WEED RESEARCH ORGANIZATION

TECHNICAL REPORT No. 81

THE SIDE EFFECTS OF ALLOXYDIM SODIUM, SETHOXYDIM, ACIFLUORFEN AND FLUAZIFOP-BUTYL ON LEGUME GROWTH AND NODULATION

J M BEBB, M P GREAVES AND W G RICHARDSON

JANUARY 1985

Price - £3.00

Agricultural and Food Research Council Weed Research Organization,
Begbroke Hill, Yarnton, Oxford, OX5 IPF

ISSN 0511 4136
ISBN 0 7084 0321 2

CONTENTS

	Page
SUMMARY	1
INTRODUCTION	1
MATERIAL AND METHODS	2
RESULTS	
ALLOXYDIM SODIUM	6
SETHOXYDIM	9
ACIFLUORFEN	14
FLUAZIFOP-BUTYL	16
ACKNOWLEDGEMENTS	19
REFERENCES	20

NOTE

BEBB, J.M., GREAVES, M.P. and RICHARDSON, W.G. The side-effects of alloxydim sodium, sethoxydim, acifluorfen and fluazifop-butyl on legume growth and nodulation. Technical Report Agricultural and Food Council Weed Research Organization 1985, 81, pp.20.

THE SIDE-EFFECTS OF ALLOXYDIM SODIUM, SETHOXYDIM, ACIFLUORFEN AND FLUAZIFOP-BUTYL ON LEGUME GROWTH AND NODULATION.

J.M. BEBB, M.P. GREAVES and W.G. RICHARDSON

AFRC Weed Research Organization, Begbroke Hill,
Yarnton, Oxford OX5 1PF

Summary

The effects of four herbicides (alloxydim sodium, sethoxydim, acifluorfen and fluazifop-butyl), were examined on growth and nodulation of five representative leguminous plants; peas, dwarf french beans, field bean, clover and fenugreek.

Effects on plant growth were variable, with factors such as: time of spraying, fertilizer application and sample date all playing a part in this variation.

Alloxydim sodium slightly inhibited pea growth and nodulation, but this effect was minimized when the plants were sprayed at the 6 leaf stage, rather than the 3 leaf stage. Sethoxydim, sprayed at high doses, decreased nodulation in most legume species. Acifluorfen caused a reduction in growth of dwarf french beans and field beans. Nodulation of fenugreek and clover can be severely reduced by fluazifop-butyl, though clover may recover after time.

Introduction

The selectivities of new herbicides are investigated at WRO on a large number of crop and weed species grown in pots. One objective of these studies is to discover crop susceptibilities and to obtain experience of the type of effects produced by each compound.

Amongst the crop species examined are a number of legumes and, since, any effect of herbicides on nodulation could have serious consequences, nodulation is examined visually on legumes treated in all activity and selectivity tests. Any herbicide effecting nodulation in these tests may then be examined in more detail in subsequent experiments. This report describes the results of such experiments on four herbicides.

There are limitations to these experiments. One is that, only one crop variety and one soil type is used. Also plant responses in pot experiments can be very different to those in the field. Thus, the results described should be regarded with caution.

Material and Methods

Soil

A sandy loam soil (Begbroke North), taken from a field at WRO was used for all experiments. The organic matter content is 4.1%, clay content 15% and the pH was 7.0. The soil was sieved (5 mm), mixed with the fertilizers and pesticides shown in Table 1, and placed in 12.5 cm pots.

Fertilizer

Osmocote, controlled release fertilizer, (Sierra Chemicals Europe, Nuverheidsweg 5, Heerlen, Nederland):-
Brown: NPK 15:12:15; short-term release (3-4 months).
Blue: NPK 18:11:10; long-term release (8-9 months).

Vitax QS3, controlled release fertilizer, (Steetly Chemicals Ltd., Liverpool Road North, Burscough, Ormskirk, Lancs L40 OSB) NPK 12:6:5; medium term release (6 months).

Inoculum

In some experiments the plants were inoculated with Rhizobium spp. as shown in Table 2.

A starter culture (100 mls) of Rhizobium spp. was grown in a yeast mannitol liquid medium (Vincent J M, 1970) at 18^{o}C for 5 days with stirring and aeration. This was used to inoculate a 2 litre batch of the same medium and grown for a further 5 days at 18^{o}C, and then mixed with dried, sieved peat to give a moisture content of approximately 50%. The peat inoculum was incubated for a further 5 days at 18^{o}C, and approximately 1 g was added with each seed as it was planted.

Greenhouse Conditions

All experiments were done under greenhouse conditions. During the period October - March additional lighting was provided with sodium lights giving a 14 hour day length. Plants were watered from above as required and when necessary supported with stakes. Maximum, minimum and mean temperatures for each experiment are shown in Table 1.

Spraying

All the herbicides were applied with a laboratory pot sprayer operating at a pressure of 207 kPa (30 lb in^{-2}) at a constant speed 30 cm above the plants.

Sampling Procedure

Replicate pots were removed from the greenhouse at the appropriate sampling time. The shoots were cut off at soil level, fresh weights of shoots and pods (if present), were measured. After drying overnight at 105°C the dry weights were also recorded. Roots were removed from the pots and washed to remove the adhering soil, care being taken not to damage or detach any nodules. Greaves M.P., Lockhart L.A. and Richardson W.G. (1978) assessed nodulation in two ways; by excising the nodules and weighing them, and nitrogenase analysis. Neither method proved satisfactory, as the removal of the nodules was excessively time consuming, and the nitrogenase activity varied according to light intensity. In all our experiments the degree of nodulation was assessed visually. The nodulation of the control plants, which were healthy in appearance, unless otherwise stated, was scored as 10 and all treatments scored by comparison. This technique does not permit viable statistical analysis. Root systems were blotted to remove excess water, and fresh and dry weights were recorded. Other experimental details are recorded in Table 2.

Plants grown during tests of herbicide efficacy and selectivity were examined occasionally. Replication in these observations does not permit detailed statistical analysis and thus comments on effects must be viewed with caution.

TABLE 1

FERTILIZER TREATMENTS AND GREENHOUSE TEMPERATURES IN NODULATION EXPERIMENTS

EXPT. NO.	OSMOCOTE BROWN 15:12:15 g kg^{-1} SOIL	OSMOCOTE BLUE 18:11:10 g kg^{-1} SOIL	VITAX QS3 12:6:5 g kg^{-1} SOIL	MAGNESIUM SULPHATE g kg^{-1} SOIL	5% DDT g kg^{-1} SOIL	SUPERPHOSPHATE OF LIME g kg^{-1} SOIL	TEMPERATURES (^{o}C) MEAN	MAX.	MIN.
1	1.8	-	-	1.0	0.5	1.2	14	18	8
2	0.2,0.8,3.5	-	-	1.0	0.5	1.2	14	18	8
3	-	-	-	-	-	-	19	29	12
4	-	-	-	1.0	0.5	1.2	19	29	13
5									
Peas	-	-	-	1.0	0.5	1.2			
Dwarf French Bean	-	-	-	1.0	0.5	1.2	19	29	13
Field Bean	-	-	3.0	1.0	0.5	1.2			
6	-	1.8	-	1.0	0.5	1.2	15	23	8
7	-	-	3.0	1.0	0.5	1.2	13	17	8

TABLE 2

PLANT DATA FOR NODULATION EXPERIMENTS

EXP. NO. DATES	SPECIES	CULTIVAR	NO. PLANTS/POT INITIALLY & FINALLY	GROWTH STAGE AT SPRAY	ASSESSMENT WEEKS AFTER SPRAY	INOCULUM	HERBICIDE & DOSE $(kg\ ha^{-1})$
1 2.10.78- 9.1.79	Pea	Dark Skinned Perfection	5 - 1	3 Leaf & 6 Leaf	3,6,10	Rhizobium leguminosarum RCR 1045	Alloxydim sodium 2
2 12.10.78-10.1.79	Pea	Dark Skinned Perfection	5 - 1	3 Leaf	3,6,10	Rhizobium leguminosarum RCR 1045	Alloxydim sodium 2
3 22.5.79-27.7.79	Pea	Dark Skinned Perfection	5 - 1	3 Leaf 6 Leaf	3,6,8	-	Sethoxydim 0.1,0.4,1.6
4 4.7.79- 3.9.79	Pea	Dark Skinned Perfection	5 - 1	3 Leaf & 6 Leaf	3,5	-	Sethoxydim 1.0
5 4.7.79-18.9.79	Pea	Dark Skinned Perfection	5 - 1	3 Leaf	3,7	-	Sethoxydim 0.4,1.0,1.6
14.9.79-15.11.79	Dwarf french bean	The Prince	3 - 1	2 Unifoliate leaves	3,6	Rhizobium phaseoli RCR 3605	0.4,1.0,1.6
29.11.79- 6.3.80	Field bean	Maris Bead	3 - 1	3 Leaf	4,8	-	0.4,1.0,1.6
6 20.2.79- 1.6.79	Pea	Dark Skinned Perfection	5 - 1	pre-emergence	6,11,14	Rhizobium leguminosarum	Acifluorfen 0.1,0.4,1.6
7 19.11.79-13.3.80	White Clover	Kent Wild	10 - 5	2-3 Leaves	4,10	-	Fluazifop-butyl 0.1,0.4,1.0

Results

ALLOXYDIM SODIUM

Code Number NP48, BAS 9021
Trade names Fervin, Clout.
Chemical name 2-(1-allyloxyaminobutylidene)-5,5-dimethyl-4-methoxycarbonyl cyclohexane-1,3-dione (sodium salt)
Source Nippon Soda Co. Ltd., Agrochemicals Department, 221 Ohtemachi, Chiyoda-ku, Tokyo, Japan.
Formulation 75% w/w a.i. water soluble powder.
Spray volume 345 l ha^{-1}.
Spray rates used in experiments 2 kg a.i. ha^{-1}.
Information available and suggested use

The suggested post-emergence use is for control of grass weeds. Broad-leaved weeds are resistant. Dosage for annual weeds, 1.0 - 2.0 kg a.i. ha^{-1}; for perennials 1.5 - 2.5 kg a.i. ha^{-1}, two application times being advisable. Recommended for use in sugar beet, cotton and rape. Other tolerant crops include:- groundnut, potato, beans, sunflower, tobacco, vines and various vegetables. Also active pre-emergence but not recommended due to its short persistence in soil. See also Richardson and Parker (1978).

Results

Experiment 1

Table 3. Effect of growth stage at spraying on response of peas to alloxydim sodium (2kg a.i. ha^{-1}).

	Spray Stages					
	3 leaf			6 leaf		
Sample time (wks after spraying)	3	6	10	3	6	10
Shoot dry wt.▽	94	88	76*	96	ND	87
Root dry wt.▽	93	89	78*	89	ND	96
Nodule index	ND	10	8.5	10	ND	13

▽ Results expressed as % of control
* Significant difference from control at $P < 0.05$
ND - Not Determined

Comments on Results

Experiment 1 (Table 3)

Spraying at the 3 leaf stage decreased the root and shoot dry weights at both 3 and 6 week sample dates. Ten weeks after spraying the decreases were statistically significant. The reduction in root dry weight at 10 weeks was accompanied by a small but noticeable reduction in nodulation. No significant weight decreases occurred with peas sprayed at the 6 leaf stage, and nodulation appeared to be slightly increased by the herbicide. Slight, non-signficant reduction in pod yield was associated with the herbicide treatment at both growth stages.

Similar results were found in earlier experiments by Greaves *et al.*, (1978).

Experiment 2

Table 4. Effect of fertilizer level on the response of peas to alloxydim sodium (2 kg a.i. ha^{-1})

Fertilizer level ($g\ kg^{-1}$ soil)		Sample time (weeks after spraying) 3	6	10
		Shoot dry wt.▽		
0		97	95	82*
0.2		95	93	91
0.8		89	84*	80
3.5		90	77*	95
		Root dry wt.▽		
0		90	73*	82*
0.2		84	66*	76*
0.8		88	90	72*
3.5		64*	61*	111
		Pod dry wt.▽		
0		ND	ND	184*
0.2		ND	ND	156
0.8		ND	ND	103
3.5		ND	ND	184
		Nodule index		
0	Control	10	10	10
	Herbicide	9	8	9.5
0.2	Control	3	7	7.5
	Herbicide	2	5	6.5
0.8	Control	1	3	3.5
	Herbicide	1	4	2.5
3.5	Control	0	1	0.5
	Herbicide	0	0	0

▽ Results expressed as % of control
* Significant difference from control at $P < 0.05$
ND Not Determined

Comments on Results

Experiment 2. (Table 4)

Alloxydim sodium treatment reduced shoot dry weight at all fertilizer levels, confirming the results following spraying at the 3 leaf stage in experiment 1. This effect increased with time after spraying up to the final assessment at 10 weeks, except at the 3.5 g kg^{-1} fertilizer level when the maximum effect occurred at 6 weeks. As shoot dry weights varied appreciably, the only statistically significant effects occurred at 10 weeks (0 fertilizer) and 6 weeks (3.5 g kg^{-1} fertilizer). Root dry weights were reduced by the herbicide at all fertilizer levels. The results were less variable than those of the shoots and, thus the effects were more frequently statistically significant.

Increasing the amount of fertilizer decreased nodulation markedly at all sample dates, and caused the replacement of large, pink, healthy nodules with small, white, ineffective nodules. The herbicide had only a slight additional effect on nodule density. Herbicide treatment appeared to increase pod yield at all fertilizer levels, but the effect was significant only when no fertilizer was used, it was also noted that at this fertilizer level the plants flowered earlier than all other treatments.

The plants grown at the 3.5 g kg^{-1} fertilizer level were very much larger than those grown at all other fertilizer levels. Consequently retention of the herbicide was affected, being 7 to 15 times higher than plants grown at lower fertilizer levels. Retained herbicide was removed from plants by washing with 0.1M NaOH. The alloxydim sodium was partitioned into hexane and determined by gas liquid chromatography (pers. comm. E. G. Cotterill). Considering the very large increase in retention it is reassuring that the effects on plant growth and nodulation are not increased proportionally.

Conclusions

Alloxydim sodium has only slight inhibitory effects on pea growth and nodulation. These effects are minimized or eliminated if the plants are sprayed at the 6 leaf stage, rather than the 3 leaf stage.

SETHOXYDIM

Code number NP 55, ARD 34/02
Chemical name 2-(N-ethoxybutyrimidoyl)-5-(2-ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one.
Source May & Baker Ltd., Ongar Research Station, Fyfield Road, Ongar, Essex, UK.
Formulation 19.3% w/v a.i. emulsifiable concentrate
Spray volume 370 l ha^{-1}.
Spray rates used in experiments 0.1, 0.4, 1.0, and 1.6 kg a.i. ha^{-1}.
Information available and suggested uses.

Used to control grass weeds in broad leaved crops. The herbicide is absorbed by both roots and shoots, and because of its short persistence its main use is post-emergence. Efficiency and speed of action is increased by warm wet conditions, and decreased by cold dry conditions. Tolerant crops include peas, field beans, dwarf french beans, onions and several other vegetables.

RESULTS

Experiment 3.

Table 5. Effect of dose rate of sethoxydim on growth and nodulation of peas

Dose (kg ha^{-1})	Sample time (weeks after spraying) 3	6	8
	Shoot dry wt.▽		
0.4	102	94	94
1.0	91	95	101
1.6	99	74	88
	Root dry wt.▽		
0.4	98	103	97
1.0	92	117	110
1.6	93	101	92
	Nodule index		
0.4	10	10	5
1.0	6	8	6
1.6	3	4	4

▽ Results are expressed as % of control

Comments on Results

Experiment 3 (Table 5).

There was no significant decrease in root and shoot dry weights at any of the sample times. Nodulation was markedly reduced at the higher herbicide concentrations, and by the final assessment similar reductions were found in the lower doses. There was no effect on the pod yield.

Experiment 4.

Table 6. Effect of growth stage at spraying on response of peas to sethoxydim ($1\ kg\ ha^{-1}$)

	Growth stages at spraying			
	3 leaf		6 leaf	
Sample time (weeks after spraying)	3	5	3	5
Shoot dry wt. ▽	126	106	94	87
Root dry wt. ▽	110	104	97	101
Nodule Index	8	4	8	7

▽ Results are expressed as % of control

Comments on Results

Experiment 4. (Table 6).

The plants in this experiment were grown in soil with no added fertilizer, and the experiment had to be terminated early due to severe growth of downy mildew on all the peas. Thus, the results must be interpreted with caution. However, it does appear that there was no harmful effect of the herbicide on the plant growth, although after 5 weeks nodulation appeared to be inhibited in plants sprayed at the 3 leaf stage.

Experiment 5

Table 7 The effect of sethoxydim at 3 dose rates on peas

Herbicide dose ($kg\ ha^{-1}$)	Sample time (weeks after spraying) 3	7
	Shoot dry wt.▽	
0.4	101	107
1.0	97	115
1.6	99	103
	Root dry wt. ▽	
0.4	96	112
1.0	93	111
1.6	93	105
	Pod dry wt. ▽	
0.4	ND	114
1.0	ND	116
1.6	ND	115
	Nodule index	
0.4	9	6
1.0	7	6
1.6	6	8

▽ Results expressed as % of control

ND Not determined

Table 8 The effect of sethoxydim at 3 dose rates on dwarf french beans

Herbicide dose ($kg\ ha^{-1}$)	Sample time (weeks after spraying) 3	6
	Shoot dry wt.▽	
0.4	106	101
1.0	94	99
1.6	103	95
	Root dry wt.▽	
0.4	125	105
1.0	118	106
1.6	118	87

▽ Results expressed as % of control

Table 9. The effect of sethoxydim at 3 dose rates on field beans

Herbicide dose ($kg\ ha^{-1}$)	Sample time (weeks after spraying) + VITAX 4	+ VITAX 8	- VITAX 8
	Shoot dry wt.▽		
0.4	88	84*	93
1.0	82	91	94
1.6	72*	79*	96
	Root dry wt.▽		
0.4	89	83	81
1.0	72*	83	81
1.6	77*	64*	74
	Nodule index		
0.4	3	3	7
1.0	1	5	5
1.6	5	1	3

▽ Results expressed as % of control
* Significant difference to control at $P \leqslant 0.05$

Comments on Results

Experiment 5 (Tables 7-9)

Peas (Table 7)

The peas sprayed with a high concentration of sethoxydim showed signs of spray damage, scorching of the lower leaves. By the final harvest all the peas were badly infected with mildew, so care must be taken in interpretation of the results. Sethoxydim had little if any effect on the root and shoot dry weights of the peas at either harvest time. Nodulation was reduced, but pod yield increased slightly with herbicide dose.

Dwarf french beans (Table 8)

Growth was poor, and consequently the plants were harvested early. There was little effect of sethoxydim on the shoot dry weights, and only a slight stimulation of root growth at the 3 week sampling. The plants did not nodulate, despite being inoculated with *Rhizobium phaseoli*, and being grown in soil not amended with fertilizer.

Field beans (Table 9)

The main part of the experiment consisted of field beans grown in soil amended with Vitax QS3, and a smaller section in soil without Vitax. Initial observation of all the beans showed that the plants sprayed with the highest dose of sethoxydim showed signs of spray damage, lower leaves being scorched and dying off.

The growth of plants in soil with fertilizer were inhibited by sethoxydim with reductions in both the root and shoot dry weights. Nodulation was severely inhibited.

The beans grown in soil with no Vitax showed little effect of sethoxydim on the shoots, but there were reductions in the root dry weights, and a reduction in nodule index, increasing with dose.

There were more nodules on beans grown in soil with no fertilizer than those grown with fertilizer.

Herbicide Selectivity Evaluation (Richardson, West and Parker, 1980)

Table 10. Effects of sethoxydim on fenugreek, field bean, pea and white clover.

Herbicide dose (kg ha^{-1})	Fenugreek	Field bean	Pea	Clover
		Shoot dry wt. ▽		
0.1	56	ND	96	114
0.4	75	65	79	99
1.6	73	86	73	98
		Root dry wt. ▽		
0.1	59	ND	87	101
0.4	74	67	76	86
1.6	75	106	73	79
		Nodules		
0.1	5	ND	7	10
0.4	11	6	5	10
1.6	6	5	8	10

▽ Results expressed as % control Sampled 5 weeks after spraying.

Herbicide Selectivity Evaluation (Richardson, West and Parker, 1980)

Table 11. Effect of different types of application of sethoxydim on dwarf french beans.

Herbicide application:-	A	B	C
Herbicide dose ($kg\ ha^{-1}$)			
	Shoot dry wt.▽		
0.4	122	91	106
1.6	130	98	71
	Root dry wt.▽		
0.4	54	136	123
1.6	82	133	100

▽ results expressed as % control. Sampled 8 weeks after spraying.
A - pre-emergence; soil surface sprayed.
B - pre-emergence; herbicide incorporated into soil.
C - post emergence.

Comments on Results

Herbicide Selectivity Evaluation (Tables 10 and 11) (Richardson, West & Parker, 1980)

Work done in routine herbicide tests included experiments on the effect of sethoxydim on several legumes. Root and shoot dry weights of peas were reduced by up to 27% at the highest herbicide concentration and nodulation was also reduced. Fenugreek and field beans were affected similarly except at the highest concentration where the root dry weights of field beans were slightly increased. There was little effect on clover.

Different application methods of sethoxydim were tested on dwarf french beans. Spraying directly onto the soil surface prior to emergence resulted in a marked reduction of root dry weight, particularly at the lowest dose, but there was no increase in shoot weight. In contrast, when the herbicide was incorporated into the soil after pre-emergence application, root dry weight was increased and shoot weights were scarcely affected. Post-emergence treatment also resulted in an increase of root dry weight, but only at the low dose. There was some reduction of the shoot growth at the high dose. Again, this species did not nodulate.

Conclusions

Effects of sethoxydim on plant growth were generally small and variable. Nodulation was decreased, particularly by the higher herbicide dose rates, in all the legume species tested except clover.

ACIFLUORFEN Sodium

Code number RH 6201
Trade name Blazer
Chemical name Sodium 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate
Source Rohm & Haas (UK) Ltd., Lennig House, 2, Masons Avenue, Croydon, Surrey, CR9 3NB UK.
Formulation 48% w/v a.i. aqueous concentrate, sodium salt.
Spray volume 437 l ha^{-1}.
Spray rates used in experiments 0.1, 0.4 and 1.6 kg ha^{-1}.
Information available and suggested uses

A contact and residual herbicide, pre- and post-emergence control of most broadleaf weeds in all large seeded legumes (soyabean, peas, beans, peanuts). Current problem weeds such as cocklebur, velvetleaf, morningglory are susceptible at 0.56 kg ha^{-1}. Its chemical, physical and biological properties have been reported by Johnson et al 1978.

Results

Experiment 6

Table 12. The effect of a pre-emergence spray of acifluorfen on growth of peas

Herbicide dose (kg ha^{-1})	Sample date (wks after spraying/planting)		
	6	11	14
	Shoot dry wt.▽		
0.1	110	88	98
0.4	129	100	98
1.6	116	104	118
	Root dry wt.▽		
0.1	107	111	64
0.4	141*	103	82
1.6	122	60	90
	Pod dry wt.▽		
0.1	ND	ND	97
0.4	ND	ND	92
1.6	ND	ND	93

▽ Results expressed as % of control
* Significant difference from control at $P < 0.05$
ND Not Determined

Comments on Results

Experiment 6. (Table 12)

At the early sample date there was a tendency towards stimulation of both root and shoot dry weights, the stimulation of root dry weight being significant at 0.4 kg ha^{-1}. At the final harvest, this effect had generally reversed into a slight reduction. Nodulation was poor throughout the experiment, despite inoculation with the appropriate rhizobium culture, thus nodulation was not assessed. Pod dry weights were only slightly reduced.

Herbicide Selectivity Evaluation (Richardson, West and Parker, 1979)

Table 13. Effects of acifluorfen on growth of dwarf french beans and field beans.

Herbicide dose (kg ha^{-1})	DWARF FRENCH BEANS	FIELD BEANS
	Shoot dry wt. ▽	
0.1	87	89
0.4	83	87
1.6	52	66
	Root dry wt. ▽	
0.1	105	116
0.4	79	86
1.6	41	68

▽ Results expressed as % of control
Plants assessed 6 weeks after spraying.

Comments on results

Herbicide Selectivity Evaluation (Table 13)

This experiment showed a reduction in root and shoot dry weights in both dwarf french beans and field beans, the effect increased with dose in both cases. No nodulation assessment was made due to poor nodulation of both species.

Peas were also tested in this experiment but only at 1.6 kg ha^{-1}, and at this dose there was a reduction in root and shoot dry weight to 84 and 98% of control respectively. Nodulation was also reduced to an index value of 6.

Conclusions

In general acifluorfen had little significant effect on pea growth, although nodulation was reduced. However, the reduction in growth of dwarf french beans and field beans may be of some concern, and will need further investigation.

FLUAZIFOP-BUTYL

Code number PP009
Trade name Fusilade
Chemical name Butyl 2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy] propionate
Source ICI Plant Protection Ltd., Jealotts Hill Research Station, Bracknell, Berks RG12 6EY UK.
Formulation 25% w/v a.i. emulsifiable concentrate.
Spray volume 370 l ha^{-1}.
Spray rates used in experiments 0.1, 0.4, 1.0 and 1.6 kg ha^{-1}.
Information available and suggested uses

Selective post-emergence herbicide for control of annual and perennial grass weeds in broad-leaved crops (sugar beet, winter oil seed rape, field beans, cabbage, potatoes). Weeds controlled include; rye grass, wild oats, black grass, barren brome and couch. Treatment is only necessary on the appearance of the weeds.

Results

Experiment 7

Table 14. The effect of fluazifop-butyl on white clover

Herbicide dose (kg ha^{-1})	Sample time (weeks after spraying)		
	+ VITAX		- VITAX
	4	10	10
	Shoot dry wt.▽		
0.1	98	96	93
0.4	89	91	ND
1.0	72*	92	87
1.6	86	93	89
	Root dry wt.▽		
0.1	94	95	95
0.4	86	87	ND
1.0	70*	97	97
1.6	85	99	103
	Nodule index		
0.1	1	8	5
0.4	3	7	ND
1.0	1	7	5
1.6	3	6	5

▽ Results expressed as % control
* Significant difference from control at $P \leq 0.05$
ND Not determined

Comments on Results

Experiment 7 (Table 14).

In soil amended with fertilizer, fluazifop-butyl caused small reductions in both root and shoot dry weights at all concentrations. This effect was statistically significant at the 1.0 kg ha^{-1} dose 4 weeks after spraying, but by 10 weeks the plants had recovered. In the absence of fertilizer the effects at 10 weeks were similar.

In fertilized soil, nodulation, was initially severely affected by all doses but showed some recovery, after 10 weeks. In contrast, in unfertilized soil nodulation was markedly reduced by all doses 10 weeks after treatment.

Herbicide Selectivity Evaluation (Richardson, West and Parker, 1980)

Table 15. Effect of post emergence treatment with fluazifop-butyl on growth and nodulation of white clover and dwarf french beans.

Herbicide dose (kg ha^{-1})	CLOVER	DWARF FRENCH BEANS
		Shoot dry wt.▽
0.1	107	106
0.4	147	119
1.6	109	66
		Root dry wt.▽
0.1	129	94
0.4	160	105
1.6	148	90
		Nodule index
0.1	9	ND
0.4	6	ND
1.6	4	ND

▽ Results expressed as % control
Plants assessed 5 weeks after spraying

Table 16. Effect of post emergence treatment with fluazifop-butyl on growth and nodulation of fenugreek, pea and field bean.

Herbicide dose (kg ha^{-1})	FENUGREEK	PEA	FIELD BEAN
	Shoot dry wt.▽		
0.1	103	81	86
0.4	132	89	89
1.6	116	112	88
	Root dry wt.▽		
0.1	91	87	96
0.4	113	74	90
1.6	98	89	83
	Nodule Index		
0.1	3	7	5
0.4	1	8	7
1.6	3	10	9

▽ Results expressed as % of control
Plants assessed 5 weeks after spraying

Table 17. Effect of fluazifop-butyl on the growth of dwarf french beans

Herbicide Treatment:- Herbicide dose (kg ha^{-1})	A	B	C	D
	Shoot dry wt.▽			
0.1	97	118	80	107
0.4	74	100	99	87
1.6	88	82	79	87
	Root dry wt.▽			
0.1	101	119	67	82
0.4	75	112	95	72
1.6	104	94	73	70

▽ - Results expressed as % of control
A - Post-emergence, foliar spray only
B - Post-emergence, soil drench
C - Pre-emergence, soil surface sprayed
D - Pre-emergence, herbicide incorporated into soil
Plants assessed 8 weeks after treatment

Comments on Results

Herbicide Selectivity Evaluation (Table 15-17)

Earlier work at WRO (Richardson, West and Parker, 1980) (Table 15) showed that although nodulation of clover was progressively reduced by increasing dose rate both shoot and root growth showed increases due to herbicide treatment.

Dwarf french beans showed only very slight and variable growth responses, except for a 34% decrease in shoot dry weight caused by 1.6 kg ha^{-1} fluazifop-butyl. Nodulation did not occur with this species.

Fluazifop butyl increased shoot dry weights of fenugreek and caused small and variable effects on root growth. With peas and field bean, both root and shoot dry weights were generally reduced.

Nodulation was severely inhibited in fenugreek at all doses, despite only slight effects on roots and shoots. In contrast nodulation of pea and field bean was only slightly reduced, the effect being greatest at the lowest dose.

Assessment of the effect of application method (Table 17) showed that, in general, root and shoot growth were reduced by pre-emergence treatments, particularly when the herbicide was not subsequently incorporated. Only at 0.4 kg ha^{-1} did post-emergent treatment cause any notable reduction.

Conclusions

Fluazifop-butyl effects on growth of the species tested were generally small. However, the increased shoot growth of fenugreek and clover is of interest. Nodulation of fenugreek and clover can be markedly reduced, though, in the case of clover at least, this may recover some time after spraying (Table 14).

Although pre-emergence treatment of dwarf french bean caused damaging effects, this is at present of little practical importance as the herbicide is only recommended for post-emergence use.

ACKNOWLEDGEMENTS

The authors are grateful to the W.R.O. Statistics section for their help in the statistical analysis of the data. We are also most grateful to Mrs M. Cox for the preparation and typing of this report.

REFERENCES

GREAVES, M.P., LOCKHART, L.A. and RICHARDSON, W.G. (1978). Measurement of herbicide effects on nitrogen fixation by legumes. Proceedings 1978 British Crop Protection Conference - Weeds.

JOHNEN, B.G., DREW, E.A. & CASTLE, D.L. (1979). Studies on the effect of pesticides on symbiotic nitrogen fixation. In Soil borne plant pathogens (Ed. Schippers, B. & Gams, W.) 44, 513-523.

JOHNSON, W.O., KOLLMAN, G.E., SWITHENBANK, C. and YIH, R.H. (1978). RH 6201 (Blazer) : A new broad spectrum herbicide for post-emergence use in soyabeans. Journal of Agricultural and Food Chemistry, 26, (1), 285-286.

RICHARDSON, W.G. and PARKER, C. (1978). The activity and post-emergence selectivity of some recently developed herbicides: NP 48, RH 5205 and pyridate. Technical Report Agricultural Research Council Weed Research Organization, 49, pp.38.

RICHARDSON, W.G., WEST, T.M. and PARKER, C. (1979). The activity and pre-emergence selectivity of some recently developed herbicides: R 40244, AC 206784, pendimethalin, butralin, acifluorfen and FMC 39821. Technical Report Agricultural Research Council Weed Research Organization, 57, pp.71.

RICHARDSON, W.G., WEST, T.M. and PARKER, C. (1980). The activity and post-emergence selectivity of some recently developed herbicides: R40244, DPX 4189, acifluorfen, ARD 34/02 (NP 55) and PP 009. Technical Report Agricultural Research Council Weed Research Organization, 61, pp.57.

VINCENT, J.M. (1970). A manual for the practical study of root-nodule bacteria. IBP Handbook No.15, Blackwell Scientific Publications, Oxford. 116-120.

ABBREVIATIONS

ångström	Å
Abstract	Abs.
acid equivalent*	a.e.
acre	ac
active ingredient*	a.i.
approximately equal to*	≃
aqueous concentrate	a.c.
bibliography	bibl.
boiling point	b.p.
bushel	bu
centigrade	C
centimetre*	cm
concentrated	concd
concentration	concn
concentration x time product	ct
concentration required to kill 50% test animals	LC50
cubic centimetre*	cm^3
cubic foot*	ft^3
cubic inch*	in^3
cubic metre*	m^3
cubic yard*	yd^3
cultivar(s)	cv.
curie*	Ci
degree Celsius*	^oC
degree centigrade	^oC
degree Fahrenheit*	^oF
diameter	diam.
diameter at breast height	d.b.h.
divided by*	÷ or /
dry matter	d.m.
emulsifiable concentrate	e.c.
equal to*	=
fluid	fl.
foot	ft
freezing point	f.p.
from summary	F.s.
gallon	gal
gallons per hour	gal/h
gallons per acre	gal/ac
gas liquid chromatography	GLC
gramme	g
hectare	ha
hectokilogram	hkg
high volume	HV
horse power	hp
hour	h
hundredweight*	cwt
hydrogen ion concentration*	pH
inch	in.
infra red	i.r.
kilogramme	kg
kilo ($x10^3$)	k
less than	<
litre	l.
low volume	LV
maximum	max.
median lethal dose	LD50
medium volume	MV
melting point	m.p.
metre	m
micro ($x10^{-6}$)	μ
microgramme*	μg
micromicro (pico: $x10^{-12}$)*	μμ
micrometre (micron)*	μm (or μ)
micron (micrometre)* †	μm (or μ)
miles per hour*	mile/h
milli ($x10^{-3}$)	m
milliequivalent*	m.equiv.
milligramme	mg
millilitre	ml

† The name micrometre is preferred to micron and μm is preferred to μ.

millimetre*	mm
millimicro* (nano: $x10^{-9}$)	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	$>$
multiplied by*	x
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million	ppm
parts per million by volume	ppmv
parts per million by weight	ppmw
percent(age)	%
pico (micromicro: $x10^{-12}$)	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	±
post-emergence	post-em
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.

pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch	in^2
square metre*	m^2
square root of*	$\sqrt{\ }$
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables etc.

WEED RESEARCH ORGANIZATION

TECHNICAL REPORTS

(Price includes surface mail; airmail £2.00 extra)

(* denotes Reports now out of print)

6. The botany, ecology, agronomy and control of Poa trivialis L. rough-stalked meadow-grass. November 1966. G P Allen. Price - £0.25

7. Flame cultivation experiments 1965. October 1966. G W Ivens. Price - £0.25

8. The development of selective herbicides for kale in the United Kingdom. 2. The methylthiotriazines. Price - £0.25

10. The liverwort, Marchantia polymorpha L. as a weed problem in horticulture; its extent and control. July 1968. I E Henson. Price - £0.25

11. Raising plants for herbicide evaluation; a comparison of compost types. July 1968. I E Henson. Price - £0.25

*12. Studies on the regeneration of perennial weeds in the glasshouse; I. Temperate species. May 1969. I E Henson. Price - £0.25

13. Changes in the germination capacity of three Polygonum species following low temperature moist storage. June 1969. I E Henson. Price - £0.25

14. Studies on the regeneration of perennial weeds in the glasshouse. II. Tropical species. May 1970. I E Henson. Price - £0.25

15. Methods of analysis for herbicide residues. February 1977. (second edition). Price - £5.75

16. Report on a joint survey of the presence of wild oat seeds in cereal seed drills in the United Kingdom during spring 1970. November 1970. J G Elliott and P J Attwood. Price - £0.25

17. The pre-emergence selectivity of some newly developed herbicides, Orga 3045 (in comparison with dalapon), haloxydine (PP 493), HZ 52.112, pronamide (RH 315) and R 12001. January 1971. W G Richardson, C Parker and K Holly. Price - £0.25

18. A survey from the roadside of the state of post-harvest operations in Oxfordshire in 1971. November 1971. A Phillipson. Price - £0.25

*19. The pre-emergence selectivity of some recently developed herbicides in jute, kenaf and sesamum, and their activity against Oxallis latifolia. December 1971. M L Dean and C Parker. Price - £0.25

* 20. A survey of cereal husbandry and weed control in three regions of England. July 1972. A Phillipson, T W Cox and J G Elliott. Price - £0.35

21. An automatic punching counter. November 1972. R C Simmons. Price - £0.30

22. The pre-emergence selectivity of some newly developed herbicides: bentazon, BAS 3730H, metflurazone, SAN 9789, HER 52.123, U 27,267. December 1972. W G Richardson and M L Dean. Price - £0.25

23. A survey of the presence of wild oats and blackgrass in parts of the United Kingdom during summer 1972. A Phillipson. Price - £0.25

24. The conduct of field experiments at the Weed Research Organization. February 1973. J G Elliott, J Holroyd and T O Robson. Price - £1.25

25. The pre-emergence selectivity of some recently developed herbicides: lenacil, RU 12068, metribuzin, cyprazine, EMD-IT 5914 and benthiocarb. August 1973. W G Richardson and M L Dean. Price - £1.75.

26. The post-emergence selectivity of some recently developed herbicides: bentazon, EMD-IT 6412, cyprazine, metribuzin, chlornitrofen, glyphosate, MC 4379, chlorfenprop-methyl. October 1973. W G Richardson and M L Dean. Price - £3.31

27. Selectivity of benzene sulphonyl carbamate herbicides between various pasture grasses and clover. October 1973. A M Blair. Price - £1.05

28. The post-emergence selectivity of eight herbicides between pasture grasses: RP 17623, HOE 701, BAS 3790, metoxuron, RU 12068, cyprazine, MC 4379, metribuzin. October 1973. A M Blair. Price - £1.00

* 29. The pre-emergence selectivity between pasture grasses of twelve herbicides: haloxydine, pronamide, NC 8438, Orga 3045, chlortoluron, metoxuron, dicamba, isopropalin, carbetamide, MC 4379, MBR 8251 and EMD-IT 5914. November 1973. A M Blair. Price - £1.30

30. Herbicides for the control of the broad-leaved dock (<u>Rumex obtusifolius</u> L.). November 1973. A M Blair and J Holroyd. Price - £1.06

31. Factors affecting the selectivity of six soil acting herbicides against <u>Cyperus rotundus</u>. February 1974. M L Dean and C Parker. Price - £1.10

32. The activity and post-emergence selectivity of some recently developed herbicides: oxadiazon, U-29,722, U-27,658, metflurazone, norflurazone, AC 50-191, AC 84,777 and iprymidam. June 1974. W G Richardson and M L Dean. Price - £3.62

33. A permanent automatic weather station using digital integrators. September 1974. R C Simmons. Price £0.63.

34. The activity and pre-emergence selectivity of some recently developed herbicides: trifluralin, isopropalin, oryzalin, dinitramine, bifenox and perfluidone. November 1974. W G Richardson and M L Dean. Price - £2.50

35. A survey of aquatic weed control methods used by Internal Drainage Boards, 1973. January 1975. T O Robson. Price - £1.39

36. The activity and pre-emergence selectivity of some recently developed herbicides: Bayer 94871, tebuthiuron, AC 92553. March 1975. W G Richardson and M L Dean. Price - £1.54

37. Studies on Imperata cylindrica (L.) Beauv. and Eupatorium odoratum L. October 1975. G W Ivens. Price - £1.75

38. The activity and pre-emergence selectivity of some recently developed herbicides: metamitron, HOE 22870, HOE 23408, RH 2915, RP 20630. March 1976. W G Richardson, M L Dean and C Parker. Price - £3.25

39. The activity and post-emergence selectivity of some recently developed herbicides: HOE 22870, HOE 23408, flamprop-methyl, metamitron and cyperquat. May 1976. W G Richardson and C Parker. Price - £3.20

40. The activity and pre-emergence selectivity of some recently developed herbicides: RP 20810, oxadiazon, chlornitrofen, nitrofen, flamprop--isopropyl. August 1976. W G Richardson, M L Dean and C Parker. Price - £2.75.

41. The activity and pre-emergence selectivity of some recently developed herbicides: K 1441, mefluidide, WL 29226, epronaz, Dowco 290 and triclopyr. November 1976. W G Richardson and C Parker. Price - £3.40.

42. The activity and post-emergence selectivity of some recently developed herbicides: KUE 2079A, HOE 29152, RH 2915, Triclopyr and Dowco 290. March 1977. W G Richardson and C Parker. Price - £3.50

43. The activity and pre-emergence selectivity of some recently developed herbicides: dimefuron, hexazinone, trifop-methyl, fluothiuron, buthidazole and butam. November 1977. W G Richardson and C Parker. Price - £3.75.

44. The activity and selectivity of the herbicides: ethofumesate, RU 12709 and isoproturon. December 1977. W G Richardson, C Parker, & M L Dean. Price - £4.00

45. Methods of analysis for determining the effects of herbicides on soil soil micro-organisms and their activities. January 1978. M P Greaves, S L Cooper, H A Davies, J A P Marsh & G I Wingfield. Price - £4.00

46. Pot experiments at the Weed Research Organization with forest crop and weed species. February 1978. D J Turner and W G Richardson. Price - £2.70

47. Field experiments to investigate the long-term effects of repeated applications of MCPA, tri-allate, simazine and linuron - effects on the quality of barley, wheat, maize and carrots. July 1978. J D Fryer, P D Smith and J W Ludwig. Price - £1.20.

48. Factors affecting the toxicity of paraquat and dalapon to grass swards. March 1978. A K Oswald. Price - £2.90

49. The activity and post-emergence selectivity of some recently developed herbicides: NP 48, RH 5205 and Pyridate. May 1978. W G Richardson and C Parker. Price - £2.50

50. Sedge weeds of East Africa - II. Distribution. July 1978. P J Terry. Price - £1.50

51. The activity and selectivity of the herbicides methabenzthiazuron, metoxuron, chlortoluron and cyanazine. September 1978. W G Richardson and C Parker. Price - £2.20.

52. Antidotes for the protection of field bean (Vicia faba L.) from damage by EPTC and other herbicides. February 1979. A M Blair. Price - £1.35

53. Antidotes for the protection of wheat from damage by tri-allate. February 1979. A M Blair. Price - £2.00

54. The activity and pre-emergence selectivity of some recently developed herbicices: alachlor, metolachlor, dimethachlor, alloxydim-sodium and fluridone. April 1979. W G Richardson and C Parker. Price - £3.00

55. The activity and selectivity of the herbicides carbetamide, methazole, R 11913 and OCS 21693. May 1979. W G Richardson and C Parker. Price - £1.80

56. Growing weeds from seeds and other propagules for experimental purposes. July 1979. R H Webster. Price - £1.10

57. The activity and pre-emergence selectivity of some recently developed herbicides: R 40244, AC 206784, pendimethalin, butralin, acifluorfen and FMC 39821. December 1979. W G Richardson, T M West and C Parker - Price - £3.55

58. The tolerance of fenugreek (Trigonella foenumgraecum L.) to various herbicides. December 1979. W G Richardson. Price - £1.55

59. Recommended tests for assessing the side-effects of pesticides on the soil microflora. April 1980. M P Greaves, N J Poole, K H Domsch, G Jagnow and W Verstraete. Price - £2.00

60. Properties of natural rainfalls and their simulation in the laboratory for pesticide research. September 1980. R C Simmons. Price - £1.25

61. The activity and post-emergence selectivity of some recently developed herbicides: R 40244, DPX 4189, acifluorfen, ARD 34/02 (NP 55) and PP 009. November 1980. W G Richardson, T M West and C Parker. Price - £3.75

62. The activity and pre-emergence selectivity of some recently developed herbicides: UBI S-734, SSH-43, ARD 34/02 (= NP 55), PP 009 and DPX 4189. February 1981. W G Richardson, T M West and C Parker. Price - £3.50

63. The activity and post-emergence selectivity of some recently developed herbicides: SSH-41, MB 30755, AC 213087, AC 222293 and Dowco 433. May 1981. W G Richardson, T M West and C Parker. Price - £3.50

64. The activity and pre-emergence selectivity of some recently developed herbicides: chlomethoxynil, NC 20484 and MBR 18337. March 1982. W G Richardson, T M West and C Parker. Price - £3.00

65. A system for monitoring environmental factors in controlled environment chambers and glasshouses. June 1982. R C Simmons. Price - £1.50

66. The activity and pre-emergence selectivity of some recently developed herbicides: AC 213087 and AC 222293. December 1982. W G Richardson, T M West and C Parker. Price - £2.00

67. The activity and post-emergence selectivity of some recently developed herbicides: trifopsime, glufosinate, RH 8817, MBR 18337 and NC 20484. December 1982. W G Richardson, T M West and C Parker. Price - £3.25

68. The activity and pre-emergence selectivity of some recently developed herbicides: WL 49818, WL 82830, WL 83627, WL 83801 and DPX 5648. December 1982. W G Richardson, T M West and C Parker. Price - £4.00

69. The activity and late post-emergence selectivity of some recently developed herbicides: AC 252925, DOWCO 453, HOE 33171 and HOE 35609. March 1983. W G Richardson, T M West and G P White. Price - £3.25

70. The potential of various herbicides for selective control of weed grasses and Stellaria media in newly sown ryegrass/clover leys and ryegrass seed crops. May 1983. F W Kirkham Price - £1.75

71. A feasibility study of the use of chemicals for rural amenity areas. Sponsored by the Countryside Commission. September 1983. E J P Marshall Price - £5.00

72. The activity and late post-emergence selectivity of FBC 32197. November 1983. W G Richardson, T M West and G P White. Price - £1.25

73. Paraquat persistence - statistical analysis of the WRO long term trial. January 1984. R J Hance, T H Byast, P D Smith and T M Weight. Price - £1.00

74. The activity and post-emergence selectivity of some recently developed herbicides: AC 252214, DPX-T6376, and chlorazifop. February 1984. W G Richardson, T M West and G P White. Price - £2.00.

75. The effect of temperature and soil moisture on the activity of isoproturon and chlortoluron on Alopecurus myosuroides and winter wheat. May 1984. A M Blair. Price - £2.00

76. A laboratory rainfall simulator for pesticide studies. May 1984. R C Simmons. Price - £2.00

77. Experiments on the effects of the herbivorous fish, grass carp (Ctenopharyngodon idella Val.) on aquatic vascular plants, algae, zooplankton and phytoplankton and the importance of water temperature on the success of weed control. September 1984. M C Fowler. Price - £3.50.

78, The activity and post-emergence selectivity of some recently developed herbicides: MCPA-thioethyl, MT-124, tridiphane, aclonifen and RST 20024 H. October 1984. W G Richardson and T M West. Price - £5.40

79. A preliminary study on the effect of some agricultural herbicides on a range of field margin flora. November 1984. J E Birnie. Price - £2.50

80. The activity and pre-emergence selectivity of some recently developed herbicides: imazaquin, isoxaben, metsulfuron-methyl, aclonifen and orbencarb. December 1984. W G Richardson and T M West. Price - £6.50

81. The side effects of alloxydim sodium, sethoxydim, acifluorfen and fluazifop-butyl on legume growth and nodulation. January 1985. J M Bebb, M P Greaves and W G Richardson. Price - £3.00