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The pre- and post-emergence activity and selectivity of the herbicide amidosulfuron (HOE 075032)

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1. SUMMARY

Pot experiments were used to investigate the phytotoxicity of the herbicide amidosulfuron (HOE 075032). In the initial experiment, amidosulfuron at 5, 15, 45 and 135 g a.i. ha^{-1} was applied using four different methods to determine the type of activity and the routes of herbicide entry into the plants of six selected species. In separate experiments, amidosulfuron at 5, 15, 30 and 60 g a.i. ha^{-1} was tested for pre- and post-emergence activity and selectivity on up to 19 temperate crop species and 29 temperate weed species.

In the first experiment, amidosulfuron was found to be considerably active against kale and Polygonum amphibium when applied post-emergence to the foliage only or when allowed to act via the soil only (as a soil drench treatment); at the higher doses, the soil-only treatment also reduced the growth of perennial ryegrass. When applied pre-emergence, the herbicide also showed activity against kale, Polygonum amphibium and perennial ryegrass; soil surface sprays were generally more active than soil incorporated treatments.

Pre-emergence treatments of amidosulfuron at 60 g a.i. ha^{-1}, in the selectivity experiment, were tolerated by wheat, barley, oat, dwarf bean and field bean, while sugar beet and lettuce were particularly sensitive to 5 g a.i. ha^{-1}. Many of the dicotyledonous weeds tested, including Galium aparine, were controlled by 30 g a.i. ha^{-1} applied pre-emergence. Veronica persica and most of the monocotyledonous weeds tested showed appreciable tolerance to 60 g a.i. ha^{-1}.

In the post-emergence experiment, excellent tolerance was shown by wheat, barley, oat, dwarf bean and linseed to amidosulfuron, at 60 g a.i. ha^{-1}. Several dicotyledonous weeds tested including Galium aparine, cruciferous spp., polygonaceous spp. and annual Compositae spp. were effectively controlled or considerably suppressed by post-emergence treatments of amidosulfuron at 30 g a.i. ha^{-1}. However, some dicotleydonous weeds, e.g. Veronica persica and Solanum nigrum, were unaffected and others, e.g. Chenopodium album and Viola arvensis, were not adequately controlled by 60 g a.i. ha^{-1}. All monocotyledonous weeds tested were tolerant to 60 g a.i. ha^{-1}.

2. INTRODUCTION

The pre- and post-emergence activity and selectivity of new herbicides are investigated by LARS Crop and Environmental Sciences Department on a range of temperate crop and weed species, grown in pots. This information can indicate possible alternative uses to those specified by the originating company, e.g. weed control in minor crops, and give pointers to potential problems, e.g. effects on non-target species. Although in these investigations, only one crop variety or source of weed species is sown in one soil type at one depth, the results provide guidelines for more detailed studies where warranted.

Amidosulfuron is a new herbicidal active ingredient discovered and developed by Hoechst AG. The information received from Hoechst UK (now AgrEvo) suggests that amidosulfuron has potential for post-emergence control of a range of broad-leaved weeds in cereals at rates of 30-60 g a.i. ha^{-1} and shows possibilities for the control of Rumex spp. at 45 g a.i. ha^{-1}, a dose which is reported to be tolerated by the meadow grasses, Lolium perenne, Phleum pratense and Poa pratense, and not damaging to white clover.

One advantage reported for this herbicide, over other sulfonylurea herbicides used in cereals, is its activity against the intractable weed Galium aparine (D'Souza et al. 1993). The suggested timing for amidosulfuron application in the UK is post-emergence of the weeds. For Galium aparine it may be applied from February, if the weeds are actively growing, up to the flower bud-visible stage. The activity of amidosulfuron on Galium aparine, applied from mid-February to April, is reported to be superior to that of its competitors (D'Souza et al. 1993).

Hacker et al. (1990), investigating the mode of action of amidosulfuron, showed that uptake is mainly via plant shoots though some root uptake occurs (Mueller-Wilmes, 1993) especially at high soil moisture levels. As with other sulfonylurea herbicides, selectivity is dependent on differential rates of herbicide metabolism; tolerant species can metabolise the herbicide rapidly to inactive metabolic products (Kocher and Lotzsch, 1993). Microbial action is reported to be the predominant factor causing the degradation of amidosulfuron in the soil (Hacker et al. 1990). Most of the active ingredient remains in the top 20cm soil layer (Fent et al. 1992). Leterrier and Gavanier (1992) reported that, after a five year field study, all crops in a normal rotation can be safely sown following a spring application of amidosulfuron.

This report gives information on the pre- and post-emergence activity and selectivity of amidosulfuron in temperate species. Results of an experiment to investigate the response of plants to amidosulfuron applied separately to the shoot, root or seed, are also included to provide information on the route of herbicide entry into the plant, and the type and degree of phytotoxicity.

3. MATERIALS AND METHODS

3.1 Herbicide details

Source: Hoechst (UK) Ltd., Agriculture Division, East Winch Hall, East Winch, King's Lynn Norfolk PE32 1HN

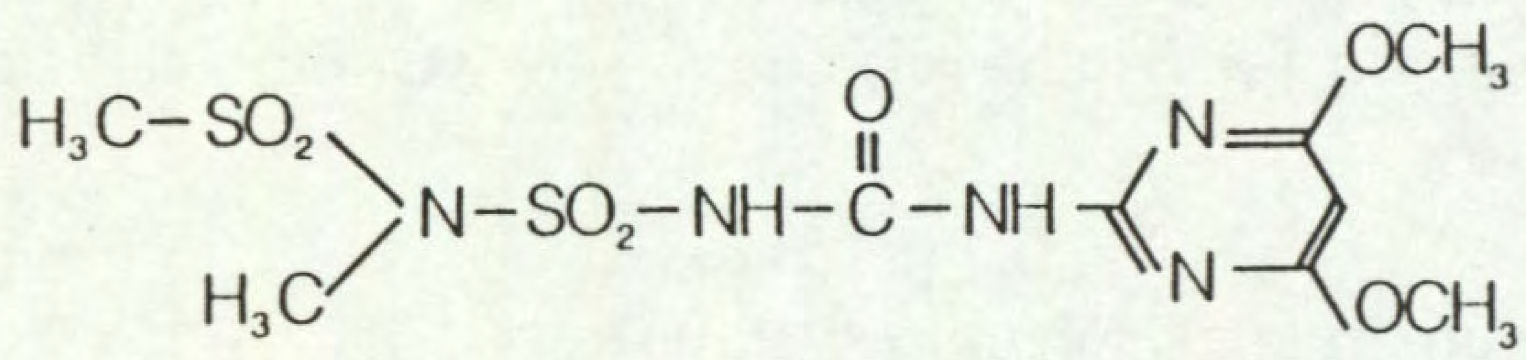
Code number: HOE 075032

Common name: Amidosulfuron

Trade names: GRATIL or ADRET (France)
EAGLE (UK)

Chemical name (IUPAC): 3-(4,6-dimethoxypyrimidin-2-yl)-1-(N-methyl-N-methyl-sulfonyl)urea

Chemical structure:



Formulation used: 75% water-dispersible granule

Doses applied: Activity experiment:-
5, 15, 45 and 135 g a.i. ha^{-1}

Selectivity experiments:-
5, 15, 30 and 60 g a.i. ha^{-1}

3.2 Activity experiment

This was carried out in a glasshouse on six species, using the techniques described by Richardson and Dean (1974). The four annual species were raised from seeds, and the two perennials from rhizome fragments, in 9 cm diameter pots containing a Mendip sandy clay loam (Table 1). Environmental conditions and dates of spraying and assessments are given in Table 2. Species information and the growth stages of plants at spraying and assessment are summarised in Appendix 1. Herbicides were applied by four different methods.

(i) A post-emergence spray to the foliage only, avoiding contact with the soil

(ii) A post-emergence soil drench, avoiding contact with the foliage

(iii) Pre-emergence to the soil surface

(iv) Pre-emergence with thorough incorporation to 5 cm depth before planting

There were three replicates for each treatment. After spraying, pots were set out in three randomised blocks per species in a heated glasshouse (Table 2) where normal daylight was supplemented by mercury vapour lamps to provide 14 h photoperiods. Irrigation was by hand watering and for (i) and (ii) above this was onto the soil only, avoiding the foliage.

3.3 Pre-emergence selectivity experiment

For each species, seeds, rhizomes or roots were planted prior to spraying in 9 cm diameter plastic pots containing a Mendip sandy clay loam (Table 1) with Osmocote 18.10.12 fertiliser added at 3.3 g litre^{-1}. Numbers of seeds per pot, depths of sowing and seed sources are described in Appendix 2.

To improve germination, Chenopodium album seeds were kept in a 0.1M potassium nitrate solution for 48 h in the light before sowing and Fallopia convolvulus seeds were stored at 4°C in moist sand for two weeks before sowing. The brassica crops, cruciferous weeds and Veronica persica were given a soil drench with Aaterra WP (containing the active ingredient etridiazole), at 1.0 g litre^{-1}, one week after spraying to prevent damping-off disease.

The herbicide was applied as a pre-emergence surface spray using a laboratory track sprayer. This was fitted with an 80015E Lurmark flat fan Evenspray nozzle delivering 308 litres ha^{-1} at a pressure of 210 kPa (30 psi) and moving at 0.5 m sec^{-1}, 30 cm above the stationary pots. There were three replicates for each treatment. After spraying, pots were set out in three randomised blocks per species in a heated glasshouse (Table 2) where normal daylight was supplemented by mercury vapour lamps to provide 14 h photoperiods. Irrigation was by overhead hand watering.

3.4 Post-emergence selectivity experiment

Plants were grown outside in 9 cm plastic pots containing Mendip loam plus fertiliser (as described in 3.2). Sowing dates were staggered so that the majority of species would reach a pre-determined growth stage (2-4 leaves) by the time of spraying. Before spraying, each species was thinned to the same number per pot. Plant numbers and growth are recorded in Appendix 3.

The herbicide was applied using a laboratory track sprayer fitted with an 80015E Lurmark flat fan nozzle delivering 280 litres ha^{-1} at a pressure of 210 kPa (30 psi) and moving at 0.5 m sec^{-1}, 45 cm above the target area of the plants. After spraying, plants were protected from rainfall for 24 h and then put outside in three randomised blocks per species. Watering was by natural rainfall plus additional overhead hand watering as necessary. One week after spraying, pots were moved into a well ventilated glasshouse with automatic bright light shading to prevent extreme temperatures. This allowed individual watering of pots to maintain a uniform soil moisture level between pots having differing irrigation requirements due to the varying herbicide effects on the plants and, thus, reduced exaggerated effects from waterlogging or drought. Outside and glasshouse temperatures for the duration of the experiment are summarised in Table 2.

3.5 Assessments

Assessments were made five to six weeks after spraying pre-emergence, and three to four weeks after spraying post-emergence. Survivors were counted and scored for vigour on a 0-7 scale as follows:

0 = completely dead
1 = moribund, but not all tissue dead
2 = alive, with some green tissue, but unlikely to make much further growth
3 = very, stunted, but apparently still making some growth
4 = considerable inhibition of growth
5 = readily distinguishable inhibition of growth
6 = some detectable adverse effect as compared with untreated - colour difference, morphological abnormality, epinasty or slight reduction in growth
7 = indistinguishable from untreated control

Histograms of data are presented for each treatment on each species, showing both plant survival and plant vigour, calculated as percentages of untreated controls. Observed selectivities, determined using the criteria specified, are presented in Tables 3 and 4, along with comments highlighting important results.

3.6 Soil analysis and environment conditions

Table 1. Soil analysis - Mendip sandy clay loam

Particle size analysis (%)		
Coarse sand	(600 μm - 2 mm)	6
Medium sand	(212 μm - 600 μm)	10
Fine sand	(63 μm - 212 μm)	36
Silt	(2 μm - 63 μm)	33
Clay	(<2 μm)	15
Organic matter (%)		3.2
pH (in water 1 : 2 soil : water ratio)		6.1

3.6 Table 2. Soil and environment conditions

Experiment	Activity	Pre-em. selectivity	Post-em. selectivity	
Dates of spraying	7 May 1992	10 Feb 1993	26 Jun 1992 & 1 Jul 1992	
Main assessment completed	13 Jul 1992	5 Apr 1993	6 Aug 1992	
Temperature (°C)	Glasshouse	Glasshouse	Outside	Glasshouse
Mean	21	15	16	20
Maximum	31	22	26	29
Minimum	10	9	5	11
Relative humidity (%)				
Mean	71	69	-	76
Maximum	94	92	-	95
Minimum	38	42	-	48

4. RESULTS

4.1 Symptoms of amidosulfuron damage to plants

When applied pre-emergence, amidosulfuron did not stop germination of sensitive broad-leaved species, but growth was often inhibited at the cotyledon leaf stage, shoots gradually turning chlorotic then necrotic with eventual death. Broad-leaved plants that survived past the cotyledon stage often had growth of the main shoot inhibited causing proliferation of small side shoots from the cotyledon leaf axils, these shoots sometimes having tiny 'strap-like' leaves with interveinal chlorosis. Some species, e.g. brassicas, appeared miniaturised due to suppression of shoot and root growth and the lack of stem elongation between the leaves. Grasses were generally more tolerant than broad-leaved species although growth of shoots and roots of some small seeded grass species was suppressed initially, causing a miniature appearance, but plants often recovered well.

Following post-emergence treatments, the most obvious symptoms on sensitive broad-leaved species were a rapid inhibition of meristems in both shoots and roots followed by gradual yellowing, chlorosis, necrosis and death. At lower doses, or on less sensitve species, initial inhibition of the main shoot growing point was followed by production of new shoots from older leaf axils. As in the pre-emergence treatments, these axillary shoots had little stem elongation between leaves, which often showed interveinal chlorosis. Grasses were, generally, tolerant of post-emergence treatments and symptoms were observed in the activity experiment only when the herbicide was applied as a soil drench, at high doses on plants of the small seeded species, perennial ryegrass.

The symptoms observed are similar to those produced by other sulfonylurea herbicides developed for broad-leaved weed control in cereals, e.g. chlorsulfuron, metsulfuron-methyl, thifensulfuron-methyl, tribenuron-methyl and triasulfuron.

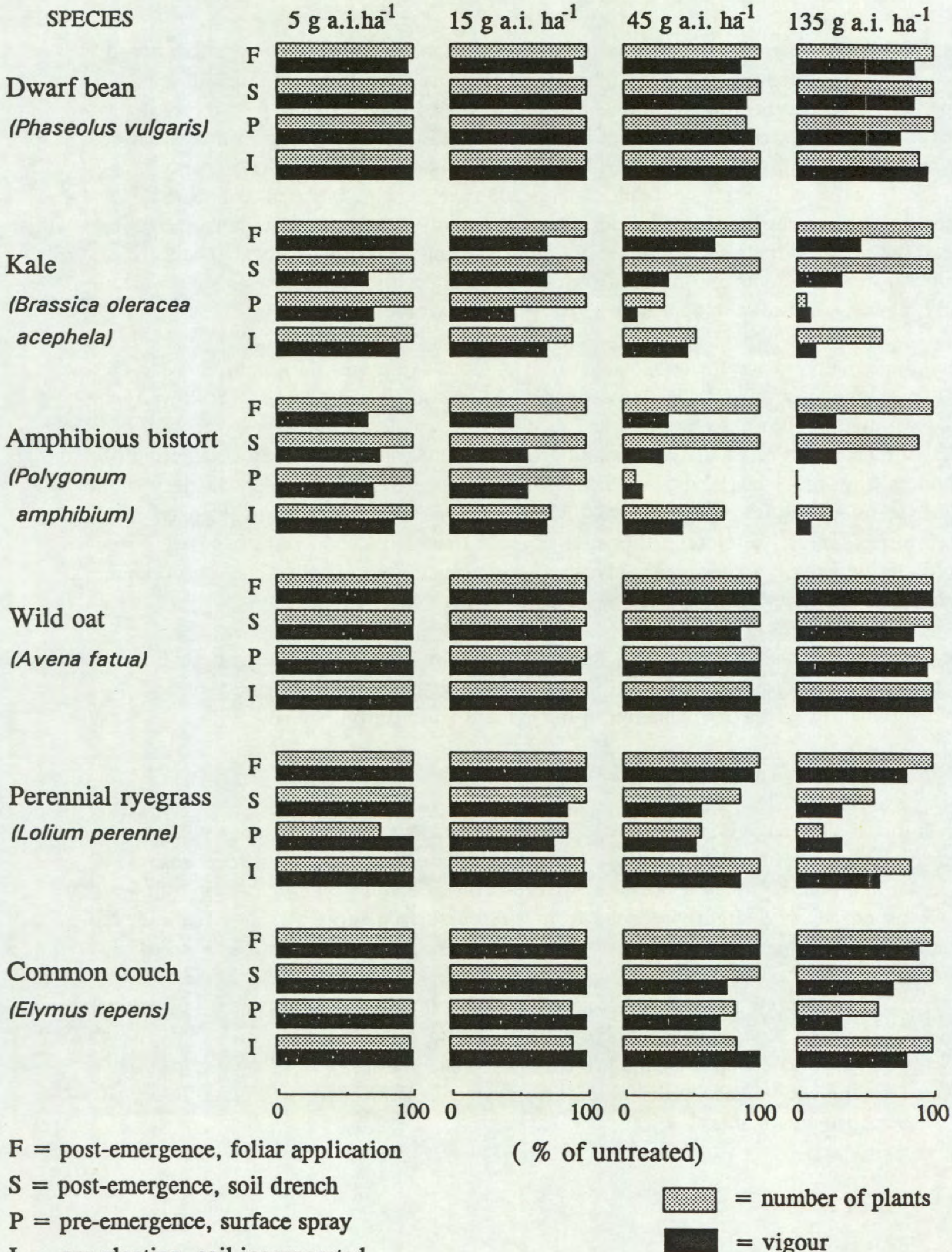
4.2 Activity experiment (Figure 1)

Amidosulfuron showed varying degrees of activity on the six selected species when applied pre-emergence. Soil surface sprays were generally more active than soil incorporated treatments, although both had a considerable effect on kale and Polygonum amphibium. Dwarf bean growth was slightly reduced from the soil surface spray at 135 g a.i. ha^{-1}, the highest dose tested, but was unaffected by the soil incorporated treatment. Growth of perennial ryegrass was considerably suppressed by 45 g a.i. ha^{-1} applied as a pre-emergence surface spray but was unaffected by the soil incorporated treatment at this dose, and only moderately reduced by the incorporation treatment at 135 g a.i. ha^{-1}. The growth of Elymus repens was reduced by the pre-emergence surface spray at 135 g a.i. ha^{-1} but unaffected by the equivalent dose as a soil incorporated treatment. Avena fatua tolerated all pre-emergence treatments.

Figure 1

ACTIVITY EXPERIMENT

Amidosulfuron (HOE 075032)



F = post-emergence, foliar application

S = post-emergence, soil drench

P = pre-emergence, surface spray

I = pre-planting, soil incorporated

Amidosulfuron also showed activity when applied post-emergence either to the foliage only or to the soil only (as a soil drench). Some species, particularly kale and perennial ryegrass, appeared more susceptible to the soil drench treatments, whereas growth of Polygonum amphibium was considerably suppressed by both applications. Dwarf bean and Avena fatua were unaffected by all post-emergence treatments and Elymus repens growth was only slightly reduced by soil drenches at 45 and 135 g a.i. ha^{-1}.

4.3 Pre-emergence selectivity (Table 3 and Figures 2-4)

Wheat, barley, oat, dwarf bean and field bean were tolerant of pre-emergence, soil surface applications of amidosulfuron at 60 g a.i. ha^{-1} and maize was unaffected by 15 g a.i. ha^{-1}. Pea, parsnip and linseed were tolerant of 5 g a.i. ha^{-1}, a dose that caused moderate growth suppression of brassica crops, white clover, carrot and sunflower. Sugar beet and lettuce were particularly sensitive to 5 g a.i. ha^{-1}, the lowest dose tested.

A wide range of broad-leaved weed species were susceptible to amidosulfuron applied pre-emergence. Although 5 g a.i. ha^{-1} did not adequately control any weed species, it did cause considerable growth suppression of several. At 15 g a.i. ha^{-1} eleven broad-leaved weed species were susceptible, including the Compositae, Cruciferae, Chenopodium album, Viola arvensis and Rumex obtusifoius and at 30 g a.i. ha^{-1}, Galium aparine, Stellaria media and Solanum nigrum were very sensitive. Lamium purpureum, Convolvulus arvensis and one grass species, Poa trivialis, were controlled at 60 g a.i. ha^{-1}. Fallopia convolvulus and Veronica persica were not adequately controlled by 60 g a.i. ha^{-1}. The large seeded grass weeds, Avena fatua and Bromus sterilis, were virtually unaffected by 60 g a.i. ha^{-1}, and growth of most other grass weeds tested was only moderately reduced.

Table 3 Crop tolerance and weed sensitivity to pre-emergence treatments of Amidosulfuron (HOE 075032)

Dose (g a.i.ha^{-1})	Tolerant crops (plant number or vigour reduced by less than 15%)	Sensitive weeds (plant number or vigour reduced by 70% or more)
60	Wheat Barley Oat Dwarf bean Field bean	Lamium purpureum Convolvulus arvensis Poa trivialis (plus species listed below)
30	(Species listed above)	Galium aparine Stellaria media Solanum nigrum (plus species listed below)
15	(Species listed above plus) Maize	Raphanus raphanistrum Sinapis arvensis Chrysanthemum segetum Matricaria perforata Senecio vulgaris Polygonum lapathifolium Chenopodium album Spergula arvensis Viola arvensis Papaver rhoeas Rumex obtusifolius
5	(Species listed above plus) Pea Parsnip Linseed	No weeds sensitive
Sensitive crops (severe damage or kill at 5 g a.i.ha^{-1})		Tolerant weeds (no or only slight to moderate effects at 60 g a.i.ha^{-1})
Sugar beet Lettuce		Veronica persica Avena fatua Bromus sterilis

Figure 2 PRE-EMERGENCE SELECTIVITY EXPERIMENT

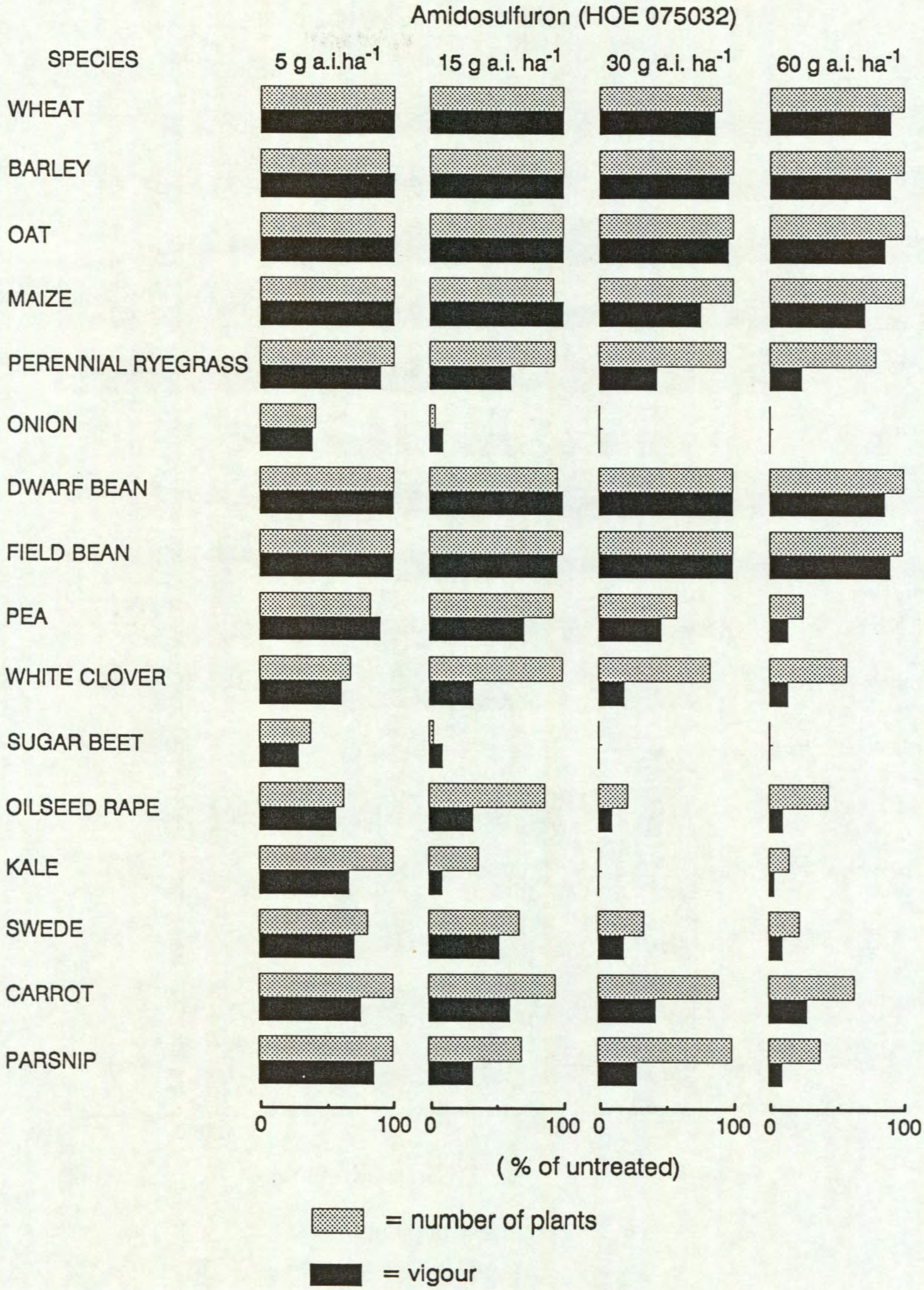


Figure 3 PRE-EMERGENCE SELECTIVITY EXPERIMENT

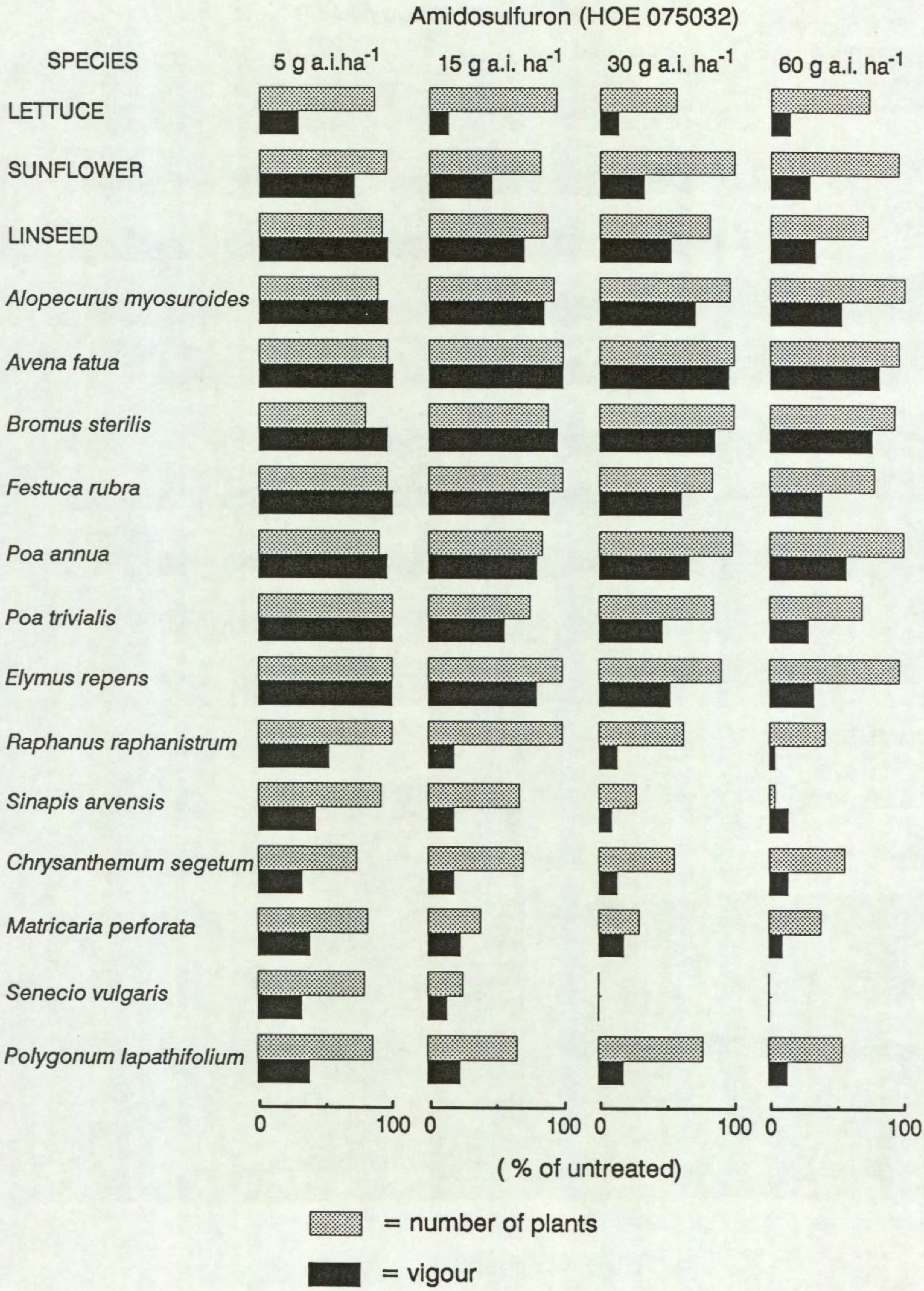
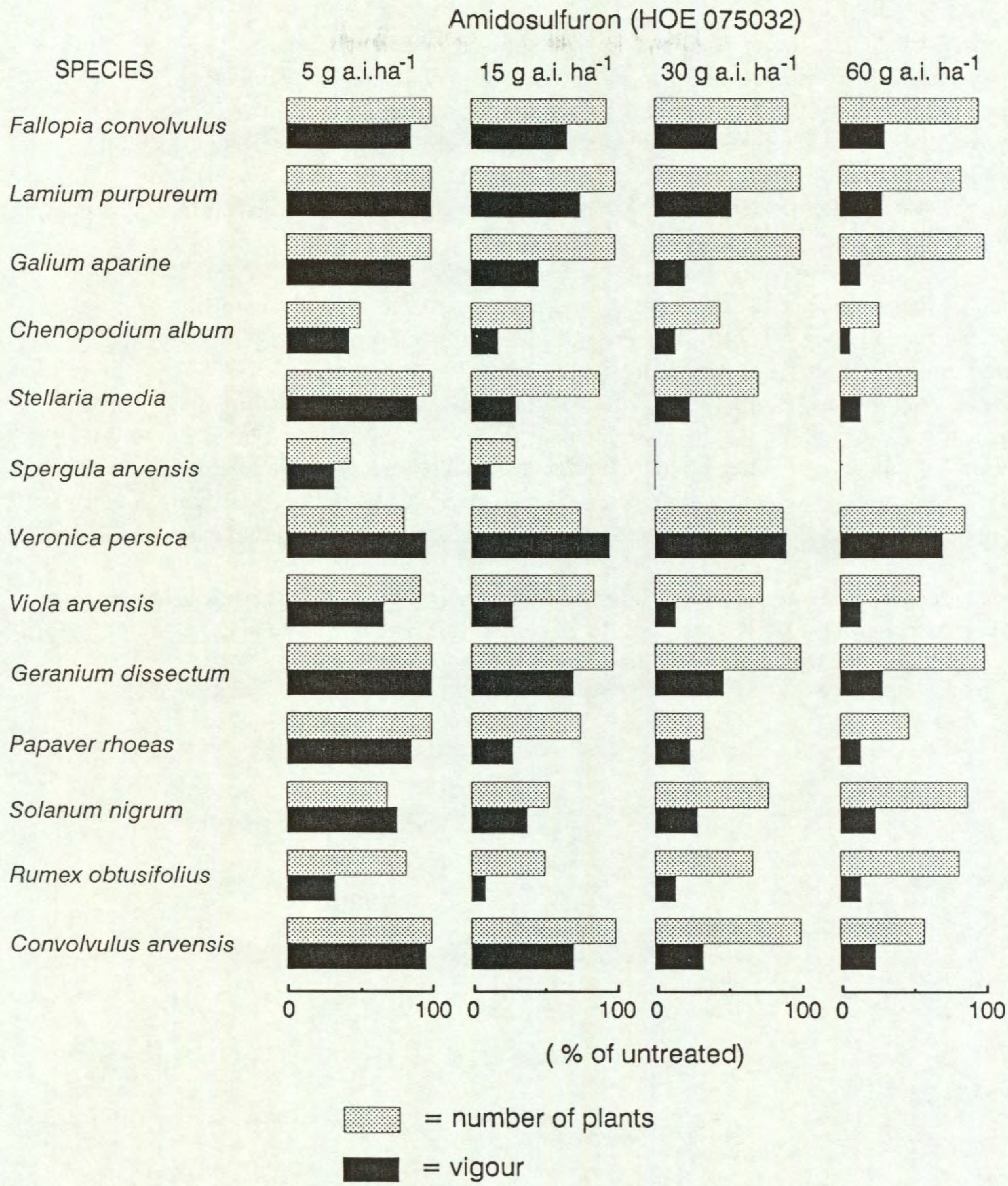


Figure 4 PRE-EMERGENCE SELECTIVITY EXPERIMENT



4.4 Post-emergence selectivity (Table 4 and Figures 5-7)

Wheat, barley, oat, dwarf bean and linseed showed excellent tolerance to amidosulfuron applied post-emergence at 60 g a.i. ha^{-1}. Growth of maize and perennial ryegrass was only slightly reduced at 60 g a.i. ha^{-1} and not affected by 30 g a.i. ha^{-1}. The only other crops showing some tolerance were field bean and white clover, which were unaffected by 5 g a.i. ha^{-1}, the lowest dose tested. Sunflower proved particularly sensitive to 5 g a.i. ha^{-1} which also caused considerable growth suppression of sugar beet, oilseed rape, parsnip and lettuce.

None of the weed species tested were sensitive to post-emergence treatments of amidosulfuron at 5 g a.i. ha^{-1}. The growth of several important broad-leaved weeds, including Galium aparine, was appreciably reduced at 15 g a.i. ha^{-1}, but Sinapis arvensis was the only weed effectively controlled at this dose. Growth of Galium aparine, Matricaria perforata and Raphanus raphanistrum was completely inhibited by 30 g a.i. ha^{-1}. The growth of several other broad-leaved weeds, including such intractable species as Polygonum aviculare, Rumex obtusifolius and Geranium dissectum, was considerably suppressed at 30 g a.i. ha^{-1}; complete growth inhibition was achieved at 60 g a.i. ha^{-1}.

Three broad leaved species, Lamium purpureum, Veronica persica and Solanum nigrum, were unaffected by 60 g a.i. ha^{-1}, while Chenopodium album, Viola arvensis and Cirsium arvense recovered well after inhibition of main shoot growth.

Table 4 Crop tolerance and weed sensitivity to post-emergence treatments of amidosulfuron (HOE 075032)

Dose ($g\ a.i.ha^{-1}$)	Tolerant crops (plant number or vigour reduced by less than 15%)	Sensitive weeds (plant number or vigour reduced by 70% or more)
60	Wheat Barley Oat Dwarf bean Linseed	Chrysanthemum segetum Polygonum aviculare Polygonum lapathifolium Spergula arvenis Geranium dissectum Rumex obtusifolius Convolvulus arvensis (plus species listed below)
30	(Species listed above plus) Maize Perennial ryegrass	Raphanus raphanistrum Matricaria perforata Galium aparine (plus species listed below)
15	(Species listed above)	Sinapis arvensis
5	(Species listed above plus) Field bean Pea	No weeds sensitive
Sensitive crops (severe damage or kill at 5 $g\ a.i.ha^{-1}$) Sunflower Lettuce Parsnip Oilseed rape Sugar beet		Tolerant weeds (no or only slight to moderate effects at 60 $g\ a.i.ha^{-1}$) Lamium purpureum Veronica persica Solanum nigrum Cirsium arvense Graminaceous weeds

Figure 5 POST-EMERGENCE SELECTIVITY EXPERIMENT

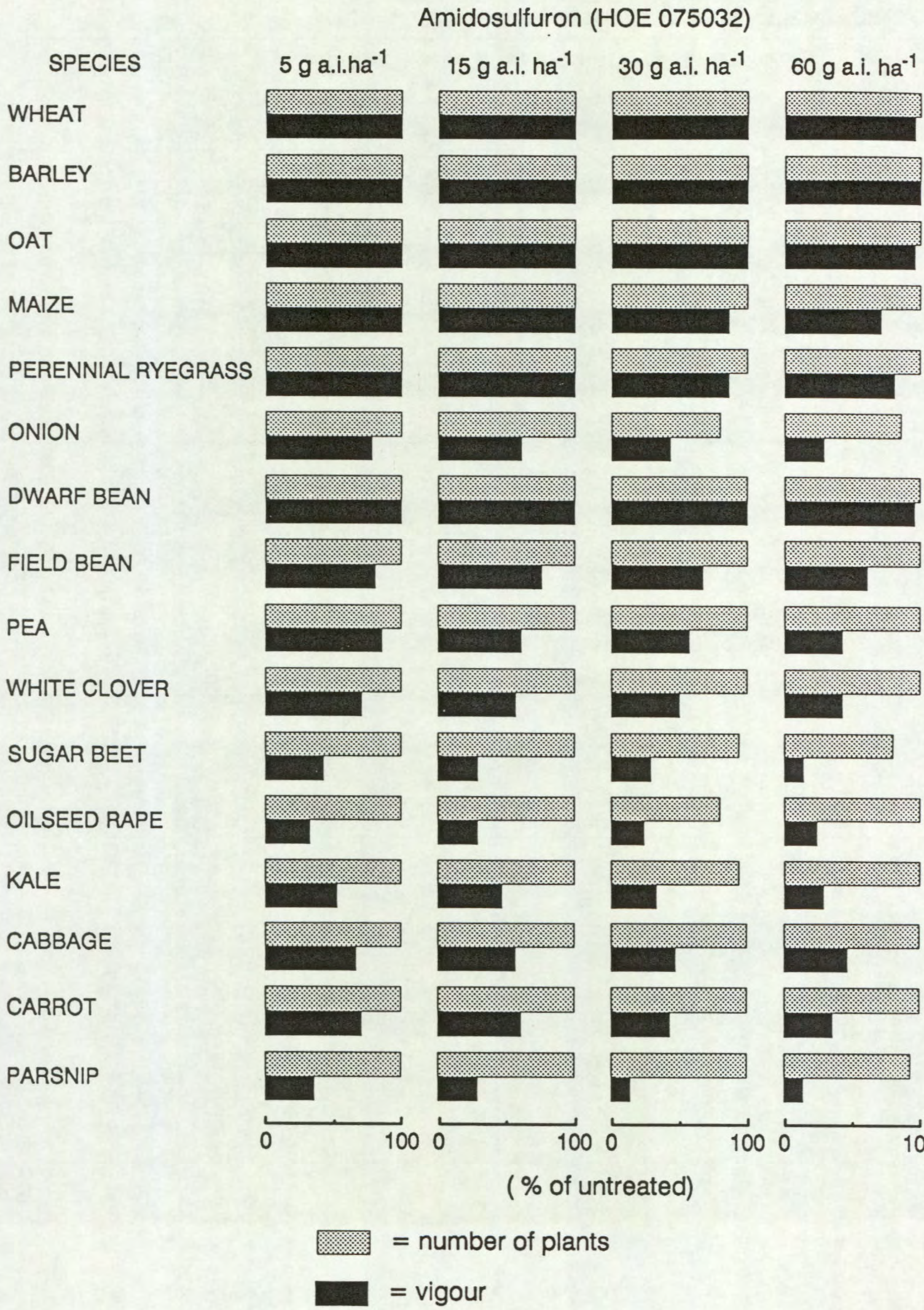


Figure 6 POST-EMERGENCE SELECTIVITY EXPERIMENT

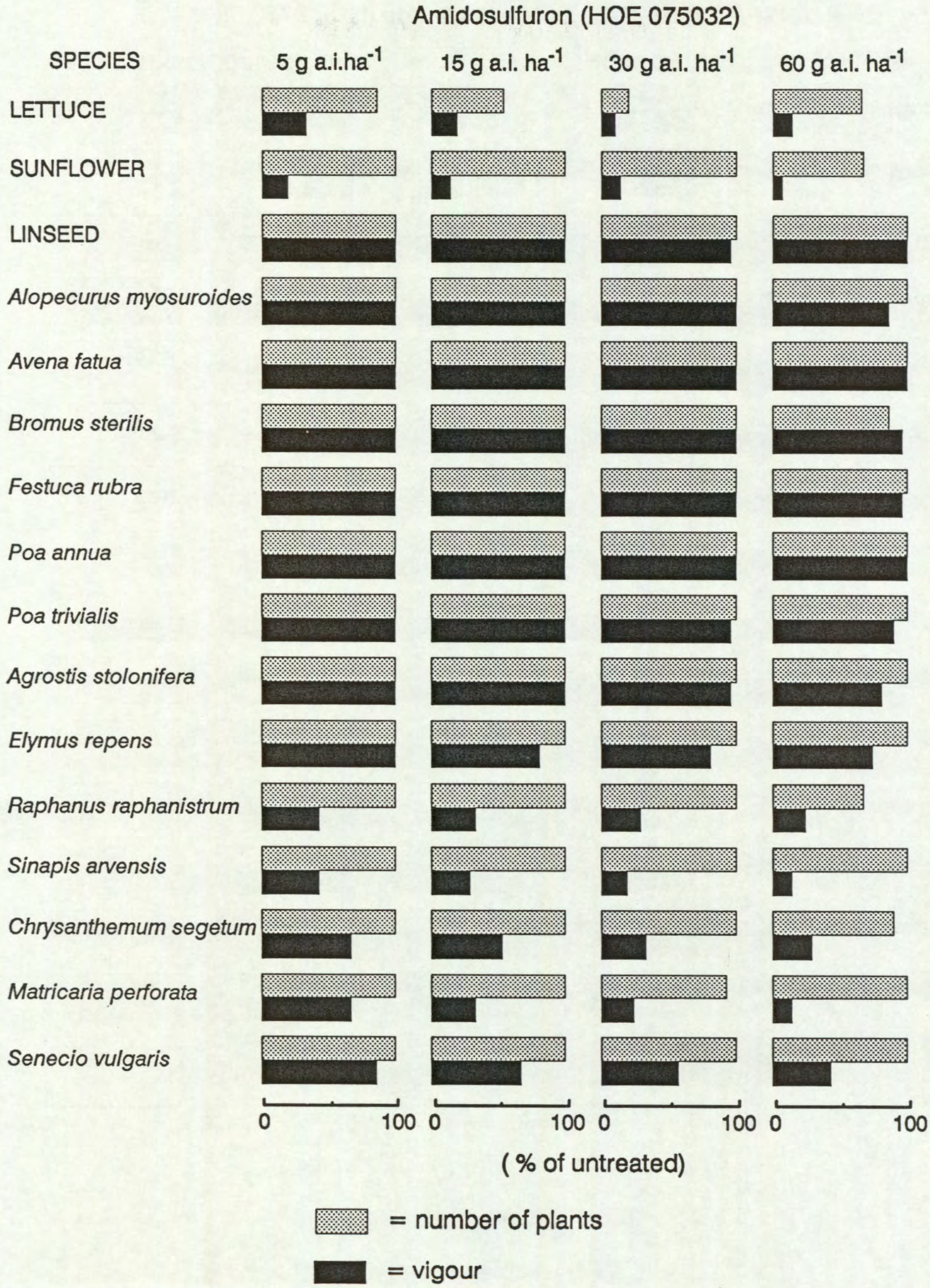
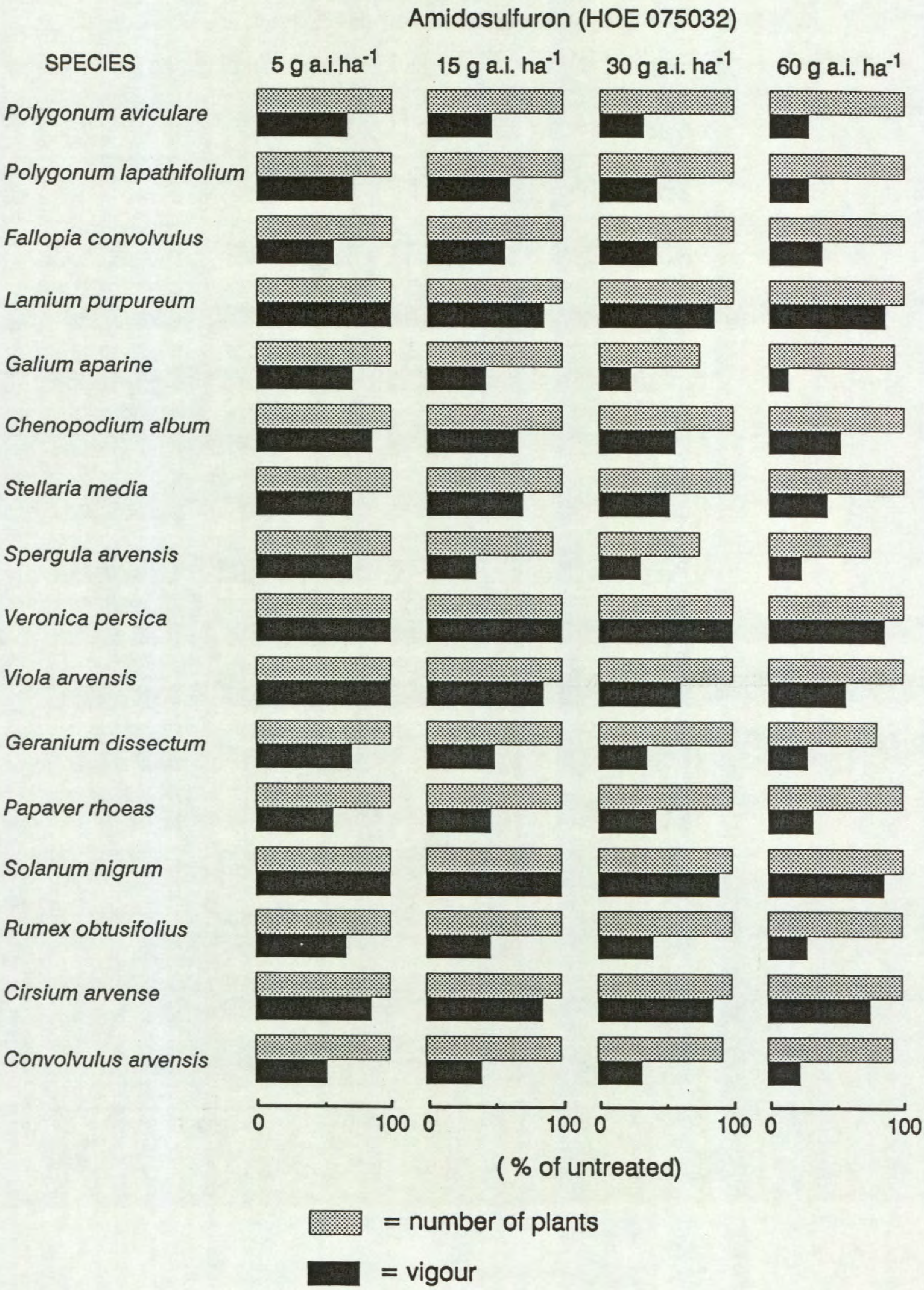


Figure 7 POST-EMERGENCE SELECTIVITY EXPERIMENT



5. Discussion

The results from these experiments generally agree with the information receieved from Hoechst. However, we found more soil activity than expected from amidosulfuron as, according to the Hoechst information, amidosulfuron activity was predominantly through the foliage. Our initial experiment showed that amidosulfuron can exhibit activity on susceptible species when applied either pre- or post-emergence, and that post-emergence treatments can have a considerable effect when applied to the soil only or when applied to the foliage only, as shown by its activity against kale and Polygonum amphibium. This soil activity may have been exaggerated due to the plants having regular irrigation which maintained a high level of soil moisture within the pots. However, this does suggest that a combination of shoot and root uptake may give the most effective weed control from post-emergence treatments. Therefore, spraying when the soil has a high soil moisture content would probably be advantageous for maximum herbicide activity.

Results from our selectivity experiment also showed that amidosulfuron can have considerable activity when applied pre-emergence. The range of broad-leaved weeds controlled by pre-emergence soil surface sprays at 30 g a.i. ha^{-1} was impressive, while wheat, barley and oat remained tolerant. Again, this level of activity may be related to the regular irrigation, keeping the soil at a relatively high moisture content and creating optimum conditions for herbicide uptake into the emerging shoots and roots. Some crop species were very sensitive to amidosulfuron when applied pre-emergence, sugar beet and oilseed rape being damaged by 5 g a.i. ha^{-1}. Under field conditions the reported rapid breakdown of amidosulfuron by soil microbes (Hacker et al. 1990) indicates that no problems of 'carry over' should occur when these sensitive species are used as following crops in normal rotations, this is supported by Letterier and Gavanier (1992) in their five year field study. Work by West (unpublished data), from a glasshouse pot experiment, found residues of amidosulfuron remained active against sensitive species for longer periods after spraying onto the surface of soil that had been stored at a low moisture content, and probably had very low initial levels of microbial activity.

Our post-emergence selectivity experiment showed that amidosulfuron is indeed active against Galium aparine and that wheat, barley and oat showed excellent tolerance. The range of broad-leaved weeds controlled by amidosulfuron agreed well with those from Hoechst trials (personal communication). The list of important weeds inadequately or poorly controlled by amidosulfuron, which includes Veronica persica, Viola arvensis, Cirsium arvense and all grass weeds, also agrees with results from Hoechst. In this experiment Chenopodium album was also inadequately controlled by a post-emergence application at 60 g a.i. ha^{-1}, however, in Hoechst trials good control of this species was achieved. These results suggest that mixtures or sequences with other herbicides will be required for broad-spectrum weed control. Some target herbicides to include with amidosulfuron to complement its weed control spectrum, assuming their compatability, might be bromoxynil, ioxynil, clopyralid and, perhaps, other short-persistence sulfonylurea herbicides such as tribenuron-methyl or thifensulfuron-methyl for problem broad-leaved weeds, and isoproturon, diclofop-methyl or fenoxaprop-ethyl for the important grass weeds.

The tolerance of dwarf bean, in our initial experiment, to high doses of amidosulfuron applied post-emergence to either foliage or soil, and its tolerance to 60 g a.i. ha^{-1} applied pre- or post-emergence in the selectivity experiments, is worth mentioning, as some problem dicotyledonous weeds of this crop were controlled. Linseed tolerance to amidosulfuron at 60 g a.i. ha^{-1}, applied post-emergence, is also of interest as several potential problem weeds of this increasingly popular crop were controlled. Both of these results may warrant further investigation.

The tolerance of grasses, especially perennial ryegrass, to amidosulfuron is particularly interesting when considering the sensitivity of the perennial weed, Rumex obtusifolius (broad-leaved dock). Recent work by West (unpublished data) found that, after treating established Rumex obtusifolius with 30 g a.i. ha^{-1} and 60 g a.i. ha^{-1} of amidosulfuron (with 0.1% v/v of Agral added to the spray solution) regrowth was severely suppressed or prevented. This suggests a potential use in grassland situations.

Other recent work by West (unpublished data) found amidosulfuron at 45 and 90 g a.i. ha^{-1} (with 0.25% v/v of Agral added to the spray solution) gave excellent control of Pteridium aquilinum (bracken) in a trial on a natural stand of bracken in the Quantock Hills. Again this is of special interest because of the grass tolerance and, thus, its potential for use in hill pastures.

In conclusion, the activity against Galium aparine and some other dicotyledonous weeds, low dose rates and the reported short degradation period in soil should make amidosulfuron a useful post-emergence herbicide, either used alone or in mixtures or sequences, for weed control in cereals. Furthermore our results indicate that this herbicide has potential for post-emergence use against some problem dicotyledonous weeds in minor UK crops, such as dwarf bean and linseed, and also for use against some problem perennial weeds in grassland situations.

6. ACKNOWLEDGEMENTS

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APPENDICES

APPENDIX 1. Species Information for Activity Experiment

Species	Cultivar (source)	Nº of seeds or plants pot^{-1} pre-em	Nº of seeds or plants pot^{-1} post-em	Depth of planting (cm)	Growth stage of untreated plants at:- Spraying post-em	Assessment pre-em	Assessment post-em
Dwarf bean (Phaseolus vulgaris)	The Prince (Nickerson)	3	2	2	1 trifoliate expanding	3 trifoliates flowering	3 trifoliates flowering
Kale (Brassica oleraceae acephala)	Marrowstem (Nickerson)	12	4	0.5	2.5-3 leaves	6 leaves	7 leaves
Polygonum amphibium (amphibious bistort)	[a] WRO Clone 1	4	3	1.5	4 leaves	15 leaves	11 leaves, + axillaries
Perennial ryegrass (Lolium perenne)	Parcour (British seedhouses)	12	8	0.5	3 leaves	5 leaves, 6 tillers	5 leaves, 8 tillers
Avena fatua (wild oat)	[b] LARS 1989	10	5	1	3 leaves	6 leaves, 1 tiller	8 leaves, 2 tillers
Elymus repens (common couch)	[b] LARS	6	5	1	3-4 leaves	7 leaves, 2 tillers	7 leaves, 2 tillers

[a] WRO denotes rhizome collected from stockbed plants originally propagated at the Weed Research Oganization, Oxford, but now maintained at Long Ashton Reseach Station. [b] LARS denotes seed or rhizome collected from stockbed plants propagated and maintained at Long Ashton Research Station.

APPENDIX 2. Species Information for Pre-emergence Experiment

Species	Cultivar or source	No. pot^{-1}	Depth of planting (cm)	Growth stage of untreated controls at assessment
Wheat (*Triticum aestivum*)	Longbow	8	1	5 leaves, 2 tillers
Barley (*Hordeum vulgare*)	Pastoral	8	1	5 leaves, 1 tiller
Oat (*Avena sativa*)	Solva	8	1	5 leaves
Maize (*Zea mays*)	LG 11	4	2	6 leaves
Perennial ryegrass (*Lolium perenne*)	Parcour	12	0.5	6 leaves, 4 tillers
Onion (*Allium cepa*)	White Lisbon	10	0.5	6 leaves
Dwarf bean (*Phaseolus vulgaris*)	The Prince	4	2	3 trifoliates, flower buds
Field bean (*Vicia fabia*)	Maris Bead	4	1.5	7 leaves, flower buds
Pea (*Pisum sativum*)	Meteor	4	1.5	8 leaves, flowering
White clover (*Trifolium repens*)	Huia	15	0.25	8 stolons, up to 6 trifoliates on stolons
Sugar beet (*Beta vulgaris*)	Hilma	10	1	6 leaves
Oilseed rape (*Brassica napus oleifera*)	Libravo	12	0.5	5 leaves
Kale (*Brassica oleracea acephala*)	Marrowstem	12	0.5	5 leaves
Swede (*Brassica napus*)	Marian	12	0.5	5 leaves
Carrot (*Daucus carota*)	Scarlet Horn	15	0.5	6 leaves
Parsnip (*Pastinaca sativa*)	Avon Resister	20	0.5	5 leaves
Lettuce (*Lactuca sativa*)	Webbs Wonderful	12	0.5	5 leaves
Sunflower (*Helianthus annuus*)	Frankasol	6	1.5	2 pairs leaves

APPENDIX 2. (cont'd) Species Information for Pre-emergence Experiment

Species	Cultivar or source	No. pot^{-1}	Depth of planting (cm)	Growth stage of untreated controls at assessment
Linseed (*Linum usitatissium*)	Norlin	8	0.5	75 leaves
Alopecurus myosuroides (Blackgrass)	Herbiseed	20	0.25	5 leaves, 3 tillers
Avena fatua (Wild oat)	LARS/NP	10	1	5 leaves
Bromus sterilis (Barren brome)	LARS/NP (Stock 34)	10	1	6 leaves, 2 tillers
Festuca rubra (Red fescue)	Herbiseed	20	0.5	5 leaves, 5 tillers
Poa annua (Annual meadow-grass)	Herbiseed	25	0.25	5 leaves, 5 tillers
Poa trivialis (Rough meadow-grass)	Herbiseed	25	0.25	5 leaves, 3 tillers
Elymus repens (Common couch)	LARS (Stockbed)	6	1.5	5 leaves, 1 tiller
Raphanus rapanistrum (Wild radish)	Herbiseed	20	0.5	9 leaves, flower buds
Sinapis arvensis (Charlock)	Herbiseed	20	0.5	7 leaves, flowering
Chrysanthemum segetum (Corn marigold)	Herbiseed	25	Surface	8 leaves
Matricaria perforata (Scentless mayweed)	Herbiseed	25	Surface	10 leaves
Senecio vulgaris (Groundsel)	Herbiseed	25	Surface	10 leaves, flower buds
Polygonum lapathifolium (Pale persicaria)	Herbiseed	20	0.5	7 leaves
Fallopia convolvulus (Black bindweed)	Herbiseed	20	0.5	6 leaves
Lamium purpureum (Red dead-nettle)	Herbiseed	20	0.5	5 pairs leaves, flower buds
Galium aparine (Cleavers)	LARS (Stockbed)	20	0.5	8 whorls on stems, + axillaries
Chenopodium album (Fat hen)	Herbiseed	30	0.25	8 leaves, flower buds

APPENDIX 2. (cont'd) <u>Species Information for Pre-emergence Experiment</u>

Species	Cultivar or source	No. pot^{-1}	Depth of planting (cm)	Growth stage of untreated controls at assessment
Stellaria media (Common chickweed)	Herbiseed	25	0.25	8 pairs leaves on stems, + axillaries
Spergula arvensis (Corn spurrey)	Herbiseed	15	0.25	6 whorls on stems, + axillaries
Veronica persica (Common field speedwell)	Herbiseed	25	0.25	4 pairs leaves, + axillaries
Viola arvensis (Field pansy)	Herbiseed	25	0.25	7 leaves, + axillaries
Geranium dissectum (Cut-leaved cranesbill)	Herbiseed	20	0.5	8 leaves
Papaver rhoeas (Common poppy)	Herbiseed	50	0.25	16 leaves
Solanum nigrum (Black nightshade)	Herbiseed	20	Surface	6 leaves + axillaries
Rumex obtusifolius (Broad-leaved dock)	Herbiseed	25	0.25	5 leaves
Convolvulus arvensis (Field bindweed)	Herbiseed	20	0.5	7 leaves on main stem, 4 side branches

APPENDIX 3. Species information for Post-emergence Experiment

Species	Cultivar or source	No. plants pot^{-1}	Growth stage of untreated controls: At spraying	Growth stage of untreated controls: At assessment
Wheat (*Triticum aestivum*)	Longbow	5	3 leaves	7 leaves, 3 tillers
Barley (*Hordeum vulgare*)	Pastoral	5	3 leaves	6 leaves + flag, 2 tillers
Oat (*Avena sativa*)	Solva	5	3 leaves	7 leaves + flag, stem swollen
Maize (*Zea mays*)	LG 11	3	3 leaves	6 leaves
Perennial ryegrass (*Lolium perenne*)	Parcour	8	4 leaves	7 leaves, 8 tillers
Onion (*Allium cepa*)	White Lisbon	5	2.5 leaves	6 leaves
Dwarf bean (*Phaseolus vulgaris*)	The Prince	2	Unifoliates expanded	5 trifoliates, flowered
Field bean (*Vicia faba*)	Maris Bead	3	3 leaves	10 leaves, flower buds
Pea (*Pisum sativum*)	Meteor	3	3 leaves	10 leaves, flowered
White clover (*Trifolium repens*)	Huia	5	7 trifoliates	5 stolons, 5-10 trifoliates on stolons
Sugar beet (*Beta vulgaris*)	Hilma	5	4 leaves	10 leaves
Oilseed rape (*Brassica oleracea oleifera*)	Libravo	5	3 leaves	7 leaves
Kale (*Brassica oleracea acephala*)	Marrowstem	5	3 leaves	6 leaves
Cabbage (*Brassica oleracea capitata*)	Xmas Drumhead	5	2.5 leaves	9 leaves
Carrot (*Daucus carota*)	Scarlet Horn	5	2.5 to 3 leaves	6 leaves
Parsnip (*Pastinaca sativa*)	Avon Resister	5	3 leaves	5 leaves
Lettuce (*Lactuca sativa*)	Webbs Wonderful	5	4 leaves	10 leaves
Sunflower (*Helianthus annuus*)	Frankasol	3	2 pairs leaves	5 pairs leaves

APPENDIX 3. (cont'd) Species information for Post-emergence Experiment

Species	Cultivar or source	No. plants pot^{-1}	Growth stage of untreated controls: At spraying	Growth stage of untreated controls: At assessment
Linseed (*Linum usitatissium*)	Norlin	5	15 leaves	70 leaves, flowering
Alopecurus myosuroides (Blackgrass)	Herbiseed	5	3.5 leaves, 1 tiller	12 tillers
Avena fatua (Wild oat)	LARS/NP	5	3.5 leaves, 1 tiller	7 leaves + flag, stem swollen
Bromus sterilis (Barren brome)	LARS/NP (Stock 34)	5	3.5 leaves	6 leaves, 4 tillers
Festuca rubra (Red fescue)	Herbiseed	5	4 leaves, 2 tillers	25 tillers
Poa annua (Annual meadow-grass)	Herbiseed	5	5 leaves, 3 tillers	20 tillers
Poa trivialis (Rough meadow-grass)	Herbiseed	6	4 leaves, 2 tillers	20 tillers flowering stems
Agrostis stolonifera (Creeping bent)	Herbiseed	5	4 leaves, 3 tillers	12 tillers, flowering stems
Elymus repens (Common couch)	LARS (Stockbed)	4	3.5 leaves, 1 tiller	9 leaves, 1-2 tillers
Raphanus raphanistrum (Wild radish)	Herbiseed	3	2.5 leaves	6 leaves, flowering
Sinapis arvensis (Charlock)	Herbiseed	5	4 leaves	6 leaves, flowered
Chrysanthemum segetum (Corn marigold)	Herbiseed	3	6 leaves,	17 leaves, axillaries, flowering
Matricaria perforata (Scentless mayweed)	Herbiseed	4	6 leaves	14 leaves, axillaries, flowering
Senecio vulgaris (Groundsel)	Herbiseed	4	4 leaves	10 leaves, flowering
Polygonum aviculare (Knotgrasss)	Herbiseed	1	6 leaves, 2 branches	20 leaves, many axillaries
Polygonum lapathifolium (Pale persicaria)	Herbiseed	4	3.5 leaves	10 leaves, flowering
Fallopia convolvulus (Black bindweed)	Herbiseed	4	3 leaves	18 leaves, axillaries, flowering
Lamium purpureum (Red dead-nettle)	Herbiseed	4	4 pairs leaves	8 pairs, 2 main side, branches, flowering

APPENDIX 3. (cont'd) Species information for Post-emergence Experiment

Species	Cultivar or source	No. plants pot^{-1}	Growth stage of untreated controls: At spraying	Growth stage of untreated controls: At assessment
Galium aparine (Cleavers)	LARS (stockbed)	4	3 whorls, 2 small branches	10 whorls on 6 main branches, axillaries
Chenopodium album (Fat hen)	Herbiseed	4	6 leaves	15 leaves, axillaries, flowering
Stellaria media (Common chickweed)	Herbiseed	4	5 pairs leaves, 2 branches	10 pairs leaves on branches, flowering
Spergula arvensis (Corn spurrey)	Herbiseed	4	2 whorls 2 branches	4 whorls on 5 main branches, flowering
Veronica persica (Common field speedwell)	Herbiseed	4	3 pairs leaves	6 pairs leaves, 4 main branches, flowering
Viola arvensis (Field pansy)	Herbiseed	4	5 leaves	9 leaves, axillaries, flowering
Geranium dissectum (Cut-leaved cranesbill)	Herbiseed	4	5 leaves	22 leaves
Papaver rhoeas (Common poppy)	Herbiseed	4	6 leaves	14 leaves, axillaries, flowering
Solanum nigrum (Black nightshade)	Herbiseed	4	4 leaves	9 leaves, axillaries, flowering
Rumex obtusifolius (Broad-leaved dock)	Herbiseed	4	4 leaves	8 leaves
Cirsium arvense (Creeping thistle)	LARS stock	2	6 leaves	10 leaves, + axillaries
Convolvulus arvensis (Field bindweed)	Herbiseed	4	4 leaves	13 leaves on main stem, 6 branches, + axillaries

APPENDIX 4 Addresses of UK seed suppliers

British Seedhouses
Portview Road
Avonmouth
Bristol
England

Nickerson Seeds
Rothwell
Lincoln LN7 6DT
England

Herbiseed
The Nurseries
Billingbear Park
Wokingham RG11 5RY
England

APPENDIX 5 ABBREVIATIONS

acid equivalent	a.e.	minute	min
active ingredient	a.i.	more than	$>$
approximately equal to	$\approx$	organic matter	o.m.
centimetre	cm	page	p.
cultivar (s)	cv.	pages	pp.
degree centigrade	°C	part per million	ppm
emulsifiable concentrate	EC	per	$^{-1}$
equal to	=	percent(age)	%
gramme	g	plus or minus	±
hectare	ha	post-emergence	post-em
hour	h	pre-emergence	pre-em
hydrogen ion concentration	pH	relative humidity	r.h.
kilogramme	kg	second	s
less than	$<$	soluble liquid	SL
litre	l.	species (singular)	sp.
maximum	max	species (plural)	spp.
metre	m	sub-species	ssp.
micrometre	μm	temperature	temp
milligramme	mg	varietas	var.
millilitre	ml	volume per volume	v/v
millimetre	mm	water dispersible granule	WG
minimum	min.	wettable powder	WP

APPENDIX 6

CROP AND ENVIRONMENTAL SCIENCES DEPARTMENT
IACR, LONG ASHTON RESEARCH STATION

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. May 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. A Philipson. Price £0.25

19.* The pre-emergence selectivity of some recently developed herbicides in jute, kenaf and sesamum, and their activity against Oxalis 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 Philipson, T W Cox and J G Elliot. Price £0.35

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

22. The pre-emergence selectivity of some newly developed herbicides: bentazon, BAS 373OH, 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 Philipson. 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: bentazone, 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 (Rumex obtusifolius L.). November 1973. A M Blair and J Holroyd. Price £1.06

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

32. The activity and post-emergence selectivity of some recently developed herbicides: oxadizon, 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 Simmonds. Price £0.63

34. The activity and pre-emergence selectivity of some recently developed herbicides: trifluralin, ispropalin, 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, chloronitrofen, 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 and M L Dean. Price £4.00

45. Methods of analysis for determining the effects of herbicides on soil micro-organisms and their activities. January 1978. M P Greaves, S L Cooper, H A Davies, J A P Marsh and 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 herbicides: 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 (Amended version to be printed in 1986)

60. Properties of natural rainfalls and their simulation in the laboratory for pesticide research. September 1980. R C Simmonds. 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 Simmonds. 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 Commision. 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 Simmonds. 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

82. An IRGA system for continuous monitoring of CO_2 and H_2O vapour exchange in replicate plants growing in controlled environments. January 1985. C R Merritt and R C Simmonds. Price £3.00

83. A laboratory pot sprayer for use with controlled environment chambers. February 1985. R C Simmonds and J A Drinkwater. Price £2.50

84. Maps of the changes in the weeds of Boddington Barn field over twenty years (1961-1981). March 1985. R J Chancellor. Price £4.50

85. The use of bentazone and pyridyl herbicides alone and in mixtures for the control of creeping thistle (Cirsium arvense L.) in grassland. April 1985. W G Richardson, A K Oswald and T M West. Price £1.50

86. The activity and pre-emergence selectivity of some recently developed herbicides: metazachlor, butamifos, MT-124, tridiphane, MK 616 and prodiamine. May 1985. W G Richardson and T M West. Price £7.00

87. The potential use of grass growth retardants at Sullom Voe terminal, Shetland. A report prepared for W J Cairns and Partners, 16 Randolph Crescent, Edinburgh, Environmental Consultants to BP Petroleum Development Ltd as Operators of Sullom Voe Terminal. May 1985. E J P Marshall. Price £3.00

88. A further study of the effect of six cereal herbicide treatments on a range of broad-leaved field margin plants. June 1985. J E Birnie. Price £2.50

89. The activity, pre- and post-emergence selectivity of diflufenican. December 1985. W G Richardson and T M West. Price £3.00

90. The pre-emergence selectivity in warm-climate species of some recently developed herbicides: imazaquin, AC 263499, cinmethylin and isoxaben. January 1986. C Parker and A K Wilson. Price £2.60

91. The activity, pre-emergence selectivity and persistence of some recently developed herbicides: DOWCO 453, quizalofop-ethyl, BAS 517 00H, cinmethylin, AC 263499 and RST 20024H. W G Richardson and T M West. Price £6.20

92. The activity and post-emergence selectivity of some recently developed herbicides: SMY 1500, PPG 884, PPG 1259 and DPX-M 6316. W G Richardson and T M West. February 1986. Price £4.20

93. The pre-emergence selectivity in warm-climate species of some recently developed herbicides: metazachlor, RST 20024H, orbencarb and diflufenican. C Parker and A K Wilson. February 1986. Price £2.70

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96. Studies of the flora in Arable Field Margins. E J P Marshall. October 1986. Price £3.50

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99. The pre-emergence selectivity in warm-climate species of some recently developed herbicides: SMY 1500, PPG 884, PPG 1259, DPX-M 6316 and FMC 57020. A K Wilson and C Parker. August 1988. Price £5.00

100. The post-emergence selectivity in warm-climate species of some recently developed herbicides: AC 263499, BAS 514, CGA 131036, DPX L5300, and DPX A7881. A K Wilson. August 1988. Price £3.50

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107. Pre-emergence and post-emergence selectivity and persistence of the herbicide UBI C4874. T M West. August 1992. Price £4.00

108. The activity, pre-emergence and post-emergence selectivity and persistence of the herbicide SAN 582 H. T M West. January 1993. Price £4.00

109. The pre- and post-emergence activity, selectivity and persistence of the herbicide fluoroglycofen-ethyl (RH 0265). T M West. April 1993. Price £4.00