The effects of the tree growth regulator Paclobutrazol on fast growing trees and application to utility and amenity arboriculture

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Introduction/Background

In Britain electric utility companies are under a legal duty to maintain their overhead power line (OHPL) networks free of interruptions where reasonably practicable. Trees are one of the principal causes of unplanned service interruptions on the OHPL networks and since 2002 electric utilities have been under increasing pressure from the regulatory authorities to reduce the number of interruptions/faults that are caused by trees and other vegetation. The electric utilities have a statutory duty to maintain their OHPL free of tree-caused service interruptions in so far as is reasonably practicable in normal and abnormal weather conditions.

In order to do this, the electric utilities must maintain progressive and proactive utility vegetation management (UVM) programmes and prune trees back to maintain the recommended minimum clearance distances between the trees and the OHPLs. These distances are set out in the Energy Networks Association (ENA) Technical Specification (TS) 43-8 'Overhead Line Clearances' (2004). Often this means that trees have to be pruned much further back than the required distance, so that the clearance will be maintained for the life of the pruning cycle, which can be anything from three to five years.

Of course the rate of re-growth of trees following pruning is the determining factor in setting the actual pruning cycle. Some trees re-grow faster than others, and research shows that trees across the UK are growing faster than has been predicted (Humphries 2011). When climate change is factored in there is a significant increase in predicted re-growth rates by 2020 (Humphries, 2011). Some trees are so fast growing that re-growth will erode the clearance distances inside the duration of the cycle and they have to be re-pruned mid-way through the cycle. These trees are known as 'cycle busters' – ash, poplar and willow for example.

The projected increased growth rates notwithstanding, pruning high value amenity trees and restricted cuts on the LV network present major problems for most DNOs in the UK. There is understandable public resistance to pruning trees in prominent locations, such as rural villages and village greens or conservation areas, or prominent street trees where the overhead LV network is close to or through crowns (O'Callaghan, 2012a). Restricted cuts occur when landowners refuse consent for the full amount of cutting necessary to provide the required clearances that would last for the duration of the cutting cycle, but do allow the minimum amount of cutting to keep the trees clear of the OHPLs at that point in time. This means that the DNO has to return to the site every year at worst or every other year at best to re-prune the tree(s) to maintain the clearance. Restricted cuts are a major drain on UVM resources, as cutting teams have to return to the properties every year or every other year and such visits typically cost three to five times as much as the cost of keeping the same team busy day to day on regular clearance work (O'Callaghan 2012b).

Tree growth regulators (TGRs)

TGRs have been used in UVM programmes in the USA and Canada since the 1980s to deal with the cycle busters and to extend pruning cycles. They have not, to date, been used in the UK utility sector, although they are used in orchards to regulate fruit growth for human consumption. Although there is a range of TGRs available, the most effective compound is Paclobutrazol (PBZ), which is available in the UK under the trade name 'Cultar'. The retardant activity is not accompanied by phytotoxicity or scorch, even when applied at higher rates. The principal mode of action of PBZ is that it inhibits the biosynthesis of gibberellins which in turn inhibits cell elongation of stem and leaf tissue. PBZ is readily taken up through the roots, stems and leaves but is transported almost exclusively in the xylem to its site of action, the sub-apical meristem, where it has a long-term (3–5 year) persistent growth-retarding effect on shoot growth of trees. Research in the USA and Canada has consistently shown that PBZ can effectively extend the pruning cycle for up to four years and reduce the frequency of visits necessary to deal with restricted cuts.

Although PBZ has not been used in the UK, research has shown that PBZ significantly reduced the growth rates of ash, common lime, sycamore and Leyland cypress in North-West England (Hotchkiss 2003).

It seemed reasonable, therefore, to investigate the effects of PBZ in the UK further by expanding Hotchkiss' work to cover the acknowledged fast-growing trees in various locations across the UK, including those that are most commonly found on or adjacent to the OHPL networks. The aim of the project is to investigate whether or not PBZ can retard the growth of trees sufficiently to make it viable for use in UVM programmes in the UK.

A research project to test the efficacy of PBZ on amenity trees that impact overhead power lines in the UK was initiated in 2009 with four DNOs representing 10 licence areas participating, i.e. Western Power Distribution (WPD) including what was formerly E.ON UK Central Networks; Northern Powergrid (formerly CE-Electric); Scottish & Southern Energy (SSE); and UK Power Networks (UKPN) (formerly EdF Energy). This research is funded through the Regulator's Innovation Fund Initiative (IFI) Scheme. The research is led by the Bartlett Tree Research Laboratory at Reading University with field assistance from ADAS. The aim of the project is to determine if PBZ is effective in slowing the post-pruning growth of the fastest-growing

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tree species in the UK. If it is shown to be effective, the aim is to apply for a licence from the Chemicals Regulation Directorate (CRD) to allow PBZ to be used on amenity trees.

Materials and methods

Six field trials were selected, located throughout the UK, representing a diverse range of bio-climatic zones with at least one research site covering each of the participating network operators' licence areas, i.e. Boxworth in Cambridgeshire, Drayton in Warwickshire, Hull in Humberside, Myerscough in Lancashire, Raglan in Monmouthshire and Reading in Berkshire (Figure 1A). The tree species selected for PBZ evaluation represented those that occur commonly on or near overhead networks, i.e. alder, ash, birch, hawthorn, Leyland cypress, lime, Norway spruce, oak, poplar, sycamore and willow. Trees selected for project purposes were, tagged and measured (diameter at breast height (dbh) measured at 1.4m above ground).

In order to validate the experimental results and to provide observational sites for the participating DNOs, the project proposed to treat a small number of trees on four sites for each DNO. Where it was not possible for four sites to be provided it was agreed to treat a greater number of trees on the reduced number of sites provided. In total 12 observation sites were selected throughout the UK, representing a diverse range of bio-climatic zones with at least two sites covering each of the participating network operator's licence areas (Figure 1B).

PBZ was applied using a Rainbow Treecare Soil Injection System®, based on 1m×1m spacing to an area three times the diameter of the trunk. A maximum of 250ml of TGR plus dilutant was injected per point to a depth of 20–25cm at a pressure of 2bar (30psi). This was split into a minimum of four equal applications around the base of the tree. The only exception to this was where the calculated dose was significantly less than 250ml; in this case the number of injection points was reduced to three. The quantity of PBZ injected was based on manufacturer's recommended rates as determined by tree species and dbh (Rainbow Tree Care, 2007). At each field site 30 trees per species were used – 15 PBZ treated and 15 water treated controls in 3 replicates of 5 pairs of trees. Trees were treated in July and August 2009, under an experimental licence from the CRD. Following treatment both the treated and control trees were pruned to reduce the crowns by 15% by top and side pruning.

During the growing seasons (July–August) of 2009, 2010, 2011 and 2012 measurements were taken of the girth of the trees at dbh and extension growth of the test and control trees. In addition, a number of tree vitality measurements were recorded on PBZ treated and non-treated trees. These included chlorophyll fluorescence, chlorophyll measurement, and leaf electrolyte leakage, all of which are reliable indicators of vitality (Percival, 2004 & 2005). Root cores were taken from all the trees pre and post treatment to measure the density of fine roots pre and post PBZ application.

Results

The results of the trials fall into two categories: (1) the effects of PBZ on tree health and vitality; and (2) the effects of PBZ on tree growth.

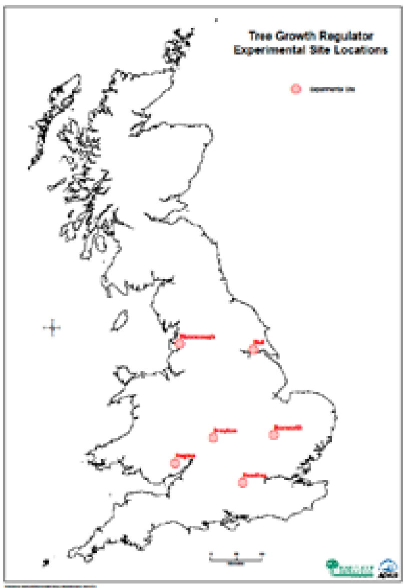

Figure 1A: The locations of the experimental sites across the UK

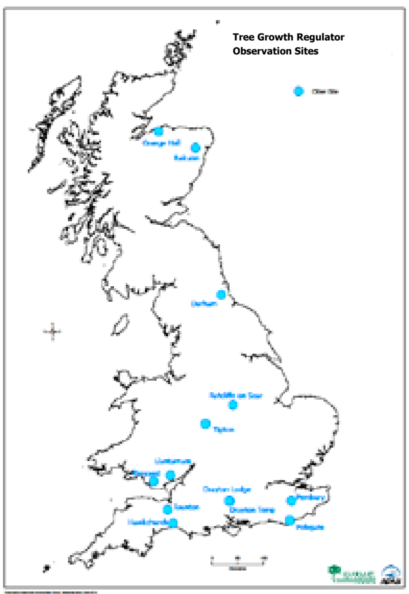

Figure 1B: The observational plots across the DNO licence areas in the UK

Soil injection application of PBZ using the Rainbow Tree Care Soil Injector®.

A Minolta chlorophyll meter SPAD 502 measuring the chlorophyll content of leaves in the field.

1. *The effects of PBZ on tree health*

No phytotoxic effects (leaf burn, reductions in leaf photosynthetic activity) caused by PBZ application have been recorded irrespective of planting site (field or observational) or species, as of the end of the 2012 growing season. Close to 2000 trees have been treated and none have shown any symptoms of phytotoxicity in the four years of the trial.

With respect to tree vitality, effects were manifest as an increase in leaf photosynthetic activity (higher PI values), greener leaves (higher SPAD readings as a measure of leaf chlorophyll content) and reduced electrolyte leakage (higher plant cell wall strength) in PBZ treated trees compared to the untreated control trees. These effects were recorded in both the 2010 and 2011 growing seasons but not as much in the 2012 growing season, indicating the effects of PBZ on improved tree vitality are starting to 'wear off' for some but not all tree species.

Increased tree vitality recorded in PBZ treated trees over untreated trees in 2010 and 2011 suggests beneficial effects caused by PBZ application.

Application of PBZ in 2009 resulted in increased root dry weight in most PBZ treated trees in 2010. However, in 2011 and 2012 this trend in root growth data was not, in most instances, evident. Indeed in the majority of cases root dry weight was reduced in PBZ treated trees compared to non-PBZ treated controls.

Data collected at each of the observation sites to the end of the 2012 growing season supports the results of the field trials. However, due to the limited number of replications at each observational site these data have not been included in the overall experimental data.

2. *The effects of PBZ on tree growth*
Application of PBZ has resulted in reduced shoot extension growth over three years in the majority of tree species trialled, the exceptions being poplar, willow and Norway spruce. The effects of PBZ on growth varied with site location. For example, reductions in stem extension of ash were 78.7% (2010), 13.7 % (2011) and 23.1% (2012) at the Drayton site. By contrast the rates were 45.6% (2010), 21.1% (2011) and +13.3% (2012) at the Boxworth site. Marked differences in growth rates between tree species were recorded following PBZ application. Reduction in stem extension in English oak and beech ranged from 38.5% to 75.1% and 12.8% to 41.7% respectively, while effects on stem extension of poplar and willow ranged from 2.65% to 24.34% and 11% to 32% respectively.

The 2012 data show that in many cases the effects of PBZ are not as great as those recorded in 2011. With respect to Scots pine, poplar, willow, Leyland cypress, silver birch, sycamore, English oak, field maple, Norway spruce the general trend was that in 2012 the growth rates were lower than untreated control trees, but not significantly so in many cases. With respect to lime, hawthorn, alder, apple and evergreen oak growth rates were significantly reduced in PBZ treated trees by between 30% to 60%.

The effects of PBZ on tree growth were found to vary between the field trial sites. For example:

- Growth of English oak was reduced by 50% averaged across three growing seasons at the Raglan site and by 25% at the Reading site when averaged across three growing seasons.
- Stem extension of sycamore was reduced by 9% averaged across three growing seasons at the Boxworth site and by 44% at the Drayton site when averaged across three growing seasons.
- Differences in soil conditions may account for these responses.

Based on the recorded data for all species tested, it is possible to categorise trees by their responses to PBZ as 'Sensitive', 'Intermediate' and 'Tolerant', as shown in Table 1.

Discussion and Conclusions

The results of the trials suggest that the use of PBZ to control the growth of 11 genera of tree would be both effective and cost effective, particularly for restricted cuts and high value amenity trees. Results from a previous IFI Project on tree re-growth rates reveal that 77% of trees on or adjacent to the OHPL networks across the whole of the UK comprise just eight genera: alder, ash, birch, hawthorn, hazel, oak, sycamore and willow (Humphries, 2011). Of these, two genera (alder and hawthorn) are 'sensitive' to the effects of PBZ; and four (ash, birch, oak and sycamore) are 'intermediate' in their response to PBZ. Of the remaining two genera (hazel and willow), hazel was not tested and willow is tolerant to the effects of PBZ (poplar comprises <2% of the trees on the overhead line networks nationally). It is gratifying to see that Leyland cypress has intermediate sensitivity to PBZ as this species can be a major problem on LV networks.

The combined results of this PBZ trial and the tree growth rate study (Humphries, 2011) suggest that PBZ will be a cost effective way of slowing the growth of six genera of tree on or adjacent to overhead power lines. However, the variation in effects between sites suggests that decisions on its use and on what species will have to be taken at the licence area level.

The implications for the amenity sector are also positive as local authorities could use PBZ to extend the time intervals between pruning regimes of street, park and other publicly owned trees. There could also be a place for the use of PBZ in the private amenity sector for management of amenity trees in business parks, university campuses, golf courses and other large estates.

The finding that treatment with PBZ significantly increased the production of fine roots in the year following treatment is interesting. This finding mirrors that of Watson (1996) and could have implications for enhanced tree stability. In the USA PBZ is regularly applied to trees where underground utilities have been installed through trenching to encourage increased production of fine roots (Chaney 2003) and enhanced stability. This is an area that could be further investigated in Britain.

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Table 1: Tree species effects – the numbers in brackets represent the mean extension growth reduction over three growing seasons: 2010, 2011 and 2012

Sensitive	Intermediate	Tolerant
lime (45.8%)	English oak (37.4%)	willow (17.9%)
evergreen oak (60.6%)	beech (33.3%)	poplar (3.5%)
hawthorn (38.1%)	silver birch (21.5%)	Norway spruce (+3.1%)
apple (49.6%)	sycamore (35.1%)	
alder (40.9%)	Scots pine (29.1%)	
	ash (27.5%)	
	Leyland cypress (28.2%)	

Sensitive: A minimum of 3 years growth reduction ranging from 30%–60%
Intermediate: A minimum of 2 years growth reduction ranging from 50%–75% with effects starting to wear off in year 3, i.e. @ 25% growth reduction.
Tolerant: Little effect on PBZ. Probably not cost effective to treat these trees.