Project title:	Evaluating the potential of plant growth regulators to limit growth on tree and hedging species
Project number:	HNS 187a
Project leader:	David Talbot, ADAS UK Ltd.
Report:	Final report, April 2016
Previous report:	HNS 187 Annual report, April 2015
Key staff:	David Talbot, Project leader John Atwood, Consultant to project James Durnford, Scientific officer Chris Dyer, ADAS Statistician
Location of project:	Wyevale Transplants, Russels End Farm, Bromsberrow, Herefordshire, HR8 1PB.
Industry Representative:	Jamie Dewhurst and Ed Holmes, J & A Growers, Bradshaw Farm, Wasperton, Warwick, Warwickshire, CV35 8EB.
Date project commenced:	01 March 2013
Date project completed (or expected completion date):	02 April 2016

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

Horticulture Consultant

ADAS UK Ltd

Signature  Date 12/03/16.

Report authorised by:

John Atwood

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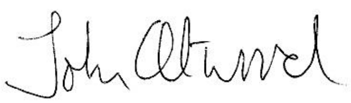

Signature Date 01/04/16

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GROWER SUMMARY

Headline

- *Populus* responded to chlormequat, reducing the rate and number of applications reduced damage to an acceptable level.
- Confidential product HDC POO4 proved effective on *Sorbus* and an EAMU has been applied for.

Background and expected deliverables

The forestry sector is one of the key market outlets for two year old field-grown tree species, however plants over the 90 cm specification mark 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 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 to the total cost.

The work undertaken in this project builds on research from project HNS 187; to find alternative ways of reducing the vigour of field-grown tree and hedging crops in nursery production to meet specifications. Undercutting during the growing season is the current method of regulating growth, however, this is not effective during wet summers, because it does not provide a sufficient stress response in plants when soils are moist. A planned number of applications of chemical plant growth regulators has the potential to limit the growth of vigorous species, irrespective of the weather, if carefully timed and managed. Chemical plant growth regulators can be applied throughout the growing season (as long as label or EAMU restrictions covering rates and application number are observed) giving growers more precise control of crop growth, even in wet summers, helping to ensure that the majority of plants do not exceed the height specifications set for crops.

Summary of the work and main conclusions

All of the plant growth regulators used within this trial have the potential to regulate the growth of selected tree and hedging species. All the species within the trial responded to at least one plant growth regulator in both 2013 and 2014 (a number of active ingredients were examined). Trials carried out in 2015 were designed to build upon the results obtained previously; the application rates and timings of plant growth regulators were adjusted in line with the growth and expected response of the test plant species. Treatments used in 2015 are shown in Table 1.

Within this project the following percentages of untreated crops in 2014 exceeded the 90 cm height specification: *Alnus glutinosa* (82.5%), *Betula pendula* (92.5%), *Populus x canadensis* 'Robusta' (80%), *Prunus avium* (12.5%) and *Sorbus aucuparia* (67.5%). The weather (a cold spring resulting in a three week delay to the start of the growing season, followed by a cool summer with low night time temperatures often in single figures) during 2015 resulted in a poor growing season, therefore the percentages of untreated crops exceeding 90cm was much lower relative to 2014. The following percentages of untreated crops exceeded 90 cm in 2015: *Alnus glutinosa* (17.5%), *Betula pendula* (72.5%), *Populus x canadensis* 'Robusta' (7.5%), and *Sorbus aucuparia* (0%)

Rates of Stabilan 750 (75% chlormequat) applied to *Populus* were reduced from the rates used in 2014 in order to minimise plant phytotoxicity sysmptoms. The number of treatments of Stabilan 750 applied to *Populus* was also reduced in some instances to determine if this still resulted in useful growth regulation while minimsining the level of phytotoxicity. Confidential product HDC POO4 was applied with a shorter spray interval than in 2014 to *Alnus* to establish whether this would result in a better level of growth regulation.

Table 1. Growth regulator products used in experimental treatments 2015

Product name	**Active ingredient**	**Rate (l/ha or kg/ha) applied with 1000 l water/hectare**	**Authorisation status**
Untreated			
Stabilan 750 + Activator 90 (0.1%)	750 g/l chlormequat	15.3 l/ha	Label
		12.2 l/ha	
HDC POO4*	Confidential	Confidential	Not approved (used under experimental permit)
Stabilan 750 + Activator 90 (0.1%) + HDC POO4*	750 g/l chlormequat + confidential	15.3 l/ha + confidential	Label + not approved (used under experimental permit)

* No Foam (anti foaming product; a polydimethyl silicone emulsion) was added at at 1 drop per litre of spray solution.

Reduced rates of chlormequat applied in 2015 still resulted in slight phytototoxic damage, although damage was less severe than in the previous year and was considered commercially acceptable by the industry representatives when assessed during mid-September.

Although HDC POO4 caused slight damage to *Alnus* and *Sorbus*, any phytotoxic damage caused by this treatment was considered commercially acceptable throughout the trial.

The treatments that resulted in the greatest mean height reduction by species during 2013, 2014 and 2015 are shown in Table 2.

It should be noted that whilst high rates of chlomequat (as Fargro Chlormequat) gave the greatest height reduction for four plant species (at the full rate used in 2013), it also caused extensive leaf yellowing. This product has since been revoked from use.

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

Species	**2013**	**2014**	**2015**
Alnus	Fargro Chlormequat	HDC POO4	None*
Betula	Fargro Chlormequat	Moddus	None*
Populus	Fargro Chlormequat	Stabilan 750	Stabilan 750
Prunus	POO3 (foliar spray)	HDC POO4	Species not included in 2015
Sorbus	Fargro Chlormequat	HDC POO4	HDC POO4

* Untreated controls had the shortest plants relative to plots treated with plant growth regulators.

Stabilan 750 (chlormequat) significantly reduced the height of *Populus* in 2014, compared to untreated controls. Therefore chlormequat was the only growth regulator tested on *Populus* in 2015. Based on these findings, chlormequat is likely to be the most effective growth regulator for use on *Populus* to manage growth.

Some adjuvants are claimed to enable rates of chlormequat to be reduced, while maintaining efficacy, potentially reducing the level of any phytotoxic damage. More frequent, less damaging and potentially more effective, lower rate applications could commence earlier in the growing season. There still may need to be a compromise between slight phytotoxic damage and effective growth regulation with chlormequat on some species, unless a safer solution can be found.

HDC POO4 was the most effective treatment on *Sorbus* and *Prunus*, and also the most useful treatment on *Alnus.* From observations, Moddus appeared to be the most useful on *Betula,* however this result should be treated with caution as the differences in plant height between treatments were not statistically significant.

HDC POO4 was used in these trials under an experimental permit. As HDC POO4 performed well on *Sorbus,* an application for an EAMU to permit its use in ornamental plant production and forest nurseries has been applied for by AHDB.

Financial benefits

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

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% of the stock can often reach over 100 cm in height in the second year of field production.

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 species could be unmarketable in some years, this equates to a potential loss of up to £45,000 per hectare.

Limiting height variability within crop species also speeds up the grading process saving £105 per hectare in labour.

Action points for growers

- Plan to trial the use of plant growth regulators as part of the production schedule (always leave some untreated as a comparison). Suitable products include plant growth regulators (with appropriate authorisation) containing chlormequat at appropriate rates and HDC POO4 (if an EAMU can be obtained). Test plant growth regulators on vigorous species or cultivars to determine plant response.

- There is a need to appreciate a crop's growth in line with the prevailing weather to determine when best to commence applications of plant growth regulators. Ensure that plants have put on sufficient 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. There may be a need to reduce rates or delay the first application if crop growth is poor.

- Be aware that some fungicides e.g. triazoles such as Folicur and Topas can have a growth regulatory effect (see HNS 156) which needs to be taken into account, particularly when these products are used in conjunction with plant growth regulators.

- Monitor crops after treatment and aim to reapply plant growth regulators when extension growth commences again. For the species tested, this is typically three weeks after the previous application.

- Very vigorous species such as *Betula* may respond to more frequent lower rate applications of plant growth regulators.
- Allow sufficient time for plant growth regulators to be thoroughly absorbed by treated plants - take account of weather forecasts and avoid the application of overhead irrigation immediately after treatment.
- HDC POO4 has potential for use as a growth regulator on *Alnus*, *Prunus* and *Sorbus* provided an EAMU can be obtained for use in ornamental plant production.

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, which is a maximum of 90 cm for most markets. 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 soil type is a loamy sand. Soil analysis was carried out in each field after the *Populus* cuttings had been inserted and other species had been planted (as one year old 20 – 40 cm transplants). The results of the soil analysis for 2013 and 2014 are included in the previous annual reports, results from 2015 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)
Hazledene (*Alnus, Betula* and *Sorbus*)	5.6	4 (59.6)	2+ (196)	2 (71)
Foxbury (*Populus*)	7.2	5 (100)	2+ (238)	2 (82)

The soil pH was not within the range for optimum nutrient availability (between pH 6 and 6.5) however no symptoms of high (lime induced chlorosis) or low (manganese toxicity)? were noted. Phosphorus (P) indices were all Index 3 or above therefore no additions were made. Potassium (K) was index 2+ in both fields that trials were carried out in during 2015 so potassium was applied according to reccomendations (RB209 8th ed). 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 trials reported here were carried out within commercial crops at Wyevale Transplants, and hence were in different fields. The soil type was the same in each field. Each trial was laid out as a randomised block, treatments were randomised within each species, with four replicates. Plots were 2 metres long and 1.2 metres wide. There were severn 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: *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. With the exception of *Prunus avium* the plant species were kept the same throughout the three years of trials in order to generate comparable data. *Prunus* was not included in 2015 trials as it had proved not to be as vigorous as the other species and HDC POO4 was identified as providing sufficient growth regulation on this species. No fungicides with growth regulatory effects were applied to trial plots.

Overhead irrigation was supplied by a rain gun as deemed necessary by the grower during 2013 and 2014 but not within 24 hours of plant growth regulator application. No irrigation was applied to treated plots during 2015.

Two or three applications of the plant growth regulators were applied as a foliar spray at two or three week intervals, during the growing season allowing for prevailing weather conditions. Application dates and dates of assessment are tabulated by species in Table 3.

Table 3. PGR Application dates by species and dates of assessments

Date and species treated	**Date of assessment by species**
24/06/2015 – First application all species.	09/07/2015 – First phytotoxicity assessment *Alnus.*
09/07/2015 – Second application *Alnus.*	15/07/2015 – Second phytotoxicity assessment all species.
15/07/2015 – Second application *Betula, Populus* and *Sorbus.*	22/07/2015 – Third phytotoxicity assessment *Alnus.*
22/07/2015 – Third and final application *Alnus.*	05/08/2015 – Forth phytotoxicity assessment all species.
06/08/2015 – Third and final application *Betula, Populus* and *Sorbus.*	28/08/2015 – Fifth and final phytotoxicity assessment all species.

Rates used and timings are as listed in Table 4. Plant growth regulators were applied using an Oxford precision plot sprayer with a 03/F110 nozzle delivering a medium spray quality in 1000 L/ha water.

Table 4. Growth regulator products used in experimental treatments

Treatment number	**Product name**	**Active ingredient**	**Rate (/ha or kg/ha)**	**Approval status**	**Application timing**
1	Untreated				
2	Stabilan 750 + Activator 90 (0.1%)	750 g/l chlormequat	15.3l/ha	Label	3 applications, 3 weeks apart.
3	Stabilan 750 + Activator 90 (0.1%)	750 g/l chlormequat	15.3l/ha	Label	2 applications, 3 weeks apart.
4	Stabilan 750 + Activator 90 (0.1%)	750 g/l chlormequat	12.2l/ha	Label	3 applications, 3 weeks apart.
5	Stabilan 750 + Activator 90 (0.1%) + HDC POO4	750 g/l chlormequat & Confidential	12.2l/ha & Confidential	Label and Not authorised	3 applications, 3 weeks apart.
6	HDC POO4	Confidential	Confidential	Not authorised	3 applications, 3 weeks apart.
7	HDC POO4	Confidential	Confidential	Not authorised	3 applications, 2 weeks apart

No Foam (anti foaming product; a polydimethyl silicone emulsion) was added to all treatments at at 1 drop per litre of spray solution.

Phytotoxicity assessments were carried out three weeks after treatment. 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 were recorded from 10 plants within the central region of each plot; and these were repeated at the end of the growing season on 14 October 2015.

Results

Definitions of phytotoxicity scores are listed in Table 5. Mean phytotoxicity scores at all assessments are shown in tables 6-10. 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 460 g/L) resulted in phytotoxic damage in the first year of trials (2013) prior to the product's withdrawal. Stabilan 750 (chlormequat 750 g/L) was used instead from 2014, and was applied to give a lower rate of chlormequat in 2014. The rate was further lowered from 15.3l/ha in 2014 to 12.2l/ha in 2015. The 15.3l/ha rate was also applied to *Populus* to aid comparison of the results in 2015 to those obtained in 2014. This higher rate was also included to see if sufficient growth control could be achieved by allowing the crop to put on more growth before plant growth regulator applications commenced. Despite this the lower rate used, chlormequat again resulted in phytotoxic damaged to plants in the 2015 trials and was more damaging than any of the other treatments (Tables 6-10). The symptoms included marginal leaf scorch on all species, and slight interveinal yellowing was also noted *Alnus* and *Populus*. However phytotoxic damage associated with the chlormequat treatment in 2015 was less severe than in 2014 and 2013 on all species, and *Alnus, Betula* and *Populus* started growing away from damage three weeks after the final application. In 2014, all of the species grew away from damage caused by chlormequat and were considered commercially acceptable by the industry representatives during their assessment on 18th September 2014. In 2015 HDC POO4 was tank mixed with a lower rate of chlormequat to determine if there was a synergistic affect between the two plant growth regulators. The phytotoxic damage associated with this tank mix was characteristic of the damage caused by chlormequat.

Table 5. 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

HDC POO4 resulted in paler, narrower leaves on *Sorbus.* A similar effect was noted on *Alnus* where the leaves were smaller following treatment. These effects started to be noted three weeks after treatment. Symptoms caused by HDC POO4 were however considered to be within commercially acceptable limits on *Sorbus* in both 2014 and 2015, despite generally poor growth, in 2015 trials.

Table 6. Assessment 1, Mean phytotoxicity scores 09/07/2015 (*Alnus* only).

	Treatments						
Species	1 Untreated	2 Stabilan 750 (15.3l/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3l/ha x 2) + Activator 90 (0.1%))	4 Stabilan 750 (12.2l/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2l/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)
Alnus	9	-	-	-	6	-	9

Table 7. Assessment 2, Mean phytotoxicity scores 15/07/2015.

	Treatments						
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)
Alnus	9	-	-	-	6	-	8
Betula	9	-	-	-	7	-	-
Populus	9	5	N/A*	6	-	-	-
Sorbus	9	-	-	-	-	7	-

***No PGRs applied to Treatment 3 prior to this assessment.**

Table 8. Assessment 3, Mean phytotoxicity scores 22/07/2015.

	Treatments						
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)
Alnus	9	-	-	-	6	-	8

Table 9. Assessment 4, Mean phytotoxicity scores 05/08/2015.

	Treatments						
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)
Alnus	9	-	-	-	6	-	8
Betula	9	-	-	-	6	-	-
Populus	9	5	5	6	-	-	-
Sorbus	9	-	-	-	-	8	-

Table 10. Assessment 5, Mean phytotoxicity scores 28/08/2015.

	Treatments						
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)
Alnus	9	-	-	-	4.5	-	8
Betula	9	-	-	-	7	-	-
Populus	9	4	6	4.5	-	-	-
Sorbus	9	-	-	-	-	8	-

Final height measurements on 14/10/2015 are shown in Table 12, as are the results of the statistical analysis. For comparison, the mean final height measurements from the 2014 trial are shown in Table 11,

None of the treatments applied to *Alnus* or *Betula* in 2015 reduced either of these species' mean height. All Stabilon 750 treatments reduced the mean height on *Populus.* Stabilan 750 applied three times resulted in the greatest reductions in mean height on *Populus,* when compared to the untreated control and Stabilon 750 applied twice*.* This showed that chlormequat has to be applied early in the season on *Populus* to achieve significant reductions in crop height.

For *Sorbus*, HDC POO4 resulted in a significant reduction in mean average height in *Sorbus* compared to the untreated control. This confirmed previous results that HDC POO4 is an effective growth regulator for *Sorbus*.

Table 11. 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 POO3 as a foliar spray	4 Regalis	5 HDC POO4	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 12. Mean height of all species in cm, recorded on 14/10/2015; at the end of the growing season.

	Treatments								
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)	F pr	LSD
Alnus	73.05	-	-	-	81.60	-	77.28	0.158	9.05
Betula	103.05	-	-	-	108.03	-	-	0.415	13.91
Populus	58.60	39.75	53.85	41.10	-	-	-	<.001	7.67
Sorbus	49.15	-	-	-	-	40.00	-	0.043	8.75

Table 13 shows the mean percentage of plants at or above 90 cm at the end of the 2014 growing season, in order of treatment. Table 14 shows the mean percentage of plants at or above 90 cm at the end of the 2015 growing season.

The results clearly show that *Betula* was the most vigorous species within the 2015 trial (as was the case throughout these trials); none of the treatments applied to *Betula* resulted in a greater percentage of the crop falling within the height specifications of the forestry sector (up to 90 cm).

The treatments that resulted in useful crop height reductions are highlighted in bold in tables 13 and 14. Table 13 shows that in 2014, for *Alnus*, treatment HDC POO4 gave a significant reduction in the percentage of plants above the <90 cm specification. However there was no significant difference between treatments in 2015. Although HDC POO4 may have the potential to reduce the percentage of *Alnus* exceeding 90 cm, results have not been consistent.

For *Populus* Stabilan 750 gave a significant reduction in the percentage of plants above the <90 cm specification (Table 13) in 2014. This was confirmed in 2015 (Table 11) demonstrating that Stabilan 750 (chlormequat) is the most effective plant growth regulator tested to date to help prevent excessive growth on *Populus.*

There was also a significant improvement in the percentage of *Sorbus* at or below 90cm treated with HDC POO4 in 2014. In 2015 HDC POO4 was again the most effective treatment for height reduction on *Sorbus* tested to date, although in this year none of the *Sorbus* exceeded 90 cm, due to..?.

Table 13. 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 POO3 as a foliar spray)	4 Regalis	5 HDC POO4	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

Table 14. Mean percentage of plants by species and treatment at or above 90cm on 14/10/2015.

	Treatments								
Species	1 Untreated	2 Stabilan 750 (15.3 L/ha x 3) + Activator 90 (0.1%)	3 Stabilan 750 (15.3 L/ha x 2) + Activator 90 (0.1%)	4 Stabilan 750 (12.2 L/ha x 3) + Activator 90 (0.1%)	5 Stabilan 750 + HDC POO4 (12.2 L/ha + confidential x 3) Activator 90 (0.1%)	6 HDC POO4 (3wk apart)	7 HDC POO4 (2wk apart)	F pr	LSD
Alnus	17.5	-	-	-	27.5	-	17.5	0.412	18.66
Betula	72.5	-	-	-	70	-	-	0.829	27.13
Populus	7.5	**0**	**0**	**0**	-	-	-	0.113	7.38
Sorbus	0	-	-	-	-	**0**	-	N/A	N/A

Discussion

The work carried out in 2015 for project HNS 187a tested treatments to regulate the growth of four vigorous species *(Alnus glutinosa, Betula pendula, Populus x canadensis* 'Robusta' and *Sorbus aucuparia)* grown from cuttings and graded one year old transplants. The aim of this final year of the project was to to refine and build on the results obtained in 2013 and 2014 carried out under HNS 187. The two most effective growth regulators from HNS 187, chlormequat (as Stabilan 750), and HDC POO4, were applied to all of the aforementioned species either singly or as a tank mixture. The application timings (and in one case the number of applications) were adjusted to attempt to match plant growth regulator activity with the growth characteristics of individual species.

Work undertaken in both HNS 187 and HNS 187a showed that all of the growth regulators tested have the potential to regulate the growth of field-grown tree and hedging subjects. As expected, each species responded differently to the growth regulators tested. For example it proved difficult to regulate the growth of *Betula* which is particularly vigorous. Only chlormequat resulted in a mean height to specification below 90 cm in *Betula.* However the high rates of chlormequat used in 2013 trials on Betula resulted in unacceptable phytotoxicity. Whilst lowering the rate of chlormequat on *Betula* in subsequent years has reduced the phytotoxic damage to an acceptable level the lower rates have not provided the desired growth regulation. There may be a need to commence chlormequat applications earlier in the season on *Betula,* and there may also be a need for an increased number of more frequent, lower rate applications.

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.

Phytotoxicity has been a problem on all species treated with chlormequat throughout 2013, 2014 and 2015, 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. Reducing the rates of chlormequat helped to reduce the phytotoxic response and for some species plants grew away by the end of the growing season. Damage was still evident although it was considered to be within commercially acceptable limits. When plants are dispatched, these affected leaves will have fallen and would no longer detract from the quality of the plant. In the second year of the project it was confirmed that the foliar symptoms do not persist to the following year by lifting treated plants in November 2013, cold storing and planting out in the spring of 2014.

Reducing the rate of chlormequat reduced the phytotoxic damage to a commercially acceptable level in 2014, however some species treated with lower rates of chlormequat in 2015 showed more phytotoxic damage at the last assessment than the same species in 2014. Given that extension growth was slower in 2015, plants took longer to grow away from phytotoxicity associated with chlormequat applications. As expected there was a trade-off between a reduction in phytotoxic damage and a useful reduction in height in many treatment-species combinations.

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 some species, unless a safer option can be found.

Despite reducing the rate of chlormequat in 2015 the effects on *Populus* still resulted in excessive growth regulation. This was attributed to the poor growing season in 2015 as it was felt that these treatments would have delivered useful results in a more typical growing season. This also indicated that there is still further scope to reduce both the rate of chlormequat on *Populus* and the number of applications.

Growers will need to 'read the crops' growth and take account of the weather and growing conditions before deciding on a rate of chlormequat to use on responsive crops such as *Populus.* For instance in 'poor' growing seasons there may be no need to apply any growth regulators on *Populus.* There is a risk that excessive growth regulator use could result in plants not meeting the necessary height specifications and thus not realising their maximum potential financial value. In order to decide on a appropriate rate of use it is necessary to consider what percentage of a given species typically exceeds height specifications in an average growing season before making such decisions.

The results obtained in 2015 have shown that it is possible to commence plant growth regulator application later in the season than previously tested and still achieve reductions in average mean height. An alternative approach would be to commence with lower rate applications in July, increasing the rate applied in subsequent applications in line with crop growth, if necessary.

Alnus, Betula and *Populus* did not respond to either Regalis or HDC POO3 sprays in year one, however *Prunus and* Sorbus did. Therefore Regalis and HDC POO3 sprays were only applied to these two species in the 2014 trials. This allowed Regalis and HDC POO3 to be compared to new treatments in 2014 (HDC POO4 and Moddus) whilst determining the potential of these plant growth regulators in the future.

HDC POO4 resulted in a significant reduction in height on *Sorbus* in both years that this growth regulator was tested (2014 and 2015). HDC POO4 also resulted in a 65 percent reduction in plants at or above 90 cm at the end of the 2014 growing season and was the safest treatment tested on *Sorbus*. However *Sorbus* growth in 2015 was poor within all trial plots and none of the *Sorbus* exceeded 90cm, even in untreated controls. The poor growth of *Sorbus* in 2015 was thought to be a field effect, possibly associated with localised soil compaction as the host nursery's commercial crop of *Sorbus* in adjacent beds grew better than the untreated controls within the trial. HDC POO4 also performed well on other species in 2014, including *Alnus* where its use resulted in a 17.5% reduction of the crop exceeding 90cm compared to unteated controls. HDC POO4 was also one of the best treatments applied to *Prunus* in 2014 where its use resulted in a 2.5% reduction of the crop exceeding 90cm, compared to untreated controls. HDC POO4 showed a tendancy to be more effective for *Alnus* in 2014 when applied three times at a three rather than two week spray interval (as in 2015).

HDC POO4 has consistently proved to be a more promising treatment than both Regalis and HDC POO3 on *Prunus* and *Sorbus.* Given that HDC POO3 is less effective on the species tested than HDC POO4 and it has a label restriction preventing its use on soil grown crops it is unlikely that an EAMU for the use of HDC POO3 for use on field-grown stock will be progressed.

Growers should carry out their own in house trials to give them the confidence to embrace the results of this work, to utilise plant growth regulators 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.

Further work will be necessary to assess the potential of a wider range of plant growth regulators authorised for use in the arable sector. Some adjuvants claim to reduce phytotoxic damage and the amount of active required to regulate plant growth. Such adjuvants could help to obtain useful results with plant growth regulators that have previously proved to be too damaging. They could also help growers to utilise different actives and could extend plant growth regulator recommendations onto different species or cultivars.

Manipulating fertiliser applications could be another approach for growth control. Rather than applying a standard rate of base dressing to all crops, fertiliser usage could be varied to control the growth of vigorous crops. It may be better to delay applying nitrogen to vigorous crops until there is a crop need or until more growth is required to make height specifications. Crops grown with less nitrogen may respond better to the plant growth regulators tested in this programme of work. Undercutting may have to be used throughout the season in conjunction with regular low rates of growth regulators and reduced rates of nitrogen fertilisers to regulate the growth of this species in the future.

Conclusions

All 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 to some extent addressed by reducing the rates of this growth regulator in the third 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. Three years of trials have confirmed that in a typical growing season chlormequat is the most effective plant growth regulator on *Populus* but it has proven difficult to find an effective but crop-safe rate of use for other species. 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. The experimental product HDC POO4 appears promising for *Alnus, Prunus* and *Sorbus* and AHDB has applied for an EAMU application for use as a growth regulator in ornamental plant production. Unfortunately the rates requested were declined but the industry has the option to request an EAMU for one application if appropriate in the future. Unfortunately HDC POO4 and chlormequat did not seem to have a synergistic effect on the species tested in 2015. *Betula* proved to be the least responsive of the species tested and was the most difficult species to regulate height. *Betula* clearly responds to chlormequat however this plant growth regulator will have to be used in conduction with cultural techniques in order to regulate growth.

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. Growers should bear in mind that results can vary depending upon the growing season.

Knowledge and Technology Transfer

AHDB Grower Magazine article March 2016.

Results were presentated at The AHDB / HTA Tree and Hedging Group on 02/09/2015.

References

MAFF. (1988) Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209) 5TH Edition. (Printed 1988).

Defra (2010) Fertiliser Manual (RB209) 8th Edition (Printed June 2010).

Center For Applied Nursery Research. (2002) Effect of Timing of applications on plant growth retardant efficacy and growth of non-responsive herbaceous perennials (on-line). Available from http://www.canr.org/02018.pdf (Printed 20 February 2012).

Hamaker, C.K., Engle, B.E., Heins, R.D. and Carlson, W.H. (1996) Using growth regulators to control height of herbaceous perennials. *Grower Talks on Perennials.* September 1996.

HDC / HRI. (1995). Plant growth Manipulation of Hardy Nursery Stock Subjects HDC/HRI Seminar (26/27 September 1995). HDC: Kent.

International Society for Horticultural Science (2003). Persistence of plant growth regulator effects on perennial plants in the nursery (on-line). Available from: http://www.actahort.org/members/showpdf?booknarnr=624_31 (Accessed 21 February 2012).

Kim, Y.H., Khan, A.L., Hamayun, M., Kim, J.T., Lee, J.H., Hwang, I.C, Yoon, C.S. and Lee I.J. (2009) Effects of prohexadione calcium on growth and gibberellins contents of *Chrysanthemum morifolium* R. *cv* Monalisa White. *Scientia Horticulturae* 123, pp 423 – 427.

Nadia, M., Khessawneh, A.L., Karam, N.S. and Shible R.A. (2005) Growth and flowering of black iris (*Iris nigricans* Dinsm) following treatment with plant growth regulators. *Scientia Horticulturae* 107, pp 187 – 193.

Appendices

Appendix 1. Layout of 2014 trials.

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