Project title:	Evaluating the potential of plant growth regulators to limit growth on tree and hedging species
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Project leader:	David Talbot, ADAS UK Ltd.
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

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.

David Talbot

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Signature Date 12/03/15.

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GROWER SUMMARY

Headline

- All species tested responded to chlormequat, but leaf yellowing was a problem depending on the rate used.
- All the plant species tested in 2014 responded to at least one of the plant growth regulators used.

Background

The work was undertaken to find alternative ways of reducing the vigour of field-grown tree and hedging crops in nursery production. Undercutting during the growing season is the current method of regulating growth, however this is not effective during wet summers, because undercutting does not provide a sufficient stress response in plants when soils are moist. A planned number of applications of plant growth regulators has the potential to limit the growth of vigorous species, if carefully timed, irrespective of the weather. Plant growth regulators can be applied throughout the growing season giving growers more precise control of crop growth, even in wet summers, helping to ensure that the majority of plants do not exceeded height specifications.

Summary

All of the plant growth regulators used within this trial have the potential to regulate the growth of selected tree and hedging subjects. All the species within the trial responded to at least one plant growth regulator in both 2013 and 2014. Three applications of plant growth regulators were applied at three weekly intervals, commencing in early July. Treatments used in 2014 are shown in Table 1.

Stabilan 750 (75% chlormequat) was used instead of Fargro Chlormequat (46% chlormequat) in 2014 as Fargro Chlormequat became unavailable during the period of the trial, and has a final use date of 31/11/15. Stabilan 750 (75% chlormequat) is a more concentrated product and possesses a label approval for use on ornamentals. Rates of Stabilan 750 were reduced to take account of both the more concentrated product and the fact that rates of Fargro Chlormequat used in 2013 resulted in unacceptable phytotoxicity in several plant species.

Table 1. Growth regulator products used in experimental treatments 2014

Product name	Active ingredient	Rate (l/ha or kg/ha) applied as 1000l water/Hectare	Approval status
Untreated			
Stabilan 750*	750 g/l chlormequat	15.3l/ha (all species excluding *Sorbus)*	Label
		7.6l/ha *(Sorbus)*	
HDC P003 (foliar spray) *(Prunus* & *Sorbus* only)	Confidential	Confidential	Not authorised
Regalis** *(Prunus* & *Sorbus* only)	10% w/w prohexadione calcium	1 kg on 18/06/13, 1 kg/ha on 10/07/13, and 0.5 kg/ha on 06/08/13	EAMU
HDC P004	Confidential	Confidential	Not authorised
Moddus	250g/l	0.2 l/ha	EAMU

*chlormequat treatment included Activator 90 at 1ml/l of water.
**Regalis treatment included 2.5 ml of X-Charge per litre of water.

Reduced rates of chlormequat in 2014 still resulted in some phytototoxic damage, although less severe than the previous year on most of the test species and was considered commercially acceptable by the industry representatives in mid September.

HDC P003 and Regalis (prohexadione calcium) were only used on *Prunus* and *Sorbus* in 2014 as these were the only two species that responded to these plant growth regulators in 2013. HDC P003, applied only as a foliar treatment via a weed wiper in 2013, did not result in significant reductions in height so this method was not pursued. Moddus (trinexapac-ethyl) and HDC P004 were included in the trials carried out in 2014 to test additional plant growth regulators. Although HDC P004 and Moddus caused slight damage on some of the test species, phytotoxic damage caused by these treatments was considered commercially acceptable throughout the trial.

The treatments that resulted in the greatest mean height reduction by species during 2013 and 2014 are shown in Table 2:

Table 2. Treatments during the trial that resulted in the greatest mean height reduction.

Species	2013	2014
Alnus	Fargro Chlormequat	HDC P004
Betula	Fargro Chlormequat	Moddus
Populus	Fargro Chlormequat	Stabilan 750
Prunus	P003 (foliar spray)	HDC P004
Sorbus	Fargro Chlormequat	HDC P004

It should be noted that whilst Fargro Chlomequat gave the greatest height reduction for four species at the full rate used in 2013 it also caused leaf yellowing. Stabilan 750 (chlormequat) had the most effect on the height of *Populus* resulting in a significant reduction in height compared to untreated controls. Stabilan 750 (chlormequat) and PO004 also resulted in the most significant reduction in mean height of *Prunus.* Although Stabilan 750 (chlormequat) resulted in a greater height reduction in *Prunus* than HDC PO004, the latter which was less damaging, appeared to result in a more even crop, so may be a better commercial treatment if an EAMU is granted. All treatments other than Moddus resulted in a significant reduction in the mean height of *Sorbus.*

The best potential treatments can be summarised for each species:

Chlormequat is likely to be the most effective growth regulator on *Populus* to prevent excessive growth. HDC PO004 was the most effective treatment on *Sorbus,* HDC PO004 was considered the most useful treatment on *Alnus.* Moddus appeared visually the most useful on *Betula* however this result should be treated with caution as differences were not statistically significant. It should also be noted that 2014 was the first year that Moddus had been used in these trials.

HDC P003 and P004 were used in these trials under an experimental permit. HDC P004 performed well on *Sorbus* and resulted in similar growth regulation as HDC P003 in the case of *Prunus,* therefore an application for an EAMU to permit the use of HDC P004 in ornamental plant production and forest nurseries will be sought.

Not all the plant species responded to the different growth regulators in the same way. Therefore in the third year of trials under HNS 187a, treatments will be refined further in an attempt to optimise growth control for specific species.

Financial Benefits

For species where there is no need for a central leader, crops can be mechanically topped at a cost of £150/ha. However, for many crops this is not an option as it would have a detrimental impact on subsequent growth following planting out.

The forestry sector is one of the key market outlets for two year old field-grown tree species, however plants over 90 cm have reduced marketability. The landscape sector tends to specify one and two year old tree and hedging plants at 80 – 100 cm in height. Plants over 100 cm can normally be substituted for 80 – 100 cm crops to landscapers providing that they are sold at the same price. Although this is a way of clearing some taller stock, extra height variation within crops adds about 5% to the grading cost which typically equates to an additional labour cost of £105 per hectare.

Despite growers using cultural techniques such as undercutting to limit the growth of certain species (e.g. *Alnus incana, Alnus glutinosa, Betula pendula, Prunus avium, Sorbus aucuparia* and *Tillia platyphyllos)* in the second year of production, approximately 50 percent of the stock can reach over 100 cm tall in the second year of field production. Within the trial the following percentages of untreated crops exceeded the 90 m height specification: *Alnus glutinosa* (82.5%), *Betula pendula* (92.5%), *Populus x canadensis* 'Robusta' (80%), *Prunus avium* (12.5%) and *Sorbus aucuparia* (67.5%).

Based on an average of 300,000 plants to the hectare on a typical bed-based system, and an average price per plant of £0.30, and with a worst case scenario that up to half of the aforementioned species would be unmarketable in some years, this equates to a loss of up to £45,000 per hectare.

To summarise:

Limiting height variability speeds up grading, saving £105 per hectare in labour.

Minimising the percentage of crops 90cm or over could also potentially result in up to £45,000 worth of additional marketable crops per hectare.

Action Points

- Plan to trial the use of plant growth regulators as part of the production schedule (always leave some untreated as a comparioson) suitable products include Regalis and plant growth regulators (with appropriate authorisation) containing chlormequat at appropriate rates. Test plant growth regulators on vigorous species or cultivars to determine plant response.
- There is a need to 'read' a crop's growth in line with the season to determine when best to commence applications of plant growth regulators. Ensure that plants have put on sufficient extension growth to take up plant growth regulators prior to commencing applications. Field grown transplants are typically at the optimum growth stage to commence plant growth regulaton application between mid June and early July depending on the season.Be aware that some fungicides e.g. triazoles such as Folicur, Nativo 75WG* and Topas can have a growth regulatory effect (see HNS 156) which needs to be taken account of, particularly if used in conjunction with plant growth regulators.
- Monitor crops after treatment with plant growth regulators and aim to reapply plant growth regulators when extension growth starts again. For the species tested this is typically three weeks after the previos application.
- Very vigerous species such as *Betula* may respond to more frequent lower rates of plant growth regulators.
- Allow sufficient time for plant growth regulators to be taken up by treated plants prior to the application of irrigation, take account of the weather and irrigation schedules before application.

SCIENCE SECTION

Introduction

Growth control in field-grown stock has to date relied on undercutting as the main way of limiting plant growth during the growing season. Weather conditions can prevent undercutting having the desired effect, resulting in stock putting on excessive growth in its second year and therefore being over specification (90 cm). For some vigorous species there may be a limited or even no market for up to 50% of the crop which could result in lost sales of up to £45,000 per hectare. Whilst landscapers will take some of this taller stock, the additional grading and space taken up during cold storage and transport also adds to costs. There is potential for chemical plant growth regulators to be utilised to limit the height of a range of field-grown tree and hedging species/cultivars. This would result in stock that could be sold to a wider range of customers and would reduce grading, cold storage and transport costs.

Materials and methods

The experiments were carried out at Wyevale transplants, Hereford. The plant species were kept the same in the second year of the trials in order to generate comparable data. Future work in different projects will focus on plant growth regulators on different species or cultivars.

The soil type is a naturally free draining loamy sand. Soil analysis was carried out in and around plots in each field after the *Populus* cuttings had been inserted and other species had been planted (as one year old 20 – 40 cm transplants). Base fertiliser comprising of 170kg/ha of Muriate of Potash (K^20 60%, K 49.8%) and 150kg/ha of Nitram (34.5% Ammonium Nitrate) was applied prior to planting in April. The results of the soil analysis for 2013 are included in the previous annual report, results from 2014 are shown in Table 2:

Table 2. Soil analysis of experimental plots

Field name and species	Soil pH	P Index (available mg/l)	K Index (available mg/l)	Mg Index (available mg/l)
North Bank - *Alnus*	5.9	4 (58.2)	3 (241)	2 (76)
Rough Ground – *Populus*	6.1	3 (43.6)	3 (301)	2 (97)

Vinnis – *Betula, Prunus* & *Sorbus*	5.3	4 (64.4)	2+ (236)	2 (75)
Foxbury – All replanted stock (*Alnus, Betula, Populus Prunus* & *Sorbus)*	7.3	5 (79.6)	2+ (224)	2 (67)

Soil pH was close to pH 6 and 6.5, the range for optimum nutrient availability. Although the pH was slightly above or below the optimum in some fields, crop growth did not seem to be affected. Phosphorus (P) indices were all Index 3 or above, despite no phosphorus being applied to the crop. Phosphorus indices should not be maintained above Index 3 as phosphorus contributes to eutrophication of water. RB209 Fertiliser Reccomendations state that potassium (K) should be applied to all fields at Index 3 and below at planting. Therefore Potassium (K) was slightly low at North bank and Rough Ground and was low at both Vinnis and Foxbury. Magnesium (Mg) was also slightly low in all four fields. RB209 Fertiliser Reccomendations state that Magnesium should be applied at 25kg/ha at Index 2 and below prior to planting. The slightly low concentrations of potassium indicate that annual applications of Muriate of Potash should be maintained or increased slightly, There is also a need to topdress all fields with magnesium to raise levels to Index 3. Plant growth in all fields did not appear to adversely affect plant growth.

Trials were carried out within commercial crops, and hence over four different fields; the soil type was the same in each field. Trials were laid out in commercial crops at Wyevale Transplants, Hereford as a randomised block, randomised within each species, with four replicates. There were five treatments including an untreated control. Treatments applied to each species are shown in Appendix 1.

In consultation with the industry, the following species were used in both 2013 and 2014: *Alnus glutinosa, Betula pendula, Populus x canadensis* ‘Robusta’*, Prunus avium* and *Sorbus aucuparia.* They were selected for their vigour and because they are widely grown. All species with the exception of *Populus* were planted out into pre-prepared beds in early April as one year old graded, cold stored, field-grown seedlings. *Populus* were inserted in March as hardwood cuttings directly into pre-prepared beds, and fertiliser was broadcast over the cuttings in April.

Overhead irrigation was supplied by a rain gun as deemed necessary by the grower. No irrigation was applied to treated plots within 24 hours of plant growth regulator application.

Three applications of the plant growth regulators were applied as a foliar spray at approximately three week intervals allowing for prevailing weather conditions on the 20/06/14, 11/07/14 & 30/07/14. Rates used are as listed in Table 3. Plant growth regulators were applied using an Oxford precision plot sprayer with a 03/F110 nozzle delivering a medium spray quality

Phytotoxicity assessments were carried out three weeks after treatment on the following dates: 11/07/2014, 30/07/14 and 20/08/14. Phytotoxicity was scored on a 0 – 9 scale with 0 representing plant death and 9 being comparable with the controls. In addition to phytotoxicity scores, height measurements recorded from 10 plants within the central region of each plot; and these were repeated at the end of the growing season on 22/10/2014.

Stabilan 750 (75% chlormequat), a more concentrated product which has on label uses for ornamentals was used instead of Fargro Chlormequat (46%) which is under revocation. The rates of Stabilan 750 were reduced as Stabilan 750 is a more concentrated product. Rates of of Fargro Chlormequat used in 2013 resulted in unacceptable phytotoxicity. Therefore a much lower rate of Stabilan 750 was applied in 2014 in order to apply a lower concentration of chlormequat to the test species

Table 3. Growth regulator products used in experimental treatments

Treatment number	Product name	Active ingredient	Rate (l/ha or kg/ha) applied as 1000l water/Hectare	Approval status
1	Untreated			
2	Stabilan 750*	750 g/l chlormequat	15.3l/ha (all species excluding *Sorbus)*	Label
			7.6l/ha *(Sorbus)*	
3	HDC P003 (foliar spray)	Confidential	Confidential	field-grown Not authorised

	(Prunus & *Sorbus* only)			
4	Regalis** *(Prunus* & *Sorbus* only)	10% w/w prohexadione calcium	1 kg on 18/06/13, 1 kg/ha on 10/07/13, and 0.5 kg/ha on 06/08/13	Specific off label approval (SOLA) 2866/2008. The split dose of Regalis was discussed and agreed with BASF, the products authorisation holder.
5	HDC P004	Confidential	Confidential	Not authorised
6	Moddus	250g/l	0.2 l/ha	EAMU3062/2010

*__chlormequat treatment to include Activator 90 at 1ml/l of water.__

****Regalis treatment to include 2.5 ml of X-Charge per litre of water.**

Statistical analysis was carried out by the ADAS statistician Chris Dyer and is reported within the results to 95% significance .

Three plants from each plot were labelled in autumn 2013, and were lifted by the host grower and cold stored to replicate how a commercial crop would be treated prior to sale. These plants were planted out on the nursery in spring 2014 (24/04/14) to be grown on for a season to determine if any of the plant growth regulators applied the previous year had any detrimental effects on the growth of any of the five species tested.

Results

Definitions of phytotoxicity scores are listed in Table 4. Mean phytotoxicity scores at all assessments are shown in tables 5, 6 & 7. Least significant differences (LSD) have not been included because in nearly all cases, the score was the same for all replicates of a treatment on an individual species.

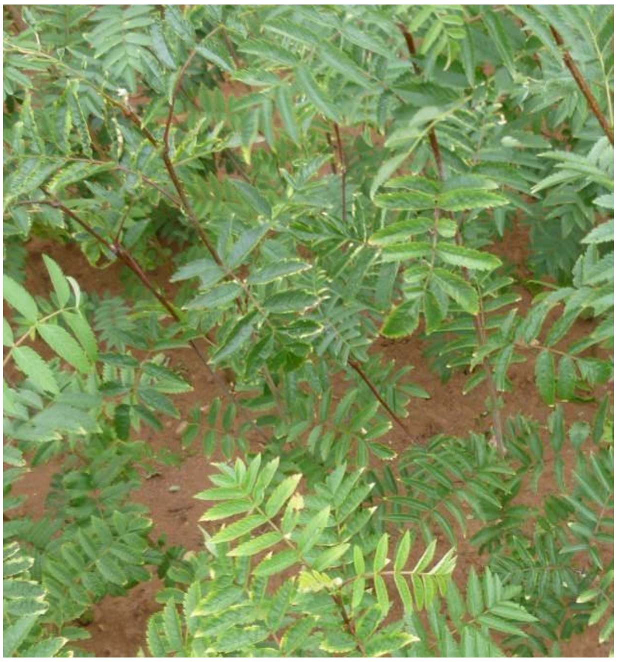
Fargro Chlormequat (chlormequat) resulted in phytotoxic damage in the first year of trials and as a result Stabilan 750 (chlormequat) was applied at a lower rate in 2014. Despite this chlormequat again resulted in phytotoxic damaged to plants in 2014 trials and was significantly more damaging than any of the other treatments assessed (refer to tables 5, 6 & 7). Pytotoxic damage in 2014 was less severe than in 2013 on all species with the exception of *Alnus*. It should be noted that *Alnus, Betula* and *Populus* started growing away from damage caused by application, three weeks after the final application, as shown in Table 7. All of the species grew away from damage caused by treatment 2 (chlormequat) and were considered commercially acceptable by the industry representatives during their assessment on 18/09/14*.* At each assessment, all species in treatment 2 were given a lower phytotoxicity score than other treatments. The phytotoxicity symptoms arising from chlormequat treatments included marginal leaf scorch on all species, and interveinal yellowing was also noted on some species (Figure 1).

Phytotoxic damage on *Alnus*.

Phytotoxic damage on *Betula*.

Phytotoxic damage on *Populus*.

Phytotoxic damage on *Prunus*.



Phytotoxic damage on *Sorbus*.

Figure 1. Phytotoxic damage caused by two applications of chlormequat, 30/07/14.

Table 4. Key to phytotoxicity scores.

Score	Definition
4	Damaged or reduced growth
6	Slightly damaged or reduced growth
7	Very slightly damaged but still commercially acceptable
8	Commercially acceptable (barely affected)
9	Comparable with untreated control

Damage caused by treatment 5 (HDC P004) and Moddus was considered to be within commercially acceptable limits on *Populus, Prunus* and *Sorbus.* This damage was initially seen at the first assessment (three weeks after treatment), *Sorbus* grew away from this initial damage and further damage was considered commercially acceptable on this species. HDC P004 resulted in paler leaves on *Populus* and *Sorbus,* and *Sorbus* leaves were also slightly narrower than those of untreated controls.

Table 5. Assessment 1, Mean phytotoxicity scores 11/07/2014.

	Treatments					
Species	1 Untreated	2 Stabilan 750	3 HDC P003 as a foliar spray	4 Regalis	5 HDC P004	6 Moddus
Alnus	9	6	-	-	9	9
Betula	9	6	-	-	9	9
Populus	9	6	-	-	8	9
Prunus	9	6	9	9	8.5	9
Sorbus	9	6	9	9	7.5	8

Table 6. Assessment 2, Mean phytotoxicity scores 30/07/2014.

	Treatments					
Species	1 Untreated	2 Stabilan 750	3 HDC P003 as a foliar spray	4 Regalis	5 HDC P004	6 Moddus
Alnus	9	4	-	-	9	9
Betula	9	6	-	-	9	9
Populus	9	6	-	-	8	9
Prunus	9	6	9	9	9	9
Sorbus	9	6	9	9	8	8.5

Table 7. Assessment 3, Mean phytotoxicity scores 20/08/2014.

	Treatments					
Species	1 Untreated	2 Stabilan 750	3 P003 as a foliar spray	4 Regalis	5 HDC P004	6 Moddus
Alnus	9	6	-	-	8	9
Betula	9	8.25	-	-	9	9
Populus	9	7	-	-	8	9
Prunus	9	6	9	9	9	9
Sorbus	9	6	9	9	8	8.5

Phytotoxic damage on *Populus*.   Phytotoxic damage on *Sorbus*.

Figure 2. Commercially acceptable phytotoxic damage caused by two applications of HDC P004, 30/07/14.

The mean final height measurements on 22/10/2014 are shown in table 8, as are the results of the statistical analysis. Treatment 5 was the only treatment on *Alnus* that reduced mean average height. Treatment 5, 2 and 6 reduced mean average height on *Betula.* None of the height reductions were significant on *Alnus* or *Betula* at (95% significance). Treatment 2 was the only treatment to reduce mean average height on *Populus,* when compared to untreated controls. There was a significant difference in heights of *Populus* between treatment 2 and treatments 1, 5 & 6 (95% significance). This showed that Stabilan 750 (T2, chlormequat) had the most effect on mean height of *Populus.*

Treatments 2, 3, 4 and 5 all resulted in a reduction in mean average height in both *Prunus* and *Sorbus* compared to the untreated control. In *Prunus* Treatment 6 is significantly different to treatment 2 and 5 at (95% significance). This confirmed that Stabilan 750 (T2, chlormequat) and HDCP004 resulted in a more significant reduction in mean height of *Prunus* than Moddus.

Sorbus: Treatment 1 & 6 is significantly different to treatment 2, 3, 4 and 5 at (95% significance). This proved that all treatments other than Moddus resulted in a significant reduction in mean height on *Sorbus*.

Table 8. Mean height of all species in cm, recorded on 22/10/2014; at the end of the growing season, the best treatments are shown in bold.

	Treatments							
Species	1 Untreated	2 Stabilan 750	3 HDC P003 as a foliar spray	4 Regalis	5 HDC P004	6 Moddus	F pr	LSD
Alnus	104.1	103.2	-	-	**101.8**	107.8	0.388	7.62
Betula	120	113.4	-	-	117.6	**108.3**	0.097	9.76
Populus	115.9	**65.8**	-	-	128.2	126.3	<.001	20.73
Prunus	66.5	**56.4**	64.4	66	60.5	72.1	0.044	9.37
Sorbus	112.3	100	82.9	94.9	**75.8**	112.8	<.001	12.00

Table 9 shows the mean percentage of plants at or above 90 cm at the end of the growing season, in order of treatment. The results clearly show that *Betula* was the most vigorous species within the trial (as was the case in 2013); none of the treatments applied to *Betula* resulted in a useful reduction in crop percentage within the specifications of the forestry sector (up to 90 cm). There was no significant difference in the percentage of plants at or below 90cm between treatments applied to *Betula* or *Prunus* at (95% significance)

The treatments that were considered of most use and resulted in reduced crop height are highlighted in bold in tables 8 and 9. Table 9 shows there was a significant difference in the percentage of plants at or below 90cm between treatment 5 and treatments 1, 2 & 6 in *Alnus* (95% significance). This indicates that HDCP004 may have a place in reducing the percentage of *Alnus* exceeding 90cm.

There was a significant difference in the percentage of plants at or below 90cm in *Populus* between treatment 2 and treatments 1, 5 & 6 (95% significance). This shows that Stabilan 750 (T2, chlormequat) is likely to be the most effective plant growth regulator to help prevent excessive growth on *Populus.* There was also a significant difference in the percentage of

Sorbus at or below 90cm between treatment 5 and treatments 1, 2, 3, 4 & 6 (95% significance), this confirms that HDCP004 was the most effective treatment on *Sorbus*.

Table 9. Mean percentage of plants by species and treatment at or above 90cm on 22/10/2014.

	Treatments							
Species	1 (Untreated)	2 Stabilan 750	3 (HDC P0003 as a foliar spray)	4 Regalis	5 HDC P004	6 Moddus	F pr	LSD
Alnus	82.5	90	-	-	**65**	85	0.031	16.05
Betula	92.5	92.5	-	-	97.5	90	0.638	13.13
Populus	80	**7.5**	-	-	95	87.5	<.001	19.95
Prunus	12.5	**0**	7.5	10	10	20	0.148	14.12
Sorbus	67.5	52.5	30	47.5	**2.5**	77.5	<.001	22.11

Tables below show mean heights of all species treated with chlormequat in 2013 and 2014 (Table 10). Table 11 shows the mean percentage of species treated with chlormequat in 2013 and 2014 that were at or over 90 cm at the end of the growing season.

Applying plant growth regulators via a weed wiper in year one was not effective and so was not explored any further.

Table 10. Mean height of all species in 2013 and 2014 – untreated and treatment 2 (Fargro Chlormequat 2013, Stabilan 750 2014).

	Treatments			
Species	1 Untreated 14/10/13	1 Untreated 22/10/14	2 Fargro Chlormequat 14/10/13	2 Stabilan 750 22/10/14
Alnus	61.00	104.1	53.18	103.2
Betula	102.43	120	81.00	113.4
Populus	84.38	115.9	54.42	65.8
Prunus	49.25	66.5	46.70	56.4
Sorbus	68.08	112.3	22.70	100

Table 11. Mean percentage of plants by (untreated and chlormequat treatments) at or above 90cm on 14/10/2013 and 22/10/14.

	Treatments			
Species	1 Untreated 14/10/13	1 Untreated 22/10/14	2 Fargro Chlormequat 14/10/13	2 Stabilan 750 22/10/14
Alnus	0	82.5	2.5	90
Betula	82.5	92.5	47.5	92.5
Populus	42.5	80	0	7.5
Prunus	0	12.5	0	0
Sorbus	20	67.5	0	52.5

Discussion

The aim of this work was to regulate the growth of five vigerous species *(Alnus glutinosa, Betula pendula, Populus x canadensis* 'Robusta', *Prunus avium* and *Sorbus aucuparia)* grown from cuttings and graded one year old transplants. Three applications of plant growth regulators were applied during the growing season to test their ability to regulate the growth of up to five species. Where species had not responded to certain plant growth regulators in previous trials these species / treatment combinations were not repeated. Three growth regulators (Stabilan 750, P004 and Moddus) were applied to all of the aforementioned species whilst HDC P003 and Regalis were only applied to *Prunus* & *Sorbus.*

Work undertaken in 2013 showed that all of the growth regulators tested have the potential to regulate the growth of field-grown tree and hedging subjects. As expected, different species responded to the actives in the growth regulators in different ways; for example it proved difficult to regulate the growth of *Betula* in both 2013 & 2014, and only chlormequat resulted in an average height reduction in all species at the end of the growing season, compared to untreated controls. Maximum legal rates of the growth regulators were used in 2013 as there was no available data on effective rates for the species tested. It was deemed necessary to use high rates initially in order to get a plant response, given the vigour of the species tested.

The high rates of chlormequat resulted in excessive stunting in *Sorbus* in 2013; indicating that this species is very responsive to it. Unfortunately reducing the rate of chlormequat for this species in 2014 did not result in a commercially acceptable level of growth regulation. HDC P004 resulted in a significant reduction in height on *Sorbus*; this treatment also resulted in a 65 % reduction in plants at or above 90 cm at the end of the growing season and was the safest treatment tested. P004 also performed well on other species including *Alnus* where its use resulted in a 17.5% reduction of the crop exceeding 90cm compared to unteated controls. P004 was also one of the best treatments applied to *Prunus* where its use resulted in a 2.5% reduction of the crop exceeding 90cm, compared to untreated controls.

Phytotoxicity was a problem on all species treated with chlormequat in 2013, and resulted in unsightly leaf yellowing. This yellowing can be perceived as a quality problem by customers when visiting nurseries during the growing season to place orders and view reserved stock. When plants are dispatched, these affected leaves will have fallen and would no longer detract from the quality of the plant. To prove this, plants from each treatment (including untreated controls) were labelled and lifted in November 2013, and cold stored and re-planted out in the spring of 2014 to check that the growth of treated plants was not affected (Annual report 2014). Treated plants grew away when planted in 2014 as shown in figure 3.

Alnus replanted.

Betula replanted.

Populus replanted.

Prunus replanted.

Sorbus replanted.

Figure 3. Plants treated in 2013 were coldstored and replanted in 2014, they all grew away with no negative effects.

Given the apparent compromise between crop damage and achieving growth regulation in some species, customers may have to accept some yellowing (associated with chlormequat) on the foliage of some species of growing crop in order to enable growers to keep the height of vigorous species within their height specifications. Stabilan 750 (chlormequat) resulted in a 72.5% reduction of *Prunus* exceeding 90cm compared to untreated controls. Although Stabilan 750 (chlormequat) was more damaging than HDCP004 on *Prunus,* it was more effective with no treated plants exceeding 90cm (compared to 12.5% of controls and 10% of those treated with HDCP004). There is potential to use chlormequat at lower rates on *Prunus* which should help to minimise damage to an acceptable level. The alternative is likely to be lower profitability as it is difficult to command a higher price to allow for wastage of a percentage of trees which exceed customer specifications because they are too tall. All other treatments in 2013 caused slight phytotoxicity but the plants quickly grew away from the damage, which was considered to be within commercially acceptable limits. Treatments in 2014 were generally less damaging, but despite reducing the rate of chlormequat on all species, the effects on *Populus* still resulted in excessive growth regulation. There is still further scope to reduce the rate of chlormequat on *Populus* and the number of applications. There is potential to use some of the plant growth regulators assessed to date in tank mixes to determine if there is a useful synergistic effect. This concept will be tested in the project extension that has been granted to continue the work in 2015.

Unfortunately the formulation of chlormequat (Fargro Chlormequat 460 g/l) used during 2013 has not been supported by the authorisation holder, Nufarm UK Limited, and has a final use date of 31/11/2015. Stabilan 750 is another product containing chlormequat with label uses in ornamental plant production. This product currently has a final use date of 03/12/2016 and for this reason was used in the second year's trials. Stabilan 750 is the same formulation as Fargro Chlormequat but is a higher concentration. Stabilan 750 was used in the second year of the trials (as reported above) at a much lower rate and concentration than Fargro Chlormequat in an attempt to minimise potential phytotoxic damage.

Reducing the rate of chlormequat reduced the phytotoxic damage to a commercially acceptable level in all species apart from in *Alnus.* As expected there was a trade-off between a reduction in phytotoxic damage and a useful reduction in height in many treatment-species combinations.

In these trials three applications were applied three weeks apart during the growing season. More frequent low rate applications of chlormequat may minimise phytotoxicity to an acceptable level, whilst still providing useful growth regulation of some difficult to control species, particularly those that are known to respond to this growth regulator.

Three applications of Moddus were applied in 2014 under experimental permit, the maximum total dose permitted per crop, under the current EAMU, was applied over three applications. This showed that the rate of Moddus is insufficiently high to provide sufficient growth regulation of the species tested within this trial.

Three applications of HDC P004 were applied under an experimental permit. This product evened up the growth of many of the species tested within the trials carried out in 2014. Phytotoxicity effects from this plant growth regulator were negligible on all species tested. Like many plant growth regulators not all species responded in the same way to HDC P004, the foliage of *Populus* treated with this plant growth regulator was a paler green than untreated controls.

It is well known that various plant species respond in different ways to plant growth regulators. *Alnus, Betula* and *Populus* did not respond to either Regalis or HDC P003 sprays in year one, however *Prunus and* Sorbus did. Therefore Regalis and HDC P003 sprays were only applied to these two species in the 2014 trials. This allowed Regalis and HDC P003 to be compared to new treatments in 2014 (HDC P004 and Moddus) whilst determining the potential of these plant growth regulators in the future. HDC P004 looks to be a more promising treatment than both Regalis and HDC P003 on *Prunus* and *Sorbus.* Given that HDC P004 is a more effective product on the species tested than HDC P003, combined with the fact that HDC P003 has a label restriction preventing its use on soil grown crops it is unlikely that HDC will seek to get an EAMU for the use of HDC P003 for use on field-grown stock.

Betula is very vigorous and it proved difficult to control growth in both 2013 & 2014. It is likely that undercutting will have to be used throughout the season in conjunction with regular low rates of growth regulators to regulate the growth of this species in the future.

Figure 3 shows that assessments of the growth of the five species treated in 2013, lifted, cold stored and planted in 2014. The assessments showed that the next season's growth was not affected by growth regulators applied the previous growing season. This should give growers the confidence to embrace the results of this work to utilise plant growth regulators as a tool to limit plant growth of field-grown tree and hedging subjects in the future. This should help to limit wastage within this sector, helping to increase nurseries competitiveness and profitability .

Conclusions

All three of the plant growth regulators used within this trial have potential for use in the production of field-grown tree and hedging subjects. Only a limited number of species have been tested to date and it is important to remember that different species and cultivars react differently to the same treatments. Problems associated with phytotoxicity caused by chlormequat were largely addressed by reducing the rates of this growth regulator in the second year of the trials. A lower rate of chlormequat will reduce phytotoxic damage to an acceptable level but does not always provide the desired growth regulation. AHDB has applied for an EAMU to enable growers to make use of P004, if granted this product has the potential to play a role in the production of vigerous species such as *Alnus, Prunus* and *Sorbus. Populus* is responsive to Stabilan 750 (chlormequat), and this plant growth regulator has the potential to significantly reduce growth in this species. Lower rates or a reduced number of applications are likely to be required to prevent excessive growth regulation whilst reducing phytotoxic damage. Regular low rate applications of Stabilan 750 (chlormequat) have the potential to help regulate the growth of *Betula* whilst minimising phytotoxicity to an acceptable level Growers are encouraged to carry out their own trials with plant growth regulars on a small proportion of their crop prior to applying treatments to commercial crops.

Knowledge and Technology Transfer

HDC News article postponed to spring of 2016 as agreed with HDC as this will translate results to growers prior to the 2016 growing season. Results to date were presentated at The AHDB / HTA Tree and Hedging Group.

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Appendices

Appendix 1. Layout of 2014 trials.

PlotNo	Blocks	Plots	Treatment	Species
1	1	2	6	Alnus
2	1	4	5	Alnus
3	1	5	1	Alnus
4	1	6	2	Alnus
5	2	2	6	Alnus
6	2	4	2	Alnus
7	2	5	5	Alnus
8	2	6	1	Alnus
9	3	1	5	Alnus
10	3	2	1	Alnus
11	3	4	6	Alnus
12	3	5	2	Alnus
13	4	1	5	Alnus
14	4	2	1	Alnus
15	4	3	6	Alnus
16	4	6	2	Alnus
17	5	1	5	Betula
18	5	2	1	Betula
19	5	4	2	Betula
20	5	6	6	Betula
21	6	1	5	Betula
22	6	2	2	Betula
23	6	3	6	Betula
24	6	6	1	Betula
25	7	3	6	Betula
26	7	4	2	Betula
27	7	5	1	Betula
28	7	6	5	Betula
29	8	1	6	Betula
30	8	3	1	Betula
31	8	4	2	Betula
32	8	6	5	Betula
33	9	2	2	Populus
34	9	3	5	Populus
35	9	4	1	Populus
36	9	6	6	Populus
37	10	1	2	Populus
38	10	3	5	Populus
39	10	4	1	Populus
40	10	5	6	Populus
41	11	1	5	Populus
42	11	2	6	Populus
43	11	3	1	Populus
44	11	5	2	Populus
45	12	1	5	Populus
46	12	2	6	Populus

47	12	5	1	Populus
48	12	6	2	Populus
49	13	1	2	Prunus
50	13	2	5	Prunus
51	13	3	1	Prunus
52	13	4	3	Prunus
53	13	5	4	Prunus
54	13	6	6	Prunus
55	14	1	5	Prunus
56	14	2	6	Prunus
57	14	3	2	Prunus
58	14	4	4	Prunus
59	14	5	3	Prunus
60	14	6	1	Prunus
61	15	1	5	Prunus
62	15	2	6	Prunus
63	15	3	4	Prunus
64	15	4	2	Prunus
65	15	5	1	Prunus
66	15	6	3	Prunus
67	16	1	6	Prunus
68	16	2	2	Prunus
69	16	3	3	Prunus
70	16	4	4	Prunus
71	16	5	5	Prunus
72	16	6	1	Prunus
73	17	1	3	Sorbus
74	17	2	5	Sorbus
75	17	3	1	Sorbus
76	17	4	4	Sorbus
77	17	5	2	Sorbus
78	17	6	6	Sorbus
79	18	1	6	Sorbus
80	18	2	5	Sorbus
81	18	3	3	Sorbus
82	18	4	4	Sorbus
83	18	5	1	Sorbus
84	18	6	2	Sorbus
85	19	1	5	Sorbus
86	19	2	2	Sorbus
87	19	3	3	Sorbus
88	19	4	4	Sorbus
89	19	5	6	Sorbus
90	19	6	1	Sorbus
91	20	1	4	Sorbus
92	20	2	3	Sorbus
93	20	3	5	Sorbus
94	20	4	1	Sorbus
95	20	5	6	Sorbus
96	20	6	2	Sorbus