheat only), 24 May, 25 June and finally when the crops were ripe (9 August for winter wheat and 26 August for the spring cereals). At sampling, the number, length and dry weight of shoots of A. repens seedlings, and at the last sampling the dry weight of rhizomes, was measured. The cereal shoots were weighed fresh and a sub-sample dried to obtain the total dry weight; the number of shoots, and at later samplings, ears in the sub-sample were counted. The green area of 20 cereal shoots from each sample was measured using an Electroplan leaf area machine. The leaf area index of the spring cereals (the ratio of the green area of the crop per unit area of land) was calculated for the first two samplings. Grain yield of all plots was estimated using a small thresher (Garvie & Welbank, 1967).

Experiment II.

This experiment, also on clay with flints at Rothamsted, tested all combinations of spring barley and spring field beans undersown with ryegrass, red clover or nothing on the growth of seedlings of A. repens and also on the growth from rhizomes (Barnard & Dyke,1972). It was set out as 4 blocks of 2 plots each split into 3, the crops being sown on 26 March, undersown on 31 March and 100 couch seeds sown in 2 x 0.09 m^2 areas in all sub-plots on 1 April. Couch seedlings were removed from the crop just before they were harvested (19 August for barley and 10 September for beans), counted, dried and weighed. Rhizome lengths were also measured.

RESULTS

Experiment I.

The winter wheat seed bed was extremely cloddy and for the month after drilling was very dry. Nevertheless, the crop grew very lush over a mild winter as did also Stellaria media (chickweed) which covered most of the plots. The wheat became too advanced for herbicide spraying in spring. Insufficient A. repens seedlings emerged and survived (c. 12%) to permit comparisons with the growth of seedlings in the spring cereals. By the beginning of August the mean weight of the weed seedlings was 24 mg without nitrogen and 70 mg with it. None of the seedlings produced rhizomes.

In the spring cereals more than half the seeds of A. repens gave seedlings; emergence was very protracted, occurring over two months. None emerged in March, which was very cold, a large number in early April, few in late April (there was no rain in April until the 23) and there was a further flush of germination in early May, probably as a result of heavy rain during 23-26 April (Table 1).

Table 1

Number and percentage of A. repens seedlings emerging at different times

	Before 14 April	14-19 April	20-29 April	30 April - 6 May	7-20 May	After 20 May
No.	208	47	54	124	106	38
Per cent	36	8	11	21	18	6

Although care is needed in interpreting the amount of growth made by seedlings emerging at different times, it is clear that the amount of growth made by the weed seedlings depended greatly on when they emerged (Table 2). Because of the cumulative effect of the advantages of early emergence, the extent of difference between early and late emergence was greatest at the final sampling. Fourteen seedlings had rhizomes at the last sampling and these were ones that had emerged before mid-April. The maximum weight per seedling was 280 mg and the maximum amount of rhizome 117 mg.

Table 2

Mean dry weight(mg) at sampling of seedlings that emerged at different times

	Time of emergence					
	Before 14 April	14-19 April	20-29 April	30 April - 6 May	7-20 May	After 20 May
24 May	15(66)	7(21)	8(24)	4(32)	2(47)	1(19)
25 June	28(72)	27(12)	10(12)	7(50)	4(42)	2(12)
26 August	76(70)	75(14)	29(18)	17(42)	8(17)	5(7)

(Figures in parentheses are number of seedlings on which the means are based)

The amount of growth made by the A. repens seedlings growing in spring wheat was almost trebled by nitrogen but except at the earliest sampling this increase was smaller in barley. Without added nitrogen the weed seedlings made as much growth in barley as in wheat but with nitrogen they made more growth in wheat than in barley. (Table 3)

Without nitrogen the total shoot growth of wheat and barley, like that of the weed seedlings, differed little at the first two samplings; with nitrogen that of barley only slightly, but not significantly, exceeded wheat. At the final sampling the figures for barley are probably subject to sampling error, since it is unlikely that there would be a decrease between the end of June and August in shoot dry weight or an increase in shoot number without nitrogen.

Table 3.

Mean dry weight*(mg) at sampling of A. repens seedlings from spring cereals

	24 May			25 June			26 August		
	N_o	N_1	S. E.	N_o	N_1	S. E.	N_o	N_1	S. E.
From barley	3	10	±1.4	8	16	±2.4	38	50	±10.8
From wheat	4	13		10	27		29	77	
S. E,	±1.4			±3.4			±8.7		

(*In general, the proportion of seedlings emerging at different dates was similar, but to make comparisons between treatments fairer values were adjusted by covariance analysis for emergence date. Because of large variations within treatments, analyses were also made on logarithmic transformations of the data; the level of differences were similar to those shown in Table 3.)

There were more barley than wheat plants in April (285 compared to 250/m^2), and these also tillered more during May. Because of this greater number of shoots, especially with nitrogen, barley had a much larger leaf area index than wheat (Table 4). The final grain yields (at 85% d.m.) with and without added nitrogen, were spring wheat 4.1 and 5.3, spring barley 5.8 and 5.8 and winter wheat (severely damaged by birds) 2.6 and 4.3 tonne/ha.

Table 4

Shoot dry weight (g/m^2), number of shoots/m^2 and leaf area index of Barley (B) and Wheat (W) at sampling

		24 May			25 June			26 August		
		N_o	N_1	S. E.	N_o	N_1	S. E.	N_o	N_1	S. E.
Shoot dry weight	B	170	343	±12.6	621	1048	±70.6	*863	970	±46.6
	W	165	304		641	982		875	1158	
	S. E.	±11.3			±91.5			±37.8		
Shoot number	B	860	1222	±44.3	808	1145	±102.6	927	924	±51.4
	W	646	994		432	567		397	493	
	S. E.	±33.8			±118.6			±17.8		
Leaf area index	B	2.9	7.1	±0.40	6.0	11.7	±1.05			
	W	2.2	4.6		4.3	6.5				
	S. E.	±0.44			±1.28					

*includes ears

Experiment II.

The couch seedlings in barley and in beans were sampled at different times so strict comparisons cannot be made between them.

Barley was evidently more competitive than beans as fewer seedlings survived in it. Undersowing in both crops greatly decreased the number of weed seedlings surviving (Table 5). The seedlings which survived grew more in beans than in barley; undersowing greatly decreased the amount of growth, especially in beans. An average of 5 metres length of rhizome was produced per sample area in beans but none in barley. In interpreting the results of this experiment it must be borne in mind that because the seeds were sown thickly there must also have been intra-specific competition in many treatments.

Table 5

Percentage and weight of seedlings per sample area recovered from barley and beans not undersown(-) or undersown with ryegrass(R) or red clover (C)

	Barley			Beans		
	-	R	C	-	R	C
Per cent seedlings recovered	42	27	9	67	20	5
Total shoot dry weight(g)	0.41	0.16	0.07	15.9	2.4	0.4
Rhizome dry weight(g)	-	-	-	4.8	0.9	0.4
Rhizome length(m)	-	-	-	5.4	1.1	0.1

DISCUSSION

Agropyron seedlings made little growth in cereals in these two experiments but the large amount in beans indicated that they are potentially vigorous. Few formed rhizomes in cereals and whether these would further infest the land would depend on post-harvest operations. In the first experiment seeds were sown thinly so that the fate of individual seedlings could be followed.

Many factors may have predisposed the weed to be susceptible to competition from the cereals and these included rough seed beds and inclement spring weather. Also, the cereal crops themselves were vigorous; with nitrogen in Experiment I the two spring cereals yielded more than 5 tonne/ha and although yields were not assessed in Experiment II the barley plots also appeared to be high yielding. Crop yield itself is however not an adequate reflection of its competitive ability. For example, in the experiment reported by Cussans (1970) wheat was more competitive to A. repens than was barley but it yielded less grain. Crops like the winter wheat in Experiment I may be very competitive in the early stages but later suffer from pests and diseases which could reduce yield.

The amount of growth made by the weed seedlings depended not only on the crop in which they were growing and its nitrogen supply but also on when they emerged. The time of emergence is important in competition as it determines what part of the available resources the weed and crop can respectively exploit. On average both crop and weed responded to nitrogen, barley more so than spring wheat and A. repens seedlings more in spring wheat than in barley. It therefore appears that the weed seedlings benefitted from the added nitrogen more than they suffered from increased shading by the crop and that the response of the weed to nitrogen was to a large degree determined by the crop. Barley, especially with nitrogen was more competitive than wheat because it produced more shoots, more of which survived and so had a greater leaf area index which possibly shaded the seedlings more. The difference in shoot dry weight of the two crops with nitrogen in May and June (when competition was presumably severe) was small indicating that the different competitive ability of the two cereals was related to the different habit or disposition of growth rather than to the total amount. The pattern of growth of crop and weed differed as might be expected, since the first were annuals and the second perennial. The crop made most growth in May and June but the weed in July and August, when crop competition was less intense.

Competition not only affected the amount of growth made by the weed seedlings but also their survival. Only a small number survived in winter wheat, possibly because of competition from broad-leaved weeds. Different degrees of competition also affected seedling survival in the second experiment. The larger amount of growth made by the weed seedlings in beans than in barley is similar to the findings of Cussans (1968 and 1970) and Barnard and Dyke (1972), with A. repens rhizomes. The effects of undersowing also resembled those found by Barnard and Dyke.

On the basis of these results, provided stubble cultivations were promptly and efficiently done after cereal harvest, the small amount of rhizome produced by the seedlings would be unlikely to further infest the land. However, it is rash to generalise from the results of one year's work; further studies are needed over a wider range of conditions before attempting to define under what conditions A. repens seedlings might be important. Further experiments are in progress or planned which include different cereals, nitrogen, and time of emergence of A. repens seedlings as factors likely to affect the outcome of competition. Agrostis gigantea will also be included in these experiments.

Acknowledgments

I thank G. V. Dyke and A. J. Barnard for allowing me to sow A. repens in Experiment II, and G. W. Cussans for helpful discussions.

References

CUSSANS, G. W. (1968) The growth and development of Agropyron repens(L.)Beauv. in competition with cereals, field beans and oil seed rape. Proc. 9th Br. Weed Control Conf., 131-136.

CUSSANS, G. W. (1970)A study of the competition between Agropyron repens(L.)Beauv. and spring sown barley, wheat &field beans. Proc.10th Br.Weed Control Conf., 337-343.

BARNARD, A. J. & DYKE, G. V. (1972)Suppression of couch grass by ryegrass or clover undersown in barley or beans. Rep. Rothamsted Exp.Stn for 1971, Pt.1, 257-258.

GARVIE, D. W. & WELBANK, P. J. (1967)A rasp-drum laboratory thresher & cleaner. J. agric. Engng. Res., 12, 229-232.

WILLIAMS, E. D. (1971) Germination of seeds and emergence of seedlings of Agropyron repens (L.)Beauv. Weed Res., 11, 171-181.

WILLIAMS, E. D. & ATTWOOD, P. J. (1971) Seed production of Agropyron repens(L.) Beauv. in arable crops in England & Wales in 1969. Weed Res., 11, 22-30.

DIFFERENCES IN GROWTH OF FOUR CLONES OF AGROPYRON REPENS (L.) BEAUV.

W. Pooswang, P. A. Huxley and W. R. Buckley
Horticultural Research Laboratories, University of Reading

Summary The growth of spaced, pot-grown plants of four morphologically different clones of couch grass was examined during the period June, 1970 to June, 1971. By the end of the first growing season the most vigorous clone had a total dry weight and rhizome dry weight about 25% greater than the least vigorous one and the distribution of dry weight varied between clones by 5 to 15% for root, from 45 to 58% for rhizome and only from 37 to 40% for the aerial parts. Total available carbohydrate in the rhizome varied from 0.39 to 0.45 g/g/plant. The most vigorous clone continued growing into the autumn but not overwinter as did one of the originally "less vigorous" ones. Overall, 50% shade diminished total plant, rhizome and root dry weight to 57%, 50% and 30% of that of the unshaded treatment but clones did not respond similarly to shade. Late defoliation (August) diminished total plant and rhizome dry weight by 24% and 40% respectively compared with only 14% and 7% respectively for early defoliation (June) and all clones responded similarly.

INTRODUCTION

Agropyron repens (L.) Beauv. occurs naturally as an important weed from as far north as the limits of cultivation in the Arctic down to North Temperate Africa, and it exhibits a range of morphological forms (Palmer and Sagar, 1963). Little is known of any physiological differences between such forms and the experiment reported here was designed to study the extent of difference in vegetative growth using four clones chosen for their morphological dissimilarity. The study was undertaken to provide data on the main growth characteristics which contribute to the success of this plant as a weed and to indicate the extent to which differences in growth patterns between clones might influence any measures taken for their control.

MATERIALS AND METHODS

Rhizome material of four clones of Agropyron repens (L.) Beauv. was obtained from the Weed Research Organisation, Begbroke Hill. The clones were "Begbroke", "Headington", "No. 9" and "No. 25", designated hereafter as B, H, N and T respectively.

For this experiment single, spaced couch plants, selected for uniformity at the three-leaf stage from plants propagated from rhizome pieces about 2.5 cm long, were grown on in 20 cm diameter plastic pots, either shaded or unshaded and subjected to defoliation on three separate occasions. The experiment was set out factorially in four randomised blocks with eight main treatments i.e. shaded or unshaded and defoliated in June, July or August, 1970, or not at all. Each of the main treatments was split for the four clones.

A vermiculite, sand, gravel medium was used (2:1:2 by volume), with a commercial base fertilizer of 13:13:20 at 1.76 kg/m^3; magnesium lime stone and chalk were mixed in at the rate of 1.16 kg/m^3. During the growing season commercial fertilizer was applied twice a week and water was applied daily. For shade, two layers of green "Netlon" were used to achieve about 50% light reduction. Defoliation was carried out at compost level with scissors.

The experiment started on the 7th June, 1970 and plants were sampled on seven occasions, just prior to defoliation treatments when these were imposed, and with the final harvest at the end of June, 1971. At each harvest the dry weights of root, rhizome, stem, green leaf and dead and senescent leaf were obtained and leaf area was calculated from the length and breadth of sample leaves; the leaf area per plant was then estimated from the ratio of leaf area/leaf dry weight. Usually 10-30 leaves from each sub-plot were measured at each harvest. An analysis of total carbohydrate was carried out on the material harvested in December, 1970 using the Shaffer-Somogyi method (Smith et al 1964, Heinze and Murneek 1940).

RESULTS

Growth of whole plants

The progress of total dry weight is shown in Fig. 1. From June to October all four clones exhibited sigmoid growth curves. Although not statistically significant ($p = 0.05$) from October to December total weights diminished slightly. Between December to March all clones increased in dry weight again and, at the start of the second season, growth was rapid in spring and early summer from March to June - the final harvest - although the rate of growth was slower than in the previous summer.

By October in the first season the four clones differed considerably in total dry weight. The largest was clone H (mean of all treatments 42.5 g/plant) and N, T and B were respectively 87, 78 and 74% of this value (all differences statistically significant at the 1% level in October and December except clones T and B which were not significantly different from one another even at the 5% level). At the final harvest in June 1971 the ranking order had changed to H, T, N, B with only H significantly different ($p = 0.05$) from all the others.

The overall effect of shade by October was to reduce plant dry weight by 43% (from 46.0 to 16.2 g/plant). Comparing clones, mean dry weight of unshaded plants was 52.4, 46.7, 43.0 and 42.0 g/plant (H, N, B, T, respectively) and, shade affected B most with the total plant weight being 46% of that of unshaded plants. H, N and T had approximately the same degree of response to shade and dry weight was reduced to 62%, 59% and 58% of the unshaded treatment respectively. During August, September, October the differences between clones did not achieve statistical significance but they did during the early growing season (July) and during the winter (December and March harvests). The interaction between clone and shade was also significant at these times ($p = 0.05$ or less).

All four clones responded similarly to the three defoliation treatments which subsequently brought about statistically significant differences in total dry weight ($p = 0.01$). Mean total dry weight of undefoliated plants in October was 42.5 g/plant and, overall, defoliation early in the growing season (June) reduced whole plant weight by only 14% by October but defoliation in July and August decreased plant dry weight in October by 22 and 24% respectively.

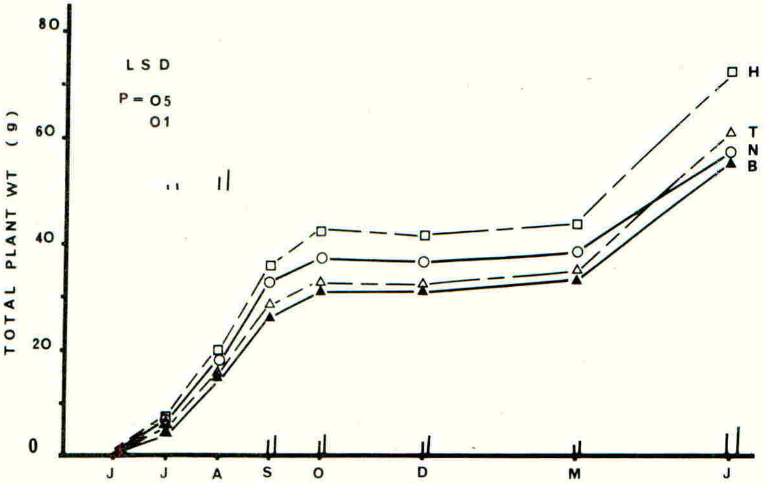


Fig. 1 Increase in total plant dry weight/plant with time for four clones.

Rhizome growth

New rhizome was produced during the first month after setting out the plants and there was an exponential increase in rhizome dry weight up to the September harvest (Fig. 2). Between September and October the rate of increase diminished and from October to December, although there was no increase in whole plant weight (Fig. 1), rhizome weight increased slightly and shoot weight decreased. By October clone H had produced the greatest rhizome dry weight (overall mean of all treatments was 19.4 g/plant and clones T, B and N had 90, 82 and 73% of this value respectively). All differences were significant at p = 0.05 or less except that between clones T and B. In December the rhizome dry weight of clone H increased slightly to 20.5 g/plant with T, B and N approximately the same percentage of this as before. This ranking order, H > T > B > N, was not the same as that for whole plant dry weight which was H > N > T > B.

Shade had an important effect on rhizome production. Overall rhizome dry weight was halved (from 22.6 to 10.9 g/plant) by submitting plants to about 50% daylight throughout the growing season. By October dry weight of rhizome of the unshaded clones was in the order H > T > B > N (mean weight of H was 25.4 g/plant and T, B, N were 93, 89 and 74% of this value respectively) but clones did not respond similarly to shade under which the ranking order was H > T > N > B. (Mean weight of H was 13.4 g/plant and T, N, B were 85, 71 and 69% of H respectively). Again, clone B was the most affected by shade, rhizome dry weight being reduced by 59% of the unshaded weight (22.6 to 9.3 g/plant) while T, N and H were reduced by 52, 49 and 47% respectively when compared with unshaded plants (23.6 to 11.4, 18.7 to 9.5 and 25.4 to 13.4 g/plant respectively).

Defoliation also significantly decreased the amount of rhizome produced. Plants which had been defoliated late in the growing season (August) produced the smallest amount of rhizome. Defoliation in June, July and August when compared overall in October to the undefoliated treatment (mean 21.4 g/plant), reduced rhizome weight by 7, 25 and 40% respectively. However, all clones responded similarly to different times of defoliation.

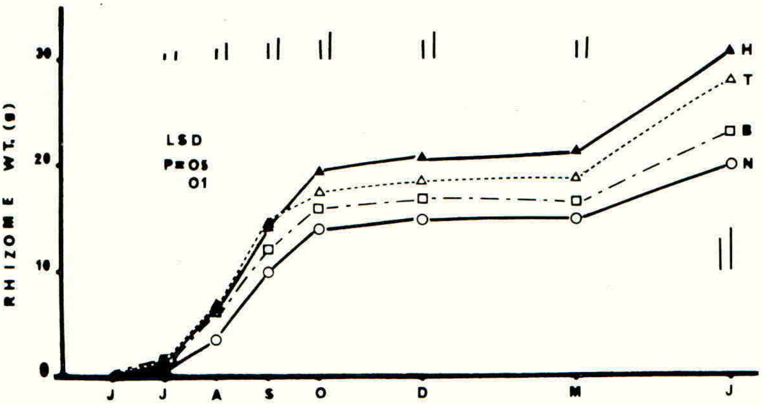


Fig. 2 Increase in rhizome dry weight/plant for the four clones.

Mean values of total available carbohydrate reserves in the rhizomes harvested in December were 0.45 (H, 0.41 (N), 0.40 (B) and 0.39 (T) g/g of dry rhizome weight respectively (standard error of difference ± 0.028, p = 0.05). Shade reduced the overall reserves significantly by 17%, that is from 0.45 to 0.38 g/g of rhizome dry weight (p = 0.001) and although there was no statistically significant interaction between clone and shade, shade reduced total carbohydrate in rhizomes of clone T by 0.045 g/g dry weight and this was about half the effect on H, N and B (0.076, 0.083 and 0.095 g/g dry weight, S.E.± .039 at p = 0.05). Defoliation at different times of the growing season made no difference to the proportion of carbohydrate in the rhizomes at the end of the growing season.

Between clones the rhizomes differed morphologically as indicated by Table 1. From the mean of three harvests the internodes of N were the heaviest and longest followed by H, B and T.

Table 1

Mean differences in length (cm) and dry weight (g) of 100 rhizome internodes from three harvests - 128 plants from each harvest

	Weight of 100 internodes				Length of 100 internodes			
Clone	Dec.	March	June	Mean	Dec.	March	June	Mean
B	4.30	5.04	5.68	5.00	347	425	387	386
N	7.88	7.91	10.18	8.66	390	441	421	417
T	3.54	3.43	4.61	3.86	368	351	348	356
H	6.26	5.24	7.44	6.31	416	410	403	410
S.E.diff (p = 0.05)	0.41	0.40	0.60		18.2	19.9	19.3	

Root growth

Changes in dry weight of root are shown in Fig. 3. There were highly significant differences between clones. Throughout the whole experimental period clone N produced the greatest root dry weight. By October the order of root dry weight was N > H > B > T and the mean of clone N was 4.21 g/plant; H, B and T produced only 79, 41 and 36% of this root weight respectively.

Overall, shade diminished the mean root dry weight by 70% (from 4.14 to 1.24 g/plant in October). This reduction was proportionally greater than for the whole plant or rhizome weight which were reduced under shade by only 43 and 53% respectively. For individual clones shade diminished root dry weight by 76, 71, 68 and 66% for B, N, H and T respectively when compared with unshaded plants. Because clone B was so adversely affected by shade, the order of root dry weight when unshaded was N > H > B > T (6.50, 5.04, 2.78 and 2.25 g/plant respectively), and under shade it was N > H > T > B.

After the first two defoliations (D_1 and D_2), these treatments lessened the subsequent increase in root dry weight when compared with the control (D_0) and after the third defoliation in August (D_3) root weight was actually less at the subsequent September harvest than it had been in August. By the end of the first growing season, in October, undefoliated plants (D_0) had the highest root dry weight (3.2 g/plant) whereas D_1 and D_2 with almost equal root weight (17% less) ranked second and D_3 (30% less than D_0) had the smallest root weight, but only D_0 and D_3 were significantly different ($p = 0.05$). By March, all treatments had approximately the same root dry weight, D_0 decreasing and D_3 increasing in root weight overwinter. By the final harvest in June, 1971, plants which the previous season had had the smallest root weight then achieved a greater root weight than plants from the other three treatments ($p = 0.05$).

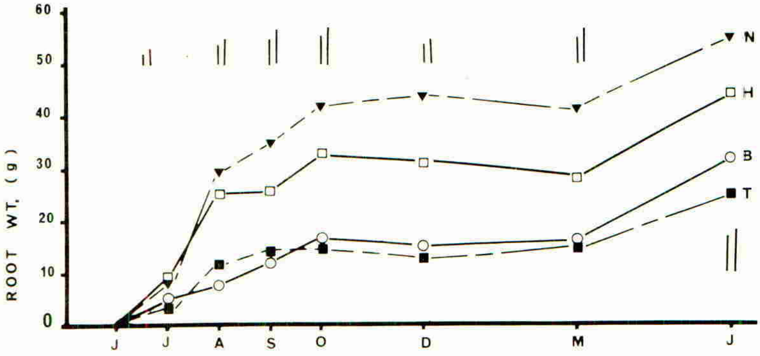


Fig. 3 Increase in root dry weight/plant for the four clones.

Distribution of dry weight

Table 2 shows the distribution of dry matter for the four clones in October and December, 1970. Total dry matter did not increase over this period (Fig. 1) so that the increased percentage dry matter in rhizomes was a consequence of movement of material from the aerial parts. Root weight remained a roughly constant fraction of the whole on both occasions. Clone N had a greater percentage root dry weight than any of the others, 16% compared with 9, 6 and 5% for H, B. T respectively in December. At both harvests the ranking order of percentage dry matter in the rhizomes was T < B < H < N, being 64, 60, 59 and 49% respectively in December.

Leaf area

During the early growing season, July and August, all clones rapidly produced leaves (Fig. 4). After August leaf growth slowed down and leaves of clone T

Table 2

Distribution of dry weight in four clones of *Agropyron repens* (L.) Beauv. (%)

	October			December		
Clone	root	rhizome	shoot	root	rhizome	shoot
B	6	54	40	6	60	34
N	15	45	40	16	49	35
T	5	58	37	5	64	31
H	9	53	38	9	59	32

started to senesce, the other following after September. As old leaves senesced, the rhizome tips in the soil turned up to form new aerial shoots. The leaves of these overwintered and shoots started active growth again in the following year.

During the first two months clones H and N produced approximately the same leaf area (respectively 377 and 389 cm^2/plant in July, 901 and 834 cm^2/plant in August, S.E. diff. (p = 0.05) ± 65.86). These were both significantly larger leaf areas per plant than for clones T and B (respectively 303 and 247 cm^2/plant in July, 640 and 663 cm^2/plant in August). H maintained a more rapid increase in green leaf area at the end of the season from August to September than the other three clones. For all clones leaf area reached a minimum in December although some green leaf was maintained throughout the winter. By March, there was a change of order in leaf area as clones T and B then had the larger leaf areas per plant (191 and 185 cm^2/plant, S.E. diff. (p = 0.05) ± 29) and N and H were smaller (156 and 132 cm^2/plant). By June of the following year, at which time the plants were filling the pots, differences in leaf area between clones were small and not statistically significant.

Compared with unshaded plants shade significantly (p = 0.01) reduced leaf area per plant during the early period of rapid growth (July in the first year and March in the second, by 38 and 39% respectively); at other times there were no differences between the two treatments. Under shade clone B suffered most and leaf area was

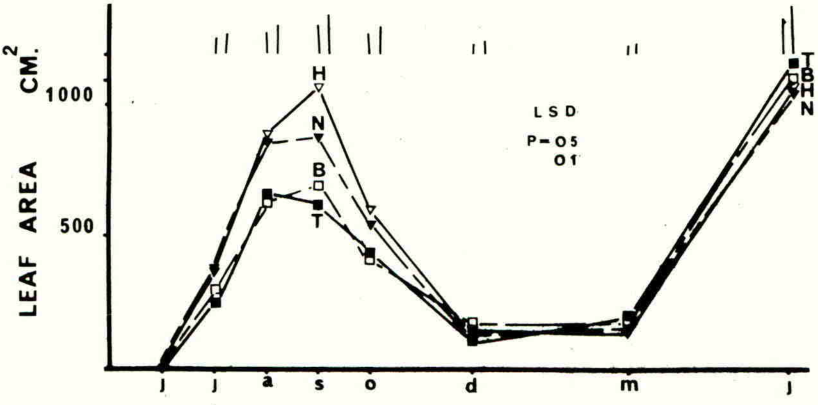


Fig. 4 Changes in leaf area/plant for the four clones.

always less than in the unshaded treatment.

Defoliation at the different times during the first growing season significantly reduced the area of new leaves subsequently produced in that season and times of defoliation had effects on immediate and subsequent leaf regrowth. Defoliation in June (D_1) led immediatly to a slow recovery of leaf area but recovery was rapid when plants were defoliated in July (D_2) and August (D_3). The rate of increase of leaf area after these last two defoliations was approximately the same. Plants defoliated in July (D_2) subsequently tended to maintain production of green leaf area from August to September faster than either those defoliated in June (D_1) or undefoliated plants (D_0). Similarly, plants defoliated in August (D_3) did not suffer a decline in green leaf area during September to October at the same rate as was found in the other treatments.

DISCUSSION

Clones There are clearly large differences in growth physiology between the clones studied.

Clone H was the most vigorous over the duration of the experiment. It achieved the greatest whole plant weight, leaf area and rhizome weight although it invested proportionally less in rhizome than clones T and B. The rhizomes of clone H stored the highest percentage total carbohydrate although clones did not differ very markedly in this respect. In addition, clone H grew more actively in the late autumn (September-October) than any of the others under these experimental conditions but no active growth occurred overwinter (December-March) and there was possibly a decline in leaf area in this period.

Clone N was most different in morphological form with thick rhizomes and broad leaves which became partly prostrate with age; it was of moderate vigour. The rhizomes had a similar carbohydrate content to clones B and T. Total plant weight ranked second but the weight of rhizome per plant was lowest. This clone had about twice the amount of root of any other.

Clone T, a narrow leaved selection, was also of moderate vigour. The whole plant weight in the first season was a little more than the smallest (clone B). Clone T had the greatest proportion of dry matter in rhizome material but rhizome weight per plant ranked only second highest and root weight per plant was lowest. Leaf area increased overwinter and the plants increased in total size by spring 1971 so that by the end of the experiment these plants had the highest leaf area of all and they ranked second in order in whole plant and rhizome weight.

Clone B was the least vigorous and whole plant weight remained lowest throughout. This clone suffered most from shading and the effect was even more drastic on rhizome and root weight than on the aerial parts of the plant.

Shade All clones were seriously affected by shade at the level applied. Overall, it lessened rhizome weight and slightly reduced the amount of carbohydrate stored and it markedly diminished root growth. Plants were made so much smaller by shade that, often, total leaf area was less than that of unshaded plants (derived data are to be published elsewhere).

Defoliation Defoliation late in the season had a far greater effect than when applied earlier on - indeed, defoliation in early summer made hardly any difference to total weight in the autumn. Defoliation limited growth of rhizome more than growth of the whole plant but even the greatest effect (overall 40% decrease in rhizome weight for defoliation in August) was less than that obtained by shading from June on (50% decrease in rhizome weight). The clones showed no differences in response to defoliation either in terms of dry weight or in total carbohydrates stored in the rhizome. Root growth was severely effected by defoliation, particularly late defoliation, and there was also a long term effect on subsequent root growth which suggests that the normal phasing of root and shoot growth had been disturbed by the treatment. Similarly, there was an immediate effect of defoliation in stimulating regrowth of new leaf which then did not senesce as early in the autumn as did the leaves of non-defoliated plants.

This account has selected the more obvious differences between clones which might help explain, in part, some of their differences in productivity, although further information from the field plots is also required. Plant material subjected to the treatments described here was later taken for experiments with herbicides and further data will be made available on the effects which pre-conditioning the plants the previous season by shading and defoliation had on their subsequent responses.

References

HEINZE, P. H. and MURNEEK, A. E. (1940) Comparative accuracy and efficiency in determination of carbohydrates in plant material. Missouri Agr. Exp. Sta. Res. Bull. 314.

PALMER, J. H. (1958) Studies on the behaviour of the rhizomes of *Agropyron repens* (L.) Beauv. 1 The seasonal growth and development of the parent plant and rhizome. New Phytol., *57*, 145-159.

PALMER, J. H. and SAGAR, G. R. (1963) *Agropyron repens* (L.) Beauv. (*Triticum repens* L., *Elytrigia repens* (L.) Nevski). J. Ecol., *51*, 783-794.

SMITH, D. et al (1964) Extraction of total available carbohydrates from grass and legume tissue. Plant Physiol., *39*, 960-962.

TURNER, D. J. (1968) The response to defoliation of different strains of *Agropyron repens* and *Agrostis gigantea*. Proc. 9th Brit. Weed Cont. Conf., 149-155.

WILLIAMS, E. D. (1970) Effects of decreasing the light intensity on the growth of *Agropyron repens* (L.) Beauv. in the field. Weed Res., *10*, 360-366.

Proc. 11th Br. Weed Control Conf. (1972)

THE IMPLICATIONS OF "LATE SPRING DORMANCY" IN RHIZOMES OF AGROPYRON REPENS (L.) BEAUV. IN BRITAIN

R.R.B. Leakey and R.J. Chancellor
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF
D. Vince
Dept. of Horticulture, University of Reading, Whiteknights, Reading, Berks.

Summary This paper reports for the first time the occurrence in Britain of innate dormancy in 1-node fragments of A. repens rhizomes. 1-node fragments were incubated at 23°C in the dark for 21 days, every month from October 1970 - December 1971. It was found that innate dormancy [Late Spring Dormancy] was greatest in June and July in rhizomes of the previous year's growth. The implications of these findings are discussed.

INTRODUCTION

The only way to test for innate bud dormancy in Agropyron repens rhizomes is to cut them into 1-node fragments, as by this means the normally over-riding apical-dominance dormancy is obviated, as are any other complicating factors from other parts of the plant. In North America, Johnson & Buchholtz (1962) have demonstrated a seasonal fluctuation in growth from 2 cm, single-node rhizome fragments. In June they found little bud activity. This 'innate' dormancy was termed 'Late Spring Dormancy' to differentiate it from the lack of growth seen in some other perennial plants in the unfavourable environmental conditions of mid-summer. Nitrogen-containing substances have been found to release buds from this innate dormancy (Johnson, 1958; Meyer, 1961). A previous attempt to demonstrate the occurrence of Late Spring Dormancy in Germany was not successful (Chancellor, 1967).

METHOD AND MATERIALS

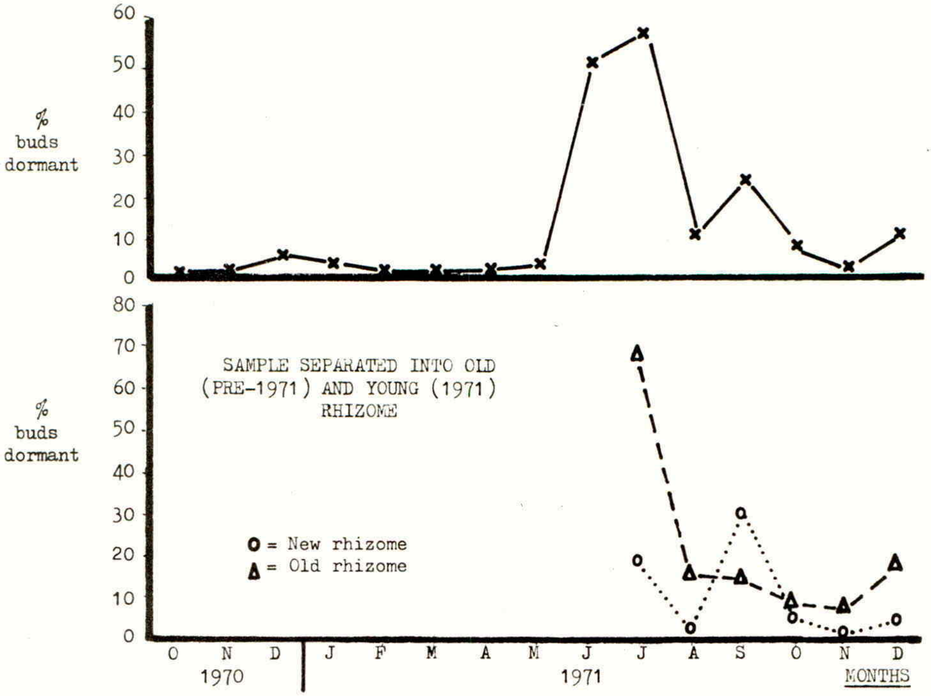
Freshly-dug rhizomes of Clone 31 (Headington Clone) of the Weed Research Organization couch-grass collection were obtained monthly (October 1970 - December 1971), at random, from an unfertilized, third-year, pure sward, which had been dug-over during the previous year. The rhizomes were washed, stripped of their roots and scale-leaves, and cut into 2 cm, 1-node fragments with the axillary bud centrally placed (i.e. similarly to Johnson & Buchholtz, 1961). Only nodes with fully developed buds were used. Five replicates of 20 fragments were sewn vertically on Whatmans 3MM chromatographic paper, and placed in perspex growth boxes (described by Chancellor, 1968). The fragments were grown in the dark, at 23°C, with nutrients. The shoot lengths were measured to the nearest millimetre every 5 days. Buds measuring not more than 5 mm after 15 days were considered to be dormant, following Johnson & Buchholtz (1962). Results from the current and previous year's rhizome were recorded separately, from July 1971 to December 1971.

Rhizome samples have been taken for nitrogen, carbohydrate and growth-inhibitor analyses, and the results will be published elsewhere.

RESULTS

The percentage of buds from both young and old rhizomes which were dormant between October 1970 and May 1971 was low (0.0-5.0%); but in June and July there was an increase in dormancy especially in old rhizome (Fig. 1). In August there was some decrease again in dormancy, but in September, after the aerial shoots had been cut down to prevent seeding, there was a further increase in dormancy, especially this time, in new rhizome. Thereafter, there was a decline to a low level of dormancy, which continued throughout the rest of the year.

Fig. 1. Bud Dormancy in 1-node Fragments (%)



DISCUSSION

The seasonal pattern of bud activity in single-node fragments of A. repens in Britain was found, in the present study, to be similar to that reported from America by Johnson & Buchholtz (1957, 1962). It is, however, apparent that, in the present study, new rhizome was considerably more active during the dormant (June-August) period, than was found in North America. The finding of innate dormancy in Britain indicates that the previously reported occurrence in the U.S.A. is not due to any peculiarity of the climatic or edaphic factors there but is likely to be a physiological phenomenon.

New rhizomes appear to contain a relatively high level of total nitrogen, compared with old rhizomes, which enables them to utilize their carbohydrate reserves efficiently. The nitrogen content of old rhizome during the dormant period is very low (Buchholtz, 1962) and exogenous nitrogen will release buds from dormancy (Johnson, 1958). It is thought that the role of nitrogen in the control of innate dormancy may be similar to the role already described by Turner (1966, 1969) for non-dormant rhizome fragments. He found that nitrogen application increased the utilization of carbohydrate reserves. In dormant rhizome fragments it appears that the block to growth lies in the utilization of soluble sugars for growth rather than in the conversion of starch reserves to sugars (Leakey, unpublished).

The failure of the previous attempt in Germany to find innate dormancy (Chancellor, 1967) may have been due to the level of nitrogen in the soil in which the rhizome fragments were grown because it has been found that even very low levels of nitrogen are sufficient to break Late Spring Dormancy (Leakey, unpublished).

The low level of bud activity during the period of dormancy and the subsequent period of recovery from dormancy, would presumably render the rhizomes of *A. repens* susceptible to cultivations, for the inability of fragments to establish themselves as new plants would leave them open to desiccation and fungal attack. It would therefore be agronomically desirable to prolong the period of bud inactivity even though these buds would probably lose viability in the following year (Johnson & Buchholtz, 1962). To achieve this it would be necessary to prevent uptake of nitrogen from the soil, possibly by inhibiting root production which tends to continue despite the dormancy of the shoot. Several chemicals are known to inhibit root production by rhizome fragments (Chancellor & Leakey, 1972); but whether these would be suitable for use in the field is not known. Buds on the current year's rhizome are more active in summer, but less so in autumn, before becoming more active again during the winter; this is much more evident from the shoot lengths (not presented here). These young rhizomes are the most important agriculturally and thus any means of reducing the level of activity would be beneficial. In this connection removal of the aerial shoots may be of some practical significance. In the present study, shoot removal (which was carried out to prevent seed shedding and hence contamination of clonal material) when carried out in August during the period of recovery from dormancy, appeared to reduce the level of bud activity of new rhizomes in September, and may account for the higher incidence of dormancy found in early winter (Fig. I). However, shoot removal during the dormant period apparently has no effect on the level of dormancy (Johnson & Buchholtz, 1958). As shoot removal is known to reduce rhizome reserves (Turner 1966, 1969) especially under conditions of high nitrogen status (Turner 1966, 1969) and as Late Spring Dormancy appears to be regulated by nitrogen, it is possible that the effect of shoot removal in August is to reduce critically the level of nitrogen in young rhizomes. The removal of shoots by the combine at cereal harvest must therefore reduce rhizome vigour and bud activity. Cultivations a week or two after the combine could therefore lead to improved control of *A. repens*.

A second possible means of reducing bud activity, especially of the more important young rhizomes, might be by blocking sugar utilization with a chemical. A study of the inter-relationship between nitrogen and enzyme synthesis might reveal a weakness that could be exploited for control purposes, for it has been shown that there is a correlation in rhizomes between the seasonal fluctuations of one enzyme (IAA oxidase) and the nitrogen-containing compounds (Budd *et al*., (1959).

The use of nitrogen to break innate dormancy in the field is only of practical interest under the conditions of a summer fallow, which is not now used agriculturally.

Acknowledgements

We wish to thank Mrs. A. Martin and Miss P. Turner for their help with the tests and the senior author acknowledges the provision of facilities by the Director of the Weed Research Organization whilst holding a M.A.F.F. post-graduate studentship.

References

BUCHHOLTZ, K.P. (1962) Some characteristics of quackgrass and their relation to control. Proc. N. East Weed Control Conf., 16, 16-22.

CHANCELLOR, R.J. (1967) The incidence of dormancy in two-node stem and rhizome fragments of Polygonum amphibium (L.). Weed Res., 7, 323-330.

CHANCELLOR, R.J. (1968) The occurrence and growth of re-inhibited shoots and dormant buds on fragmented rhizomes of Agropyron repens (L.) Beauv. Proc. 9th Br. Weed Control Conf., 125-130.

CHANCELLOR, R.J. & LEAKEY, R.R.B. (1972) The effect of plant growth regulators on dominance in Agropyron repens (L.) Beauv. rhizomes. Proc. 11th Br. Weed Control Conf.,

JOHNSON, B.G. (1958) Natural and induced dormancy of vegetative buds in the rhizomes of quackgrass (Agropyron repens (L.) Beauv.). Thesis Univ. Wisconsin.

JOHNSON, B.G. & BUCHHOLTZ, K.P. (1957) The natural bud dormancy of quackgrass rhizomes. Proc. 14th N. Cent. Weed Control Conf., 29.

JOHNSON, B.G. & BUCHHOLTZ, K.P. (1958) Factors affecting bud dormancy. Abstr. Weed Soc. Am., 38-39.

JOHNSON, B.G. & BUCHHOLTZ, K.P. (1961) An 'in vitro' method of evaluating the activity of buds on rhizomes of quackgrass (Agropyron repens). Weeds, 9, 600-606.

JOHNSON, B.G. & BUCHHOLTZ, K.P. (1962) The natural dormancy of vegetative buds on the rhizomes of quackgrass. Weeds, 10, 53-57.

MEYER, R.E. (1961) A study of factors affecting the bud dormancy of quackgrass. Thesis Univ. Wisconsin.

MUDD, J.B., JOHNSON, B.G., BURRIS, R.H. & BUCHHOLTZ, K.P. (1959) Oxidation of indoleacetic acids by quackgrass rhizomes. Pl. Physiol. Lancaster., 34, 144-148.

TURNER, D.J. (1966) A study of the effects of rhizome length, soil nitrogen and shoot removal on the growth of Agropyron repens (L.) Beauv. Proc. 8th Br. Weed Control Conf., 538-545.

TURNER, D.J. (1968) Agropyron repens (L.) Beauv. - Some effects of rhizome fragmentation, rhizome burial and defoliation. Weed Res., 8, 298-308.

TURNER, D.J. (1969) The effect of shoot removal on the rhizome carbohydrate reserves of couch-grass (Agropyron repens (L.) Beauv.) Weed Res., 9, 27-36.

Proc. 11th Br. Weed Control Conf. (1972)

THE EFFECTS OF GRAVITY AND TEMPERATURE UPON THE REASSERTION OF DOMINANCE IN FRAGMENTED RHIZOMES OF AGROPYRON REPENS (L.) BEAUV.

R.R.B. Leakey and R.J. Chancellor
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF
D. Vince
Dept. of Horticulture, University of Reading, Whiteknights, Reading, Berks.

Summary Decapitated, 7-node fragments of A. repens rhizomes were allowed to develop new dominance systems under various positions of orientation and at several temperatures. It was found that rhizomes placed with the apical end downwards often had the new dominant shoot in a different position from those held horizontally or pointing upwards: other aspects of dominance were apparently unaffected. Temperature influenced the growth rate of shoots, the percentage of buds making growth, the time taken by fragments to achieve absolute dominance, the mean length of shoots at absolute dominance, and possibly the position of the absolute dominant.

INTRODUCTION

Much of the success of Agropyron repens as a weed is due to the correlative inhibition mechanism that develops in multi-node rhizome pieces after fragmentation, and keeps a proportion of buds dormant. Chancellor (1968, and in preparation) has observed the reassertion of dominance among axillary buds developing on rhizome fragments placed in perspex growth boxes. A new dominance system took about 10-20 days to develop, during which time many buds started into growth, but were then sequentially re-inhibited on either side of the shoot that eventually became the dominant. The new dominant usually occurred at the second or third node from the apical end of the decapitated fragment.

The present study on gravity and temperature was part of a larger programme to examine the effects of various external factors upon the development of the dominance system in rhizome fragments. In A. repens, the direction of gravitational pull has been shown to affect the polarity of shoot development from axillary buds of rhizome fragments when the rhizome apex is present (Schwanitz, 1936), and to affect the type of development of the rhizome apex, (Palmer, 1954). It is assumed that rhizome shoot growth in A. repens is influenced by auxin levels as in other plants. In Zea and Helianthus species gravity has an effect on "hormone" distribution in vertically and horizontally placed coleoptiles and hypocotyls, respectively, (Gillespie & Thimann, 1963). This finding is supported by studies using labelled IAA in poplar shoots (Leach & Wareing, 1967). In addition, Sachs & Thimann (1967) state that when branches of perennial plants are held horizontally the leader is less able to dominance. This is in agreement with observations on fruit trees by Wareing & Nasr (1958, 1961), and suggests an influence on auxin movement. The difference in dominance between erect or ascending aerial shoots held horizontally, in which dominance is lost, and naturally-occurring, horizontal rhizomes, which have very strong dominance despite their horizontal position, indicates an apparently different relationship between gravity and dominance in the two types of stem. As changing the orientation of aerial shoots affects dominance one might expect that changing rhizome orientation would also have some effect upon the developing dominance system, just as Musik & Cruzado (1953) found it affected lateral shoot development in tubers of Cyperus rotundus.

The effects of temperature on apical dominance has not received much attention. Temperature is an important factor in many aspects of plant growth, and hence might be thought to affect the developing dominance system in decapitated rhizome fragments.

METHOD AND MATERIALS

Freshly dug rhizomes of the Headington Clone of A. repens (clone 31 of the Weed Research Organization couch-grass collection) were cut into 7-node lengths without an apex, washed and then stripped of their roots and scale-leaves. The fragments were attached to sheets of Whatmans 3MM chromatographic paper, moistened with distilled water, placed in sealed glass growth boxes or jars, and kept at 23°C in the dark for 28 days. The shoots were measured to the nearest millimetre every 2-3 days.

In the first gravity experiment the decapitated fragments were sewn onto the chromatographic paper either (a) horizontally, (b) vertically, with the apical end uppermost or (c) vertically with the apical end downwards, and grown in glass boxes (50 x 30 x 2 cm).

There were three replicates per treatment, each of 6 rhizomes. The two vertical treatments were later repeated in a further experiment.

In a third experiment three replicates of four rhizomes were rotated on a klinostat, end over end around their central points at four times per hour. These were compared with fragments growing fixed in the vertical, upwards-pointing position.

In the temperature experiment the fragments were mounted on chromatographic paper attached to glass slides and incubated in sealed glass jars as described by Blair et al. (1970). These were kept in incubators at 8°C, 18°C or 28°C. The 8°C treatment was kept for 63 days, the other two for 28 days.

RESULTS

Gravity. In the first experiment there were no significant differences, at day 28, between the mean lengths of shoots arising from fragments held in different positions. The shoot growth from rhizome reserves was almost complete by day 28 (Table 1).

Table 1

Mean shoot length (mm)

Rhizome orientation	Days from start of incubation 3	5	7	10	12	14	17	19	21	24	26	28
Horizontal	8	25	42	67	80	88	95	100	104	107	109	109
Vertical (apical end up)	10	28	49	77	92	101	110	115	120	125	126	127
Vertical (apical end down)	8	24	41	64	77	85	96	103	106	110	112	113

The percentage of axillary buds making growth (defined as 1 mm or more per day) was greatest at day 3, and gradually declined until, in most instances, only one dominant shoot was left growing on each rhizome fragment. There were no significant differences between treatments in the percentage of buds making growth (Table 2).

Table 2

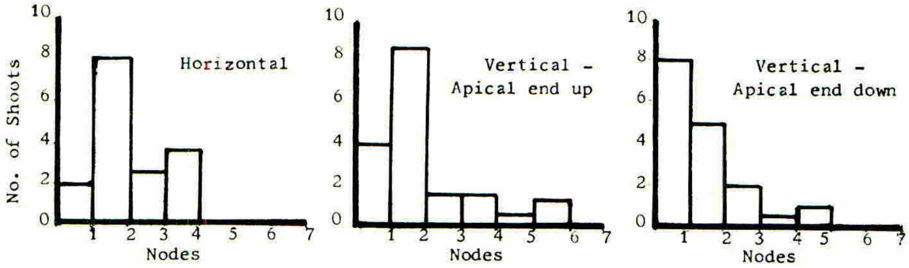
Percentage of buds making growth

Rhizome orientation	Days from start of incubation 3	5	7	10	12	14	17	19	21	24	26	28
Horizontal	89	87	69	56	43	33	28	19	19	17	10	7
Vertical (apical end up)	91	87	65	60	46	35	30	23	20	17	14	9
Vertical (apical end down)	88	84	70	57	38	36	25	22	18	15	10	10

The position of the dominant shoots was similar when rhizomes were horizontal or had the apical end pointing upwards, most of the new dominant shoots being at the second node (Fig. 1). However, rhizomes with their apical end pointing downwards had their new dominants more frequently at the first node. The number of days until absolute dominance was achieved ranged from 12-28 days, but there was no apparent correlation with rhizome orientation. Rhizomes with co-dominant shoots occurred in each treatment. When the two vertical treatments were repeated, the results showed the same tendency for dominant shoots to occur at the first node in the downwards-pointing position and at the second node when in the upwards-pointing position. There was little difference in any of the aspects of dominance investigated between the fragments that were rotated on a klinostat and those kept pointing vertically upwards.

Fig. 1 Position of Dominant Shoots

[Co-dominant shoots = $\frac{1}{2}$; Absolute dominant shoots = 1]



Temperature. The rate of shoot growth, by buds starting into growth, was greatly affected by the temperature, being greatest at 28°C and least at 8°C. Although fragments at 28°C had the greatest mean shoot length for the first three weeks their endogenous reserves were presumably utilized faster, and thus by the end of the fourth week those kept at 18°C had caught up and shoots of both groups then averaged about 80 mm (Fig. 2). However, shoot growth at 8°C was very slow. The mean shoot length was only 22 mm after 28 days and 47 mm after 63 days.

The percentage of buds making growth at 18°C and 28°C reached much the same maxima at day 5, which were not significantly different (S.E. 4.08), and thereafter

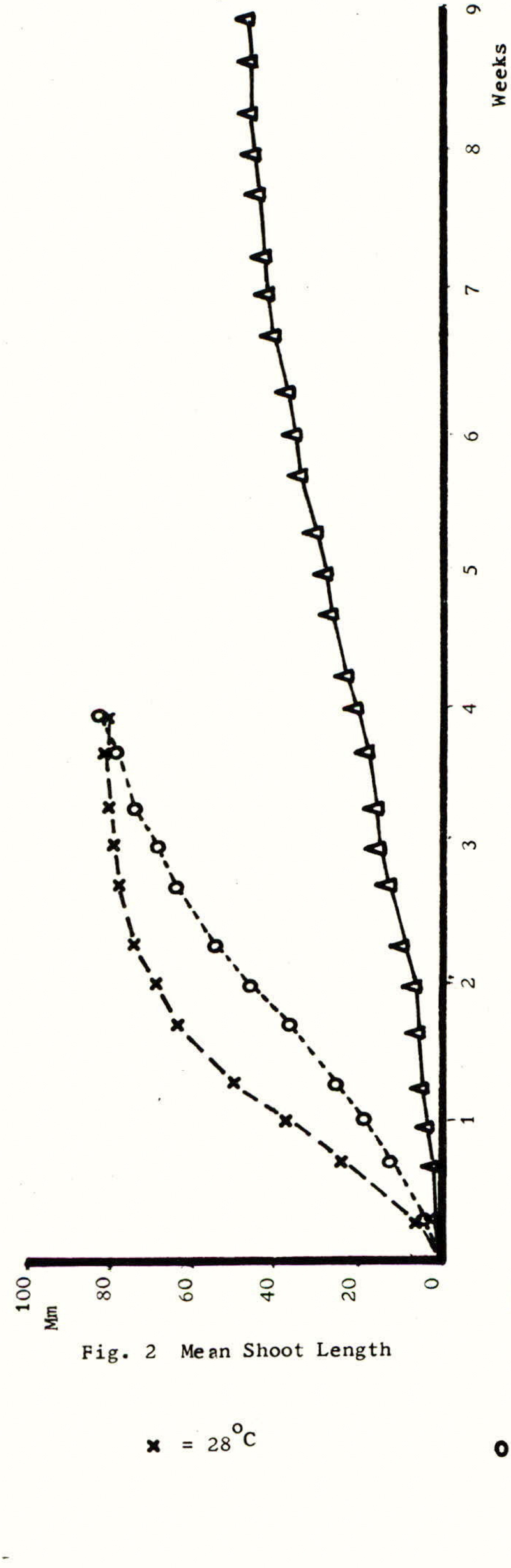


Fig. 2 Mean Shoot Length

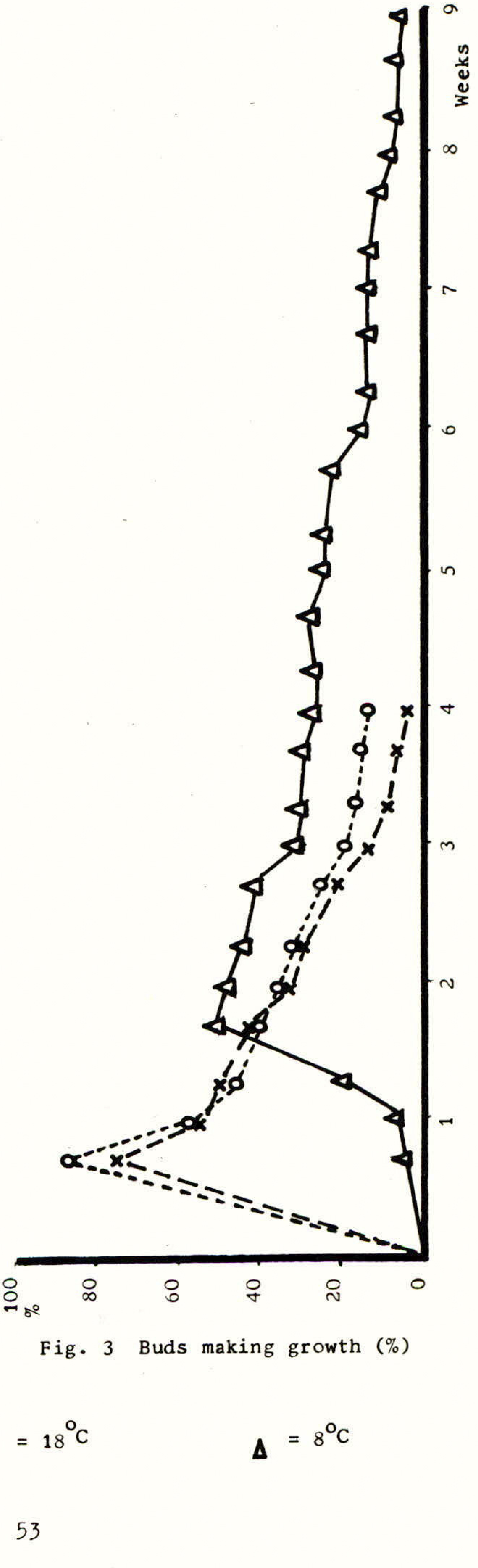


Fig. 3 Buds making growth (%)

× = 28°C

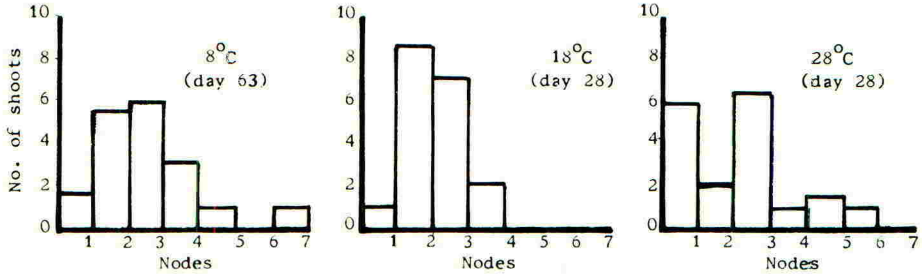
o = 18°C

Δ = 8°C

declined together. The percentage of shoots making growth after 28 days was just significantly greater at the 5% level (S.E. = 1.77) at 18°C than at 28°C(Fig. 3). In contrast the number of buds growing at 8°C was low for the first week and reached a maximum at day 12. The total then declined slowly until it was similar to the level of the other treatments by day 63. The position of the new dominant shoots differed slightly with temperature. At the lowest temperature the greatest number of dominants was at the third node, while at 18°C there were more at the second node. At the highest temperature (28°C) dominants were equally divided between nodes 1 and 3, but there was a much greater number at the node 1 position as compared with the other two treatments (Fig. 4). The length of time until absolute dominance was achieved among shoots was shortest at 28°C (12-28 days), and longest at 8°C (26-56 days).

Fig. 4 Position of Dominant Shoots

[Co-dominant shoots = $\frac{1}{2}$; Absolute dominant shoot = 1]



DISCUSSION

The basic pattern of shoot development from the axillary buds of the rhizome fragments was similar to that described by Chancellor (1968,and in preparation), Meyer & Buchholtz (1960) and McIntyre (1972). It is the modification of this basic pattern caused by variations of environmental factors that were the object of this study.

Gravity. The data presented here show that decapitated rhizomes pointing downwards develop their dominant shoots more often at the apical end than ones held horizontally or pointing upwards. This appears to be contradictory to the results obtained by Schwanitz (1936) who found that A. repens rhizome fragments, with the main apex attached, had longer shoots (although not necessarily dominants) towards the base when the rhizomes were pointing downwards at 45° or 90°, than when horizontal or pointing upwards. The differing polarity indicates some influence of the rhizome apex itself upon the position of the developing shoots. It is known that gravity affects the morphological development of the rhizome apex (Palmer, 1954), as it becomes a shoot if turned into the vertical position.

The results of the klinostat experiment indicate that the influence of the downward-pointing position is a relatively minor component of the complete rotation and has presumably been masked by the majority of time spent in the horizontal and upward-pointing positions.

Gravity can, therefore, affect not only morphology but also the maintenance of dominance and apparently the polarity of shoots when dominance is relaxed. A repetition of Schwanitz's experiment is contemplated to try and resolve further the interactions of gravity and dominance.

Temperature. Shoot growth was initially faster at the highest temperature (28°C), but the shoots at 18°C caught up after about 4 weeks and reached similar lengths. This was presumably because food reserves were limiting, and much the same in each fragment. The highest temperature simply allowed a more rapid utilization of available reserves. This rapid depletion of reserves would also explain the development of a significant difference between the number of buds growing at 18°C and 28°C at day 28 because at the higher temperature, food reserves would have been exhausted earlier. Despite the relatively very slow growth of shoots at 8°C, dominance was none-the-less established among them.

Low temperature slows down the growth rate and also increases the time to achieve absolute dominance. The rate of shoot growth may, therefore, be a factor in the establishment of a new dominance system. However, as the absolute length of the shoots when dominance was attained was considerably less at low (8°C) rather than at higher temperatures (18°C and 28°C), direct competition for available reserves is unlikely to be a major factor leading to the establishment of a new dominant shoot.

Temperature level possibly had some effect upon the position of the dominant shoot, for at the highest temperature (28°C) there appeared to be an increase of dominant shoots in the most apical position, although the bimodal distribution of dominants at nodes 1 and 3 masks the significance of this result. Whether the position of the dominant shoot is in any way connected with the time taken to achieve dominance, which differed with temperature, is unknown.

The data presented here indicates no very strong influence from gravity or temperature on the development of a new dominance system in detached, decapitated, rhizome fragments; both the treatments did, however, modify the position of the dominant shoot, and temperature affected the time taken to achieve dominance.

Acknowledgements

The senior author would like to thank the Director of the Weed Research Organization for providing facilities for this work, which was carried out whilst holding a M.A.F.F. post-graduate studentship.

References

BLAIR, A.M., CHANCELLOR, R.J. CUSSANS, G.W., HOLLY, K., HOLROYD, J., & RICHARDSON, W.G. (1970) The evaluation of herbicides on perennial weeds with special reference to Agropyron repens. Proc. 10th Br. Weed Control Conf., 126-133.

CHANCELLOR, R.J. (1968) The occurrence and growth of re-inhibited shoots and dormant buds on fragmented rhizomes of Agropyron repens (L.) Beauv. Proc. 9th Br. Weed Control Conf., 125-130.

GILLESPIE, B., & THIMMAN, K.V. (1963) Transport and distribution of auxin during tropistic response. I. The lateral migration of auxin in geotropism. Pl. Physiol., Lancaster, 38, 214-225.

LEACH, R.W.A. & WAREING, P.F. (1967) Distribution of auxin in horizontal woody stems in relation to gravimorphism. Nature, Lond., 214, 1025-1027.

McINTYRE, G.I. (1972) Studies on bud development in the rhizome of Agropyron repens II. The effects of the nitrogen supply. Can. J. Bot., 50, 393-401.

MEYER, R.E. & BUCHHOLTZ, K.P. (1960) Some factors affecting the activity and growth of buds on quackgrass rhizomes. *Proc. 17th N. Cent. Weed Control Conf.*, 37.

MUSIK, T.J. & CRUZADO, H.J. (1953) The effect of 2,4-D on sprout formation in *Cyperus rotundus*. *Am. J. Bot.*, *40*, 507-512.

PALMER, J.H. (1954) Effect of shoot orientation on leaf and shoot development. *Nature, Lond.*, *174*, 85.

SACHS, T. & THIMANN, K.V. (1967) The role of auxins and cytokinins in the release of buds from dominance. *Am. J. Bot.*, *54*, 136-144.

SCHWANITZ, F. (1936) Beiträge zur analyse der pflanzenlichen polariatät. *Beih. bot. Zbl.*, *54*, A, 520-530.

WAREING, P.F. & NASR, T.A.A. (1958) Gravimorphism in trees. Effects of gravity on growth, apical dominance and flowering in fruit trees. *Nature, Lond.*, *182*, 379-381.

WAREING, P.F. & NASR, T.A.A. (1961) Gravimorphism in trees. I. Effects of gravity on growth and apical dominance in fruit trees. *Ann. Bot.*, (N.S.), *25*, 321-340.

Proc. 11th Br. Weed Control Conf. (1972)

A STUDY ON THE PERSISTENCE OF A NATURAL INFESTATION OF AGROPYRON REPENS AND AGROSTIS GIGANTEA IN ASSOCIATION WITH TETRAPLOID ITALIAN RYEGRASS

A. D. Courtney
Field Botany Research Division, M.A.N.I., Newforge Lane, Belfast

Summary This experiment examined whether, on a natural infestation of *Agrostis gigantea* and *Agropyron repens*, a short-term grass break crop of tetraploid Italian ryegrass (*Lolium multiflorum*) could be managed, with a combination of cutting frequencies (2, 4, 8 week intervals) and rates of nitrogen fertiliser (nil, 187·5, 375 kg/ha N) to control these species. During its first full year of production the ryegrass did prevent their further proliferation and the weight of rhizome in the soil did not increase. In the second year as the herbage yields and proportion of tetraploid Italian declined both *Agropyron repens* and *Agrostis gigantea* increased their contribution in the cut herbage. A significant increase in the rhizome dry matter was recorded and was greatest on the plots cut at the eight week interval and receiving either medium or high levels of nitrogen fertiliser.

INTRODUCTION

In Northern Ireland there is a tendency for fields to be sown down to grass when the perennial grass weed problem becomes too intractable after a period of continuous cereal growing.

The purpose of this trial was basically to see whether a short grass break could be utilised as a means of combating a severe rhizomatous weed grass infestation. The results of Turner (1966) showing the considerable influence of intensive defoliation on rhizome reserves and capacity for regrowth prompted the question as to whether or not the introduction of a competitive species into the system could be a means of reinforcing control. This same point was later raised by Hakansson (1969) who subjected *Agropyron repens* growing in isolation to a range of cutting treatments. As part of a programme examining the persistence of both *Agropyron repens* and *Agrostis gigantea* in both the short and long term ley situations, a trial was designed to examine the effect of a tetraploid variety of *Lolium multiflorum* on an existing infestation. It was considered that the fast rate of establishment, wide leaf width, speed of attaining full canopy and the density of the canopy reported for tetraploid Italian cultivars made them a suitable choice as a strongly competitive species for use in this experimentation.

METHOD AND MATERIALS

The trial was conducted at the Agricultural Research Institute, Hillsborough, Co. Down, over the period 1968-71. The field on which the trial was conducted was a medium loam (dark brown) and had been continuously in spring barley from 1963 to 1967. During 1967 when still in barley, an area was selected which was heavily but uniformly infested with a mixture of both *Agropyron repens* and *Agrostis gigantea*. On the basis of rhizome samples and on herbage analysis taken at the commencement of the experiment it was found that the *Agrostis gigantea* dominated the *Agropyron repens* in the ratio of approximately 2:1.

The field was ploughed in March 1968 and the regrowth killed off by paraquat in May, prior to cultivations and the sowing down of the field. The trial comprised four replications in a randomised block design. The treatments were three levels of nitrogen (nil, 187·5 and 375 kg/ha) and three defoliation intervals (2, 4 and 8 weeks). Individual plot size was 7·32 m x 1·53 m. Soil analyses showed the field as being high in available phosphorous and medium in available potash. At seeding, 75 kg/ha of N (as Nitrochalk) was applied to the seed bed and a further 75 kg/ha was given to all plots at the beginning of August 1968. The Italian ryegrass was broadcast by hand and incorporated by raking. The seeding rate was 50 kg/ha of tetraploid Italian ryegrass (cv. Tetrone - 1,000 seed weight 4·3 gm). Only one clip was taken in the year of establishment on 19 September. In the subsequent seasons 1969 and 1970, the first clip was taken in late May and further clips at appropriate intervals up to the end of September. During this period, nitrogen was applied on four occasions in amounts of 37·5 or 75 kg/ha on the plots receiving medium and high rates respectively, so that in 1969 the total amount received was 150 kg/ha and 300 kg/ha respectively and 187·5 and 375 kg/ha in 1970. Details of the dates of application are shown at the foot of Table 1. Phosphate and potash equivalent to 187·5 kg/ha were applied to each plot in the spring of 1970. The dates of individual clips and their groupings into harvest periods are shown in Table 1.

Table 1

Dates of Individual Clips and Harvest Periods

Harvest Period		Defoliation Interval	Year 1969	1970
1	Spring cut	2,4,8	20.5	27.5
2	June/July cuts	2	6.6	11.6
		2,4	17.6	25.6
		2	3.7	8.7
		2,4,8	17.7	22.7
3	Aug/Oct cuts	2	4.8	5.8
		2,4	14.8	19.8
		2	28.8	4.9
		2,4	25.9	1.10
		8	9.10	

Dates of Nitrogen Application (37·5 or 75kg/ha)		Annual Total medium	High
1969	29 April, 17 June, 25 July, 28 August	150	300 kg/ha
1970	28 March, 27 May, 28 June, 22 July, 24 August	187.5	375 kg/ha

Phosphate and Potash equivalent to 187.5 kg/ha were applied 28 March 1970

At harvesting, the yield of green material was collected from a strip, 5·5 m in length, mown down the centre of each plot with an autoscythe cutting a 4 cm above the ground. The plot area harvested was 5·02 m^2. On each occasion the weight of green material was measured in the field, and the herbage sub-sampled for dry matter determination and botanical separation.

In the spring of 1969, 1970 and 1971, five turf cores each 0·05 m^2 were removed from the perimeter area of each plot to a depth of 15 cm and the rhizome dry matter content recorded. (Table 4).

RESULTS

The figures for the dry matter yields over the period of the trial are shown in Table 2 and the percentage contributions made by Italian ryegrass, Agropyron repens and Agrostis gigantea given in Table 3. The percentage contribution is based on the d.m. yield of each component in the harvest periods, (1) - Spring; (2) - June/July; and (3) - Aug/Oct. periods in each of the years.

Herbage Yield. In the initial cut in 1968 before the treatments were commenced, the mean plot yield from the clip on the 19 September was 2,830 kg/ha. The botanical separation indicated that 90·2% of the total d.m. was derived from tetraploid Italian, 6·3% from Agrostis gigantea and 2·3% from Agropyron repens. In the first full year of production (1969) the herbage yields were 3,325 kg/ha on the low nitrogen and most intensively defoliated plots compared with 20,343 kg/ha on the plots receiving 300 kg/ha cut at eight week intervals. The total dry matter yields increased with progressive nitrogen application and with the more lax cutting regimes.

In the second year of the trial (1970), herbage dry matter production declined to about 50% of that achieved in 1969, reflecting the reduced contribution by the tetraploid Italian ryegrass to total herbage yield.

Botanical composition. Throughout 1969, the tetraploid Italian remained dominant in the sward, contributing more than 90% of the clipped herbage, except in final harvest period under the no nitrogen treatment, when Poa spp. white clover and broad-leaved weeds were prominant. A marked decline in the proportion of the ryegrass occurred in the winter of 1969 and this continued throughout the 1970 season. Thus in the final harvest period in 1970, in the plots receiving no nitrogen and cut at two week intervals, the tetraploid Italian was only 17·5% of the herbage harvested during that eight week period. The corresponding figures were 73·9% and 61·3% on the eight week treatments receiving medium and high rates of nitrogen respectively.

The contribution of the Agrostis gigantea, which in the establishment clip taken in September 1968 was 6·3%, remained at between 0·8% and 3·4% on all plots during 1969 and no clear response to treatment was observed. In 1970 it increased to a marked extent on all treatments, particularly during harvest periods two and three. There was a response to nitrogen and also to the more lax four and eight week cutting treatments. Under the eight week cutting treatment and high nitrogen Agrostis gigantea contributed about 17% of the yield throughout the year, whereas in 1969 it had contributed between 1·7 and 3·4% of the cut herbage.

Agropyron repens was always less prominant than the Agrostis gigantea amounting to about 2·3% of the herbage in the cut taken in 1968. In the first year at the extremes of treatments there appeared to be differing trends. Under the no nitrogen and 2 week cutting interval the Agropyron repens had fallen to only 0·1% of the dry matter yield, whereas with high N/8 week defoliation period it remained at 2·3% during the second and third harvest periods.

As with the Agrostis gigantea, Agropyron repens increased during 1970. On the majority of the plots percentage contribution increased progressively throughout the season. This was most pronounced with the high N/8 week treatment where it gave 16% of total d.m. yield in harvest period 3. It showed a progressive response to both nitrogen and the more lax cutting treatments.

The results of the proliferation of the rhizomatous grass weeds during 1970 are reflected in the amount of rhizome retrieved from the turf samples taken in the

Table 2

Plot Total Herbage d.m. Yields (Kg/ha)

Nitrogen Level		0			Medium			High		
Defoliation Interval (Weeks)		2	4	8	2	4	8	2	4	8
Harvest Period	Year									
1	1969	2080	2122	2216	3008	2699	3220	3119	2887	3258
2	1969	751	1232	2089	1799	2981	7218	2647	4904	10666
3	1969	494	917	1764	1622	2794	3629	2497	3709	6419
Annual Yield		3325	4271	6069	6429	8474	14067	8263	11500	20343
1	1970	339	708	989	675	597	708	605	754	645
2	1970	444	1199	2051	1052	993	4872	2418	1471	6846
3	1970	560	1827	942	1880	2808	2348	2551	3397	2838
Annual Yield		1343	3734	3982	3607	4398	7928	5574	5622	10329

Analysis of Variance

For the treatment period each year (Harvests 2 & 3) treatment effects were highly significant $P > 0.01$
S.E. means (NxDefoliation) for this period being 1969 ± 363 kg/ha 1970 ± 358 kg/ha d.f. 24

Table 3

Sward Components as Percentage of Herbage

Nitrogen Level			0			Medium			High		
Defoliation Interval (Weeks)			2	4	8	2	4	8	2	4	8
	Harvest Period	Year									
Italian Ryegrass	1	1969	97·8	96·3	96·4	96·0	97·0	97·2	96·5	97·4	96·7
	2	1969	92·5	94·9	89·3	97·4	95·3	91·7	96·6	97·4	94·0
	3	1969	89·1	75·9	87·8	91·0	92·5	97·3	94·0	95·5	94·8
	1	1970	51·1	68·5	74·9	45·4	63·3	76·8	53·6	69·5	68·0
	2	1970	24·9	15·2	50·1	38·1	52·8	53·2	32·4	40·1	67·2
	3	1970	17·5	18·3	45·5	31·6	40·9	73·9	36·9	60·2	61·3
A. gigantea	1	1969	0·8	2·5	1·8	2·4	2·2	1·4	1·6	2·1	2·4
	2	1969	2·3	0·9	1·2	1·2	1·5	2·3	1·5	1·4	3·4
	3	1969	1·4	1·5	1·4	2·4	2·6	1·6	2·8	2·5	1·7
	1	1970	9·1	4·2	3·8	11·2	6·8	7·7	5·5	7·0	17·9
	2	1970	7·9	3·2	9·4	16·8	18·1	22·1	12·6	19·6	17·1
	3	1970	5·8	4·8	9·5	11·2	14·5	16·4	13·5	18·9	16·6
A. repens	1	1969	0·8	0·7	0·9	0·9	0·4	1·0	0·8	0·5	0·8
	2	1969	0·9	0·6	1·2	0·6	0·7	1·0	1·1	0·9	2·3
	3	1969	0·1	0·5	2·3	1·2	1·3	0·9	0·6	0·6	2·3
	1	1970	1·9	1·6	2·9	0·8	2·7	5·2	4·4	1·9	6·4
	2	1970	6·4	0·7	3·5	3·3	3·0	7·6	3·5	3·6	7·0
	3	1970	1·1	1·7	4·3	4·0	6·7	6·5	5·3	6·0	16·1

Analysis of Variance (Transformed Data) for the % d.m. contributions of each species over the treatment period (Harvests 2 & 3) showed treatment differences to be NS in 1969 but highly significant $P > 0.01$ in 1971 spring of 1971, when compared with those taken in the previous two years (Table 4). Although the rhizome weights were recorded separately for the Agrostis gigantea and Agropyron repens, there was no clear difference in their response to treatment. The combined rhizome d.m. figures (Table 4) demonstrate the general responses to defoliation and nitrogen treatments. The data provided by the turf cores taken in March 1970, shows no significant difference between treatments in rhizome dry matter per unit area as compared with the level found at the commencement of the treatments in 1969. In 1971 there were significant effects on rhizome d.m. both from nitrogen and defoliation interval treatments. The most lax cutting system (8 weeks) combined with high nitrogen had resulted in a two-fold increase in rhizomes. There had also been a significant increase at the medium N/8 week treatment. After two years of these treatments none of the combinations of nitrogen and cutting were showing a decline in the weight of rhizomes present.

Table 4

Total Rhizome d.m. g (5 x 0·05 m^2 turf cores)

Date of Sampling*	(1) 1969			(2) 1970			(3) 1971		
Defoliation Interval (Weeks)	2	4	8	2	4	8	2	4	8
Nitrogen levels									
0	12·5	12·5	18·3	10·5	10·3	7·1	10·7	7·5	11·6
medium	13·6	11·5	12·8	11·3	11·5	10·2	9·2	10·5	16·5
high	10·1	10·6	11·8	8·5	10·5	9·5	8·4	10·3	23·2

Treatments	Significance levels			S.E. mean
Nitrogen	NS	NS	*	±1·0
Defoliation	NS	NS	***	±1·0
N x D	NS	NS	*	±1·8

*Dates of Sampling
1. 29.4.69. - Prior to commencement of treatments
2. 24.3.70 - After one year of treatments
3. 5.4.71 - After two years of treatments

NS not significant * significant at 5% ** significant at 1·0% *** significant at 0·1%

DISCUSSION

On the basis of both the herbage separations and the rhizome data there is no evidence that control of either Agropyron repens or Agrostis gigantea has been achieved in the course of this trial.

As far as the defoliation treatments are concerned in the grassland context limits to both the intensity of defoliation, in terms of height and frequency of cutting, are imposed by the need to maintain herbage yields, and prevent the deterioration of the sward and the ingress of weed species. It is thus necessary to defoliate at a less frequent interval than the 10-14 days which Turner (1966, 1969) found to lead to a progressive reduction in rhizome carbohydrate reserves and the capacity for regrowth of Agropyron repens grown in isolation. Hakansson (1969), defoliating at ground level, concluded that Agropyron repens could withstand intense defoliation and at intervals of 2 weeks or longer it was likely to survive. Cutting at a height of 2 cm, he showed showed stimulated tillering and increased capacity for survival. The results of this trial confirm that the most intensive defoliation at a height of 4 cm was not in itself sufficient to control these weeds. It seems likely that control will only occur when there is effective additional competition from sown species. Although the combination of treatments with competition from tetraploid Italian ryegrass was sufficient to restrict the contribution of *Agropyron repens* and *Agrostis gigantea* in the cut herbage in the first year, an increase in these weeds occurred in 1970 as the competition from the crop declined.

The figures for rhizome production which increased during 1970, particularly under the 8 week defoliation treatment, indicate that at the 2 and the 4 week cutting frequency fresh rhizome production was still being restricted. Rhizome data (unpublished) from plots adjacent to this trial, where plots of perennial ryegrass (*Lolium perenne*) had been cut at 2, 3, 4, 5, 6 or 8 week intervals, over a period of three years (Harrington and Binnie 1971) indicated that thizome dry matter in the soil remained fairly constant at cutting frequencies up to 6 weeks. There was, however, a big increase under the 8 week defoliation treatment. These results, combined with the results of the present experiment suggest a critical cutting interval, in grassland of between 4 and 6 weeks, above which both *Agropyron repens* and *Agrostis gigantea* are likely to increase. It is concluded that a short lived companion grass species is unlikely to give control, and that a more persistent species which could withstand defoliation at about 4 week intervals for a period of years would be more successful. Roth and Albrecht (1969) have shown a decline in *Agropyron repens* in pastures where perennial ryegrass (*Lolium perenne*) or cocksfoot (*Dactylis glomerata*) were dominant, and that *Agropyron repens* increased as the proportion of *Poa trivialis* increased. Apart from its lack of persistency the tetraploid Italian, whilst making quick regrowth after cutting, did not tiller well and remained open and erect at the soil surface. It is probable that a more highly tillering species would offer greater competition.

The response to increasing nitrogen of both these rhizomatous grass species particularly in 1970 as the Italian ryegrass declined confirms the findings of Roth and Albrecht who showed that *Agropyron repens* responded to increased nitrogen application where perennial ryegrass was not dominant in the sward. Cussans (Private Communication)* in an experiment with perennial reygrass has also shown *Agropyron repens* to increase at higher levels of nitrogen and lax cutting treatments. It is likely that *Agropyron repens* will always respond to nitrogen fertiliser treatment, in a situation where other factors are not conducive to the vigorous growth of the crop.

References

HAKANSSON, S. (1969) Experiments with *Agropyron repens* (L.) Beauv. IV Response to burial and defoliation repeated at different intervals. *Lantbr. hogsk. Annlr.*, 35, 61-78.

HARRINGTON, F.J. and BINNIE, R. (1971) The Effect of Height and Frequency of cutting on grass production. *43rd Ann. Rep. Agric. Res. Inst. N.I.* 17-24.

ROTH, D. and ALBRECHT, M. (1969) Das Verhalten der Quecke (*Agropyron repens* P.B.) auf Weiden in Abhangigkeit von Bewirtschaftung und Hauptbestandsbildnern auf schweren Muschelkalkverwitterungsboden, Z. Landeskultur 10, 241-250.

TURNER, D.J. (1966) A Study of the Effects of Rhizome length, soil nitrogen and shoot removal on the growth of *Agropyron repens* (L) Beauv. *Proc. 8th Br. Weed Control Conf.* 538-545.

TURNER, D.J. (1969) The Effects of Shoot Removal on the rhizome carbohydrate reserves of Couch grass (*Agropyron repens* (L) Beauv.) *Weed Res.* 9, 27-36.

* Address: A.R.C. Weed Research Organisation, Yarnton, Oxford.

Proc. 11th Br. Weed Control Conf. (1972)

FIELD PERFORMANCE OF GLYPHOSATE DERIVATIVES IN THE CONTROL OF AGROPYRON REPENS AND OTHER PERENNIAL WEEDS

D.M. Evans

Monsanto Europe S.A. 1 Place Madou, Brussels, Belgium

Summary Field performance in widespread locations ranging from Britian to South Africa confirms the activity on perennial and annual weeds. Excellent control of Agropyron repens, Cynodon dactylon, Pennisetum clandestinum, Convolvulus arvensis and Cyperus rotundus was obtained at rates between 1.5 kg and 4 kg/ha. Glyphosate or its derivatives showed no soil activity on a variety of crops seeded immediately prior to or after treatment. Speed of action of the chemical is affected by sunlight and temperature, but has no effect on the final weedkill.

INTRODUCTION

The chemistry and general properties of the new class of herbicides represented by N-(phosphonomethyl)glycine, (Glyphosate), were first presented by Baird et al (1971) showing them to have a high degree of herbicidal activity covering both grasses and broad-leaved plants, but found to be inactivated immediately when applied to the soil thus having no soil acting herbicidal properties. Members of the group showed the capacity for translocation readily within the plant, thereby killing perennial species. The effects on Agropyron repens were reported by Baird and Begeman (1972) and on Sorghum halepense by Baird and Upchurch (1972).

Glyphosate has shown a relatively low order of animal toxicity. The mono(dimethylamine) salt showed an LD_{50} of 9,800 mg/kg on mixed sex rats and an acute skin absorption MLD for mixed sex rabbits >7,940 mg/kg. It was also classed as non-irritating to the skin and as a slight eye irritant. There are indications of a fairly rapid breakdown in the soil. Field tests were set up in locations throughout the world, results from which continue to confirm the unique herbicidal properties of Glyphosate in the control of a wide range of perennial and annual weeds.

The aim of the investigations summarized in this paper was to confirm the original findings and to define more clearly the parameters affecting performance in Europe and South Africa.

METHODS AND MATERIALS

Testing in 1971 was undertaken with the mono(dimethylamine) salt of Glyphosate formulated as a water-soluble concentrate containing 600 g/l a.e. to which a surfactant was used at 0.1% of the final spray volume. Evaluations in late 1971 and in 1972 have been made with the isopropylamine salt of Glyphosate formulated as a 360 g/l a.e. water-soluble concentrate and containing a surfactant.

Rates of use were investigated between 0.75 kg to 4 kg/ha. Experimental design was normally randomized blocks with 3 or 4 replications, comparisons being made with untreated check plots and standard materials. Applications were made with precision small plot sprayers. Diluent was normally within the range 200-400 l/ha with the exception of tests in Germany where 1000 l/ha was used. Applications were made post-emergence of the weeds at varying stages and under different weather conditions. Pre-crop emergence applications were made to test for any residual herbicide effect. Assessments were made visually on a 0-100% scale for leaf kill and for regrowth.

RESULTS

3 trials laid down in April 1971 in the United Kingdom with the mono(dimethylamine) salt of Glyphosate are summarized in table 1.

Table 1

Percent control of Agropyron repens (mean of 4 reps)

Trial site	Days after treatment	kg/ha glyphosate 0.75	1.5	3	paraquat 1.1	dalapon 9.7
Lincs	11	82	95	97	87	47
Beds	13	90	90	100	100	40
Lincs	21	90	100	100	82	55
Warwick	28	94	95	99	60	60
Beds	29	95	95	95	60	50
Lincs	31	100	100	100	20	65

Agropyron repens was killed at all rates, but the speed of action increased with increasing rates of application. The compound was slower acting than paraquat in leaf kill, but one month after application control was virtually complete and a random examination showed a good kill of the rhizomes. Significant regrowth had occurred on the paraquat plots one month after treatment. Broad-leaved weeds occurring in the trials indicated a high degree of control of *Senecio vulgaris*, *Brassica napus*, *Rumex obtusifolius*, *Taraxacum officinalis*, and *Myosotis arvensis*. Suceptible species, but requiring higher rates or longer time to die, were *Potentilla arvensis*, *Tussilago farfara*, *Polygonum convolvulus* and *Equisetum arvensis*. Autumn applications confirmed the spring results and are summarized in table 2.

Table 2

Percent control Agropyron repens (mean of 4 replications)

Trial site	Days after treatment	kg/ha glyphosate ½	2	3	aminotriazole 5.6 +thiocyanate 5.0	dalapon 12.1
Beds	7	45	72	82	7	0
Wilts	7	50	82	85	35	27
Yorks	7	42	57	70	27	22
Warwick	8	60	87	90	22	30
Warwick	14	90	95	99	35	30
Wilts	14	95	97	100	25	15
Beds	15	90	92	95	50	45
Yorks	15	72	82	91	35	30
Beds	24	100	100	100	60	40
Yorks	56	92	97	100	60	65
Yorks	107	95	100	100	100	100

The speed of kill with the autumn applications was faster than with spring applications. Treatments were made in early October on stubble. The Bedfordshire and Wiltshire sites were cultivated in November and seeded the following spring with barley, the Warwick site was ploughed and seeded with wheat in early November, the Yorkshire site was cultivated in the spring and seeded with barley. In all cases there were no adverse effects on the crops. Spring 1972 trials with the isopropylamine salt of glyphosate in the United Kingdom gave similar results and indicated that 0.5 kg/ha was insufficient to control regrowth but 2 kg/ha appeared adequate. Results are summarized in table 3.

Table 3

Percent control Agropyron repens (mean 4 replicates)

Trial site	Days after treatment	kg/ha glyphosate 0.5	2.0	4.0	aminotriazole 5.6 +thiocyanate 5.0
Oxford	15	67	86	85	57
Lincs 1	15	37	85	85	25
Lincs 1	29	40	99	99	50
Lincs 1	44	75	95	96	84
Lincs 2	15	84	95	96	47
Lincs 2	61	92	98	99	90
Lincs 2	90	53	93	96	68

Oxford treated March under warm conditions.
Lincs 1 treated in April under cold conditions.
Lincs 2 treated in May under cold conditions.

Tests undertaken in South Africa are summarized in table 4. These results show a minimum regrowth of Cynodon dactylon 430 days after treatment 14.1% at the 2 kg/ha a.e. rate of the mono(dimethylamine) salt and virtually complete control of Pennisetum clandestine after 342 days. No adverse effects were noted on peaches, apricots, apples, pears, citrus, avocado and pecan nuts. Accidental contact with lower leaves resulted in leaf chlorosis, abscission and die back of branch concerned, but no apparent effect on rest of tree.

Table 4

Percentage leaf kill Cynodon dactylon and Pennisetum clandestine

Days after treatment	kg/ha glyphosate		
	1	2	4
Cynodon dactylon			
7	53	72	82
11	68	92	98
18	82	97	100
50	97	100	100
268	100	100	100
360	88	99	97
Number of regrowth points at 260 days			
Pennisetum clandestine			
7	92	94	97
14	99	100	100
21	99	100	100
52	99	100	100
275	100	100	100
328	99.9	99.9	99.9
Number of regrowth points at 342 days	1	1	0.6

Further observation tests with the isopropylamine salt in South Africa indicated excellent control at 1 kg/ha a.e. of annual weeds including Urochloa panicoides, Eleusine africana, Amaranthus hybrides, Galinsoga parviflora, Tagetes minuta, Nidens pilosa, Erigeron spp., Digitaria sanguinalis, Schkuria pinnata, Sonchus oleraceus, Lepidium spp. Control of Cynodon dactylon was obtained at 2 kg/ha a.e. However early sprays prior to active growth required rates as high as 4 kg/ha a.e. Panicum maximum was controlled 95% after 8 weeks at 2 kg/ha. 85-90% control of Cyperus rotundus was obtained at this rate and 95% at 3 kg/ha. Excellent control of Paspalum dilitatum was obtained at 2 kg/ha.

Tests in France on Cynodon dactylon with the mono(dimethylamine) salt showed adequate control with rates in excess of 1.5 kg/ha a.e. Table 5 shows results were superior to that obtained with aminotriazole plus thiocyanate at 4.8 kg plus 4.3 kg/ha. Annual weeds occurring in the trials including Sorghum vulgare, Mercurialis annua, Polygonum aviculare and Oxalis corniculata were completely destroyed. Convolvuus arvensis and Convolvulus sepium were also killed, but some regrowth occurred. The growth of Rubus spp. was halted.

In Spain observations made 6 weeks after treatment showed control of Cynodon dactylon of 85% with 0.85 kg/ha a.e., 93% with 1.4 kg/ha a.e. and 97% with 2.75 kg/ha a.e. Dalapon at 20 kg/ha gave 92% control.

Table 5

Percentage Control Cynodon dactylon

Trials site	Days after treatment	kg/ha glyphosate 0.75	1.5	3.0	+aminotriazole 1.7 kg +thiocyanate 1.5 kg +oil 5 L. +paraquat 600 gr.
Ht Garonne	15	97	99	98	60
	50	82	90	92	80
	102	65	80	77	92
	132	67	75	65	95
					aminotriazole 4.8 kg +thiocyanate 4.3 kg
Tarn	15	77	87	95	10
	50	82	95	96	50
	100	51	73	81	50
Gers	15	90	95	97	25
	49	85	93	98	62
	77	60	88	97	30
Tarn & Garonne	14	50	60	65	10
	51	60	77	93	55
Ht Garonne	13	52	77	91	5
	29	66	93	98	61
	58	55	82	98	50

Table 6

Percent control of Agropyron repens and Convolvulus arvensis at 6 weeks

		kg/ha glyphosate			38% 19.5% 16.0% aminotriazole/simazine/MCPA
Site	Weed	0.75	1.5	4	10
Hofgut Westerhaus	*Agropyron repens*	63	90	98	82
	Convolvulus arvensis	23	50	65	95
Inglehein	*Agropyron repens*	80	100	100	100
	Convolvulus arvensis	33	100	100	100

Tests in Germany gave 90-100% control of *Agropyron repens* and between 50-100% control of *Convolvulus arvensis* at the 1.5 kg rate. Results are summarized in table 6.

No residual effects were obtained in the United Kingdom on a series of crops sprayed immediately before or after sowing at the 4 kg/ha a.e. rate. These included wheat, barley, oats, ryegrass, red fescue broad beans, runner beans, carrots, red beet. lettuce, swede, turnip, peas and cabbage.

Seasonal effects on performance were investigated in the United Kingdom and are shown in table 7. In early October during warm weather 3 weeks were required to reach maximum performance on *Agropyron repens* whereas later applications made in the cooler weather of November took 11 weeks to reach maximum effect. However, the final kill was not affected. Similar results were noted on *Stellaria media*, *Urtica repens* *Capsella bursa-pastoris* and *Senecio vulgaris*.

Table 7

Seasonal influence on performance of Glyphosate at 2 kg/ha

	T_1	T_2	T_3	T_4	T_5	T_6
Date treated	11/10/71	18/10/71	2/11/71	29/11/71	13/12/71	6/1/72
Air temp	18°C	15°C	12°C	3°C	8°C	3°C
Soil temp	13°C	11°C	10°C	3°C	6°C	4°C
r.h (%)	55	55	58	60	58	64
Weather	Dull, rain forecast	Windy, dull, rain after treatment	Windy, dry heavy dew at night	Fog, frost at night	Windy, dry	Fog foliage wet
Days after treatment	Percentage leaf kill					
7-11	42	--	30	17	--	--
22-25	85	82	--	--	42	--
32-43	87	--	80	67	--	85
53-65	85	90	90	--	100	100
73-87	77	95	--	100	--	--
108-136	75	97	100	--	--	--

DISCUSSION

Glyphosate proved to be a very active herbicide in its various formulations for the control of a wide range of species and particularly interesting for the control of perennial weeds such as *Agropyron repens* and *Cynodon dactylon* since there is translocation into the rhizomes resulting in complete kill of the plant. Rates in excess of 1.5 kg/ha a.e. seem to be necessary to prevent regrowth of *Agropyron repens*. *Cynodon dactylon* probably requires a rate between 2-3 kg/ha and *Convolvulus arvensis* in excess of 3 kg/ha. Further studies are underway to determine optimum rates. As a result of other trials the isopropylamine salt of glyphosate has been selected for further development.

Observations made by Baird and Begeman (1972) suggest that the volume of diluent can affect activity; this can explain the poorer results obtained in Germany on *Convolvulus arvensis* where 1000 l/ha were used.

Speed of action is enhanced by increased light intensity, but the ultimate kill is unaffected. This is in agreement with observations made by Upchurch and Baird (1972). Cold weather can also slow down activity as seen in table 7 but final results appear slightly better. This confirms the findings of Upchurch et al (1972). It would appear that once the chemical has been absorbed by the plant, kill is inevitable but the speed of this kill is determined by external influences. An observation trial undertaken on bracken in the summer of 1971 showed little affect during that year, but regrowth in the summer of 1972 was dramatically reduced.

No residual effects were observed in a variety of annual crops when soil was treated with glyphosate. Adequate safety was observed in a number of tree crops where directed sprays were used. The activity of glyphosate has shown consistent performance throughout the world as a translocated foliar herbicide. This factor combined with its low order of toxicity and fairly fast breakdown, make this class of herbicide extremely interesting with utilization in numerous areas such as stubble cleaning, orchards, vineyards, pre-plant treatments, plantation crops, and in forestry and industrial situations.

Acknowledgements

The author gratefully acknowledges the research and development work conducted by the development staff of Monsanto in the UK, France, Germany, Spain, and South Africa.

References

BAIRD, D.D. et al (1971) Introduction of a New Broadspectrum Post-emergence Herbicide Class Perennial Weed Control. North Central Weed Conference, USA.

BAIRD, D.D. and BEGEMAN. G.F. (1972) Post-emergence Characterization of a New Quackgrass Herbicide. North East W.S.S. Meeting, Jan. 1972.

BAIRD, D.D. and UPCHURCH, R.P. (1972) Post-emergence Characteristics of a New Herbicide MON 0468 on Johnson grass. 25th Southern WSS Meeting Jan. 1972.

UPCHURCH, R.P. and BAIRD, D.D. (1972) Herbicidal Action of MON 0573 as Influenced by Light and Soil. Western Society of Weed Science March 1972.

UPCHURCH, R.P. et al (1972) Influence of Temperature and Diluent Properties on MON 0468 Performance. W.S.S. Meeting, St. Louis 1972 - Verbal Presentation.

Proc. 11th Br. Weed Control Conf. (1972)

EFFECTS OF TFP AND NC 8438 ON AGROPYRON REPENS

A.M. Blair
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary In the autumn young plants of *Agropyron repens* in specially established 1m^2 plots were well controlled by sodium 2,2,3,3-tetrafluoropropionate (TFP) at 8.96 kg a.i./ha and by dalapon-sodium at 8.96 kg a.i./ha. Aminotriazole + ammonium thiocyanate at 3.0 kg a.i./ha was less effective. In the spring 2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranylmethane sulphonate (NC 8438) at 4.48 kg a.i./ha gave better control of *A. repens* in specially planted 1m^2 plots than the standard treatment of TCA at 33.6 kg a.i./ha. When combined with a simulated cultivation on young *A. repens* plants after emergence, 0.58 kg a.i./ha NC 8438 reduced shoot numbers by 85%. TFP and NC 8438 gave good control of *A. repens* in barley stubble. Control was improved if the stubble was rotary cultivated just before the herbicides were applied. In this situation NC 8438 at 8.96 kg a.i./ha, the dose required to control the *A. repens*, severely damaged the subsequent barley crop whereas TFP at 4.48 kg a.i./ha gave good *A. repens* control with no damage to the subsequent barley crop and a corresponding rise in barley yield.

INTRODUCTION

There is a continuing evaluation of new herbicides for control of couch (*Agropyron repens*) at the Weed Research Organization. Information from manufacturers and screening trials in the greenhouses at Begbroke is used to select herbicides for field trial. This report describes three field experiments A, B and C. Experiment A, in spring 1970, and B, in autumn 1970, were evaluation experiments on specially planted *A. repens* populations. Experiment C, in autumn 1970 examined the effects of various stubble treatments on both *A. repens* and the subsequent barley crop.

METHOD AND MATERIALS

Experiments A and B were carried out on a sandy-loam soil at Begbroke Hill Farm near Oxford. Normal seedbeds were prepared with 315 kg/ha 13.13.20 + 125 kg/ha 26N fertiliser. 12 x 150 mm rhizome fragments were planted per 1m^2 plot as described by Blair & Holroyd (1970). Experiment A was planted on 24.3.70, experiment B on 11.6.70. Preparation of the area involved rotary cultivation followed by planting and subsequent irrigation of experiment B with 20 mm water. Clonal material (Headington) was used from 'stock beds' at Begbroke. Experiment C was on a natural *A. repens* population at a farm adjacent to Begbroke Hill with a similar soil type. This experiment involved stubble treatment after harvest. Plot size in this experiment was 4 m x 6 m.

The herbicides used in these experiments were: 1) 2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranylmethanesulphonate (NC 8438 as 20% a.i. w/w w.p.); 2) T.C.A. (80.68% a.i. w/w pelletised solid); 3) sodium 2,2,3,3-tetrafluoropropionate (TFP as Orga 3045, 80.8% a.i. w/v a.c.); 4) dalapon-sodium (74% a.i. w/w s.p.);

5) aminotriazole + ammonium thiocyanate (activated aminotriazole as a 20% a.i. w/v a.c.). In experiment A NC 8438 was applied pre-emergence at 0.28, 0.56, 1.12, 2.24 and 4.48 kg a.i./ha on 24.3.70. One set of plots at the lower three doses was given, on 21.5.70, a simulated cultivation. This involved digging the plot with a spade when the A. repens had 3-4 leaves, and subsequently breaking down any soil lumps with the back of the spade to cause a bruising action on the emerged shoots. TCA at 33.6 kg a.i./ha was included in this experiment as a standard.

Treatments in experiment B applied on 1.10.70 were TFP at 2.24, 4.48, 8.96 kg a.i./ha; dalapon-sodium at 8.96 kg a.i./ha and aminotriazole + ammonium thiocyanate at 3.0 kg a.i./ha were included as standards. They were applied to A. repens at the 2-3 leaf stage. On both experiments treatments were applied using a special sprayer for small plots fitted with a 730039 'Teejet' applying 335 l/ha of water at a pressure of 210 kN/m^2.

In experiment C TFP at 1.12, 2.24, 4.48 kg a.i./ha and NC 8438 at 2.24, 4.48, 8.96 kg a.i./ha were applied (a) to undisturbed stubble on 29.9.70 when A. repens was about 50 mm in height, (b) to cultivated stubble on 29.9.70 and (c) to regrowth (A. repens 1½-2½ leaves) on 3.11.70 following cultivation on 29.9.70; 8.96 kg a.i./ha NC 8438 was applied later on 14.11.70. These were compared with standard treatments of TCA at 33.6 kg a.i./ha and aminotriazole + ammonium thiocyanate at 2.24 (applied later on 7.12.70) and 4.48 kg a.i./ha. Stubble cultivation involved rotovation to a depth of 75-100 mm. Treatments were applied using an Oxford Precision Sprayer fitted with 6502 'Teejets' in 270 l/ha of water and at 210 kN/m^2 pressure. The whole area was rotary-cultivated to depth 50-75 mm on 18.3.71 prior to drilling with 125 kg/ha Gerkra spring barley. 375 kg/ha 18.14.14 compound fertiliser was applied at drilling.

RESULTS

Results from experiments A and B are presented in Tables 1 and 2, shoot counts per plot being made on 13.8.70 and 17.5.71 respectively. Results from experiment C are presented in Tables 3 and 4. Shoot counts made on 21.9.71. of A. repens on 5 x 0.1m^2 quadrats and rhizome dry weights (100°C for 24 h) from 8 cores 0.13 m diameter x 0.2 m deep taken on 25/30.11.71 are recorded in Table 3. The dry weight of barley grain (100°C for 18 h) harvested on 11.8.71. from 4 x 0.85 m^2 quadrats per plot is recorded in Table 4.

Results from experiment A show that 4.48 kg a.i./ha NC 8438 gave good A. repens control (Table 1). Simulated cultivation alone reduced A. repens by 65%. In conjunction with cultivation 0.56 kg a.i./ha NC 8438 reduced A. repens shoots by 85%. Increasing the dose to 1.12 kg a.i./ha with cultivation did not further increase the degree of control.

8.96 kg a.i./ha TFP gave good control of A. repens in experiment B, comparable with the standard treatment of 8.96 kg a.i./ha dalapon: 3.0 kg a.i./ha activated aminotriazole was not as effective (Table 2).

In experiment C the best treatment was TFP at 4.48 kg a.i./ha applied to stubble which had been rotary cultivated prior to treatment; there was an increase in grain yield coupled with a decrease in couch shoot numbers and rhizome dry weights (Tables 3 and 4). This was more effective than the standard treatment with TCA in this experiment. The lower doses of NC 8438 gave poor control of A. repens but higher doses, although controlling the A. repens, severely damaged the subsequent barley crop. A standard treatment of activated aminotriazole gave poor A. repens control.

Table 1

Agropyron repens shoots/m^2 on 13.8.70 (experiment A)

(Mean 4 replicates, Control mean 8 replicates)

	Dose (kg a.i./ha)		log (x + 1)
NC 8438	0.28	316.5	5.67
	0.28 + simulated cultivation	93.8	4.10
	0.56	283.5	5.62
	0.56 + simulated cultivation	47.8	3.11
	1.12	115.3	4.68
	1.12 + simulated cultivation	49.3	3.90
	2.24	91.0	4.50
	4.48	15.0	2.73
TCA	33.6	21.0	2.41
Simulated cultivation		100.0	4.59
Control		301.0	5.66
S.E. treatment means comparison			± 0.553
S.E. treatment/control comparison			± 0.478

Table 2

Agropyron repens shoots/m^2 on 27.5.71 (experiment B)

(Mean 4 replicates, Control mean 16 replicates)

	Dose (kg a.i./ha)		log (x + 1)
TFP	2.24	38.8	3.53
	4.48	43.3	3.76
	8.96	12.8	0.99*
Dalapon	8.96	12.0	2.07*
Activated aminotriazole	3.0	41.0	3.43
Untreated control		110.2	4.62
S.E. treatment means comparison			± 0.560
S.E. control/treatment comparison			± 0.443

*The apparent discrepancy here is due to the log. analysis giving less weight to non-zero values; there were more zero readings on the TFP treatment.

Table 3

Shoot count of A. repens and rhizome dry weights (g) (experiment C)

(Mean of 3 replicate plots, Control mean of 6 replicates)

		Shoot counts			Rhizome dry weight		
Herbicide	Dose (kg a.i./ha)	Undisturbed stubble	Cultivated stubble	Regrowth	Undisturbed stubble	Cultivated stubble	Regrowth
TFP	1.12	33.0	27.1	26.3	12.6	6.3	8.1
	2.24	27.1	28.9	26.5	10.1	3.9	4.9
	4.48	34.7	9.3	22.8	8.1	1.6	4.3
NC 8438	2.24	35.1	19.4	20.0	8.1	3.6	2.9
	4.48	23.0	20.6	11.8	4.2	7.7	2.4
	8.96	24.2	2.2	2.0	2.8	2.1	1.5
TCA	33.60		24.3			5.3	
Activated aminotriazole	2.24	22.3			4.1		
	4.48	23.7		22.6	4.8		4.6
Untreated control		51.5	25.5	30.3	11.8	6.8	5.0
S.E. treatment means comparison		± 10.4	5.7	5.5	2.8	2.7	1.6
S.E. treatment/control comparison		± 9.0	4.9	4.8	2.5	2.3	1.4

Table 4

Dry weight (g) barley grain (experiment C)

(Mean of 3 replicate plots, Control mean of 6 replicates)

Herbicide	Dose (kg a.i./ha)	Application to Undisturbed Stubble	Application to Cultivated Stubble	Application to Regrowth
TFP	1.12	853	1034	1021
	2.24	1097	1033	1029
	4.48	964	1120	1053
NC 8438	2.24	876	1109	1141
	4.48	1023	1096	956
	8.96	902	0	0
TCA	33.60		1117	
Activated aminotriazole	2.24	1023		
	4.48	1053		1017
Untreated control		790	1006	1050
S.E. treatment means comparison		± 119.3	62.5	64.8
S.E. treatment/control comparison		± 102.2	54.1	56.1

DISCUSSION

Previous work at WRO with TFP was described by Blair & Holroyd (1970) and the experiments reported here are a continuation of this work. Weather conditions after spraying TFP can be important: because of its high solubility heavy rainfall after spraying can cause leaching to deeper soil layers (Aelbers et al., 1969). Results from field trials have shown the residual action for control of shallow germinating annual weeds is limited to 6 to 10 weeks (Aelbers et al., 1969). Under greenhouse conditions TFP @ 4.48 kg a.i./ha completely killed perennial ryegrass used as a bioassay species after 12 weeks (Richardson, et al., 1971) and even at 50 weeks under the same conditions (Richardson, 1972). However, at the highest dose used on the field experiment reported here, TFP caused no persistence problems in the subsequent barley crop. This treatment gave better control than the standard TCA when applied after cultivation; cultivation did however seem to be an important part of the control measure. Little rain fell in the 4 weeks after application of the TFP on 29.9.70; this may well have increased effectiveness of TFP by not leaching it below the rhizome region. In the subsequent 4-8 week period there was about twice the average rainfall which may partly explain the decrease effectiveness of the later application of TFP on 3.11.70. as the herbicide is mainly active through the soil (Aelbers, 1969).

Although NC 8438 was too persistent under the conditions of this experiment to fit into a cereal cropping system it may be worth considering in other crop contexts such as grass leys. There is no obvious explanation for the apparent persistence of this herbicide when applied on 29.9.70, to cultivated stubble but not when applied to uncultivated stubble. The degree of *A. repens* control can be good using NC 8438 and further consideration of combining lower doses with subsequent cultivation may be worthwhile in view of the promising results in small plots, which was however on young plants (Table 1).

Forms of cultivation other than rotovation in combination with these herbicides could increase the speed of carrying out this operation if they were effective - this aspect requires further investigation.

Acknowledgements

Thanks are due to Mr. J. Holroyd for help and advice, to Mr. M.E. Thornton for planning and spraying the experiment, Miss J.G. Sargeant, A.W. Lovegrove and M.R. Nowakowski for help in carrying out the experiments, Mr. B.O. Bartlett and Mr. C. Marshall for assistance in planning and analysis of the experiments, and the manufacturers for supplying the herbicides.

References

AELBERS, E., BASTIAANSEN, H.G. and GRYSEELS, A.J. (1969) 2,2,3,3-tetrafluoropropionate, a herbicide for the control of annual and perennial grasses in different crops. Proc. 3rd EWRC Symp. New Herbicides, 1, 17-24

RICHARDSON, W.G. (1972) Personal communication

RICHARDSON, W.G., PARKER, C. and HOLLY, K. (1971) The pre-emergence selectivity of some newly developed herbicides. WRO Technical Report (17), 12-16

Proc. 11th Br. Weed Control Conf., (1972)

STUDIES ON THE RETENTION, PENETRATION AND TRANSLOCATION OF ASULAM IN SOME PERENNIAL WEED SPECIES

A.H. Catchpole and C.J. Hibbitt
May & Baker Ltd., Ongar Research Station, Essex.

Summary Experiments indicate that spray retention by monocotyledonous weeds (Agropyron repens and Sorghum halepense) is increased by addition of wetter to a spray solution of asulam and this is accompanied by increased herbicidal activity. This increase in activity appears to be largely due to the higher dose received and to the increased dose reaching the leaf axils. It was found that application of a standard dose to the axils of A. repens gave greater activity than when applied to laminae. Addition of wetter did not increase retention or herbicidal activity for docks (Rumex obtusifolius). Retention by detached pinnae of bracken (Pteridium aquilinum) was not increased by addition of wetter. Use of asulam-ring ^{14}C showed that when applied to leaf axils of A. repens, some of the label penetrated into the plant and was rapidly translocated. A similar result was obtained for dock plants, where the highest concentration of ^{14}C in the meristematic regions of the shoots occurred after four days.

INTRODUCTION

Since the initial report of the herbicidal activity of asulam (Cottrell and Heywood, 1965) the uses and potential of this chemical have been considerably extended. It is widely used for the control of both annual and perennial grass weeds in sugar cane. It has been shown to control docks effectively in pasture (Savory and Soper, 1970 and in press) and has recently received official approval in the U.K. for grant-aided use against bracken. Promising experimental results have also been obtained for the control of temperate perennial grasses, and of wild oat in flax.

The outstanding feature of the herbicidal activity of asulam is its ability to move in the tissues of susceptible species, and consequently to control large, well established annual and perennial plants at doses similar to those required to kill seedlings. In the course of research, many data have been obtained on the inter-relationship of application method, plant morphology, translocation patterns and efficacy. Some of these are presented here.

METHODS AND MATERIALS

All the plants except bracken used in these experiments were grown in pots in the glasshouse or outdoors. In the case of bracken, fronds were cut from a local site and compound pinnae detached at the time of use. Spraying was carried out with an overhead laboratory sprayer and unless stated spraying was at 220 l/ha. Asulam was applied as 'Asulox' (40% w/v sodium salt formulation) or as the 75% potassium salt. All wetter addition was with Ethylan CP, a non-ionic polyethoxylated alkyl phenol.

Spray retention

Acid red (disodium salt of 8-acetamido-2-phenylazo-1-naphthol-3,6-disulphonic acid) was used for all spray retention studies. It has been shown (Hibbitt, 1969) that acid red is readily soluble in water, has negligible surface activity, has an optical density in aqueous solution directly proportional to concentration, is light fast, is easily washed from leaf surfaces and does not react with salts of asulam. The volume of spray retained on the plant was calculated from the optical density of the plant washings (Hibbitt, *loc. cit.*).

Topical dosing

The total volume of spray retained per plant was determined using the above method and the equivalent dose of herbicide solution was applied as droplets to the required area of the plant using an 'Agla' micro syringe.

Experiments using ^{14}C-ring labelled asulam

The adaxial surfaces of mature leaves of dock plants (aerial fresh weight 45 g) were treated with a volume of 0.5% w/v asulam solution in water equivalent to the total spray retention volume of the plants (0.8 ml). The asulam solution contained asulam-*ring* ^{14}C at a specific activity of 2.9 µCi/mg*. The plants were kept in a glasshouse during July and three replicates harvested 1, 4 and 9 days after treatment. Plants were dissected and the various parts oven-dried, ground and duplicate aliquots assessed for ^{14}C activity by a combustion method and liquid scintillation counting.

The amount of asulam remaining as a surface deposit on treated dock leaves after various times was determined. The adaxial surfaces of the 5 youngest mature leaves of plants (aerial fresh weight 64 g) were treated with the approximate spray retention volume of a 0.5% w/v asulam solution containing asulam-ring ^{14}C applied in 1 µl drops. After 2, 6, 24 and 48 hours in the glasshouse the treated leaves of 4 replicate plants were each washed with 50 ml of an aqueous 0.5% w/v asulam solution containing 0.04% w/v wetter. The ^{14}C activities of the washings were assayed by liquid scintillation counting.

Agropyron repens plants were grown from 3-node rhizome pieces. A volume (0.15 ml) of asulam solution equivalent to half the determined spray retention volume was applied per plant to the leaf axils of all stems. The applied solution contained 1.5% w/v asulam, 0.25% w/v wetter and asulam-*ring* ^{14}C to give a specific activity of 1.1 µCi/mg. Two replicate plants were harvested after 1, 4, 9 and 14 days, washed free of soil, frozen, freeze-dried and autoradiographed.

RESULTS

Table 1

Effect of wetter addition on spray retention and herbicidal activity for *Sorghum halepense* and sugar cane

		S. halepense			Sugar cane		
	Wetter % w/v	0	0.1	1.0	0	0.1	1.0
Spray retention µl/g of plant		10	65	105	32	36	34
% fresh weight reduction	(1.1 kg/ha on seedlings	24	38	100			
	(2.2 kg/ha on established plants	16	91	100			
	(3.3 kg/ha on young ratoon cane				0	0	0

* Synthesised in the radiochemistry laboratories, May & Baker Ltd.

Table 2

Effect of wetter addition on spray retention and herbicidal activity for *Agropyron repens*

Wetter % w/v		0	0.05	0.1	0.5
Spray retention µl/g		16	34	41	49
% fresh weight reduction	(1.1 kg/ha	7	38	29	71
	(3.3 kg/ha	45	81	82	96

Table 3

Effect of wetter addition on spray retention and herbicidal activity for docks (*Rumex obtusifolius*)

Wetter % w/v		0	0.05
Spray retention µl/g	(crown	8	15
	(rest of plant	45	38
% mortality	(0.55 kg/ha	16	0
	(1.1 kg/ha	100	66
	(2.2 kg/ha	100	100

Table 4

Effect of wetter and method of application on herbicidal activity for *Agropyron repens*

		% Fresh weight reduction					
		Spray application		Droplets applied to leaves		Droplets applied to leaf axils	
Wetter % w/v		0.05	0.25	0.05	0.25	0.05	0.25
Asulam kg/ha	0.55	0	24	23	0	15	24
	1.1	38	72	24	24	40	80
	2.2	58	98	36	19	57	85
	3.3	81	89	42	31	83	81

Table 5

Effect of wetter and spray volume rate on retention of spray and herbicide for bracken (*Pteridium aquilinum*)

		Spray retention µl/g		Herbicide retention (for 4.4 kg/ha) mg/g	
Wetter % w/v		0	0.1	0	0.1
Volume rate l/ha	55	24	28	1.9	2.2
	220	62	58	1.2	1.2
	534	87	73	0.7	0.6

Table 6

Effect of simulated rainfall (5mm) at various times post spraying on herbicidal activity for Agropyron repens

Time (hours) of rainfall application post spraying	% fresh weight reduction 1	2	3	6	24	48
Asulam, 6.6 kg/ha	60	83	88	75	61	86
Asulam, 3.3 kg/ha + 0.25% w/v wetter	100	100	100	100	100	100

Table 7

Effect of application to leaf tips and removal of the leaf tips after various time intervals on herbicidal activity for Agropyron repens (asulam dose = 3 kg/ha)

Time of tip removal (hours)	Fresh weight (g)
not removed	6.0
2	12.8
24	14.0
48	11.9
untreated	13.5

DISCUSSION

The herbicidal effect of asulam against susceptible species depends on the dose retained by the plant (Tables 1, 2 and 3). Results from the work so far carried out show that the lower the volume rate of the spray (consistent with good coverage), the greater the retained asulam dose: a rate of 55 l/ha has always given a greater retained dose than 220 l/ha. This is illustrated for bracken in Table 5.

The leaves of docks and bracken are relatively easy to wet and the retention of spray solution was not increased by the addition of wetter (Tables 3 and 5). The use of a wetter increased the proportion of the spray retained by the crowns (furled and sheathed leaves) of dock plants but decreased herbicidal activity. Similarly, Soper et al (1968) have shown that shielding the crown during spraying does not reduce the effectiveness of asulam and that the dose retained by the mature leaves is principally responsible for the herbicidal effect.

For S. halepense and A. repens both spray retention and herbicidal activity were increased by addition of wetter (Tables 1 and 2). Increasing wetter concentrations, up to 1.0% w/v and 0.5% w/v for S. halepense and A. repens respectively, was increasingly beneficial. For sugar cane, there was no increase in spray retention due to the addition of wetter, but in any case metabolism studies have shown that the resistance of sugar cane to asulam is physiological, and due rather to its immobility in the plant than to lack of spray retention.

Similar herbicidal effects resulted from the application of the asulam dose to A. repens plants as a spray or topically to the leaf axils (Table 4). In both cases the higher wetter concentration gave greater activity. The same dose applied to the laminae, however, showed less activity. This agrees with earlier work on

Figure 1

Change in average concentration of ^{14}C, expressed as ppm of asulam on a dry weight basis, found in various parts of docks, with time.

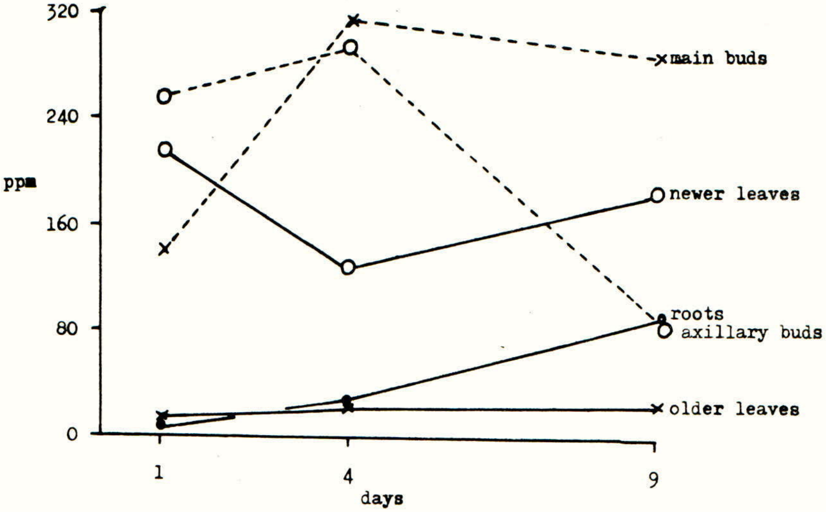
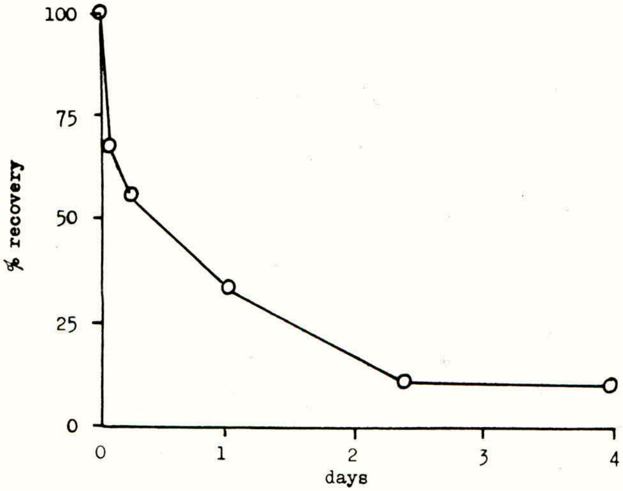


Figure 2

Change in % recovery of ^{14}C from dock leaves with time.



wild oat (Hibbitt, 1967) where the greatest activity was obtained by placing the asulam in the axil of the youngest leaf and was considerably reduced if the drop was placed on older laminae. The activity of the laminal application to A. repens was not affected by increasing the wetter concentration, suggesting that addition of wetter per se does not affect herbicidal activity.

It thus appears that the effect of increasing wetter concentration on activity against susceptible monocotyledon species may be due to increased spray retention and/or accumulation in the leaf axils and penetration into leaf sheaths, where uptake seems to be more efficient. The results presented in Table 7 confirm that penetration and translocation from a laminal application to A. repens is inefficient. Insufficient asulam entered the leaf and moved away from the area of application in 48 hours to cause noticeable herbicidal effects. On the other hand, simulated rainfall applied even one hour after a spray application of asulam failed to reduce the herbicidal activity (Table 6).

Application of asulam-ring ^{14}C to axils of A. repens plants and subsequent autoradiography confirmed that the axils are effective sites of uptake. Radioactivity was distributed throughout the leaves and rhizomes of plants one day after application. Movement to the tips of rhizomes (up to 450 mm long) occurred and there was noticeable accumulation at the tips after 4 days.

Experiments in which asulam-ring ^{14}C was applied to mature leaves of dock plants have shown a rapid movement of ^{14}C into other parts of the plant (Figure 1). After one day 9% of the applied ^{14}C activity had moved out of the treated leaves and activity was present in the growing points of the main axes and in axillary buds, confirming that a dose to the crown is unnecessary to provide activity in the growing points. This activity built up to a concentration equivalent to approximately 75 ppm on a fresh weight basis after 4 days. About 10% of the applied activity was present in the roots after 9 days and at this time 40% of the activity was associated with parts of the plant other than the treated leaves. These results tend to confirm those of Savory and Soper (1970) who showed that removal of 75% of each leaf of a dock plant one day after spraying with asulam slightly reduced the herbicidal effect, but removal after two days had no effect. The recovery by washing of ^{14}C from dock leaves treated with asulam-ring ^{14}C showed a rapid decrease with time (Figure 2), which may represent leaf uptake. Only 35% of the initial surface deposit was recoverable after one day.

It thus appears that although the effects of asulam treatment may be slow to appear, the compound penetrates and is translocated rapidly in susceptible species. Movement of the label from asulam-ring ^{14}C is throughout the plant and, in terms of concentration, especially to the meristems. It is therefore important that plants should be actively growing at the time of treatment, both to provide leaves exporting photosynthate to intercept the spray and active meristems to act as "sinks" for translocation. Thus, Caseley (1970) found much poorer control of A. repens by asulam at 6°C than 16°C. The 'dormant' or inhibited axillary buds of A. repens rhizomes do not accumulate asulam, and are therefore unaffected. On the other hand, the success of this herbicide in controlling docks and S. halepense may be due in part to a lack of inhibited buds in these plants - except for S. halepense in drought conditions. Although bracken rhizomes can remain undecayed and bear apparently healthy buds for some time after treatment, these buds mostly fail to grow when planted in favourable conditions (Holroyd et al, 1970). The activity translocated to dock roots can control regrowth from root pieces and ^{14}C is present in the new stunted leaves of plants treated with asulam-ring ^{14}C.

Asulam exerts its main effect against meristems and the greatest visual effects of treatment therefore occur in new growth. Meristems are usually killed within one to two weeks of treatment, but mature leaves present at spraying only senesce slowly. This occurs especially in bracken where there may be few visible signs of treatment until the following spring. It appears to be beneficial in some cases (e.g. docks in pasture - Savory and Soper, in press) to cut off the leaves after asulam penetration and translocation has taken place to remove the bulk of the weed, reduce further photosynthesis and perhaps to stimulate buds to grow. The effect of a similar technique on the long-term control of bracken is being investigated at present.

References

CASELEY, J.C. (1970) The effect of temperature on the performance of five herbicides used to control Agropyron repens. Proc. 10th Br. Weed Control Conf., 1, 320-325.

COTTRELL, H.J. and HEYWOOD, B.J. (1965) Benzenesulphonyl carbamates: new herbicides. Nature, 207, 655-656.

HIBBITT, C.J. (1967) Investigation to find to what extent spray characteristics and plant morphology contribute to the selectivity of a water-soluble herbicide. M.I. Biol. thesis.

HIBBITT, C.J. (1969) Growth and spray retention of wild oat and flax in relation to herbicidal selectivity. Weed Research, 9, 95-107.

HOLROYD, J., PARKER, C. and ROWLANDS, A. (1970) Asulam for the control of bracken (Pteridium aquilinum (L) Kuhn). Proc. 10th Br. Weed Control Conf., 1, 371-376.

SAVORY, B.M. and SOPER, D. (1970) Factors affecting the control of docks (Rumex spp.) with asulam. Proc. 10th Br. Weed Control Conf., 1, 358-365.

SAVORY, B.M. and SOPER, D. (in press) Response of a pasture to removal of docks (Rumex spp.) by treatment with asulam. Weed Research.

SOPER, D., TERRY, H.J. and SAVORY, B.M. (1968) Asulam for the control of docks in grassland. Proc. 9th Br. Weed Control Conf., 1, 508-514.

Proc. 11th Br. Weed Control Conf. (1972)

THE CONDUCT OF FIELD EXPERIMENTS AT THE WEED RESEARCH ORGANIZATION

J. G. Elliott, J. Holroyd and T. O. Robson
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary The conduct of field experiments at the Weed Research Organization has evolved over the 12 years of the Organization's existence. This report contains a description of the main aspects of the current system which seeks to ensure efficiency in the 250-300 field experiments carried out each year. Efficiency depends on proper planning, careful execution of the plan and intelligent interpretation of the results. The report describes how these are achieved; it also describes the supporting services which are essential to the operation of the field teams. The terms of reference and the activities of the Field Experiments Committee which co-ordinates all field experiments are described.

INTRODUCTION

The main components of research on weed control are the study of weeds, the evaluation and development of herbicides and the appraisal of cultural practices associated with weed control. At the Weed Research Organization (WRO) as elsewhere the acquisition of this knowledge takes place in laboratories, in greenhouses, by means of field experiments and by the observation of the experience of farmers. The purpose of this report is to describe the way in which field experiments at WRO are organised.

The nature of the organisation has evolved over the years as experience of weeds and herbicides has grown. For example, many weeds which form the subject of field experiments are difficult to grow artificially. Annual species may be irregular in germination and perennials may take years to establish before they can be considered representative of a natural population. There is, moreover, a danger that weed populations established artificially on an experimental station are atypical and unrepresentative of the environment in which they occur naturally. For this reason, from the earliest days, it has been the practice for a proportion of the WRO field experiments to be carried out on ordinary farms where the particular weed is a problem. Therefore, WRO field teams have always been equipped so as to be mobile. The staff have been selected and trained to carry out most of the operations required for field experiments whether at Begbroke or outside.

On many research farms the competition for facilities between experimenters and farm staff is not satisfactorily resolved: it was accepted at the creation of WRO that, although field research must have priority on Begbroke Hill Farm, this priority should not operate to the detriment of the general farming on the Station. Such a policy would in the long term reduce the efficiency of the very facilities that the experimenters use. Land and other major facilities are not distributed on a sectional or departmental basis; they are held in a pool for general use according to a pre-arranged plan. In order to plan, co-ordinate and supervise the conduct of matters connected with field experiments the Director created the Field Experiments Committee (FEC). This body has developed over the years and now holds a key position in the affairs of the Organization.

The Field Experiments Committee

The Field Experiments Committee is responsible for organising the general conduct of field experiments. Its main functions are as follows:

1. It creates rules and codes of practice to guide field experimenters in the efficient conduct of their experiments.
2. It advises on and approves plans for field experiments.
3. It allocates land at Begbroke Hill ensuring that the necessary services are made available to experimenters and liaises with the Farm Manager to ensure the appropriate cross communication of information about experimenters' requirements.
4. It co-ordinates safety procedures wherever there are potential hazards in field experiments.
5. It observes the experiments in progress and comments on any deficiencies.
6. It receives back all relevant papers when the experiments are finished and indexes the results.
7. It advises the Director on matters to do with the land, buildings and field equipment.
8. It provides a range of ancillary services such as maps for field teams when they travel, advice on hotel accommodation, weather reporting etc.

At first sight FEC would appear to have somewhat overbearing powers and indeed its authority is considerable. However, its membership does much to temper its authority. The Committee consists of three senior members of WRO who are all very experienced in the planning and conduct of field experiments. Apart from their duties with the Committee, they are Section Heads and are responsible therefore for supervising the field teams who are the originators and conductors of the experiments. Not only are the members of the Committee in a good position to understand experimenters' problems but they themselves have research commitments and are not therefore given to extending the activities of FEC more than is absolutely necessary. The Committee is assisted by a Clerical Officer working three days a week who does all the detailed clerical work which is essential to the functioning of the system.

Meetings of the Committee are held as required and, on average, about once a month. In early February and late July it is necessary for the Committee to meet more frequently to approve the large number of field experiments that are then submitted. Formal approval is required only for experiments at Begbroke Hill but the Committee finds increasingly that its advice is also sought in the planning of experiments to be placed on other farms. At the time of writing (1972) WRO has some 286 field experiments in being all of which have, to some extent, been examined by the Committee.

Since FEC is responsible to the Director, anyone dealing with the Committee may appeal to him if dissatisfied with the Committee's decisions. In reality the Committee finds that it obtains its requirements through persuasion and advice more effectively than through the use of authority. The Director rarely finds himself involved in arbitration.

It should be made clear that the Committee has no right to comment on the research subjects which form the basis of the experimental proposals that it receives; these are the prerogative of the Director and the departmental and section heads. FEC's concern is with efficient experimentation regardless of the subject.

Over the years the Committee has issued a number of instructions and items of information: these are made available to all team leaders in a booklet entitled "A Guide to the conduct of field experiments at Begbroke Hill". The guide is brought up to date each winter and is rewritten from time to time.

The planning of field experiments

Early experience showed that difficulties and failures may occur through the inadequate planning of a field experiment. It is accepted at WRO that all field experiments must be carefully planned in detail on paper before their start. The basic essentials for proper planning are that the experiment must have a clearly defined object: the treatments should be chosen to achieve this object; appropriate assessments should be carefully selected to reveal the consequences of the treatments; and the experiment should be designed according to sound statistical principles. Fulfilment of these four requirements is essential to any proposal submitted to FEC. Thereafter it is necessary to decide on the type of land and other services that may be required for the experiment. On a separate form is supplied information about the chemicals (if any) that are to be used in the experiment: advice on their toxicological hazards and therefore the safety precautions necessary is obtained from the Ministry of Agriculture personnel administering the Pesticide Safety Precaution Scheme.

The responsibility for planning the experiment, for presenting it to the Committee and for carrying it out rests with one individual known as "The officer in charge of the experiment". All matters relating to the experiments are referred to him, he is held responsible for the conduct of the experiment and the condition of land upon which it takes place from the time that it is taken over from the Farm Manager until it is returned.

A field team and its requirements

Field experiments are carried out by field teams: each field team consists of a leader and one or two assistants. The leader is usually a Scientific Officer or Higher Scientific Officer, who has been selected on the basis of past training or experience: his team is composed of Assistant Scientific Officers who are usually younger and less well qualified. In addition to its general training a team usually becomes specialised in a particular type of investigation, for example herbicide evaluation or grassland agronomy. A research section consists of a number of teams with skills appropriate to the role of the section.

The process by which a team develops its programme of work each year is as follows. Decisions on further progress in each project are reached at winter meetings between the Director and the departmental and section heads. In consultation with the section head the team leader decides upon the subjects that are to form the basis of his programme for the coming year. Once these are agreed, the team leader and his assistants plan the various details of the experiments. If the experiments are of a type necessitating placement at Begbroke Hill, a proposal is made to FEC. If a decision is taken to place the experiment on another farm, the team leader seeks a suitable site using his farmer contacts, assisted by the two Liaison Officers at Begbroke of the Agricultural Development and Advisory Service (ADAS). The decision to place the experiment at Begbroke Hill or elsewhere is governed by the circumstances of the experiment. There are certain activities that cannot be pursued on ordinary farms such as the deliberate planting of weeds or specific livestock control. On the other hand realism and wide variation in environmental circumstances are best achieved on ordinary farms. Once planning is complete and a site has been found the team's daily life is concerned with the execution of the planned programme through to the day when the experiment is concluded and there remains the summarising, interpretation and reporting of results. The activities of a team follow a seasonal pattern starting with planning during the winter, field activities during spring and summer, and writing up in autumn and early winter. The number of experiments undertaken in a year by a team varies considerably according to the complexity of the subject but averages between 15 and 25.

Once an experiment is launched, considerable responsibility rests with the team leader in the day-to-day decisions that he must make or remake according to the weather and the outcome of the treatments. To enable him to carry this responsibility he has considerable freedom of action to do what is necessary to ensure the success of the experiment and he obtains the full backing of all the resources at WRO to this end. Because of Britain's changeable weather the teams live a day-to-day existence in summer, sometimes working irregular hours, in order to keep up to date with their programmes. Efficient weather forecasting is essential and the success of a team in summer largely hinges on its leader's ability to make correct predictions of the weather, perhaps at a distance from WRO. One of the services provided by FEC is that of weather forecasting obtained from the local Meteorological Station.

The team leader can refer difficult decisions about his experiments to his section head but the latter cannot always hope to be intimately conversant with the details of all his teams' experiments which may be spread out across the country: he is in any case unlikely to be on the spot at the time. The role of the section head is to make decisions at the planning stage: once the experiments are launched he is a troubleshooter who seeks to observe and assist at points of greatest complexity and difficulty. He comes into the picture again as the results start to come in when his experience is necessary for the interpretation of results.

To ensure the field teams' mobility they are individually equipped with Land Rovers and small equipment for marking out, spraying and assessing experiments. In addition the teams may draw on a pool of larger equipment, farm tractors and machinery, most of which can be transported to outside experiments on trailers towed by Land Rovers.

The question of the distance of an experiment from base is often a difficult one to decide. It may be desirable to place an experiment in a particular area where the weed is a problem or where there is a particular farming system or contrasting climate but every extra mile from base involves valuable staff sitting in a vehicle when they might be working, and multiplies the complexities of servicing the equipment. It is a general rule that no experiment should be further away from WRO than is necessary. When away from Begbroke Hill the team leader is responsible for his team's work and good behaviour. If need be the team may stay away overnight in a hotel and a subsistence allowance is paid. Inevitably, experiments at distance involve extra hours of work and this also is paid as appropriate.

With a pre-planned programme to fulfil, committed to travel, and at the mercy of the weather, the teams are heavily dependent on the services provided at their base at Begbroke Hill. Delay in carrying out the repair of a Land Rover or the lack of an experimental chemical on the day when it is required could reduce the team to inactivity. The efficiency of the supporting services is an essential complement to the efficiency of the field teams.

The organization of supporting services

The services upon which field experimenters rely may be divided between those which are general to WRO (mostly controlled by WRO Secretary) and those which are specific to field experiments (mostly controlled by FEC). The general services consist of personnel administration, stores, engineering, carpentry and electrical workshops, vehicle maintenance and repair workshop, library and information section, canteen and social accommodation. The more specific services are: those already listed as provided by FEC, field chemical laboratory, farm services by the manager of Begbroke Hill Farm and clerical services. There are two additional services which do not fall into the categories described. WRO shares a statistical section with another ARC Institute (the Letcombe Laboratory): the section assists in the processing of experimental data using the computer at Rothamsted Experimental Station. Weather records are maintained by the Evaluation Section as a Station service. A special building provides offices, clean work rooms, general and soil processing rooms, ovens, low temperature storage, individual team stores, facilities for sprayer calibration etc. There is also a large barn in which is housed a variety of equipment designed for field experiments but too large for the team stores; in this barn are also the large experimental sprayers.

Maintenance of experimental equipment

The field experimenters themselves are responsible for the maintenance of experimental equipment. To obtain some cohesion in this task, one week in January is set aside each year. During this week (known as Maintenance Week) the checking, maintenance and repair of equipment associated with field experiments takes priority over other activities for staff of the rank of Higher Scientific Officer or below. An Equipment and Buildings Sub-Committee of FEC arranges for the examination of equipment in the autumn so that spare parts may be ordered and prepares a programme for Maintenance Week. When the week arrives the programme is put into effect using the 40 or so staff involved in field experiments. The work is communal and staff are sometimes put to work on unfamiliar equipment to widen their experience. In addition during this week, team stores are cleaned, protective clothing is examined, jets and sprayers are re-calibrated, vehicles are inspected and inventories are checked. Altogether Maintenance Week provides an opportunity for re-organization in preparation for the coming season.

Begbroke Hill Farm

The specification for a suitable farm upon which WRO might be placed was drawn up in 1956. It required that the land should be free draining with a light textured top soil. An even topography should contain large and rectangular fields. An overall size of 150 - 200 acres was required. The arable farm which forms the Western half of Begbroke Hill meets all these requirements admirably. The wet and low lying Eastern half is a valuable contrast and is maintained as grassland.

Since research takes priority over commercial activities on the farm the form of land use is designed to cope with this requirement. Field experiments can usually be divided into two categories: the majority last for one season only and with them the need is for a regular supply of ground each year which is relatively uniform in fertility and weed seed content and is free of herbicide residues; a lesser number of experiments are long term, lasting for four years or longer: the main requirement for these is lack of disturbance.

It was foreseen from the start that the provision of land for experiments in a high state of fertility and of efficient farm services could only be assured by a high standard of farming. It was also anticipated that there would be a desire to use the commercial farm as a working test-bed for new techniques developed in research. For these reasons it was considered important that efficient commercial farming should be run in balance with efficient field experimentation at Begbroke Hill and to meet this requirement a system of land use was devised that ensured a balance. The system allows the two requirements to balance: it has worked effectively and with very little friction for some 10 years.

Because the field teams do so much of the work on their own experiments, the farm staff's responsibility is limited to handing over land in a rough seedbed condition, to supplying seeds, fertilizers and machinery on demand and, in the case of certain complex machinery, to supplying an operator. To meet its commercial and experimental commitments the farm is provided with a manager, three men and one boy. Tasks requiring additional labour such as potato harvesting are assisted by casual workers. The farm manager is a key figure who spends a great deal of time assisting and advising field teams: he more than anyone else must ensure the day-to-day balance between research and farming. To do this he has to be a man of great experience and equable temperament.

Records both factual and financial are kept of all farm activities. For this purpose an accounting system was introduced within which the farm manager is regarded theoretically as a tenant of the Agricultural Research Council and pays rent for all the land at WRO. He is expected to give first priority to a contract service for experiments in which land and supplies are charged at cost. Tractors and other machinery are made available on demand and a charge is made according to a fixed scale: if a man is supplied with machinery an additional charge is made. The farm manager is expected to buy back any usable produce from the experiments. He does his own valuations and, assisted by WRO Secretary, produces a trading account each year. In a profitable year the farm is able substantially to meet the cost of services to experiments. As WRO is a state-financed organization no money changes hands in these accounting transactions but they have the important function of indicating the cost of experiments and measuring farm efficiency in relation to other commercial farms.

Experimental records

The basis of the experimental record system is that as long as an experiment is in being, ("live"), its records are held by the officer in charge. Once summarized and written up, the experiment is considered "dead" and the records are handed to the Field Experiments Committee for indexing and storage. At the time of handing over, relevant information obtained from the experiment is entered on a special form and this is transferred to cards in an index so that the information may be retrieved later if required. The index is a Carter Parratt and is similar to that used by WRO Information Section, in their production of Weed Abstracts. Thus an experimenter may concentrate his attention on his "live" experiments and his files are not encumbered with the results of past work.

During the life of an experiment the officer in charge is required to provide the Field Experiments Committee with a number of papers as follows:

1. A proposal form and, following this, a continuation proposal if the experiment lasts for more than one year.

2. An application for toxicological ('safety') clearance.

3. Details of treatments and layout when the experiment gets under way.

4. A summary of results.

5. The relevant forms for indexing.

6. All papers of the experiment when it is "dead".

Although this list may appear formidable it is the minimum necessary to ensure that sufficient information about the experiment is available to others. In practice the return of these papers may occur over a year or longer and it does not constitute a burden.

Such are the circumstances of field research at WRO that have led to the system which is now in use and which will be further described in a technical report to be issued shortly.

Proc. 11th Br. Weed Control Conf. (1972)

WEED CONTROL EXPERIMENTS IN THE TROPICS

L. Kasasian
Overseas Development Administration, Tropical Weed Section,
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary The purpose of this paper is primarily to draw attention to those ways in which weed control experiments in the tropics differ from those in temperate areas.

INTRODUCTION

For any research programme to be effective the first essential is correct priorities and it must always be borne in mind that in applied research these may be determined as much by economic and sociological factors as by purely technological ones. In tropical agriculture the need to reduce labour for weeding is generally much less pressing than in temperate areas but even in peasant agriculture there can be occasions when there is not enough labour to weed crops at the right time. Once labour-saving methods of weed control have been worked out, there is a good chance, in temperate areas, that they will be applied and this is often true of large-scale agriculture in the tropics. However, in tropical peasant agriculture this is by no means the general rule - the decisive factors are usually: (a) the unavailability of ready cash (credit is frequently difficult to get or only available at exhorbitant rates of interest) and (b) a highly conservative attitude that does not look kindly on innovation and change; in addition a lack of literacy may virtually rule out complicated or potentially dangerous techniques.

All these factors affect where one looks for answers to weed problems. It is, for example, unrealistic to work out a technique for applying soil-acting herbicides for general weed control and expecting peasant farmers to spend, what is to them, a large sum of money, if climatic conditions make weed (and even crop) germination uncertain. Again, the more herbicides a peasant farmer has to buy the greater is the chance of something going wrong and the less the chance he will buy any; it may therefore be best to try and find treatments the small farmer can use on a range of crops, even though such versatile treatments are rarely the best for any one crop. (This type of treatment may anyway be essential in areas where mixed-cropping is practiced.) I realise that this approach does encourage the spread of resistant weed species, but once the farmer is accustomed to using one herbicide, it should not be too difficult to get him to use others, when necessary, as long as costs are not increased. It may be argued that these types of problems also exist in temperate areas - this is probably true, but I am suggesting that the difference in magnitude of these factors, between temperate and tropical areas, is such that it is only in the tropics that they are likely to prove decisive.

The difficulty in establishing correct priorities in the tropics is aggravated by the isolation of agricultural specialists - this is particularly the case with weed workers as this is a field of work the importance of which is frequently not accepted. One result of this is that the highly complex field of chemical weed control is often regarded as a part-time job, thus the agronomist responsible is usually unable to devote adequate time to mastering and keeping up to date with the literature, and even if he can, he is often faced with a shortage of relevant and up to date publications. Frequently, the only other weed specialists the tropical weed agronomist sees, and with whom he can discuss weed problems in any depth, are commercial representatives. It would be unreasonable to expect entirely balanced advice from them, if for no other reason than they are of necessity more enthusiastic and better informed about the products of their own companies, than those of their competitors.

My argument is, of course, that there is little point in carrying out field experiments at all, let alone to the 'n'th degree of efficiency, if one asks the wrong questions or uses incorrect treatments and the right question may not be obvious.

LABOUR AND FIELD EQUIPMENT

As suggested above, the general (although not universal) ready availability and relative cheapness of labour in the tropics makes labour-saving techniques of less interest than in more highly developed areas. This has tended to decrease interest in new methods of weeding and where herbicides are used, to favour the use of knapsack, rather than tractor, sprayers. Many of the knapsack sprayers available at present are either not as reliable or as durable as they should be and spare parts are often difficult to obtain. Furthermore, knapsack sprayers fr quently cost as much as a peasant farmer in the tropics earns in a whole year. Unless these problems are resolved, it may therefore become necessary for herbicide agronomists in the tropics to try and develop granular treatments for crops other than rice, for even if weed control is not as good as with sprays it may still enable the small farmer to control his weeds during the critical establishment period when it may otherwise be impossible.

There are also positive aspects to be considered. For example, plentiful, cheap labour opens up the possibility of novel methods of application, such as overall soil injection, which could be entirely practicable on small holdings of 1/4 to 1/2 hectare. Cheap labour also gives the research worker a labour force that would be impossibly expensive elsewhere. Theoretically this makes it practicable to carry out time-consuming experiments and to make repeated and detailed assessments. However, the difficulty of providing adequate trained supervisors (and once one has obtained them of not losing them to more remunerative or easier employment) is apt to be a major deterrent to embarking on very ambitious programmes of labour-intensive research.

EXPERIMENTAL PROBLEMS

Workers in the tropics frequently find they lose 25% or more of their trials due to climatic troubles, pests, diseases and theft. None of these problems are exclusive to the tropics, but those who have not experienced them can easily overlook the devastating effect of torrential rainfall or prolonged drought. Pests and diseases are universal, but where they can proloferate throughout the year and are favoured by temperature and humidity, they can pose tremendous problems. There are even records of weed control trials being lost from trampling by elephants - hardly a problem in temperate areas!

Theft includes not only that of the end produce of a crop but also of shoots for cuttings, of good pegs for constructional purposes and of poor ones for firewood. Weeds may be harvested for human consumption (e.g. Amaranthus) or to feed livestock (e.g. grasses) and notices forbidding this may not be understood or may go the same way as the pegs.

One tends to guard against these, not at all uncommon, problems by not putting all one's eggs in one basket and by having as many as possible; inevitably this means a lot of small and perhaps not very exciting baskets. Another reason why agricultural research in the tropics tends to be concerned with short-term applied, rather than long-term fundamental, problems is the general lack of laboratory facilities, and in these days of increasingly expensive and sophisticated apparatus (which can be difficult to maintain) this factor must become increasingly important. I am not criticising this lack; indeed too often one sees large sums of money spent on supposedly prestigious apparatus, when the agronomists are unable to obtain even simple and cheap equipment.

EQUIPMENT FOR EXPERIMENTAL PURPOSES

In temperate areas the tendency has been to develop ever more sophisticated and expensive equipment that is quicker and easier to use. As such equipment gets talked about, the idea almost invariably gets around that it is indispensable. It cannot be said too often that the only essentials for a sprayer for experimental work are that it should be capable of delivering the spray evenly, safely and reliably and of being cleaned readily and effectively. There is no point in designing a sprayer which is easy to use if it is unreliable, or if it is difficult to repair, or if parts are difficult to get, or if it is so expensive that would-be purchasers find it prohibitive. For most purposes a 2½ litre garden compression sprayer, fitted with good nozzles and a pressure regulating valve, is entirely adequate. Such sprayers are cheap and simple and rarely go wrong and if they do, are usually easily repaired, without the need for anything more than a screwdriver, a pair of pliers, plumbers tape or some epoxy glue. Weed workers in the tropics frequently work over large areas and must therefore be self-contained. Another advantage of simple equipment is that it can be more compact and robust and thus more tolerant of being bounced around in the back of a Land Rover, over bad roads. It can also be lighter and thus easier to transport by air.

The present vogue of using liquid gas to propel the spray is all well and good if gas is available wherever and whenever wanted and is inexpensive. However, for most purposes this is a needless complication as well-designed small compression sprayers are so easy to pump up. If the tropical agronomist is personally too weary to do the pumping himself, he may well find it is cheaper and more trouble-free to employ an extra labourer just to pump up the sprayer, rather than to rely on compressors or gas, or if saving time is the major consideration then he can easily have an additional sprayer as they are so inexpensive. A word of warning may not be amiss here: however weary the agronomist is, he should avoid the temptation of letting one of his labourers spray his experiment for him.

Wheeled plot-sprayers are generally unsuitable for the tropics as rough seedbeds, drainage and irrigation ditches etc. make them difficult to use. Experiments in paddy crops are particularly difficult to spray evenly and long booms held by two men are not the answer, as anyone who has tried them knows. An additional problem is the possibility of the irrigation water moving chemicals from one plot to another. Both these problems can only be solved by having plots of a suitable shape and layout.

ASSESSMENT

It was pointed out earlier that plentiful, cheap casual labour may make detailed labour-intensive assessments more practicable in the tropics than elsewhere. Interim assessments usually pose more of a problem as the speed of plant growth makes frequent assessments essential. It is rarely that the interval between assessments can exceed a month and unusual for it to be longer than a fortnight. Moreover, the speed of attack by pests and diseases makes even more frequent assessments highly desirable if trials are not to be lost or misleading results obtained.

Thus if, spread over a wide area, one has many experiments that need frequent assessment, the only way out is to use a rapid method and generally the best compromise is to use visual assessments of plant vigour and percentage ground cover (perhaps combined into a single index).

CONCLUSION

The burden of my argument is that, in the tropics, field experimentation does not follow the path of increasing sophistication but rather that of simplification, almost of a reversion to methods used earlier in temperate areas. Whether or not such procedures can be considered advances is admittedly a matter of opinion.