Project title:	Nursery stock: Herbicide screening for tree seed beds.
Project number:	HNS 155
Project leader:	John Atwood, ADAS UK Ltd
Report:	Final report, January 2010
Previous report:	None
Key staff:	John Atwood, ADAS, Project Leader David Talbot, ADAS, Site Manager Scientific support, ADAS Rosemaund
Location of project:	J & A Growers, Wasperton, Warwick, CB35 8EB
Project coordinator:	Jamie Dewhurst, J & A Growers, Wasperton, Warwick, CB35 8EB
Date project commenced:	1 February 2007
Date completion due:	31 January 2010
Key words:	*Acer campestre,* aclonifen, *Alnus glutinosa*, annual meadow grass, *Betula pubescens*, *Betula pendula,* Boxer, broadleaved trees, Centium, clomazone, *Cornus alba, Crataegus monogyna,* dimethachlor, dimethenamid-P, Dual Gold, field pansy, florasulam, flufenacet, flumioxazinee, *Fraxinus excelsior,* Goltix WG, Groundsel, herbicides, HDC H 2, knotgrass, Mayweeed, metazachlor, metosulam, new code A, nettle, nursery stock, ornamentals, pendimethalin, *Rosa rubiginosa,* s–metolachlor, shepherds purse, *Sorbus aucuparia*, common speedwell, Springbok, Stomp 400 SC, Sumimax, Terano, Teridox, tree seedbeds, weeds, weed control

AUTHENTICATION FOR HNS 155

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

John Atwood
Senior Horticultural Consultant
ADAS UK Ltd

Signature .... Date ....

Report authorised by:

Dr Tim O'Neill
Horticulture Research Manager
ADAS UK Ltd

Signature .... Date ....

TABLE OF CONTENTS

GROWER SUMMARY

Headline

Twelve herbicide products (alone and in various mixtures) were assessed for their crop safety and efficacy in controlling annual weeds in broadleaved tree seedbeds; treatments suitable for eight tree species were identified.

Background and expected deliverables

Weed control continues to present a significant challenge for tree seedling growers. Small-seeded crops in particular are vulnerable to herbicide damage and to weed competition early in the life of the crop. Many growers rely on expensive partial soil sterilisation and hand weeding to keep the crops clean from weeds. Hand weeding is becoming increasingly expensive and soon will not be justified for the value of the crop.

The last HDC herbicide screening trial (HNS 31a) was completed over 10 years ago. Since then a number of herbicides have been withdrawn and another range of herbicides has become available. A number of new herbicides from the agricultural and vegetable sector have potential for use in tree seed-beds. Some of the characteristics of these herbicides have been determined from experimental work in vegetables (FV 256), roses (HNS 132), cut flowers (BOF 51) and other nursery stock crops (HNS 139).

The expected deliverables from this project are:

1. Information on the crop safety of selected herbicides (including both pre- and post emergence treatments) on seedbeds of key small seeded tree species, including alder (*Alnus glutinosa* (L.) Gaertn.), birch (*Betula pendula* Roth.), hawthorn (*Crataegus monogyna* Jacq.), and whitebeam (*Sorbus aucuparia* (L)) and some medium seeded broadleaved tree species, including field maple (*Acer campestre* (L.)) and ash (*Fraxinus excelsior* (L.)).

2. Information on the relative weed control efficacy of selected herbicides when used at rates suitable for small-seeded tree species, both as single treatments and as tank mixtures.
3. To provide text and illustrations for a HDC News article.
4. To provide information suitable for updating the HNS weed control handbook.

Summary of the project and main conclusions

Initial screening - 2007

Eleven herbicides (Table 1) were tested on *Alnus, Betula, Cratagus* and *Sorbus* seedbeds, alongside an untreated control. Pre-emergence treatments were applied shortly after sowing in May 2007. The post-emergence treatment, Boxer (florasulam), was applied when the crop was at the four true leaf stage.

The safest treatments were Stomp 400SC and Goltix WG, although weed control from those treatments was only moderate. Aclonifen, New Code A and Springbok were safe to a more limited range of subjects but gave better weed control. 212H 50 WP (now available as Sumimax), HDC H 2 and Terano gave good weed control but were damaging to the majority of species tested. Boxer, Centium and Dual Gold were relatively safe but with limited weed control spectra. However, Centium and Dual Gold were used in the final year of the project as tank mix partners for Stomp 400SC and Springbok. A summary of recommendations is shown in Table 5.

Table 1. Herbicide treatments used during the project and approval status

Product	Active ingredient	Product application rate[1]	Approval status	Years tested
Stomp 400SC	pendimethalin (400 /L)	1.0 – 2.0 L/ha	SOLA 2923/08	2007-9
212H 50WP	flumioxazine (50% w/w)	30 - 60 g/ha	SOLA 2881/08 for Sumimax	2007
Aclonifen	aclonifen	1.0 – 2.0 L/ha	Not in UK	2007/8
New Code A	Not disclosed	1.3 – 2.6 kg/ha	Not in UK	2007/8
Boxer	florasulam (50 g/L)	25 - 50 g/ha	SOLA 2826/08	2007
HDC H 2	Not disclosed	1.6 – 3.2 L/ha	Not in UK	2007
Centium	clomazone (360 g/L)	125 - 250 ml/ha	SOLA application submitted	2007/9
Dancer Flow	phenmedipham (160 g/L)	2.5 L/ha	SOLA 2824/08 for Betanal	2009
Dual Gold	s – metolachlor 960 (g/L)	0.8 – 1.6 L/ha	Not in UK	2007/9
Goltix WG	metamitron (70 % w/w)	1.5 – 3.0 kg/ha	SOLA application submitted	2007-9
Springbok	metazachlor + dimethenamid-P (200 : 200 g/L)	1.25 – 2.5 kg/ha	SOLA application submitted	2007-9
Terano	flufenacet +metosulam (60 : 2.5 % w/w)	375-750 g/ha	Not in UK	2007
Teridox	dimethachlor (200 g/L)	1.5 L/ha	Not in UK	2008

[1]Herbicides were applied at two rates, the higher rates were applied to *Crataegus* in 2007 and *Acer* and *Fraxinus* in 2009. The lower rates were applied to the *Sorbus, Alnus, Cornus, Rosa* and *Betula* for all applications, to *Crataegus* in 2008/9 and *Acer* and *Fraxinus* in 2008.

Screening of selected herbicides on a wider range of subjects - 2008

In 2008, five previously tested herbicides (Stomp 400SC, Goltix WG, aclonifen, New Code A and Springbok) and one new entry (Teridox (dimethachlor)) were tested on *Alnus, Betula, Cratagus* and *Sorbus* and, in addition, four larger-seeded subjects: field maple (*Acer campestre* (L.)), dogwood (*Cornus alba* (L.)), ash (*Fraxinus excelsior* (L.)) and rose (*Rosa rubiginosa* (L.)). The crop safety results noted in 2007 were largely confirmed and in addition the larger-seeded species, *Acer, Cornus, Fraxinus* and *Rosa,* were found to be tolerant of all the herbicides tested. The best weed control was achieved with aclonifen. Goltix WG performed well but persisted for only one to two months. Weed control from Stomp 400SC and Springbok was moderate and Teridox and New Code A (the latter used only at the lower rate in 2008) were disappointing. Although New Code A and aclonifen were promising for some of the species tested, a decision was made by the manufacturer not to progress them for marketing in the UK so these were excluded from further experiments.

Screening of herbicides in tank mixtures (pre and post-emergence) on a wider range of subjects and overall summary of weed control results - 2009

In 2009, two sites were used: J&A Growers, which was the trial site for the work conducted in 2007 and 2008; and, an extra site, Wyevale transplants, which provided a lighter soil type. Five herbicide treatments, including tank mixtures, were tested on *Acer, Alnus, Crataegus, Fraxinus* and *Sorbus*. *Betula* was included in the trial at Wyevale transplants but failed to germinate. The five treatments were selected from a total list of eight treatments (Table 2) on the basis of crop safety results from the previous two years.

Previous results showed that Stomp 400SC and Goltix WG were the safest treatments with good vigour scores across most species. This was confirmed in 2009, and, in addition, mixtures of Stomp 400SC with Centium or Goltix WG were some of the safer treatments. In all three years of experiments, Springbok was generally less safe than Stomp or Goltix WG but was acceptable to some species. In 2009 slightly higher rates (1.75 – 2.5 L/ha) were tested on all species, except *Sorbus,* but the lower rates (1.25-1.75 L/ha) tended to give better vigour scores than the 2.5 L/ha rate even though the lower rate was tank mixed with other herbicides.

Table 2. Pre-emergence herbicide treatments used in 2009 at Wyevale transplants

Treatment, product and application rates[1]		Acer	Alnus	Crataegus	Fraxinus	Sorbus
1	Untreated	X	X	X	X	X
2	Springbok 1.75–2.5 L/ha	X	X	X	X	
3	Springbok 1.25–1.75 L/ha + Centium 125-250 ml/ha	X		X	X	
4	Stomp 1.0-2.0 L/ha + Centium 125-250 ml/ha	X		X	X	X
5	Stomp 1.0 L/ha + Dual Gold 0.8 L/ha		X			X
6	Stomp 1.0-2.0 L/ha + Goltix WG 1.5-3.0 kg/ha	X	X	X	X	X
7	Stomp 1.0-2.0 L/ha + Springbok 1.25-1.75 L/ha	X	X	X	X	
8	Stomp 1.0 L/ha		X			X
9	Goltix WG 1.5 kg/ha					X

[1] The higher rates were applied to *Acer* and *Fraxinus.*

An 'X' indicates that the treatment was tested on that species.

Weed control results from the three years of pre-emergence experiments indicated that, of the relatively crop-safe treatments, Stomp 400SC, Goltix WG and Springbok were reasonably effective. Details of the weed species controlled are shown in Table 3. None of these treatments provided complete weed control throughout the life of the crop, although it was possible to maintain a reasonable level of weed control for the first two months when the crop is particularly vulnerable to competition. When using Stomp 400SC as a standard treatment, the addition of Goltix WG, Centium, Springbok or Dual Gold improved weed control (Figure 1) and would be safe for some subjects. Willoughby *et al.* (2003, 2007) indicated that Devrinol (napropamide 450 g/L) would also be an effective and safe tank mix partner. When using Springbok as a standard treatment, the addition of Centium generally improved weed control without affecting crop safety.

Figure 1. The effect of tank mix partners with Stomp 400SC on weed control at three recording dates (Sorbus pre-emergence herbicide experiment, Wyevale transplants 2009).

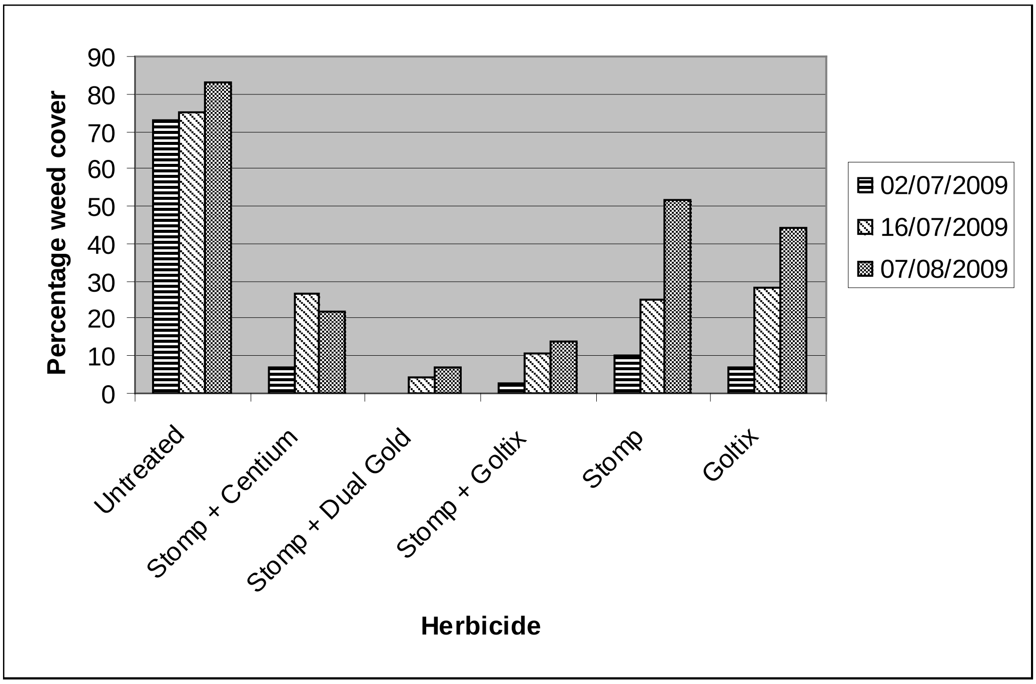


Table 3. Summary of pre-emergence herbicide efficacy against weed species

Herbicide	Rate/ha	Annual meadow	Bindweed, black	Fat hen	Groundsel	Nettle, small	Knotgrass	Pansy, field	Mayweed	Shepherds purse	Speedwell, common
Stomp 400 SC	1.0 L	**	**	****	R	***	***	**		****	****
	2.0 L	****			*	*****		****	***		*****
212H 50WP	30 g	***			*****		***	***		*****	*****
(Sumimax)	60 g	***			*****	*****		*****	*****		*****
Aclonifen	1.0 L	****	*****	****	R	*****	***	***	R	*****	*****
	2.0 L	*****			**	*****		***	*****		*****
New Code A	1.3 L	****	**	***	R	***	R	***		***	****
	2.6 L	*****			R	*****		*****	*****		*****
HDC H 2	1.6 L	*****			*****		***	**	*****	***	***
	3.2 L	*****			*****	*****		**	*****		*****
Centium	0.125 L	**			*		R	R			R
	0.250 L	*****			***	***		R	R		*****
Dual Gold	0.8 L	****			R		R	R	R	R	*****
	1.6 L	*****			****	*****		R	R		*****
Goltix WG	1.5 kg	***	***	****	***	**	**	**	*****	*****	***
	3.0 kg	*****			****	*****		**	*****		****
Springbok	1.0-1.25 L	***	R	*	***	***	**	**	****	***	***
	2.0-2.5 L	*****		*	*****	*****		**	*****		*****
Terano	0.375 L	*****			R	*****	***	***	*****	*****	*****
	0.750 L	*****			*****	*****		*****	*****		*****
Teridox	1.5 L	***	R			R	R	R		***	***

***** = ≥ 95% control, **** = ≥80 < 95% control, ***= ≥50 < 80% control,
**= ≥25 < 50% control, *= >0<25% control, R = no control

Weed control percentages are an average of all experiments where the weed/herbicide combination occurred. Where no score is shown there was insufficient data.

It was intended to apply the treatments pre crop-emergence at both sites, but at J & A Growers adverse weather conditions prevented the treatments being applied before crop-emergence. At this site treatments were modified to exclude herbicides known to be damaging post-emergence and alternative treatments were tested as post-emergence treatments (Table 4). Applications were made when the crop was at the cotyledon or cotyledon – two true leaf stage. Weeds were no larger than two true leaf.

Table 4. Post-emergence herbicide treatments used in 2009 at J & A Growers

Treatment, product and application rates[1]		Acer	Alnus	Betula	Crataegus	Fraxinus	Sorbus
1	Untreated	X	X	X	X	X	X
2	Springbok 1.75–2.5 L/ha	X	X	X	X	X	
3	Springbok 1.25–1.75 L/ha + Centium 125-250 ml/ha	X		X	X	X	
4	Centium 125-250 ml/ha	X		X	X	X	X
5	Dual Gold 0.8 L/ha		X	X			X
6	Dancer 2.5 L/ha + Goltix WG 1.5-3.0 kg/ha	X	X		X	X	X
7	Dancer 2.5 L/ha + Springbok 1.25-1.75 L/ha	X	X	X	X	X	
8	Dancer 2.5 L/ha		X				X
9	Goltix WG 1.5 kg/ha						X

[1] The higher rates were applied to *Acer* and *Fraxinus.*

Using the herbicides as post-emergence treatments was more problematical, generally causing more crop damage. The only experimental treatments to scorch, stunt or kill existing seedling weeds were Centium, Dancer and Goltix WG. The most effective treatments for removing existing weed and maintaining weed control were Dancer + Goltix WG and Dancer + Springbok. However these combinations were only safe on *Acer* and *Crataegus*. The Dancer + Springbok combination caused less loss of vigour compared with Dancer + Goltix WG. Centium was a safer post-emergence treatment and could be used on *Betula, Crataegus, Fraxinus* and *Sorbus*. An overall treatment with Aramo (tepraloxydim 50 g/L) was made to the *Alnus* and *Betula* plots to remove annual meadow grass (*Poa annua* L.). No damage was caused to the crop and the annual meadow grass was controlled.

Summery of tree species tolerance to herbicides

Crops were assessed for germination by seedling count and by visual assessment of phytotoxicity/vigour using a 1-5 scoring system; 1) Plant death, 2) Severe damage, 3) Slight damage or reduced growth, 4) Commercially acceptable damage, 5) No visible signs of damage (compared to control). Based on the germination results and crop vigour score, a summary of crop tolerance is provided in Table 5.

Table 5. Crop tolerance of pre-emergence herbicides with maximum product rate (L or kg per ha) found to be safe; summary of up to three years experiments

	Acer	***Alnus***	***Betula***	***Cornus***	***Crataegus***	***Fraxinus***	***Rosa***	***Sorbus***
Stomp 400SC	T 2.0	T 1.0	T 1.0	T 1.0	T 2.0	T 2.0	T 1.0	T 1.0
Sumimax		S	S		S			S
Aclonifen	T 1.0	S	S	T 1.0	S	T 1.0	T 1.0	S
New Code A	T 0.65	S	S	T 0.65	T 1.3	T 0.65	T 0.65	T 0.65
Boxer		T 0.025	T 0.025		mS 0.05			mS 0.025
HDC H 2		S	S		S			S
Centium	T 0.25	mS 0.125	T 0.125		T 0.25	T 0.25		T 0.125
Dual Gold		T 0.8	T 0.8		S			S
Goltix WG	T 3.0	T 1.5	mS 1.5	T 1.5	T 3.0	T 3.0	T 1.5	T 1.5
Springbok	T 1.75	T 1.25	T 1.25	T 1.5	T 1.25	T 2.5	T 1.25	S
Terano		S	T 0.375		S			S
Teridox	T 1.5	S	S	T 1.5	T 1.5	T 1.5	T 1.5	

Products found to be safe to use on particular species are shown in shaded boxes, with the maximum rate for that species.

T = Tolerant (final vigour assessment mean score ≤ 4 (commercially acceptable damage))

mS= Moderately susceptible (final vigour assessment score 3 (Slight damage/reduced growth))
S = Susceptible (final vigour assessment score < 3 (Severely reduced growth / Plant death) or germination reduced by >60%

Where no result is shown, the treatment was not tested on that species.

Where more than one year's statistically significant data was available the average was used to categorise.

Note that some species may tolerate higher rates than those tested - this is discussed further below.

Acer campestre

None of the herbicide treatments reduced germination significantly. This species was tested in 2008 and 2009. In 2008 aclonifen reduced the crop vigour initially but plants recovered fully after 3 months. All other treatments tested were safe. Willoughby et al. (2003, 2007) also showed that Acer was tolerant to Stomp 400SC at 5.0 L/ha, however the maximum approved rate is currently 3.3 L/ha.

Centium, Goltix WG, Springbok and *Stomp 400SC all have potential for use on Acer. As the crop appears to have good tolerance higher rates can be used. Mixtures of Stomp 400SC with Centium, Goltix WG or Springbok were all safe. Of these Stomp 400SC + Springbok gave the best weed control. For post-emergence weed control Dancer + Springbok or Dancer + Goltix can be used.*

Alnus glutinosa

Some herbicide treatments caused a significant reduction in the number of seedlings emerged. The safest treatments were Stomp 400SC, Goltix WG and Springbok, where the reductions were relatively minor in 2007 and 2008. However, on a lighter soil site in 2009 all reduced germination significantly. Aclonifen, New Code A and Teridox all reduced germination substantially in 2008 although aclonifen had been safer in 2007.

Stomp 400SC, Goltix WG and Springbok have potential for use on Alnus glutinosa *at low rates, either alone, or in two way tank mixtures with Stomp 400SC. However, germination and crop vigour may be reduced on very light soils. None of the post-emergence treatments tested were safe apart from an overall treatment with Aramo for control of annual meadow grass.*

Betula pendula

This crop is very sensitive to herbicides. Only Stomp 400SC and Springbok were consistently safe (2007 and 2008), having minimal effect on germination and acceptable crop vigour. Although all treatments reduced vigour initially, by the end of the season the Stomp 400SC and Springbok treatments were of acceptable quality. Although Terano, Goltix WG and aclonifen appeared safe in 2007 (on *Betula* *pubescens*) the latter two caused a substantial reduction in germination in 2008. Terano was not tested in 2008. At present there are no plans to introduce Terano in the UK, although it is available in Germany. It was not possible to make further assessments in 2009 due to a crop failure.

Stomp 400SC, Terano and Springbok have potential for use on Betula at low rates, but care is needed as this crop is subject to vigour reduction following herbicide use. Centium was acceptably safe when used either pre or post-emergence. No post-emergence treatments were safe apart from an overall application of Aramo.

Cornus alba

This crop appeared extremely tolerant of the herbicides tested. Germination and crop vigour was not affected by any of the treatments. Only one year of tests was carried out (2008) and no post-emergence tests were done. Willoughby *et al.* (2003, 2007) found that Stomp 400SC was tolerated up to 1.5 L/ha but the higher rates tested were damaging.

Stomp 400SC, Goltix WG, and Springbok all have potential for use on Cornus. It is possible that higher rates of Goltix WG and Springbok could be tolerated.

Crataegus monogyna

It had been thought that this crop was more tolerant of herbicides, so some experiments were carried out using higher rates of herbicides. Stomp 400SC (2 L/ha) and Goltix WG (3 L/ha) were safe at higher rates and Willoughby *et al.* (2003, 2007) indicated that Stomp 400SC at 5 L/ha could be tolerated, but Springbok could not be used at rates above 1.25 L/ha, without affecting germination or crop vigour. The addition of Centium to the Stomp 400SC or Springbok treatments was possible without affecting germination or vigour.

Stomp 400SC, Goltix WG and Springbok all have potential for use on Crataegus. The efficacy of Stomp 400SC could be enhanced by adding Goltix WG or Centium – the latter caused less of a growth check. The efficacy of Springbok could be enhanced by adding Centium. Springbok, Centium, Dancer and Goltix WG were also safe as post-emergence treatments.

Fraxinus excelsior

This crop appeared very tolerant of the herbicides tested. *Fraxinus* was largely unaffected by the treatments used in 2008 and 2009, including Springbok, Stomp and Goltix WG. In 2009 a higher (2.5 L/ha) rate of Springbok and combinations of Springbok and Centium caused an initial check although crops recovered well. Willoughby *et al.* (2003, 2007) also showed that *Fraxinus* was tolerant of higher rates of Goltix WG (5 kg/ha) and Stomp 400SC (7.5 L/ha) – note that the maximum approved rate for Stomp 400SC is currently 3.3 L/ha.

Stomp 400SC, Goltix WG and Springbok all have potential for use on Fraxinus. A Stomp 400SC + Goltix WG mix was also tolerated and this was one of the better treatments for weed control efficacy. Centium was the only post-emergence treatment to be safe.

Rosa rubiginosa

This crop appeared quite tolerant of the herbicides tested. Germination and was not affected by the treatments except for aclonifen which reduced germination. Stomp 400SC and aclonifen reduced crop vigour initially but there was good recovery by the end of the season. Only one year of tests was carried out (2008) and no post-emergence tests were done.

Stomp 400SC, Goltix WG, and Springbok all have potential for use on Rosa. As the crop appeared to have good tolerance, it is possible that higher rates of Goltix WG and Springbok than those tested could be used. There appeared to be some sensitivity to Stomp 400SC however.

Sorbus aucuparia

This crop is very sensitive to herbicides. Only Stomp 400SC, New Code A and Centium were consistently safe in all years tested, having minimal effect on germination and acceptable crop vigour by the end of the season. Goltix WG was safe in two out of three years tested. Aclonifen, and Springbok were more damaging reducing either germination or vigour in at least one of the three years tested. Willoughby *et al.* (2003) found that *Sorbus* was tolerant of Stomp 400SC at 0.825 L/ha but not at 2.5 L/ha and did not tolerate Goltix WG even at the low 1.7 kg/ha rate. Devrinol (napropamide 500 g/L) was reported to be an acceptable treatment however.

Stomp 400SC, Goltix WG and Centium have potential for use on Sorbus, but care is needed as this crop is subject to vigour reduction following herbicide use and results from Goltix WG have been variable for safety. A Stomp 400SC + Goltix WG mix gave the best weed control. Centium, Dual Gold and Dancer were also safe for use as post-emergence treatments.

Financial benefits

The production of tree seedlings is an important sector of the amenity tree market with production of 60 million seedlings per annum and sales of £15 million. Broadleaved tree seedlings make up the majority of the market. The financial benefits to the industry of the project should result from:

- More reliable control of weeds through the development of a broader range of herbicide programmes.
- The provision of alternative herbicide options when dazomet is withdrawn.
- Reduced losses and reduced costs due to weed competition and hand weeding.

Initial indications are that some of the current cost of hand weeding seedbeds of broadleaved tree species might be reduced, although it is unlikely to be eliminated. The current hand-weeding cost is estimated at £1,800/ha. This figure is based on three weeding sessions of 100hrs/ha at £6/hr (£600 per session).

Action points for growers

- Stomp 400SC, Goltix WG, Centium and Springbok can be used in seedbeds for most of the tree species tested, but for some species the maximum rate of use is relatively low.
- The two way tank mixtures Stomp 400SC + Goltix WG or Springbok, and Springbok + Centium were more effective for weed control and could be tolerated by some of the tree species.

- The most effective treatments for post-emergence use were Centium, Dancer (similar to Betanal Flo), and Goltix WG. Centium could be used on a wide range of species but only *Acer* and *Crataegus* tolerated Dancer and Goltix WG.
- Aramo (tepraloxydim 50 g/L) was successfully used in *Betula* and *Alnus* as an overall post-emergence control to remove annual meadow grass across all the experimental herbicide plots.

SCIENCE SECTION

Introduction

Weed control continues to present a significant challenge for tree seedling growers. Small-seeded crops, in particular, are vulnerable to herbicide damage and also to weed competition early in the life of the crop. Many growers rely on expensive partial soil sterilisation and hand weeding to keep the crops clean from weeds. Hand weeding is becoming increasingly expensive and soon will not be justified for the value of the crop.

The last HDC herbicide screening trial for tree seedbeds (HNS 31a) was completed over 10 years ago. Since then a number of herbicides have been withdrawn and another range of herbicides have become available.

A comprehensive herbicide screening programme was done in the period 1976-81 at Luddington EHS (Cooper, 1982) from which recommendations were developed for the use of Quintex (propham/fenuron/CIPC), Enide (diphenamid), simazine, Tenoran (chloroxuron), Dacthal (chlorthal-dimethyl) and Brasoran + Kerb (azipotryne + propyzamide). Unfortunately only Dacthal and Kerb remain currently available for use.

Further herbicide screening was carried out on a range of tree seedlings HNS 31 & HNS 3a (Brough, 1993; 1997) indicating that, of the herbicides tested, Venzar (lenacil), Butisan (metazachlor) and Flexidor (isoxaben) had some potential for use in tree seedbeds, but the safe rate of use was relatively low and did not give adequate weed control. Unfortunately follow-up post-emergence applications were found to give an unacceptable level of damage.

Further studies were carried out by Willoughby *et al*. (2003, 2007) screening a number of herbicides on a range of tree species including *Acer, Alnus*, *Betula*, *Cornus, Fraxinus, Crataegus* and *Sorbus*. They found that Devrinol (napropamide) and Stomp 400SC (pendimethalin) had some potential for use in tree seedbeds although *Betula* suffered damage from both. *Acer, Crataegus and Fraxinus* tolerated a full (4.4 + 5 L/ha) rate Devrinol-Stomp mixture, but *Sorbus, Cornus* and *Alnus* were fully tolerant of Devrinol only. Where lower rates were used, *Sorbus* was tolerant of Stomp 400SC (0.825 L/ha) and *Alnus* and *Cornus* were tolerant at 1.5 L/ha. Devrinol is most effective when applied during winter months when soil conditions are damp and light levels low. However, the approval covers use up until the end of April on forest seedbeds so it could be used on spring-sown seedbeds. If conditions are dry at application irrigation would be required to incorporate the herbicide to avoid the risk of rapid photo-degradation. Goltix WG (metamitron), Flexidor 125 and Butisan S were also tested by Willoughby *et al.* (2003), but where the highest application rates were used (15 kg/ha, 3 L/ha and 3.75 L/ha respectively) only *Acer* was tolerant. *Fraxinus* was tolerant of medium rates of Goltix WG (5 kg/ha), and low rates of Butisan S (0.42 L/ha).

Brough (1997) concluded that the use of a partial soil sterilant, Basamid (dazomet) was necessary to achieve adequate weed control. In commercial practice, Basamid is now used for some small-seeded tree crops mainly to counter re-plant problems, but also to provide some measure of weed control. Basamid is relatively expensive and whilst it reduces the weed population in the seedbeds it does not provide any residual weed control. At present, commercial practice is to follow up with low rates of Stomp 400SC. However, weed control is not always adequate with this combination.

More recently a further range of herbicides have become available with potential for use in seed-raised horticultural crops. A number of these have been successfully used in field vegetable crops (FV 256, FV 270) (Knott, 2006a,b) including Centium (clomazone), 212H - now named Sumimax (flumioxazine), aclonifen, Boxer (florasulam) and HDC H 2. Centium was successfully used in certain seed-raised cut flower crops (BOF 51) (Hanks, 2005). A further herbicide range including New Code A, Dual Gold (s – metolachlor), Terano (metosulam + flufenacet) and Springbok (metazachlor + dimethenamid-p) were used in screening experiments on nursery stock (HNS 139) (Atwood 2006, 2007) and roses (HNS 132) (Burgess, 2006). It is thought that some of these herbicides may have potential for use in tree seed-beds.

The current study aims to determine the relative efficacy and crop safety of new herbicides for control of weeds in vulnerable seedling tree species.

In the first year, 11 herbicides (Stomp 400SC, Sumimax, aclonifen, New Code A, Boxer, HDC H 2, Centium, Dual Gold, Goltix WG, Springbok and Terano) were tested on four small-seeded tree species (*Alnus glutinosa* (L.), *Betula pubescens* Ehrh., *Crataegus monogyna* Jacq. and *Sorbus aucuparia* (L)). Although Boxer, Centium and Dual Gold were safe to a number of subjects, weed control was poor at the rates used, so it was decided not to proceed with these products in the second year. However, Centium and Dual Gold were used in conjunction with other herbicides in the third year trials. Sumimax, HDC H 2 and Terano were damaging to the majority of subjects, so trials on these herbicides were discontinued after the first year.

In the second year, 6 herbicides (Stomp 400SC, aclonifen, New Code A, Goltix WG, Springbok and Teridox (dimethachlor)) were tested on 4 small-seeded (*Alnus glutinosa, Betula pendula* Roth., *Crataegus monogyna* and *Sorbus aucuparia*) and 4 larger-seeded tree species (*Acer campestre* (L.), Gaertn., *Cornus alba* (L.), *Fraxinus excelsior* (L.) and *Rosa rubiginosa* (L.).

In the third (final) year, two sites were used, the extra site providing a lighter soil type. Five herbicide treatments, including tank mixtures designed to give better weed control spectra, were tested on four small-seeded (*Alnus glutinosa, Betula pendula, Crataegus monogyna* and *Sorbus aucuparia*) and two larger-seeded tree species (*Acer campestre, Fraxinus excelsior*). The 5 treatments were selected from a total list of 8 treatments on the basis of crop safety results from the previous two years. It was intended to apply all treatments pre crop-emergence, but at one of the two sites (J & A Growers) adverse weather conditions prevented the treatments being applied before crop-emergence. At this site treatments were modified to exclude herbicides known to be damaging post-emergence such as Stomp 400SC and alternative treatments were tested as post-emergence treatments.

Materials and Methods

Crop details

A total of 12 seedbeds were prepared, six at each of the host nurseries (Site A – J&A Growers, Site B – Wyevale transplants), comprising of one of each of the test species used in the experiment; *Acer campestre* (L.), *Alnus glutinosa* (L.) Gaertn., *Betula pendula* Roth., *Crataegus monogyna* Jacq., *Fraxinus excelsior* (L.), and *Sorbus aucuparia* (L).

Site A – J&A Growers

The soil (medium sandy loam) was initially cultivated using a Lemkin Rubin cultivator; beds were then formed using a 1.35 m Bartschi bed former on 30 March 2009. Soil analysis showed the soil to have pH 5.8, P index 4, K index 2- and Mg index 3, organic matter 1.0%.

A base dressing of 500 kg/ha Norsk Hydro complex partner (N 12%, P_2O_5 11%, K_2O 18%, MgO 3% + S) was incorporated into the bed on 1 April 2009, prior to sowing.

For small-seeded species (*Alnus, Betula* and *Sorbus),* seed was mixed with fine sand and sown directly on the soil surface. All other species were sown directly at a depth of 10 mm on 29 April 2009 using an Egedal combi 5 row drill (25 cm between rows) with the intention of producing a final density of 200 plants per meter of bed. The following seed rates were used:

Species	***Seed rate***	***Provenance***
Acer campestre	2.00 kgs per 100m	UK405
Alnus glutinosa	0.26 kgs per 100m	UK102
Betula pendula	0.22 kgs per 100m	UK403
Crataegus monogyna	7.50 kgs per 100m	UK203
Fraxinus excelsior	4.60 kgs per 100m	UK107
Sorbus aucuparia	0.60 kgs per 100m	UK403

The seed source was Forestart Ltd and was of various UK provenances. After sowing, 25B horticultural grit (2 to 5 mm) was applied at a target depth of 3 mm.

Given the incessant high winds after seed sowing, it was not possible to apply pre-emergence herbicides as planned since some species had started to germinate. Therefore it was decided to apply post-emergence treatments to provide useful crop safety information for growers in a similar situation. Post-emergence herbicides were applied to *Acer* & *Fraxinus* on 23/05/09, *Crataegus* & *Sorbus* on 28/05/09 and *Alnus* & *Betula* 05/06/09. All plots were hand weeded prior to the application of post emergence herbicides to remove any weeds larger than two true leaves. Abundant annual meadow grass had germinated within the *Alnus* & *Betula* plots so it was decided to apply Aramo (tepraloxydim 50 g/L) (ref. SOLA 2813/08) in addition to the post emergence herbicides to control grass weeds up to 5 tillers. All *Alnus* & *Betula* plots, excluding controls, were treated with Aramo. After 11 days the annual meadow grass started to appear paler and subsequently died.

There was a total of 29 mm rainfall within the 10 days prior to applying treatments to *Acer* & *Fraxinus*; no rainfall fell in the 10 days after application of post emergence herbicides.

There was a total of 21 mm rainfall within the 10 days prior to applying treatments to *Crataegus* & *Sorbus*; no rainfall fell in the 10 days after application of post emergence herbicides.

Only 2 mm of rainfall fell on the 28 May in the 10 days prior to herbicide application. Heavy rain fell (9 mm) during the late afternoon / early evening of the day that herbicides were applied to the *Alnus* & *Betula* plots. A further 28 mm of rain fell on 6 June with an additional 21 mm on 7 June; a total of 68 mm fell in the 10 days post herbicide application.

Irrigation was applied after sowing, as required. Two top dressings of 75 kg/ha calcium nitrate were applied on 24 June 2009 and again on 27 July 2009. Apart from the experimental treatments, no pesticides were applied.

Site B – Wyevale transplants

The soil (sand) was initially cultivated using a Howard rotavator; beds were then formed with a Tomlin bed rake and roller on 28 April 2009. Soil analysis showed the soil to have pH 7.0, P index 4, K index 2+ and Mg index 3, organic matter 1.0%.

For all species, seed was mixed with fine sand and sown directly on the soil surface on 5 May 2009 using an Egedal combi 5 row drill (25 cms between rows) with the intention of producing a final density of 200 plants per meter of bed. The following seed rates were used:

Species	***Seed rate***	***Provenance***
Acer campestre	6.40 kgs per 100m	Hungarian
Alnus glutinosa	0.20 kgs per 100m	UK403
Betula pendula	0.20 kgs per 100m	UK403
Crataegus monogyna	6.00 kgs per 100m	UK203
Fraxinus excelsior	5.20 kgs per 100m	UK201
Sorbus aucuparia	0.44 kgs per 100m	UK403

The seed source was Forestart Ltd and was of UK provenance, excluding the *Acer campestre*. After sowing, Moneystone bunker sand was applied at a target depth of 3 mm.

There was no rainfall, but a total of 16 mm irrigation during the 10 days prior to applying treatments; the next rainfall was 10 mm on 15 May 2009, 13 mm on 17 May 2009, 5 mm on 18 May 2009 and 5 mm on 19 May 2009. Temperatures were normal for the time of year.

No base dressing of fertiliser was incorporated prior to sowing and irrigation was applied after sowing as required. A top dressing of 105 kg/ha Vitax Approved Natural Pelleted 111 NPK 4.5-4.5-4.5+0.8%Mg was applied on the 29 May 2009. A second top dressing of 100 kg/ha Sinclair 5-Star Nitrogen 25-1-0-2.5MgO+TE was applied on the 10 July 2009. Apart from the experimental treatments, no pesticides were applied.

Experimental design

Experiments were laid out in a randomized split plot design with two treatment factors: (i) chemical treatment (Tables 6 - 10) (main plots) and (ii) tree species (sub-plots); with three replicate blocks. Sub plots at site A (J&A Growers) were 1.5 m x 2 m, apart from *Crataegus* plots which were 1.5 m x 1.5 m, whilst sub plots at Site B (Wyevale Transplants) plots were 1.25 m x 1.3 m. The experimental layouts are shown in Appendices 1 and 2. Results were examined by Analysis of Variance.

All treatments were applied in 400 L water/ha at 2-bar pressure using a CO_2-pressurised Oxford Precision Sprayer with a 1.5 m boom and F03-110 spray nozzles. Treatments (Tables 8 and 9) were applied pre-emergence of crop and weeds at Site B (Wyevale Transplants) on 13 May 2009. Persistent high winds prevented the application of pre – emergence treatments at Site A (J&A Growers). Therefore, only post emergence treatments were applied at this site (Tables 6 and 7).

Table 6. Higher rate post-emergence herbicide treatments at Site A (J&A Growers) - *Acer, Fraxinus*

Treatment number and product application rate	
1	Untreated
2	Springbok 2.5 L/ha
3	Springbok 1.75 l/ha + Centium 0.250 L/ha
4	Centium 0.250 L/ha
6	Dancer 2.5 L/ha + Goltix WG 3.0 kg/ha
7	Dancer 2.5 L/ha + Springbok 1.75 L/ha

Table 7. Lower rate post-emergence herbicide treatments at Site A (J&A Growers) **–** *Alnus, Betula, Crataegus, Sorbus*

Treatment number and product application rate		Alnus	Betula	Crataegus	Sorbus
1	Untreated	X	X	X	X
2	Springbok 1.75 L/ha	X	X	X	
3	Springbok 1.25 L/ha+ Centium 0.125 L/ha		X	X	
4	Centium 0.125 L/ha		X	X	X
5	Dual Gold 0.8 L/ha	X	X		X
6	Dancer 2.5 L/ha + Goltix WG 1.5 kg/ha	X		X	X
7	Dancer 2.5 L/ha + Springbok 1.25 L/ha	X	X	X	
8	Dancer 2.5 L/ha	X			X
9	Goltix WG 1.5 kg/ha				X

An 'X' indicates which species received treatments

.

All *Alnus* & *Betula* plots, except treatment 1 (untreated), were sprayed with Aramo 1.5 L/ha in addition to the listed treatments as a separate spray.

Table 8. Lower rate pre-emergence herbicide treatments at Site B (Wyevale Transplants) *Alnus, Betula, Crataegus, Sorbus*

Treatment, product and application rate		Alnus	Betula	Crataegus	Sorbus
1	Untreated	X	X	X	X
2	Springbok 1.75 L/ha	X	X	X	
3	Springbok 1.25 L/ha+ Centium 0.125 L/ha		X	X	
4	Stomp 1.0 L/ha + Centium 0.125 L/ha		X	X	X
5	Stomp 1.0 L/ha + Dual Gold 0.8 L/ha	X	X		X
6	Stomp 1.0 L/ha + Goltix WG 1.5 kg/ha	X		X	X
7	Stomp 1.0 L/ha + Springbok 1.25 L/ha	X	X	X	
8	Stomp 1.0 L/ha	X			X
9	Goltix WG 1.5 kg/ha				X

Table 9. Higher rate pre-emergence herbicide treatments at Site B (Wyevale Transplants) *Acer, Fraxinus*

Treatment number, product and application rate	
1	Untreated
2	Springbok 2.5 L/ha
3	Springbok 1.75 l/ha + Centium 0.250 L/ha
4	Stomp 2.0 L/ha + Centium 0.250 L/ha
6	Stomp 2.0 L/ha + Goltix WG 3.0 kg/ha
7	Stomp 2.0 L/ha + Springbok 1.75 L/ha

Table 10. Herbicide product details and approval status

Product	Active ingredient	Approval status
Stomp 400SC	pendimethalin (400 /L)	SOLA 2923/08
Centium	clomazone (360 g/L)	SOLA (application submitted)
Dancer Flow	phenmedipham (160 g/L)	SOLA 2824/08 (for Betanal)
Dual Gold	s – metolachlor 960 (g/L)	Not in UK
Goltix WG	metamitron (70 % w/w)	SOLA (application submitted)
Springbok	metazachlor + dimethenamid-P (200 : 200 g/L)	SOLA (application submitted)

Where a SOLA application has been submitted, products may be used in the same situations as currently approved. For example, Goltix WG is approved for use on outdoor crops such as sugar beet, so it may be used under the Long-Term Arrangements for Extension of Use on outdoor ornamentals. When a SOLA is issued, it may restrict the ornamental crops that the product may be used on.

Assessments

Weed control Site A – J&A Growers

The effects of post-emergence herbicides on weed seedlings present at time of application was recorded on *Alnus* & *Fraxinus* on 29 May 2009, on *Sorbus* & *Crataegus* on 4 June 2009 and *Alnus* & *Betula* on 16 June 2009. Number of weed seedlings was not recorded, as in the previous years. This was because weed seedlings were difficult to assess, as different post-emergence herbicides did not kill all weeds present at the same rate. Percentage weed cover (including the weed species present) was also noted on *Acer, Fraxinus, Sorbus* & *Crataegus* plots on 3 July 2009 and on *Betula* & *Alnus* on 22 July 2009. A further assessment of percentage weed cover and the weed species present was noted on all plots on 13 August 2009.

Weed control Site B – Wyevale Transplants.

The number of weed seedlings was recorded on 11 June 2009. Assessments were made using two 0.135 m^2 quadrats per sub-plot, randomly placed within the central region of the sub-plot. Further assessments of percentage weed cover (including the weed species present) were made on 16 July 2009 and 07 August 2009 on a whole plot basis.

Crop assessments Site A – J&A Growers

The effects of post-emergence herbicides on tree seedlings present at time of application was recorded on *Alnus* & *Fraxinus* on 29 May 2009, on *Sorbus* & *Crataegus* on 4 June 2009 and *Alnus* & *Betula* on 16 June 2009. Crop vigour and phytotoxicity were assessed on *Acer, Fraxinus, Sorbus* & *Crataegus* plots on 3 July 2009 and on *Betula* & *Alnus* on 22 July 2009. Numbers of seedlings was not recorded as in previous years, as tree seedling numbers were largely unaffected by post emergence herbicides. *Fraxinus* was the exception as seedling numbers were reduced by some treatments. In this case, assessments were made using two 0.135 m^2 quadrats per sub-plot, randomly placed within the central region of the sub-plot on 22 July 2009. A further crop vigour and phytotoxicity assessment was conducted on all plots on 13 August 2009. All crop vigour and phytotoxicity assessments were conducted using a scoring system (Table 11)

Crop assessments Site B – Wyevale Transplants

The number of weed tree seedlings was recorded on 11 June 2009. Assessments were made using two 0.135 m^2 quadrats per sub-plot, randomly placed within the central region of the sub-plot. Further assessments of crop vigour and phytotoxicity were made on 20 July 2009 and 7 August 2009. All crop vigour and phytotoxicity assessments were conducted using a scoring system (Table 11).

Table 11. Phytotoxicity and crop vigour score key

Score	Nature of phytotoxicity damage
1	Plant death
2	Severally damaged and/or reduced growth
3	Slight damage/slightly reduced growth
4	Commercially acceptable damage
5	No visible signs of damage
	(compared to control).

Results and Discussion

Crop assessments

Crop germination

Germination was more variable, particularly at Wyevale transplants in 2009 compared with 2008 and 2007 at J & A Growers. At Wyevale transplants *Sorbus aucuparia* and *Crataegus monogyna* germinated normally, but *Alnus glutinosa, Acer campestre* and *Fraxinus excelsior* had poorer germination and *Betula pendula* failed to germinate at all. At this site the *Acer campestre* and *Fraxinus excelsior* were surface sown rather than drilled and this may have affected germination and could have increased susceptibility to herbicide damage. Germination was good for all species at J & A Growers, but the *Alnus glutinosa* and *Betula pendula* germinated a month after sowing, much later than the other species. At the J & A Growers site all treatments were applied post-emergence.

Pre-emergence treatment effects on tree seedling numbers are shown in Table 12 for the Wyevale transplants site.

None of the treatments reduced *Acer campestre,* or *Fraxinus excelsior* germination significantly compared with the untreated control. Previous results had also indicated *Acer* and *Fraxinus* to be tolerant of the herbicides tested.

Sorbus aucuparia is considered relatively sensitive to herbicides. Only Stomp 400SC and New Code A were consistently safe in both 2007 and 2008, having minimal effect on germination. Springbok and Goltix WG gave more variable results reducing either germination or vigour in one of the two years tested. In 2009 on a lighter soil type at Wyevale transplants, although there were some numerical differences, the only treatment to significantly reduce germination was the Stomp 400SC + Dual Gold treatment. Stomp 400SC, Goltix WG and Centium could still be considered relatively safe treatments.

Table 12. Number of crop seedlings per m^2 following pre-emergence herbicide treatment – Wyevale transplants site

Treatment No	**Product**	***Acer***	***Alnus***	***Crataegus***	***Fraxinus***	***Sorbus***
1	Untreated	62.7	95.7	194.4	122.5	337.3
2	Springbok	83.3	18.5	86.4	163.6	
3	Springbok + Centium	59.7		132.7	107.1	
4	Stomp + Centium	78.2		142.0	86.4	246.0
5	Stomp + Dual Gold		17.6			81.2
6	Stomp + Goltix	87.4	24.7	79.3	124.4	399.3
7	Stomp + Springbok	97.7	14.5	117.0	118.2	
8	Stomp		18.5			225.3
9	Goltix					329.9
	P	0.032	0.020	0.050	ns	0.010
	df	10	10	10		8
	LSD	23.33	46.75	72.64		150.87

Note: Where no value is shown, the treatment was not applied to that species.

All of the treatments caused a significant reduction in the number of *Alnus glutinosa* seedlings. This is similar to 2007 and 2008, where *Alnus glutinosa* was found to be susceptible to a range of herbicides, although the reductions were relatively minor for Stomp 400SC, Goltix WG and Springbok in those years. In 2009, a higher rate (1.75 L/ha) of Springbok was used (compared with 1.25 L/ha in the previous years) this may account for the poorer germination. However, the rate of Stomp 400SC was similar in all years and it is possible that the lighter soil at Wyevale transplants compared with that at J & A Growers could account for the effect on germination in 2009.

The Stomp 400SC + Centium and Springbok + Centium treatments were relatively safe to *Crataegus monogyna.* However, the higher (1.75 L/ha) rate of Springbok, the Stomp 400SC + Goltix WG and Stomp 400SC + Springbok combinations all significantly reduced crop germination. It had originally been thought that *Crataegus monogyna* was more tolerant of herbicides, so in 2007 higher rates of herbicides were used. However only Stomp 400SC (2 L/ha) and Goltix WG (3 L/ha) were safe at higher rates. In 2008 lower rates were used that were similar to the rates used on other crops. In addition to the Stomp 400SC and Goltix WG, Springbok was safe when used at the 1.25 L/ha rate. It would appear that 1.25 L/ha is the maximum rate of Springbok tolerated by *Crataegus monogyna,* although it appears possible to add Centium without reducing germination.

It was not possible to test the effect of pre-emergence herbicides on *Betula pendula* in 2009 as the crop at Wyevale Transplants failed to germinate. Previous years' results indicated that *Betula pendula* is very sensitive to herbicides. Only Stomp 400SC and Springbok were consistently safe in both 2007 and 2008, having minimal effect on germination. Although Goltix WG and aclonifen appeared safe in 2007 (on *Betula pubescens*) both caused a substantial reduction in germination in 2008 on *B. pendula*.

Crop vigour and phytotoxicity

Past experiments have shown that vigour reduction can be a serious problem when herbicides are used in tree seedbeds, even when applied pre-emergence. Using the scoring key (Table 11), any treatment with a mean score of greater than 3 could be commercially acceptable but scores of 4 and above are preferablel. Because treatments applied at J & A Growers in 2009 were only applied post-emergence, and were modified to take account of this, they are not comparable with previous years' results and will be considered separately.

Pre-emergence treatments

Results from 2007 and 2008 showed that Stomp 400SC and Goltix WG were the safest treatments with good vigour scores across most species. This was confirmed in 2009 and in addition, mixtures of Stomp 400SC with Centium or Goltix WG were some of the safer treatments. In all three years of experiments, Springbok was generally less safe than Stomp or Goltix WG but was acceptable to some species. In 2009, slightly higher rates (1.75 – 2.5 L/ha) were tested on all species except Sorbus'. However, the lower rates (1.25-1.75 L/ha) tended to give better vigour scores even when mixed with other herbicides.

Experiments conducted in 2007 and 2008 had shown New Code A and aclonifen to be safe for some of the species tested, but unfortunately they will not be progressed for marketing in the UK. HDC H2, Sumimax, and Terano tended to be more damaging in the earlier experiments so were not progressed.

Acer showed good tolerance to a range of herbicide treatments, including aclonifen, New Code A, Goltix WG, Springbok, Stomp 400SC and Teridox in 2008. In the 2009 experiments, *Acer* was again largely unaffected by the combination treatments, which included the previously untested Centium and a higher rate of Springbok (Table 13). These results confirm those reported by Willoughby *et al.* (2003, 2007) where *Acer pseudoplatanus*(L.) was found to be tolerant of higher rates of Stomp 400SC and Goltix WG as well as Butisan S, Flexidor 125 and Devrinol.

Table 13 . Acer – the effect of pre-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	11 June 2009	20 July 2009	7 August 2009
1.	Untreated	5.0	5.0	5.0
2.	Springbok	4.3	4.7	5.0
3.	Springbok + Centium	4.7	4.7	5.0
4.	Stomp + Centium	4.7	5.0	4.3
6.	Stomp + Goltix	4.7	5.0	5.0
7.	Stomp + Springbok	4.3	5.0	5.0
	P	ns	ns	ns

For *Alnus,* Stomp 400SC, Goltix WG and Springbok were safe in 2007 and 2008 – with Goltix WG and Springbok giving the best results. Similarly Willoughby *et al.* (2007) found Stomp 400SC up to 1.5 L/ha to be safe to *Alnus,* but not at higher rates. Williamson *et al.* (1990) also suggested that Goltix WG could have potential for use in *Alnus*. In 2009, all treatments appeared to give an initial check to vigour (Table 14) although there was some recovery by the end of the season.

Differences in vigour were not statistically significant at the 5% level of probability. However, for the 11 June recording they were significant at the 7% level. Germination for the *Alnus* was poor in 2009 and this, together with the lighter soil type at Wyevale transplants, may have affected the results (e.g. the ability to detect statistically significant differences) . It would appear there was no additional damage caused by mixing Dual Gold, Goltix or Springbok with the Stomp 400SC. There was an indication, although not statistically significant, that the higher rate of Springbok was more detrimental to crop vigour. In 2007 and 2008, aclonifen and Teridox reduced germination substantially and caused severe initial vigour reductions. Aclonifen had appeared safer in 2007 in both respects. As in 2007, New Code A, reduced germination but gave acceptable vigour.

Table 14. Alnus – the effect of pre-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	11 June 2009	20 July 2009	7 August 2009
1.	Untreated	5.0	5.0	5.0
2.	Springbok	2.3	2.7	3.0
5.	Stomp + Dual Gold	2.3	4.0	4.7
6.	Stomp + Goltix	2.7	3.7	3.7
7.	Stomp + Springbok	2.3	3.3	3.3
8.	Stomp	2.3	3.7	3.3
	P	ns	ns	ns

Only Stomp 400SC and Springbok gave acceptable germination and crop vigour in *Betula* in 2007 and 2008. Aclonifen and Goltix WG had appeared safer in 2007 but caused both germination and vigour reductions in 2008. Willoughby *et al.* (2007) found Stomp 400SC caused a 69% growth reduction on *Betula* at 1.5 L/ha – however lower rates (1.0 L/ha) were used in the current study. It was not possible to test pre-emergence treatments in 2009 because the crop failed to emerge at Wyevale transplants.

The crop vigour of *Crataegus* was relatively unaffected by treatments, including Springbok, Stomp 400SC and Goltix WG applied in 2008 and 2009 (Table 15). Treatment rates were reduced from those used in 2007 when damage occurred from Springbok. In particular the higher rates of Springbok (1.75 L/ha 2009 or 2.5 L/ha 2007) were detrimental to crop germination, whereas the 1.25 Lha rate used in 2008 and in tank mixtures with Stomp 400SC or Centium in 2009 gave acceptable results. Whilst higher rates of Springbok were damaging, it would appear that *Crataegus* can tolerate higher rates of Goltix WG (3.0 kg/ha tested in 2007) and Stomp 400SC (2.0 L/ha tested in 2007 and 5.0 L/ha tested by Willoughby *et al.* (2007)).

Table 15. Crataegus – the effect of pre-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	11 June 2009	20 July 2009	7 August 2009
1.	Untreated	5.0	5.0	5.0
2.	Springbok	3.7	5.0	4.0
3.	Springbok + Centium	3.7	4.0	4.0
4.	Stomp + Centium	4.0	5.0	4.3
6.	Stomp + Goltix	3.3	5.0	5.0
7.	Stomp + Springbok	3.7	4.3	4.7
	P	ns	ns	ns

Fraxinus was largely unaffected by the treatments, including Springbok, Stomp and Goltix WG in 2008. In 2009 the higher rate of Springbok and combinations of Springbok and Centium caused an initial check, although this was not statistically significant and crops recovered well (Table 16). These confirm the results of Willoughby *et al.* (2003, 2007) that *Fraxinus* is tolerant of higher rates of Goltix WG (5 kg/ha), and low rates of Butisan S (0.42 L/ha) as well as having good tolerance to very high rates of Stomp 400SC (7.5 L/ha).

Table 16. Fraxinus – the effect of pre-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	11 June 2009	20 July 2009	7 August 2009
1.	Untreated	5.0	5.0	5.0
2.	Springbok	3.0	5.0	4.3
3.	Springbok + Centium	3.0	4.3	3.7
4.	Stomp + Centium	3.7	5.0	4.3
6.	Stomp + Goltix	4.0	4.7	4.5
7.	Stomp + Springbok	4.0	5.0	5.0
	P	ns	Ns	ns

All treatments significantly reduced *Sorbus* crop vigour initially (Table 17) but crops, except for the Dual Gold + Stomp 400SC treatment, recovered by the end of the season. This was a similar result to 2007 and 2008 where Centium, Stomp 400SC, New Code A and Goltix WG gave acceptable crop vigour; all other treatments reduced the crop vigour substantially. Springbok was damaging in 2008 so was omitted in 2009. Dual Gold reduced crop vigour in 2009 (when used with Stomp 400SC) as it had been in 2007 when used alone. Willoughby *et al.* (2003) found that *Sorbus* was tolerant of Stomp 400SC at 0.825 L/ha but not at 2.5 L/ha and did not tolerate Goltix WG even at the low 1.7 kg/ha rate. Devrinol was reported to be an acceptable treatment however.

Table 17. Sorbus – the effect of pre-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	11 June 2009	20 July 2009	7 August 2009
1.	Untreated	5.0	5.0	5.0
4.	Stomp + Centium	3.3	4.3	4.7
5.	Stomp + Dual Gold	2.0	2.0	2.3
6.	Stomp + Goltix	3.5	3.5	4.1
8.	Stomp	3.7	4.7	5.0
9.	Goltix	4.0	5.0	5.0
	P	0.001	<0.001	<0.001
	Df	8	8	8
	LSD	0.881	0.693	0.623

Post-emergence treatments

Adverse weather conditions prevented spray treatments being applied pre-emergence of the crop at J & A Growers in 2009. A new set of treatments was devised. These new treatments excluded herbicides which are known to be damaging to tree seedlings (such as Stomp 400SC) and included a phenmedipham formulation (Dancer) to improve post-emergence control of seedling weeds.

The *Acers* were unaffected by Dancer + Goltix WG, or Dancer + Springbok (1.75 L/ha). The higher rate of Springbok (2.5 L/ha) affected vigour. particularly at the later assessment. The results for Centium were inconsistent (Table 18).

Table 18: Acer – the effect of post-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	29 May 2009	3 July 2009	13 August 2009
1.	Untreated	5.0	4.7	5.0
2.	Springbok	5.0	4.8	2.7
3.	Springbok + Centium	3.0	4.2	4.7
4.	Centium	3.0	4.2	2.7
6.	Dancer + Goltix	4.7	4.2	5.0
7.	Dancer + Springbok	5.0	4.8	5.0
	P	<0.001	ns	<0.001
	Df	10		10
	LSD	0.429		1.102

For *Alnus,* treatments appeared safe initially. However, at the second assessment vigour was reduced compared with the untreated control (Table 19). Differences were statistically significant for Dancer + Springbok and Springbok alone. At the third assessment differences were not statistically significant but there was an indication that all treatments had reduced vigour. The most marked reduction was from the Dancer + Springbok combination. The least damaging treatments were Dancer or Springbok applied alone and Dancer + Goltix, although all could be regarded as potentially damaging.

Table 19. Alnus – the effect of post-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	16 June 2009	22 July 2009	13 August 2009
1.	Untreated	5.0	5.0	5.0
2.	Springbok	5.0	3.0	3.3
5.	Dual Gold	5.0	4.0	3.0
6.	Dancer + Goltix	5.0	3.7	3.3
7.	Dancer + Springbok	5.0	2.7	2.8
8.	Dancer	4.7	4.0	3.3
	P	ns	0.044	ns
	Df		10	
	LSD		1.396	

The only post-emergence treatment that was not damaging to *Betula* was Centium (Table 20). Treatments with Springbok or Dual Gold reduced vigour substantially. Dancer and Goltix were not tested.

Table 20. Betula – the effect of post-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	Product	16 June 2009	22 July 2009	13 August 2009
1.	Untreated	4.8	5.0	5.0
2.	Springbok	5.0	2.3	2.0
3.	Springbok + Centium	5.0	2.8	2.7
4.	Centium	5.0	4.7	4.2
5.	Dual Gold	5.0	3.3	2.5
7.	Dancer + Springbok	4.7	2.7	3.3
	P	ns	0.005	0.005
	Df		10	10
	LSD		1.396	1.356

None of the post-emergence treatments affected the vigour of the *Crataegus* although Dancer + Goltix appeared to give an initial check, although this was not statistically significant (Table 21).

Table 21: Crataegus – the effect of post-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	**Product**	**4 June 2009**	**3 July 2009**	**13 August 2009**
1.	Untreated	5.0	5.0	5.0
2.	Springbok	4.0	5.0	5.0
3.	Springbok + Centium	4.0	5.0	5.0
4.	Centium	4.0	5.0	5.0
6.	Dancer + Goltix	3.0	4.0	5.0
7.	Dancer + Springbok	3.8	4.8	5.0
	P	ns	0.005	0.005
	Df		10	10
	LSD		1.396	1.356

Apart from an effect on crop vigour, treatments that included Dancer appeared to have killed some emerged *Fraxinus* seedlings (Table 22). In particular the Dancer + Springbok combination gave a significant reduction in seedling numbers from 173.7 per m^2 to 67.9 per m^2. The Springbok treatments gave a significant initial check although the plants recovered. Centium appeared safe as a post emergence treatment.

Table 22. Fraxinus – the effect of post-emergence herbicide treatment on seedling number (per m^2) and crop vigour score (1 = poor, 5 = good)

Treatment	**Product**	**Seedling No / m^2**	**Crop Vigour Score**		
			29 May 2009	**3 July 2009**	**13 August 2009**
1.	Untreated	173.7	5.0	5.0	5.0
2.	Springbok	176.8	3.0	4.7	4.7
3.	Springbok + Centium	169.7	3.0	4.0	4.7
4.	Centium	165.7	4.0	4.3	5.0
6.	Dancer + Goltix	131.8	3.8	3.8	4.7
7.	Dancer + Springbok	67.9	3.0	3.5	4.0
	P	0.006	<0.001	0.01	ns
	Df	10	10	10	
	LSD	52.55	0.214	0.737	

For *Sorbus,* treatments including Goltix WG were damaging post-emergence (Table 23). Centium, Dual Gold and Dancer appeared safe as post-emergence treatments although Centium caused an initial check.

Table 23: Sorbus – the effect of post-emergence herbicide treatment on crop vigour score (1 = poor, 5 = good)

Treatment	**Product**	**4 June 2009**	**3 July 2009**	**13 August 2009**
1.	Untreated	5.0	5.0	5.0
4.	Centium	3.0	4.0	5.0
5.	Dual Gold	4.3	3.7	4.7
6.	Dancer + Goltix	3.0	2.0	3.0
8.	Dancer	4.0	3.8	4.7
9.	Goltix	3.0	2.3	3.8
	P	<0.001	<0.001	ns
	Df	10	10	
	LSD	0.429	0.567	

Weed control assessments

Pre-emergence treatments

Lower-rate herbicides were used for the smaller seeded, more sensitive species. None of the low-rate treatments provided complete control. Stomp 400SC, Goltix WG and mixtures of Stomp 400SC with Goltix WG or Dual Gold were the most effective (Table 24). The mixtures of Stomp 400SC with Goltix WG or Dual Gold provided the best persistence compared with Stomp 400SC or Goltix WG alone. Dual Gold may have performed well at this site because of the high level of annual meadow grass against which it was particularly effective. The various combinations of Stomp 400SC, Springbok and Centium did not perform consistently well.

Table 24: The effect of pre-emergence, lower rate, herbicide treatments applied 13 May 2009 on percentage weed cover at three recording dates

Treatment	**Product**	**2 July 2009**			**16 July 2009**			**7 August 2009**		
	Crop>	A	C	S	A	C	S	A	C	S
1.	Untreated	95.0	100.0	73.0	98.1	99.0	75.0	93.3	99.0	83.3
2.	Springbok	21.7	41.7		43.3	58.3		45.0	63.3	
3.	Springbok + Centium		23.3			37.3			40.4	
4.	Stomp + Centium		53.3	6.7		65.0	26.7		65.0	55.0
5.	Stomp + Dual Gold	15.0		0	29.0		4.0	21.7		6.7
6.	Stomp + Goltix	2.3	6.7	2.7	6.7	18.3	10.7	16.7	26.7	14.0
7.	Stomp + Springbok	33.3	35.0		38.3	40.7		43.3	45.0	
8.	Stomp	11.7		10.0	56.7		25.0	55.0		51.7
9.	Goltix			6.7			28.3			44.0
	P	0.008	ns	<.001	0.014	ns	<.001	ns	ns	0.004
	Df	10		10	10		10			10
	LSD	42.99		15.19	43.25		21.46			32.91

Note: Crop codes A = *Alnus*, C = *Crataegus*, S = *Sorbus*. Where an entry is blank the species did not receive the treatment.

For the higher-rate treatments used on *Acer* and *Fraxinus*, the most effective and persistent treatment was Stomp 400SC with either Goltix WG or Springbok (Table 25). Dual Gold was not used in this trial.

Table 25. The effect of pre-emergence, higher rate, herbicide treatments applied 13 May 2009 on percentage weed cover at three recording dates

Treatment	**Product**	**2 July 2009**		**16 July 2009**		**7 August 2009**	
	Crop>	A	F	A	F	A	F
1.	Untreated	100	100	100	100	100	100
2.	Springbok	30	21.7	51.7	31.7	60.0	48.3
3.	Springbok + Centium	11.6	5.7	23.3	31.7	70.0	48.3
4.	Stomp + Centium	46.7	53.3	58.3	71.7	80.0	78.3
6.	Stomp + Goltix	6.7	1.7	15.0	21.0	26.7	38.3
7.	Stomp + Springbok	1.7	3.3	11.7	13.3	26.7	28.3
	P	0.002	<0.001	0.002	0.001	0.002	0.036
	Df	10	10	10	10	10	10
	LSD	38.65	37.82	36.12	34.06	30.01	43.87

Note: Crop codes A = *Acer*, F = *Fraxinus*

The predominant weed species were annual meadow grass (*Poa annua L.*), fat hen (*Chenopodium album L.*), scentless mayweed (*Matricaria recutita* L.), shepherd's purse (*Capsella bursa-pastoris* L.) and other grasses. Details of the weed populations are shown in Appendix 3, Tables 31 and 32. Generally, all treatments gave good control of annual meadow grass, although one Stomp 400SC + Springbok plot contained an exceptional number of small seedlings. Other grasses were less well controlled with by Goltix WG and Stomp 400SC alone. The control of grass was improved by adding Dual Gold. Higher rates of Springbok and Springbok + Centium were also effective. Fat hen was very abundant, with 20 seedlings per m^2 in the untreated plots. The best control was achieved by Stomp 400SC or Goltix WG alone or in mixtures. There were low levels of groundsel (*Senecio vulgaris* L.) but it was controlled by Goltix WG and Springbok; Stomp 400SC was ineffective. A moderate level (2.8 seedlings per m^2) of black nightshade (*Solanum nigrum* L.) appeared to be controlled by all treatments. Field pansy (*Viola arvensis* Murray) was not controlled by Stomp 400SC alone but all other treatments were effective. Mayweed was best controlled by Goltix WG and Centium; results from Stomp 400SC Springbok were variable. Shepherd's purse was the most abundant weed with 32 seedlings per m^2 in the untreated. All treatments apart from Springbok appeared to give good control. For Springbok there was slightly improved control where higher rates were used. The addition of Centium to Springbok also improved control of shepherd's purse.

Weed control results from the 2007 and 2008 pre-emergence experiments indicated that, of the relatively crop-safe treatments, Stomp 400SC, Goltix WG and Springbok were reasonably effective but each had some gaps in the weed control spectrum. Aclonifen and New Code A also had potential but were withdrawn from consideration by the manufacturers.

Post-emergence treatments

Post-emergence experiments could be divided into three batches, two with treatments applied at lower rates and at two timings (Tables 26 and 27) and one with higher-rate treatments appropriate for the larger seeded crop species (Table 28).

The treatments that had the most effect on existing seedling weeds (up to 2 true leaf) were Centium, Dancer and Goltix WG. Centium scorched and yellowed annual meadow grass, shepherd's purse, black nightshade, sow thistle, groundsel, oil seed rape and fat hen. Dancer and Goltix scorched annual meadow grass, black nightshade, shepherd's purse, small nettle and fat hen. Springbok had no effect on existing weeds. Springbok's main effect was as a pre-emergence treatment preventing further weed germination.

For the earlier (May) application, the most effective lower-rate treatments (recorded on 3 July 2009) were Dancer + either Springbok or Goltix WG, reducing the weed cover to 2.7 and 3.0 % compared with 43.3 % in the untreated control (Table 26). Springbok, Springbok + Centium and Centium alone also significantly reduced the percentage weed cover at 3 July. By 13 July the weed cover increased either by recovery or new germination although Springbok + Centium, Dancer + Springbok and Dancer and Goltix WG alone or in combination still gave a significant level of control. For the most effective treatment, Dancer + Springbok, percentage weed cover was maintained at 13.3 % compared with the untreated at 60 %.

At the later (June) application date, weed levels were lower but again the most effective treatment was Dancer + Springbok, followed by Dancer + Goltix WG, Springbok and Springbok + Centium (Table 27). There appeared to be an improvement in control at the August assessment from Springbok (51.7 % weed cover) by the addition of Centium (33.3 %), but the difference was not quite statistically significant

Where higher-rate treatments were used, the Springbok, Springbok + Centium and Centium treatments performed relatively better (Table 28) but as with the lower-rate treatments, Dancer + Springbok was the most effective treatment.

Table 26. The effect of post-emergence, lower-rate, herbicide treatments applied 28 May 2009 on percentage weed cover at two recording dates.

Treatment	**Product**	**3 July 2009**		**13 July 2009**	
	Crop>	*Crataegus*	*Sorbus*	*Crataegus*	*Sorbus*
1.	Untreated	43.3	21.7	60.0	60
2.	Springbok	13.3		51.7	
3.	Springbok + Centium	11.7		33.3	
4.	Centium	18.3	18.3	51.7	58.3
5.	Dual Gold		13.3		46.7
6.	Dancer + Goltix	3.0	4.0	23.3	23.5
7.	Dancer + Springbok	2.7		13.3	
8.	Dancer		10.0		37.7
9.	Goltix		6.7		31.7
	P	<0.001		0.002	0.024
	Df	10	10	10	10
	LSD	12.97	8.17	19.27	22.35

Note: Where an entry is blank the species did not receive the treatment.

Table 27. The effect of post-emergence, lower rate, herbicide treatments applied 5 June 2009 on percentage weed cover at two recording dates.

Treatment	**Product**	**22 July 2009**		**13 August 2009**	
	Crop>	*Alnus*	*Betula*	*Alnus*	*Betula*
1.	Untreated	17.0	14.0	38.3	30
2.	Springbok	3.0	4.3	6.7	11.7
3.	Springbok + Centium		5.3		10.0
4.	Centium		11.7		20.0
5.	Dual Gold	10.0	6.0	10.7	10.0
6.	Dancer + Goltix	5.7		9.0	
7.	Dancer + Springbok	2.7	2.3	8.3	5.8
8.	Dancer	10.7		15.0	
	P	0.035	0.007	0.006	0.029
	Df	10	10	10	10
	LSD	8.91	5.769	14.64	13.97

Note: Where an entry is blank the species did not receive the treatment.

Table 28. The effect of post-emergence, higher rate, herbicide treatments applied 23 May 2009 on percentage weed cover at two recording dates.

Treatment	**Product**	**22 July 2009**		**13 August 2009**	
	Crop>	*Acer*	*Fraxinus*	*Acer*	*Fraxinus*
1.	Untreated	83.3	43.3	86.7	81.7
2.	Springbok	81.7	13.3	91.7	66.7
3.	Springbok + Centium	60.0	11.7	90.0	68.3
4.	Centium	76.7	18.3	93.3	83.3
6.	Dancer + Goltix	13.3	3	46.7	80.0
7.	Dancer + Springbok	20.0	2.7	61.7	60.0
	P (ANOVA)	<0.001	ns	ns	ns
	Df	10			
	LSD	25.13			

Conclusions

Crop safety

Acer campestre

None of the herbicide treatments reduced germination significantly. This species was only tested in 2008 and 2009. In 2008 aclonifen reduced the crop vigour initially but plants recovered after 3 months. All other treatments tested were safe.

Centium, Goltix WG, Springbok and *Stomp 400SC all have potential for use on Acer. As the crop appears to have good tolerance relatively higher rates can be used. Willoughby* et al. *(2003, 2007) also showed that* Acer *was tolerant to Stomp 400SC at 5.0 L/ha however the maximum approved rate is now 3.3 L/ha.   Mixtures of Stomp 400SC with Centium, Goltix WG or Springbok were all safe. Of these Stomp 400SC + Springbok gave the best weed control. For post-emergence weed control Dancer + Springbok or Dancer + Goltix can be used.*

Alnus glutinosa

Some herbicide treatments caused a significant reduction in the number of seedlings emerged. The safest treatments were Stomp 400SC, Goltix WG and Springbok where the reductions were relatively minor in 2007 and 2008, but on a lighter soil site in 2009 all reduced germination significantly. Aclonifen, New Code A and Teridox all reduced germination substantially in 2008 although aclonifen had been safer in 2007.

Stomp 400SC, Goltix WG and Springbok have potential for use on Alnus glutinosa *either alone or in two-way tank mixtures with Stomp 400SC, although germination and crop vigour may be reduced on very light soils. No post-emergence treatments were safe.*

Betula pendula

This crop is very sensitive to herbicides. Only Stomp 400SC and Springbok were consistently safe in both 2007 and 2008, having minimal effect on germination and acceptable crop vigour. Although all treatments reduced vigour initially, by the end of the season the Stomp 400SC and Springbok treatments were of acceptable quality. Although Terano, Goltix WG and aclonifen appeared safe in 2007 (on *Betula pubescens*) the latter two caused a substantial reduction in germination in 2008 and Terano was not tested in 2008. At present there are no plans to introduce Terano in the UK, although it is available in Germany. It was not possible to make further assessments in 2009 due to a crop failure.

Stomp 400SC, Terano and Springbok have potential for use on Betula at low rates, but care is needed as this crop is subject to vigour reduction following herbicide use. Centium was acceptably safe when used either pre or post-emergence.

Cornus alba

This crop appeared very tolerant of the herbicides tested. Germination and crop vigour was not affected by any of the treatments. Only one year of tests was carried out (2008) and no post-emergence tests were done. Willoughby *et al.* (2003, 2007) found that Stomp 400SC was tolerated up to 1.5 L/ha but the higher rates tested were damaging.

Stomp 400SC, Goltix WG, and Springbok all have potential for use on Cornus. It is possible that higher rates of Goltix WG and Springbok could be tolerated.

Crataegus monogyna

It had been thought that this crop was more tolerant of herbicides so some experiments were carried out using higher rates of herbicides. Stomp 400SC (2 L/ha) and Goltix WG (3 L/ha) were safe at higher rates and Willoughby *et al.* (2003, 2007) indicated that Stomp 400SC at 5 L/ha could be tolerated, but Springbok could not be used at rates above 1.25 L/ha, without affecting germination or crop vigour. The addition of Centium to the Stomp 400SC or Springbok treatments was possible without affecting germination or vigour.

Stomp 400SC, Goltix WG and Springbok all have potential for use on Crataegus. The efficacy of Stomp 400SC could be enhanced by adding Goltix WG or Centium – the latter caused less of a growth check. The efficacy of Springbok could be enhanced by adding Centium. Springbok, Centium, Dancer and Goltix WG were also safe as post-emergence treatments.

Fraxinus excelsior

This crop appeared very tolerant of the herbicides tested. *Fraxinus* was largely unaffected by the treatments used in 2008 and 2009, including Springbok, Stomp and Goltix WG. In 2009 a higher (2.5 L/ha) rate of Springbok and combinations of Springbok and Centium caused an initial check although crops recovered well. Willoughby *et al.* (2003, 2007) also showed that *Fraxinus* was tolerant of higher rates of Goltix WG (5 kg/ha) and Stomp 400SC (7.5 L/ha) – note that the maximum approved rate for Stomp 400SC is now 3.3 L/ha.

Stomp 400SC, Goltix WG and Springbok all have potential for use on Fraxinus. A Stomp 400SC + Goltix WG mix was also tolerated and this was one of the better treatments for weed control efficacy. Centium was the only post-emergence treatment to be safe.

Rosa rubiginosa

This crop appeared quite tolerant of the herbicides tested. Germination and crop vigour was not affected by the treatments except for aclonifen which reduced germination. Stomp 400SC and aclonifen reduced crop vigour initially but there was good recovery by the end of the season. Only one year of tests was carried out (2008) and no post-emergence tests were done.

Stomp 400SC, Goltix WG, and Springbok all have potential for use on Rosa. As the crop appeared to have good tolerance, it is possible that higher rates of Goltix WG and Springbok than those tested could be used. There appeared to be some sensitivity to Stomp 400SC however.

Sorbus aucuparia

This crop is very sensitive to herbicides. Only Stomp 400SC, New Code A and Centium were consistently safe in all years tested, having minimal effect on germination and acceptable crop vigour by the end of the season. Goltix WG was safe in two out of three years tested. Aclonifen, and Springbok were more damaging reducing either germination or vigour in at least one of the three years tested. Willoughby *et al.* (2003) found that *Sorbus* was tolerant of Stomp 400SC at 0.825 L/ha but not at 2.5 L/ha and did not tolerate Goltix WG even at the low 1.7 kg/ha rate. Devrinol was reported to be an acceptable treatment however.

Stomp 400SC, Goltix WG and Centium have potential for use on Sorbus, but care is needed as this crop is subject to vigour reduction following herbicide use and results from Goltix WG have been variable for safety. A Stomp 400SC + Goltix WG mix gave the best weed control. Centium, Dual Gold and Dancer were also safe for use as post-emergence treatments.

Herbicide efficacy

Weed control results from the three years of pre-emergence experiments indicated that, of the relatively crop-safe treatments, Stomp 400SC, Goltix WG and Springbok were reasonably effective treatments. However, each had some gaps in the weed control spectrum. None of these treatments provided complete weed control through the life of the crop, although it was possible to maintain a reasonable level of weed control for the first two months when the crop is particularly vulnerable to competition. When using Stomp 400SC as standard treatment the addition of Goltix WG or Dual Gold improved weed control and would be safe for some subjects. The work of Willoughby *et al.* (2003, 2007) indicated that Devrinol would also be an effective and safe tank mix partner. When using Springbok as a standard treatment the addition of Centium generally improved weed control.

Using the herbicides as post-emergence treatments was more problematical, as this generally caused more crop damage. The only treatments to scorch, stunt or kill existing seedling weeds were Centium, Dancer and Goltix WG. The most effective treatments for removing existing weed and maintaining weed control were Dancer + Goltix WG and Dancer + Springbok. However these combinations were only safe on *Acer* and *Crataegus*. The Dancer + Springbok combination caused less loss of vigour compared with Dancer + Goltix WG. Centium was a safer post-emergence treatment and could be used on *Betula, Crataegus, Fraxinus* and *Sorbus*. Centium can cause temporary bleaching to the crop. Willoughby *et al.* (2007) also reported that Devrinol was relatively safe as a post-emergence treatment.

The herbicides Sumimax 50WP, HDC H2 and Terano were tested in year one of the project but were eliminated from further testing due to insufficient crop tolerance. Boxer and Teridox were tested in 2007 (Boxer) or 2008 (Teridox) but were eliminated from further testing due to poor efficacy at the rate used. New Code A and aclonifen showed promise in years one and two of the project but were eliminated as the manufacturer decided to discontinue development for the UK.

Technology transfer

An HDC News article is in preparation (January 2010).
HDC News article (November 2008)

References

Atwood, J. (2006). Control of problem weeds in Hardy Nursery Stock. 1st Annual Report for HDC Project HNS 139.

Atwood, J. (2007). Control of problem weeds in Hardy Nursery Stock. 2nd Annual Report for HDC Project HNS 139.

Brough, W. (1993). Evaluation of weed control treatments in tree and shrub seed beds and first year outdoor transplants. Final report for HDC Project HNS 31.

Brough, W. (1997). Tree and shrub seed beds: continued evaluation of weed control treatments. Final report for HDC Project HNS 31a.

Burgess, C. (2006). Roses: Triazine-free herbicide programmes. 1st Annual Report for HDC Project HNS 132.

Cooper, P. (1982). Seedbed herbicide trials. Rev. Luddington Exp. Hort. Stn for 1981 pp32-6.

Hanks, G. (2005). Outdoor flowers: an evaluation of herbicides. Final report for HDC Project BOF 51.

Knott, C. (2006a). Vegetables: Solutions to the loss of active ingredients for weed control in vegetable crops. 2nd Annual Report for HDC Project HNS 256.

Knott, C. (2006b). Brassicas: To investigate safe and effective new herbicides for weed control to replace those lost through the EU review. 2nd Annual Report for HDC Project HNS 270.

Williamson, D.R., Mason, W.L. and Clay, D.V. (1990). Repeat low dose herbicide application for weed control in forest nursery seedbeds. In Proceedings of crop detection in northern Britain, 1990, 187-92.

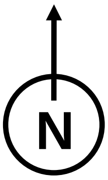
Willoughby, I., Clay, D. and Dixon, F. (2003). The effect of pre-emergent herbicides on germination and early growth of broadleaved species used for direct seeding. Forestry 76: 83-94.

Willoughby, I., Dixon, F. L., Clay, D. and Jinks, R. L. (2007). Tolerance of broadleaved tree and shrub seedlings to pre-emergence herbicides. New Forest 34:1-12.

Appendices

Appendix 1: Experimental layout Site A (J&A Growers)

Species block layout



Acer	Crataegus	Fraxinus
Sorbus	Betula	Alnus

Plot randomisation

Acer, Fraxinus

		Acer	Fraxinus
	Plot number	Treatment No	Treatment No
Block 1	1	6	6
	2	3	3
	3	4	4
	4	7	7
	5	1	1
	6	2	2
Block 2	7	7	7
	8	1	1
	9	3	3
	10	4	4
	11	6	6
	12	2	2
Block 3	13	6	6
	14	3	3
	15	4	4
	16	2	2
	17	7	7
	18	1	1

Crataegus, Betula

		Crataegus	Betula
	Plot number	Treatment No	Treatment No
Block 1	1	6	5
	2	3	3
	3	4	4
	4	7	7
	5	1	1
	6	2	2
Block 2	7	7	7
	8	1	1
	9	3	3
	10	4	4
	11	6	5
	12	2	2
Block 3	13	6	5
	14	3	3
	15	4	4
	16	2	2
	17	7	7
	18	1	1

Alnus, Sorbus

		Alnus	Sorbus
	Plot number	Treatment No	Treatment No
Block 1	1	6	6
	2	5	5
	3	8	8
	4	7	4
	5	1	1
	6	2	9
Block 2	7	7	4
	8	1	1
	9	5	5
	10	8	8
	11	6	6
	12	2	9
Block 3	13	6	6
	14	5	5
	15	8	8
	16	2	9
	17	7	4
	18	1	1

Plot dimensions

	< 1.5m >
< 1.5 / 2.0m >	Sub plot five rows of one species I I I I I < 1.35m > Bed

Table 29. Post-emergence herbicide treatments used in 2009 at J & A Growers

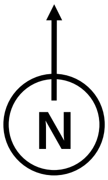
Treatment, product and application rates[1]		Acer	Alnus	Betula	Crataegus	Fraxinus	Sorbus
1	Untreated	X	X	X	X	X	X
2	Springbok 1.75–2.5 L/ha	X	X	X	X	X	
3	Springbok 1.25–1.75 L/ha + Centium 125-250 ml/ha	X		X	X	X	
4	Centium 125-250 ml/ha	X		X	X	X	X
5	Dual Gold 0.8 L/ha		X	X			X
6	Dancer 2.5 L/ha + Goltix WG 1.5-3.0 kg/ha	X	X		X	X	X
7	Dancer 2.5 L/ha + Springbok 1.25-1.75 L/ha	X	X	X	X	X	
8	Dancer 2.5 L/ha		X				X
9	Goltix WG 1.5 kg/ha						X

[1] The higher rates were applied to *Acer* and *Fraxinus*

Appendix 2: Experimental layout Site B (Wyevale Transplants)

All plots end to end not side by side

Sorbus
Betula
Roadway
Alnus
Crataegus
Roadway
Fraxinus
Acer



Acer, Fraxinus

		Acer	Fraxinus
	Plot number	Treatment No	Treatment No
Block 1	1	3	3
	2	2	2
	3	6	6
	4	4	4
	5	7	7
	6	1	1
Block 2	7	7	7
	8	2	2
	9	6	6
	10	4	4
	11	1	1
	12	3	3
Block 3	13	6	6
	14	7	7
	15	2	2
	16	3	3
	17	1	1
	18	4	4

Crataegus, Betula

		Crataegus	Betula
	Plot number	Treatment No	Treatment No
Block 1	1	4	4
	2	3	3
	3	1	1
	4	2	2
	5	6	5
	6	7	7
Block 2	7	4	4
	8	2	2
	9	6	5
	10	7	7
	11	3	3
	12	1	1
Block 3	13	2	2
	14	6	5
	15	1	1
	16	4	4
	17	3	3
	18	7	7

Alnus, Sorbus

		Alnus	Sorbus
	Plot number	Treatment No	Treatment No
Block 1	1	8	8
	2	6	6
	3	1	1
	4	2	4
	5	5	5
	6	7	9
Block 2	7	6	6
	8	2	4
	9	5	5
	10	7	9
	11	8	8
	12	1	1
Block 3	13	2	4
	14	5	5
	15	1	1
	16	8	8
	17	6	6
	18	7	9

	< 1.3m >
< 1.25m >	Sub plot five rows of one species I I I I I < 1.30m > Bed

Table 30. Pre-emergence herbicide treatments used in 2009 at Wyevale transplants

Treatment, product and application rates[1]		Acer	Alnus	Crataegus	Fraxinus	Sorbus
1	Untreated	X	X	X	X	X
2	Springbok 1.75–2.5 L/ha	X	X	X	X	
3	Springbok 1.25–1.75 L/ha + Centium 125-250 ml/ha	X		X	X	
4	Stomp 1.0-2.0 L/ha + Centium 125-250 ml/ha	X		X	X	X
5	Stomp 1.0 L/ha + Dual Gold 0.8 L/ha		X			X
6	Stomp 1.0-2.0 L/ha + Goltix WG 1.5-3.0 kg/ha	X	X	X	X	X
7	Stomp 1.0-2.0 L/ha + Springbok 1.25-1.75 L/ha	X	X	X	X	
8	Stomp 1.0 L/ha		X			X
9	Goltix WG 1.5 kg/ha					X

[1] The higher rates were applied to *Acer* and *Fraxinus*

Table 31. Weed seedlings per m^2 recorded 11 June 2009 – following lower rate pre-emergence herbicide treatment at Wyevale transplants

Treatment	Annual meadow-grass	Charlock	Corn Spurrey	Chickweed, Common	Fat Hen	Groundsel	Knotgrass	Mayweed, Scentless	Nettle, Small	Nightshade, Black	Pansy, Field	Scarlet pimpernel	Shepherds Purse	Sow Thistle, Smooth	Speedwell, Common	Grass, other	Total
1.Untreated	21.0	0.0	23.4	1.7	20.0	1.4	3.1	24.1	0.3	2.8	0.7	0.0	32.4	0.7	1.0	4.1	136.9
2.Springbok	0.0	1.5	1.0	0.0	2.6	0.0	1.5	3.1	0.0	0.0	0.0	0.0	5.1	0.5	0.0	1.0	16.5
3.Springbok + Centium	0.0	0.0	0.0	0.0	2.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	5.1
4.Stomp + Centium	0.5	0.5	1.5	0.0	2.1	2.1	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	11.8
5.Stomp + Dual Gold	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.0	3.6
6.Stomp + Goltix	0.0	0.3	1.7	0.0	1.7	0.0	0.0	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.0	1.7	6.9
7.Stomp + Springbok	3.1	2.1	6.7	0.5	3.6	0.5	2.6	3.1	0.0	1.0	0.0	0.0	5.7	1.0	0.0	0.5	30.3
8.Stomp	0.5	0.0	0.0	0.0	0.0	2.6	0.0	1.0	0.0	0.0	2.1	0.0	0.5	0.0	0.0	6.7	13.4
9.Goltix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	3.1	4.1

Note: Averaged results from *Alnus, Crataegus* and *Sorbus* plots. Individual weed species counts were not statistical analysed as data from three experiments with different treatment combinations were combined

Table 32. Weed seedlings per m^2 recorded 11 June 2009 – following higher rate pre-emergence herbicide treatment at Wyevale transplants

Treatment	Annual meadow-grass	Corn Spurrey	Chickweed, Common	Fat Hen	Groundsel	Knotgrass	Mayweed, Scentless	Shepherds Purse	Sow Thistle, Smooth	Grass, other	Total
1.Untreated	18.0	0.5	0.5	4.1	0.5	1.0	22.6	29.8	3.1	14.9	95.2
2.Springbok	0.0	0.5	0.0	5.1	0.0	0.5	0.0	12.3	0.0	0.5	19.0
3.Springbok + Centium	0.0	0.0	0.0	2.1	0.0	1.0	0.5	0.5	0.0	2.1	6.2
4.Stomp + Centium	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	11.3	11.8
6.Stomp + Goltix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
7.Stomp + Springbok	14.4	0.0	0.5	1.5	1.0	0.0	9.8	10.8	0.5	5.1	43.7

Note: Averaged results from *Acer* and *Fraxinus* plots. Individual weed species counts were not statistical analysed as data from two experiments were combined.