Seedling Tolerance of Different Grass Species to Sulfonylurea Herbicides

Solvejg K. Mathiassen, Per Kudsk and Peder E. Jensen[1]

ABSTRACT

The tolerance of seedlings of grass species to sulfonylurea herbicides was examined in pot and field experiments. In pot experiments there was a reduced tolerance in the order *Festuca rubra* L. > *Lolium perenne* L. ≥ *Poa pratensis* L. > *Festuca pratensis* Huds. Metsulfuron was more phytotoxic than triasulfuron, tribenuron and thifensulfuron while amidosulfuron injured the grass seedlings less than the other sulfonylurea herbicides. Both root and shoot uptake appeared to be important for the activity of tribenuron while amidosulfuron was primarly taken up by the roots. In general plants were more susceptible at the 1-2 leaf stage compared to the 3-4 leaf stage. In field experiments tribenuron+thifensulfuron applied to 15 different cultivars of grasses undersown in spring barley reduced growth of *Phleum pratense* L., *F. pratensis* and *L. perenne*, tribenuron+ioxynil+bromoxynil reduced the growth of *F. pratensis* while amidosulfuron did not affect the growth of any of the grass seedlings. In further field trials with *Poa pratensis* undersown in winter cereal and *Lolium multiflorum* Lam., *L. perenne*, *F. rubra* and *Dactylis glomerata* L. undersown in spring barley, triasulfuron, tribenuron, thifensulfuron and amidosulfuron occasionally retarded growth of the grasses in the first year following application. However, in all experiments growth retardation appeared to be temporary, with symptoms disappearing in the following season.

Additional index words: grass seedlings, tolerance, sulfonylurea herbicides.

INTRODUCTION

In Denmark perennial grasses for seed production are normally established in a cover crop as they do not become reproductive during the first growing season and typically they require two full growing seasons to produce an economically harvestable seed yield. It is essential for high quality seed production to keep the field free of weeds and hence it is important to initiate weed control in the cover crop. In cereals with undersown grasses the phenoxyalkanoic acid herbicides have been previously used for controlling broad-leaved weeds. However since this group of herbicides has occasionally been found in Danish groundwater (Spliid and Køppen, 1998) their use has been severely restricted, and it is no longer legal to use phenoxyalkanoic acids during the establishment phase of cereals.

In cereals without undersown grasses the phenoxyalkanoic acid herbicides have been replaced by sulfonylurea herbicides, fluroxypyr+clopyralid+ioxynil or ioxynil+bromoxynil. However, only ioxynil+bromoxynil is approved for use in cereals with undersown grasses, and constitutes together with bentazone, the only possibility for weed control. Consequently, there is a need to identify alternative herbicides for use in cereals undersown with grasses for seed production.

The sulfonylurea group consist of relatively new herbicides which can control a wide spectrum of broad-leaved weeds. Sulfonylurea herbicides are of low toxicity to humans and animals, but very active on some plants. They are used at very low rates which makes them easy to handle, and reduces the amount of active ingredient in the environment and the amount of waste. The crop metabolizes the products in a few days and there are no residues at harvest. The products degrade rather fast in soil with half lives ranging from half a day to six weeks (Brown, Lichtner, Hutchison and Saladini, 1995). The efficacy of the sulfonylureas against most relevant weed species is well-known from experiments in cereals, and the possibility of using these herbicides in cereals with undersown grasses would widen the application timing and enable a more broad spectrum weed control compared to the current possibilities. However knowledge of the susceptibility of grass seedlings to the sulfonylurea herbicides is limited.

The purpose of this study was to examine the tolerance of grass seedlings to sulfonylurea herbicides. The susceptibility to several sulfonylurea herbicides of selected grass species at different growth stages was examined in pot experiments. Further investigations concerning the foliar activity and the influence of adjuvants on the activity of the least phytotoxic herbicides were carried out on the most tolerant species, and finally the tolerance of selected grass species was examined in field trials.

MATERIALS AND METHODS

Pot experiments

Lolium perenne L. (cv. Lisabelle), *Festuca pratensis* Huds. (cv. Sebo), *Festuca rubra* L. (cv. Tamara) and *Poa pratensis* L. (cv. Balin) seeds were sown in 1 litre pots in a sandy loam soil (JB 6). The pots were placed on a gravimetric watering table in a glasshouse and were subirrigated daily to field capacity with a nutrient solution including all necessary micro and macro nutrients. After emergence the seedlings were thinned to a uniform number per pot varying from 6 to 15 depending on species.

Different growth stages at the time of herbicide application were obtained by sowing on different dates. Herbicides were applied using a laboratory pot sprayer fitted with Hardi 4110-14 flat fan nozzles delivering a spray volume of 150 litre ha^{-1}. The following commercial herbicides were included in the experiments: metsulfuron (Ally 20 DF), tribenuron (Express), thifensulfuron (Harmony), amidosulfuron (Gratil) and triasulfuron (Logran). The herbicides were applied alone or

[1] *Danish Institute of Agricultural Sciences, Department of Crop Protection, Flakkebjerg, DK-4200 Slagelse, Denmark.* *Accepted for publication 3 June 1999.*

in mixture with 0.1% of a non-ionic surfactant (Lissapol Bio). During the first three days following herbicide application 50 ml of water was applied twice to the soil surface of each pot to ensure maximum soil activity. In some experiments the importance of foliar uptake for the efficacy of the herbicide was examined using the method described by Richardson and Dean (1973). In these cases the soil surface was protected from herbicide with a layer of vermiculite to intercept any spray which might reach the soil surface during spraying. Following drying of the spray droplets and prior to watering the soil surface, the vermiculite was carefully removed.

Plants were harvested 3 to 4 weeks after application and fresh and dry foliage weights were recorded. Each treatment ws replicated three times.

All pot experiments were carried out in the autumn. The temperature in the glasshouse was 15^0 C and the daylength was kept at 16 hours by a supply of artificial light.

Field experiments
Field experiments were conducted at Roskilde Research Station and at local farms. In all experiments a split plot design with 3 replications was used. The herbicides were applied with an experimental plot sprayer equipped with Hardi 4110-12 flat fan nozzles delivering a spray volume of 200 litre ha^{-1}. The plot size in trials with 15 grass cultivars was 4 m^2 while in the other experiments plot size varied between 20 and 25 m^2.

Over two years the tolerance to tribenuron (7.5 g ha^{-1}), tribenuron+thifensulfuron (3.8+7.5 g ha^{-1}) and amidosulfuron (30 g ha^{-1}) of 15 grass cultivars undersown in spring barley was examined. Tribenuron was applied in mixture with 0.1% of a non-ionic surfactant (KG 691) and amidosulfuron in mixture with 0.4 litre ha^{-1} of an anionic surfactant (Isoblette). Applications were carried out in the end of May or the beginning of June at the 1-2 leaves stage of the grasses. The following species and cultivars were included: *Agrostis tenuis* Sibth. (cv. Baratis and Bardot), *Poa pratensis* (cv. Balin, Compact and Conni), *Poa trivialis* L. (cv. Dasas), *Festuca rubra* (cv. Pernille), *F. arundinacea* Schreb (cv. Cochise), *F. pratensis* (cv. Laura), *Lolium multiflorum* Lam. (cv. Sekim), *L. perenne* (cv. Tivoli, Borvi and Allegro), *Dactylis glomerata* L. (cv. Arnba) and *Phleum pratense* L. (cv. Topas).

In a series of experiments at local farms the tolerance of undersown grass seedlings of *L. perenne* (cv. Score, Lisabella and Gator), *L. multiflorum* (cv. Turgo), *F. rubra* (cv. Symfoni) and *D. glomerata* (cv. Reda) to different sulfonylurea herbicides was examined in eight experiments over two years. The herbicides included amidosulfuron (30 g ha^{-1}), tribenuron (7.5 g ha^{-1}) and thifensulfuron (15 g ha^{-1}). In 1996 triasulfuron (4 g ha^{-1}) was included in the experiments but it was replaced by tribenuron+thifensulfuron (3.8+7.5 g ha^{-1}) in the 1997 experiments. All herbicides were applied in mixture with a non-ionic surfactant (0.1% KG 691), except amidosulfuron which was applied in mixture with 0.4 litre ha^{-1} Isoblette. The mean temperature for the time of application was between 8 and 14^{0}C and May rainfall was about 50 mm in both years.

In three experiments over two years the tolerance of *Poa pratensis* (cv. Sobra, Primo and Opal) to tribenuron (1.9 g ha^{-1}), thifensulfuron (6 g ha^{-1}) and amidosulfuron (15 g ha^{-1}) applied alone or in mixture with isoxaben (50 g ha^{-1}) was examined. *Poa pratensis* was undersown in winter wheat two experiments) or in winter barley (one experiment). Applications were made in October and November at average temperatures of 3 to 8^0 C. Rainfall in November 1995 was 36 mm and in October and November 1996 it was 55 mm in each month. Herbicide injury was visually assessed after harvest of the cover crop and in the following growing season. A rating from 0 to 100% was used with 100% indicating that all grass seedlings were dead, while a rating of 0 indicated that growth of the grass seedlings was unaffected by the herbicide treatment. Growth of the grasses was not retarded in the seed production year in any of the experiments and therefore none of the experiments were harvested for seed.

Statistics
Analysis of variance was performed using the GLM procedure of SAS. In pot experiments means of the treatments were compared using Duncan's Multiple Comparisons Test while in the field experiments the LSD values at $P<0.05$ were calculated.

RESULTS

Pot experiments
F. rubra was more tolerant and *F. pratensis* was more susceptible to the sulfonylurea herbicides than *L. perenne* and *Poa pratensis* (Fig. 1). Metsulfuron was the most phytotoxic and amidosulfuron the least phytotoxic herbicide. In general the grass species were more susceptible at the 1-2 compared to the 3-4 leaf stage. On the basis of these results only the two least harmful sulfonylurea herbicides, amidosulfuron and tribenuron, and the two most tolerant grass species, *L. perenne* and *F. rubra*, were included in subsequent pot experiments.

The sulfonylurea herbicides exert soil as well as foliar activity. On *L. perenne* addition of a surfactant to the spray solution significantly increased the foliar activity of tribenuron (Fig. 2). Without surfactant the overall activity was greater than the foliar activity indicating that the soil activity also contributed to the overall effect. However, in mixture with the surfactant no differences were found between the foliar and overall efficacy suggesting that the improvement in foliar activity by the surfactant turned tribenuron into a predominantly foliar active herbicide. The situation was different with amidosulfuron as the surfactant did not influence the foliar activity of this herbicide. However the overall activity was significantly higher than the foliar activity, indicating that the efficacy of this herbicide could mostly be attributed to its soil activity (Fig. 2).

As in the previous experiments *F. rubra* was more tolerant to tribenuron than *L. perenne*. The foliar activity of tribenuron on *F. rubra* was not influenced by the addition of a surfactant and the contribution of soil activity to the overall activity was insignificant. The results of amidosulfuron on *F. rubra* were similar to the results on *L. perenne*, i.e. that the total activity of amidosulfuron was significantly higher than the foliar activity, indicating that root uptake played an important role.

Field experiments
In two years of experimentation with sulfonylurea herbicides applied to 15 different cultivars of grasses established in spring barley, there was no injury to any of the grasses after application of amidosulfuron. In one year tribenuron+thifensulfuron (3.8+7.5 and 7.5+15.0 g ha^{-1}) caused growth reduction of *F. pratensis* (25-30%), *Phleum pratense* (10-22%) and *L. perenne*

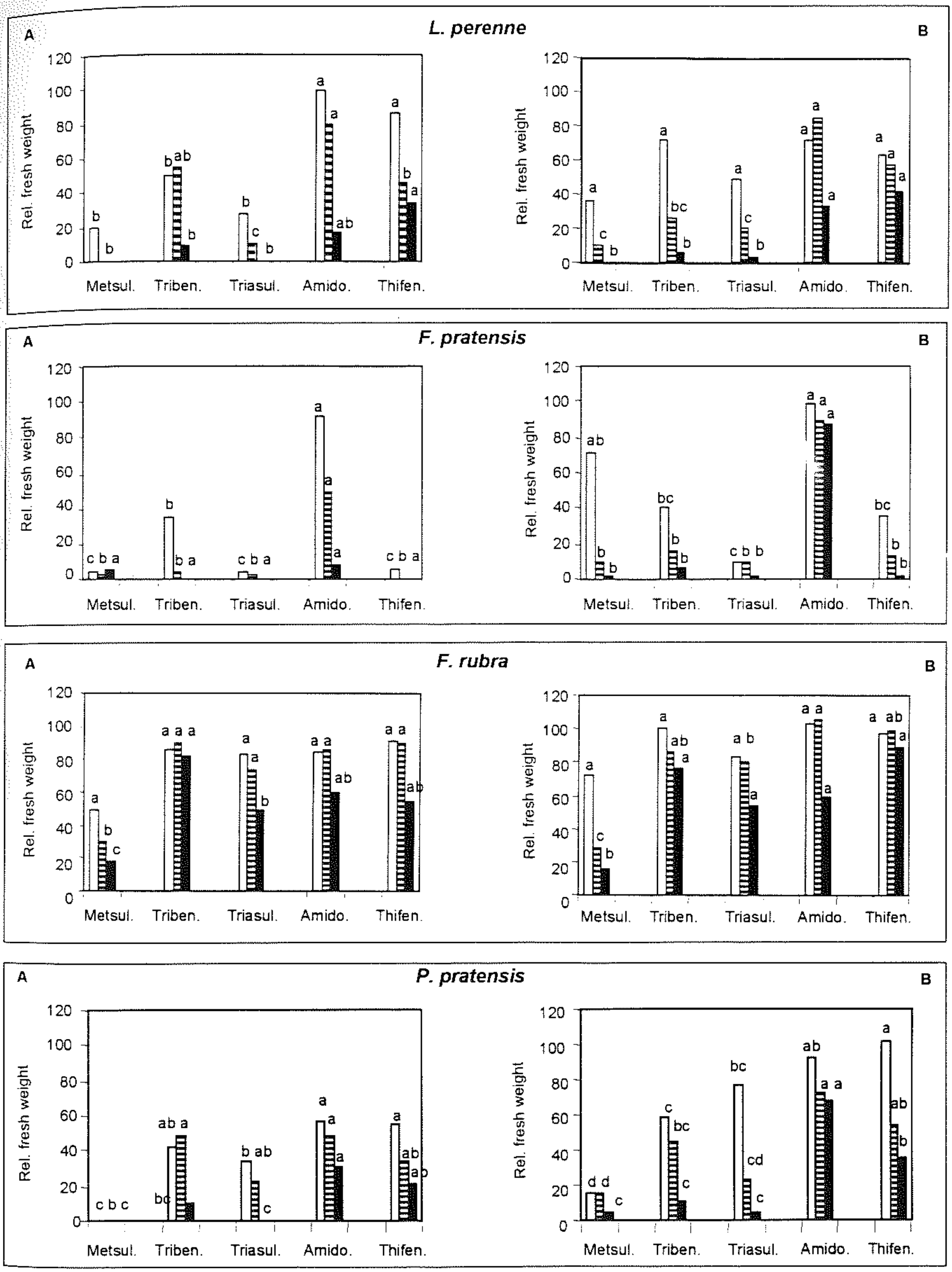

Figure 1. Relative fresh weight of *L. perenne, F pratensis. F. rubra* and *Poa pratensis* seedlings treated with metsulfuron (4 g ha^{-1}), tribenuron (7.5 g ha^{-1}), triasulfuron (4 g ha^{-1}), amidosulfuron (30 g ha^{-1}) and thifensulfuron (7.5 g ha^{-1}). The herbicides applied at ■ full rate ⊟ 1/2 and □ 1/4 of the full rate at the 1-2 leaf stage (A) and the 3-4 leaf stage (B) of pot-grown seedlings. Columns marked by the same letter within each rate are not significantly different (P<0.05) using Duncan's muliple range test.

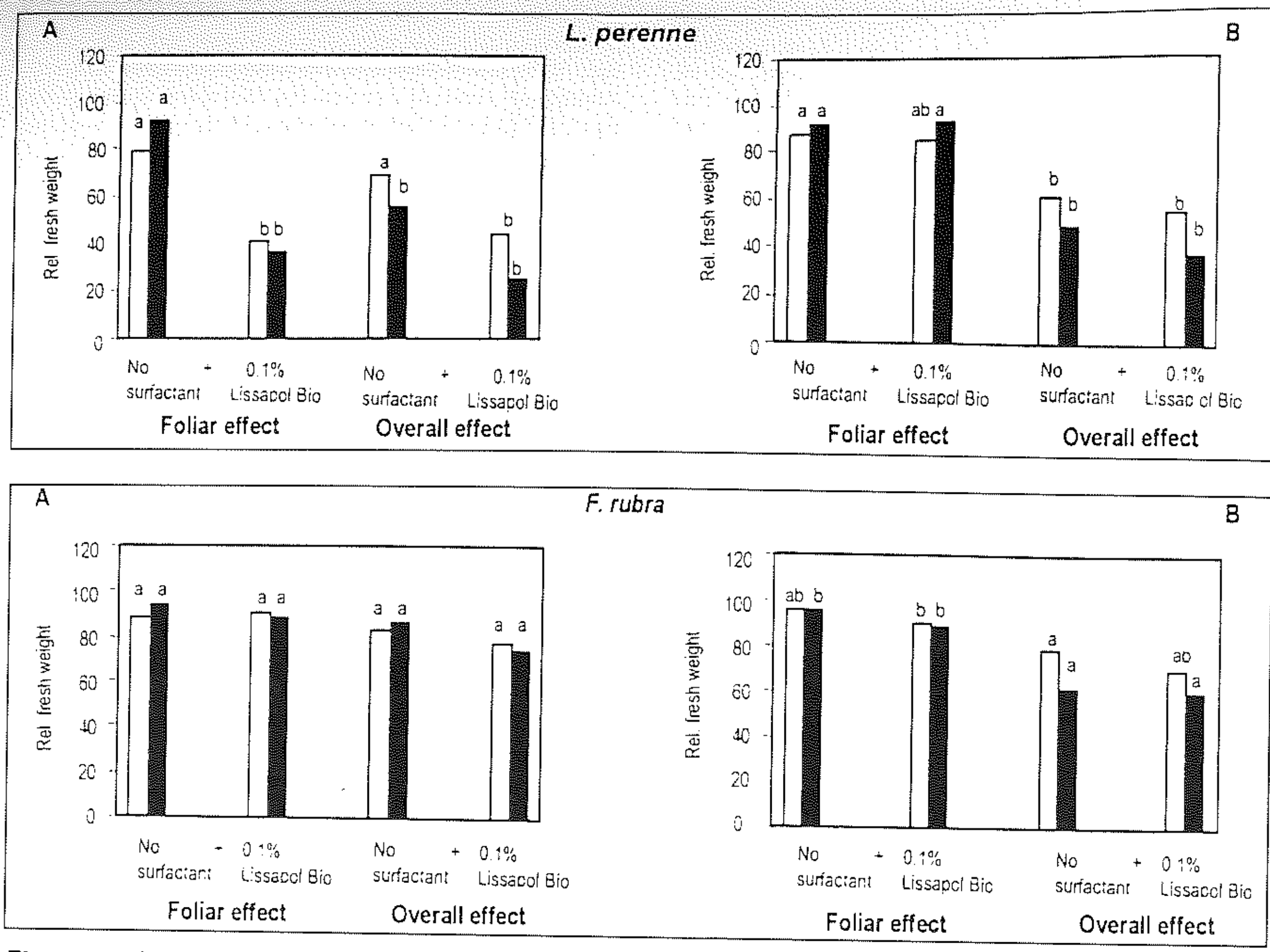

Figure 2. Foliar and overall effect of (A) tribenuron (7.5 g ha^{-1}), and (B) amidosulfuron (30 g ha^{-1}). The herbicides were applied at ■ full rate and □ 1/2 of full rate at the 1-2 leaf stage of pot-grown seedlings of *L.perenne* and *F. rubra.* Columns marked by the same letter within each rate are not significantly different ($P<0.05$) using Duncan's multiple range test.

(3-10%) in the autumn (results not shown). In addition tribenuron+ioxynil+bromoxynil (7.5+200+200 g ha^{-1}) also injured *F. pratensis* in one year.

The results of two years field experiments studying the tolerance of *L. perenne, L. multiflorum, F. rubra* and *D. glomerata* to different sulfonylurea herbicides are shown in Table 1. The grass species were established in spring barley and the herbicide applications were made in the spring when the grass seedlings had 1-2 leaves. Visual assessment of the growth of the grasses was made one (experiment 1-3, 8) or two times (experiment 4-7). In 1996 there was no injury to *L. perenne.* However injury to *L. multiflorum* as well as *D. glomerata* was observed after harvest of the barley crop, with *D. glomerata* being the most susceptible. Triasulfuron and thifensulfuron were the most phytotoxic of the herbicides while while tribenuron and in particular amidosulfuron were less phytotoxic.

In 1997 no damage was observed on *F. rubra.* The sulfonylurea herbicides did not injure *L. perenne* in experiment 3 but growth reduction was found in experiment 4. *D. glomerata* was also injured, although the growth reductions were less pronounced than in 1996. No significant difference in phytotoxicity of the sulfonylurea herbicides was found on *L. perenne* whereas the full rate of the formulated mixture of tribenuron + thifensulfuron (equal to half rates of each of the ingredients) caused less damage on *D. glomerata* than a full rate of each of the individual products.

In all trials application was carried out at the same growth stage of the grasses (11-12). In 1996 as well as in 1997 the barley crop in the trials without damage was at a later growth stage than in the trial where the grasses were injured, suggesting that tolerance may be related to different retention of the spray solution by the cover crop. In both years the later assessments showed that the plants recovered with time.

The results of three experiments on *Poa pratensis* established in winter cereals and treated with sulfonylurea herbicides in the autumn are shown in Table 2. The herbicides were applied without surfactants and rates were reduced compared to those used in the experiments shown in Table 1. Assessments in the spring showed that in 1996 almost all herbicides reduced growth of the seedlings. The only exception was tribenuron in mixture with isoxaben and we are not able to explain this result. In 1997 injury was only found following application of amidosulfuron and thifensulfuron alone or thifensulfuron in mixture with isoxaben. The more severe injury in 1996 compared to 1997 could be explained by differences in the growth stage of the cover crop. In addition the winter of 1995-96 was very cold and dry which could affect the ability of the

Table 1. The effect of sulfonylurea herbicides on seedling injury for four grass species undersown in spring barley.

		L. perenne			*L. multiflorum*				*D. glomerata*		*F. rubra*		
Experiment		1	2	3	4		5		6		7		8
Cultivar		Score	Lisabella	Score	Gator		Turgo		Reda		Reda		Symfoni
Appl. date in May/year		13/96	13/96	14/97	12/97		14 /96		13/96		16/97		23/96
Growth stage of barley		21	21	23	21		13		14		21		23
Assessment date		Aug. 96	Aug. 96	Nov. 97	Oct. 97	Nov. 97	Aug. 96	July 97	Sept. 96	July 97	Aug. 97	Nov. 97	Nov. 97
Herbicide[1]	**Rate g ha^{-1}**												
Untreated		0	0	0	0	0	0	0	0	0	0	0	0
Amidosulfuron	30	0	0	0	10	0	12	3	23	0	15	0	0
	15	0	0	0	3	0	0	3	0	0	0	0	0
	7.5	0	0	0	3	0	0	0	0	0	0	0	0
Tribenuron	7.5	0	0	0	13	0	32	5	60	7	15	0	0
	3.8	0	0	0	7	0	15	3	42	3	13	0	0
	1.9	0	0	0	3	0	0	0	30	0	0	0	0
Thifensulfuron	15	0	0	0	17	0	70	18	75	15	15	0	0
	7.5	0	0	0	17	0	48	3	60	7	0	0	0
	3.8	0	0	0	7	0	30	0	48	0	0	0	0
Triasulfuron	4	0	0	3			60	18	72	17			
	2	0	0				43	8	65	25			
	1	0	0				32	0	55	3			
Triben.+thifens.	3.8+7.5			0	13	0					3	0	0
	1.9+3.8			0	10	0					0	0	0
	1.0+1.9			0	7	0					0	0	0
LSD P<0.05[4]		n.s.	n.s.	n.s.	7.4	n.s	5.9	6.8	5.8	6.8	4	n.s.	n.s.

[1] *all herbicides applied in a mixture with 0.1% K691 except for amidosulfuron which was mixed with 0.41 ha^{-1} Isoblette*

[2] *score range from 0 = no damage to 100 = all dead*

[3] *missing values are due to the replacement of triasulfuron by tribenuron + thifensulfuron in 1997*

[4] *LSD values refer to herbicides at the same rate*

Table 2. Visual assessment of herbicide injury to *Poa pratensis* undersown in winter wheat (cv. Sobra and Opal) or winter barley (cv. Primo).

Cultivar		Sobra		Opal	Primo	
Application date: month/ date/ year		11/06/1995		11/14/1996	10/23/1996	
Growth stage of cereals at application		13		21	21	
Assessment time: Month/year		05/ 96	11/96	04/97	04/ 97	09/97
Herbicide[1]	Rate g ha^{-1}					
Untreated		0.0[2]	0.0	0.0	0.0	0.0
Isoxaben	50	0.0	0.0	0.0	0.0	0.0
Tribenuron	1.9	32.5	0.0	0.0	0.0	0.0
Tribenuron+isoxaben	1.9+50	0.0	0.0	0.0	0.0	0.0
Amidosulfuron	15	26 .3	0.0	0.0	13.8	0.0
Amidosulfuron+isoxaben	15+50	36.3	0.0	0.0	0.0	0.0
Thifensulfuron	6	31.3	0.0	0.0	7.5	0.0
Thifensulfuron+isoxaben	6+50	35.0	0.0	0.0	15.0	0.0
LSD P<0.05		9.7	n.s.	n.s.	3.3	n.s.

[1]*herbicides applied without surfactants*

[2]*score range from 0 = no damage to 100 = all dead*

grass to recover. Assessment after harvest of the cover crop revealed that the grass seedlings had recovered.

DISCUSSION

Pot experiments are a valuable tool for assessing the short-term injury of herbicides to plants under optimal conditions. However it is not possible, on the basis of pot experiments, to assess the long-term effects. Consequently, it is necessary to complement the pot experiments with field experiments.

The pot experiments revealed major differences in the susceptibility of grass species to sulfonylurea herbicides. In general the tolerance was reduced in the order *F. rubra* > *L. perenne* ≥ *P. pratensis* > *F. pratensis*. Amidosulfuron injured grass seedlings less than tribenuron and thifensulfuron while metsulfuron caused most damage to the seedlings.

In the field experiment the grass species were more tolerant to sulfonylurea herbicides than in the pot experiments. Several factors may account for this difference. Firstly in the pot experiment water was applied to the soil surface twice within the first three days after application, ensuring optimum soil activity. Secondly, in the field experiments the cover crop may have retained some of the spray solution and the assessments was not carried out until October which means that the grasses could to some extent have recovered in the meantime.

In field trials with various sulfonylurea herbicides Machéc and Cagas (1995) found that *F. pratensis* was more susceptible than *L. perenne*, *L. multiflorum* and *Poa pratensis*, and *F. rubra* was the most tolerant species. Jennéus (1998) reported that tribenuron (0.6 g ha^{-1}) applied in the spring and in the autumn to *Phleum pratense* undersown in spring barley did not affect seed yield the following year. The results of Skuterud (1998) also support our findings as he found that *P. pratensis* was more tolerant to tribenuron (4 g ha^{-1}) and amidosulfuron (40 g ha^{-1}) than to thifensulfuron (10 g ha^{-1}).

Our results clearly demonstrated that metsulfuron was the least tolerated sulfonylurea herbicide and Moyer and Kelley (1995) also recorded visual injury to *F. arundinacea* after treatment with metsulfuron (4.3, 6.3 and 8.4 g ha^{-1}). In contrast Malik (1990) found that thifensulfuron (15 and 30 g ha^{-1}) reduced crop vigour of *Phleum pratense* more than metsulfuron (3 and 4.5 g ha^{-1}) while Darwent and Lefkovitch (1995) did not find any yield reduction in *F. rubra* following application of metsulfuron (4.5 g ha^{-1}).

Besides the inherent differences in susceptibility of the grass species to sulfonylurea herbicides, differences in selectivity can to some extent be related to differences in the influence of foliar and soil activity. With foliar active herbicides activity is primarily affected by the shape, surface characteristics and angle of leaves, whereas the main factor influencing the activity of soil active herbicides is soil moisture. Tribenuron is foliar active and accordingly the activity on *L. perenne* was increased in the presence of a surfactant in the spray solution. On *F. rubra* no significant differences were found between the foliar and overall activity and application of the herbicide alone or with a surfactant. *F. rubra* is a difficult-to-wet species with very small and upright leaves at the early growth stages, which may explain the lower foliar activity on this species. Amidosulfuron was primarily a soil active herbicide and consequently the addition of a surfactant to the spray solution did not influence the activity of this herbicide significantly and accordingly the differences in susceptibility to this herbicide between the two species were less pronounced.

The results of field experiments including selected grass species established in spring barley confirmed the results obtained in the pot experiments; i.e. that amidosulfuron and tribenuron were the best tolerated herbicides and *L. perenne* and *F. rubra* were the most tolerant species. The visual assessments one year after treatment showed that all grass species recovered from injury with time. The different responses to treatments between the years and within each year seem to be related to differences in tolerance of different grass species and differences in the amount of herbicide reaching the grass seedlings due to varying growth stages of the cover crop.

The tolerance of *Poa pratensis* to the sulfonylura herbicides varied between the experiments. It is noteworthy that the treatments caused some injury to *Poa pratensis* although the rates were lower than recommended, and the herbicides were applied without surfactants. The difference in damage between the experiments might be the result of different coverage of the cover crop and different possibilities of recovering for the grass seedlings between the two years as the 1995-96 winter was very cold and dry. However no damage to *Poa pratensis* was found in any of the experiments in the autumn after harvesting the cover crop.

In general the results have shown that the tolerance of grass seedlings to sulfonylurea herbicides varied among herbicides and grass species. Susceptibility also depended on several other factors, such as growth stage of the grass seedlings, the cover crop, and whether surfactants were added to the spray solution.

Although not directly included in our experiments, climate at the time of application and soil moisture following application are factors that may also influence herbicide tolerance, and the climate following treatment can also influence the ability of plants to recover from injury.

At present none of the sulfonylurea herbicides are approved for use in cereals with grasses undersown for seed production. This study has shown that it is possible to use amidosulfuron, tribenuron and thifensulfuron in some grass species without severe growth reduction. Experience from cereals has shown that the herbicide rate can often be reduced to 1/3 to 2/3 of the recommended rate without any significant loss of efficacy (Kudsk, 1989; Fisher, Davies and Whytock, 1993). The possibility of using half or quarter rates of tribenuron, amidosulfuron or thifensulfuron alone or in combination with ioxynil+bromoxynil for weed control in the establishment year of grasses would widen the application timing and improve the possibility of keeping the number of weeds at a low level. However application of sulfonylurea herbicides in the seed production year should be avoided, as treatment at this stage often results in severe damage of the grasses and reduced seed yield (Mathiassen, unpublished data).

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REFERENCES

1. Brown H.M., Lichtner F.T., Hutchison J.M. and Saladi J.A. 1995. The impact of sulfonylurea herbicides in cereal crops. *Weeds:* 1143-1152.

2. Darwent A.L. and Lefkovitch L.P. 1995. Control of several perennial weeds in creeping red fescue (*Festuca rubra*) grown for seed. *Weed Technology* 9: 294-300.

3. Fisher N.M., Davies D.H.K. and Whytock G.P. 1993. Reliability of broad-leaved weed control in cereals using low doses of herbicide. *Proceedings of the Brighton Crop Protection Conference, Weeds:* 1223-1228.

4. Jennéus B. 1998. Weed control in timothy (*Phleum pratense* L.). In: NJF report no 121, seminar no 284 Seed Production (ed. T.A. Aamlid), 138-42.

5. Kudsk P. 1989. Experiences with reduced herbicide doses in Denmark and the development of the concept of factor-adjusted doses. *Proceedings of the Brighton Crop Protection Conference, Weeds:* 545-54.

6. Machác J. and Cagas B. 1995. The response of selected grass species to sulfonylurea herbicides. *Journal of Applied Seed Production* 13: 62. (Abstract).

7. Malik N. 1990. Weed control during establishment and yield response of timothy *(Phleum pratense). Weed Technology* 4: 598-605.

8. Moyer J.L. and Kelley K.W. 1995. Broadleaf herbicide effects on tall fescue (*Festuca arundinacea)* seedhead density, forage yield and quality. *Weed Technology* 9: 270-76.

9. Richardson W.G. and Dean M.L. 1973. The pre-emergence selectivity of some recently developed herbicides. Technical report no. 25. Agricultural Research Council, Weed Research Organization, Oxford, U.K.

10. Skuterud R. 1998. Testing of herbicides in leys and in seed production of clover and grasses. In: NJF report no 121, seminar no 284 Seed Production (ed. T.A. Aamlid), 143-50.

11. Spliid N.H. and Køppen B. 1998. An extended survey of pesticides in ground water. DJF report no 2, proceedings from 15th Danish Plant Protection Conference, Side effects ofpesticides: 31-42.