The Effects of the Tree Growth Regulator Paclobutrazol on Fast Growing Trees & Application to Utility Arboriculture

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Tree Growth Regulators (TGRs)

TGR's have been around for over 30 years and have been refined and developed over that period.

The driver for development has been the utility sector, specifically the overhead electricity networks.

The most effective compound developed so far is Paclobutrazol (PBZ).

The 'Azole' family of compounds is interesting and the effects of different Azoles ranges from very fungicidal to very regulatory.

But at each end of the spectrum some of the effects of the other end can become manifest, so there can e beneficial side effects.

This research project is probably the largest field test of PBZ ever undertaken.

Tree Growth Regulators (TGRs)

The driver for this research project was to investigate whether PBZ worked in the UK and whether it could play a positive role in reducing Vegetation management costs by extending pruning cycles.

It was funded through the UK Regulator (Ofgem) Innovation Fund Initiative (IFI) Research Scheme.

IFI funds multi-participant projects that look at innovative ways to make the system more reliable, reduce costs, and improve customer satisfaction.

Unapologetically this presentation is based on utility arboriculture research, but it does touch on applications of PBZ in the amenity and urban forestry sectors

Utility Vegetation Management (UVM)

Trees are a major cause of unplanned service interruptions (faults), and they can also provide access to live electricity lines with associated safety risks.

Electricity transmission and distribution network operators (DNOs/NOs) are required by law and/or regulation to maintain the supply free of unplanned service interruptions in so far as reasonably practicable.

Trees have to be pruned and/or removed to maintain nationally set clearance distances between trees and overhead power lines (OHPL) for reasons of safety and security of supply.

Utility Vegetation Management (UVM) Costs

In Britain, as in other countries, the cost of UVM is high.

Between 2004 and 2009 the UVM budget in Britain was GB£87 million (€100m) per year across all the UK DNOs

between 2010 and 2015 this increased to GB£134 million (€154m) per year.

The next UK regulatory cycle starts at the end of 2015 – ni UVM costs yet.

Anything that can reduce costs is desirable.

Most Common Tree Genera on the OHPL Networks

Wherever the utility is located in the world, it is true to say that over 75% of the trees on the OHPL Network is represented by six to eight genera

Across the UK, 77% of the trees on the OHPL Networks is comprised of eight species/genera:

Common Alder	(*Alnus glutinosa*)
Common Ash	(*Fraxinus excelsior*)
Birch	(*Betula* spp)
Hawthorn	(*Crataegus* spp)
Hazel	(*Corylus* spp)
Oak	(*Quercus* spp)
Sycamore	(*Acer pseudoplatanus*)
Willow	(*Salix* spp)

Humphries, S (2011) *Utility Space Degradation*: Final Report on the IFI Project, ADAS UK Ltd, www.adas.co.uk

Most Common Tree Genera on the OHPL Networks

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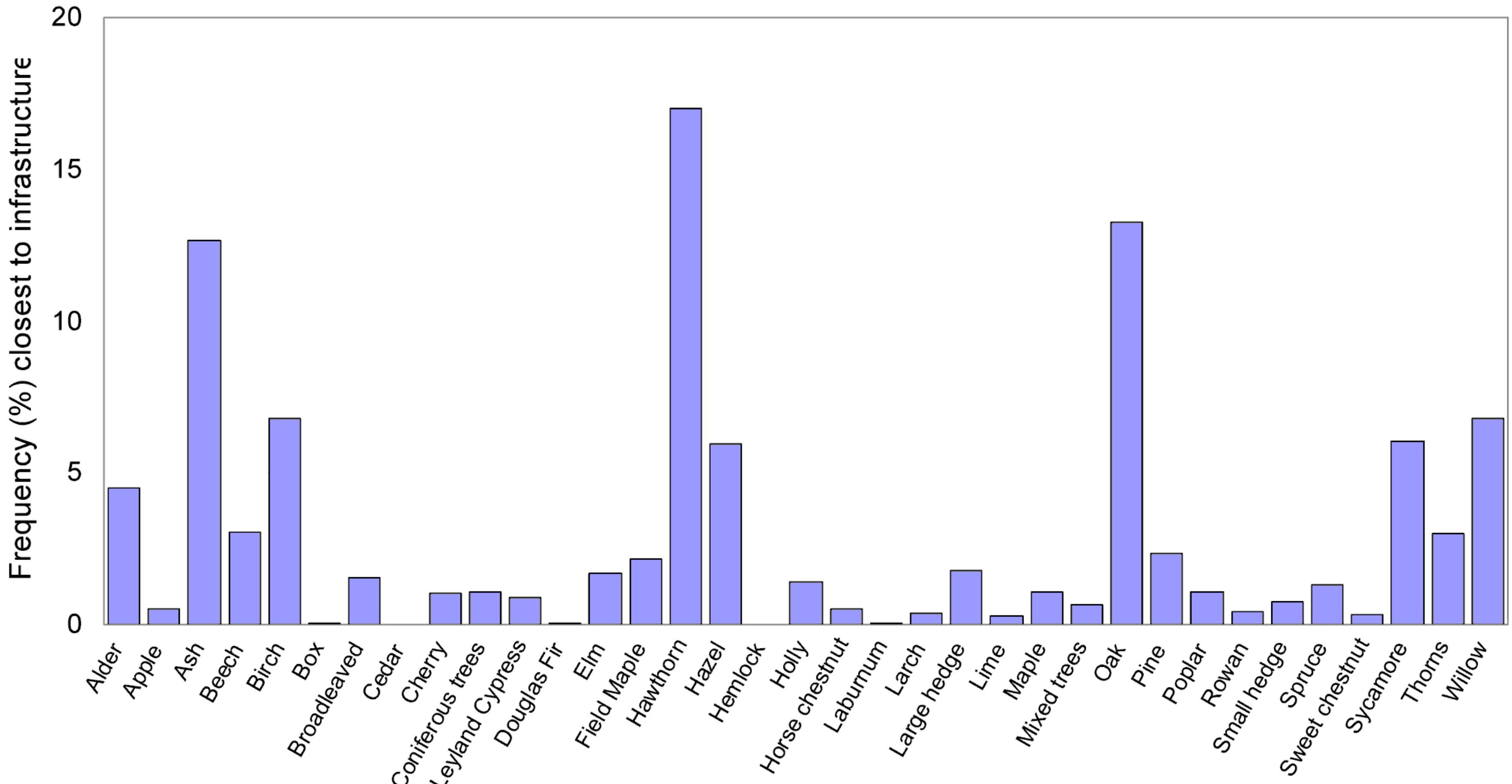
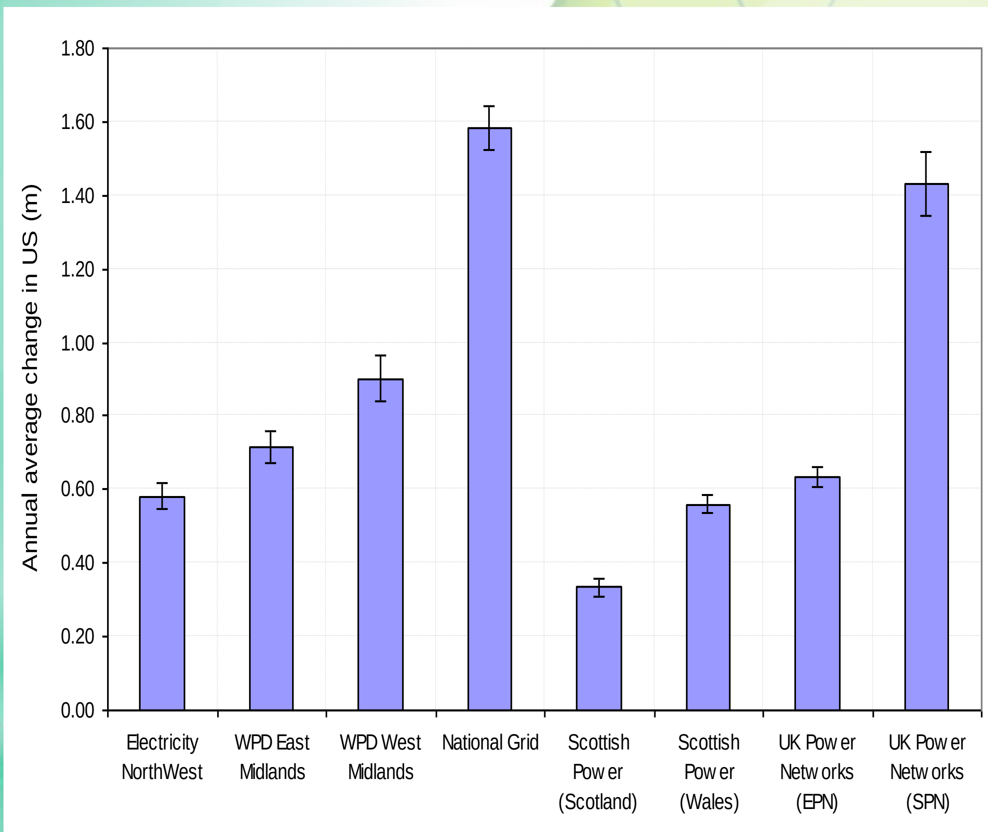
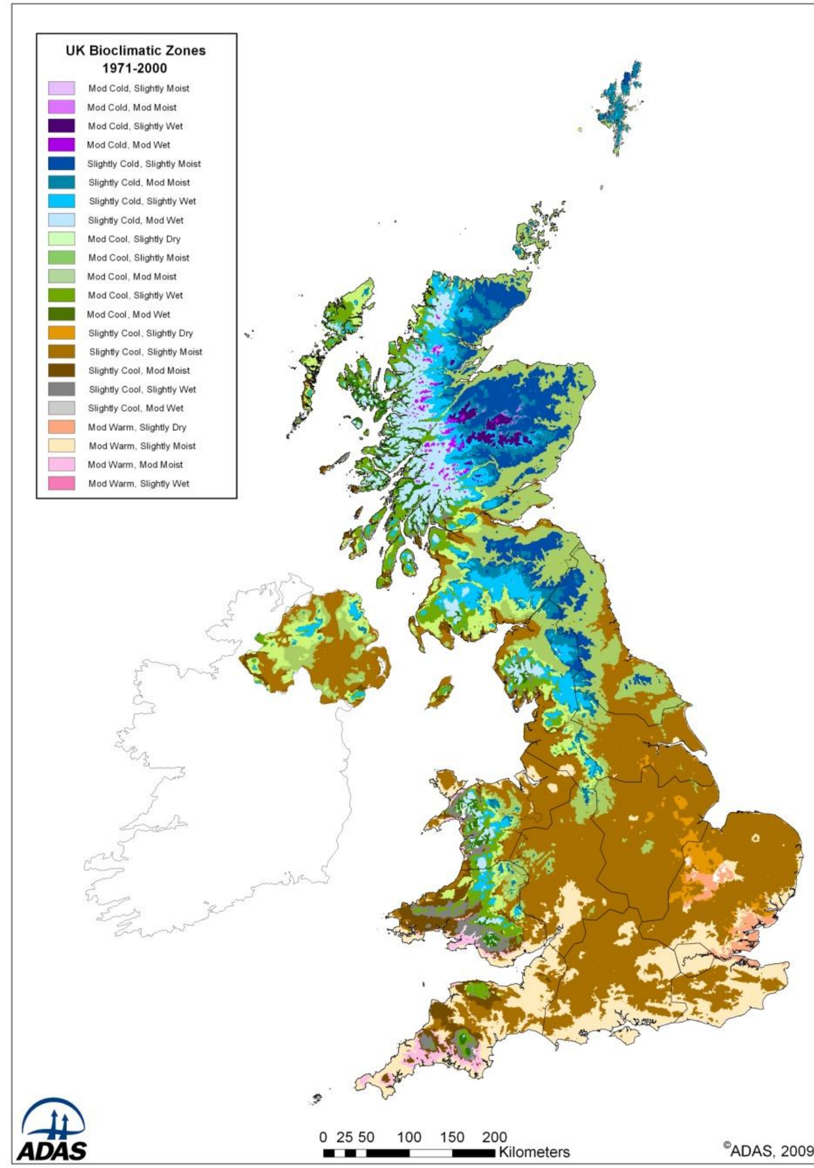


Rates of Re-growth vary cross the country by Region





Tree Growth & Climate Change

When comparisons are made with climate change projections then changes in growth rate are projected to be between 16% and 30% in the 2020 UKCIP (UK Climate Impact Project) low projection; AND

By between 16% and 40% in the UKCIP 2020 high projection

Substantial changes in growth rate and variation between regions is projected in the next ten years.

There may be some limitations on growth rate due to a reduction in rainfall and concomitant availability of water.

Controlling Tree Growth

We now know that trees are growing faster than was thought and rates of growth are projected to increase significantly within the next 10 years.

NOs encounter problems in pruning amenity trees in prominent locations such as village greens and conservation (historic) areas etc, AND

Sometimes landowners restrict cutting to the minimum necessary to obtain clearance at that point in time and the DNO has to return every year or other year to maintain clearances.

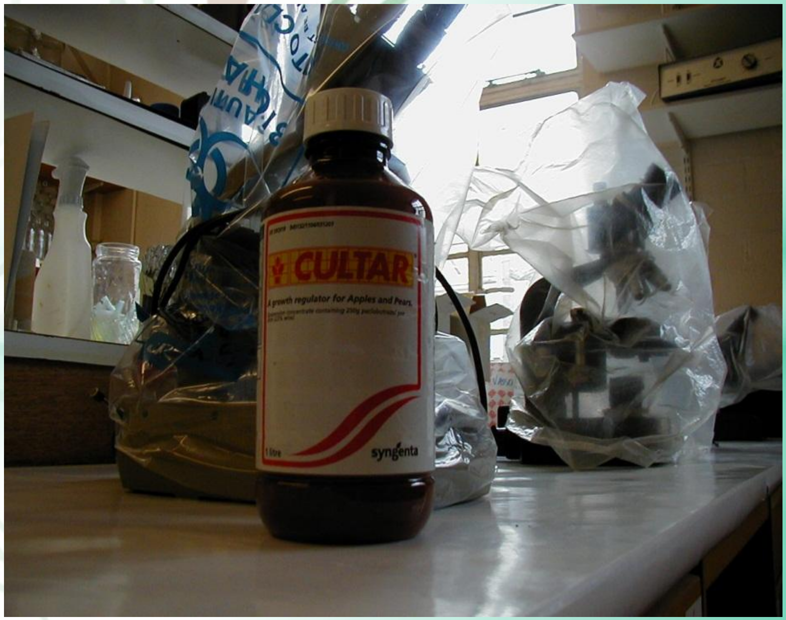
Controlling Tree Growth

Research has shown that compounds known as tree growth regulators (TGRs) can slow the regrowth rates of trees for 3 to 5 years dependant upon species;

The most effective compound currently available is Paclobutrazol (PBZ) and this has been shown to be effective in slowing regrowth rates of trees in England (Hotchkiss 2003);

PBZ is licensed for use in Britain on Apple, Cherry, Pear and Plum and for some container nursery container stock as ‘Cultar’

PBZ is commonly used in the USA & Canada in the utility sector where the trade name is ‘Cambistat’



What Is a Tree Growth Regulator?

A Tree Growth Regulator (TGR) is a specially developed compound applied to a tree to control crown (branch) growth by suppressing the production of gibberellin; the hormone that causes cell elongation.

This reduces a tree's growth and its biomass without significantly altering its appearance.

Phoenix Park Dublin May 2015

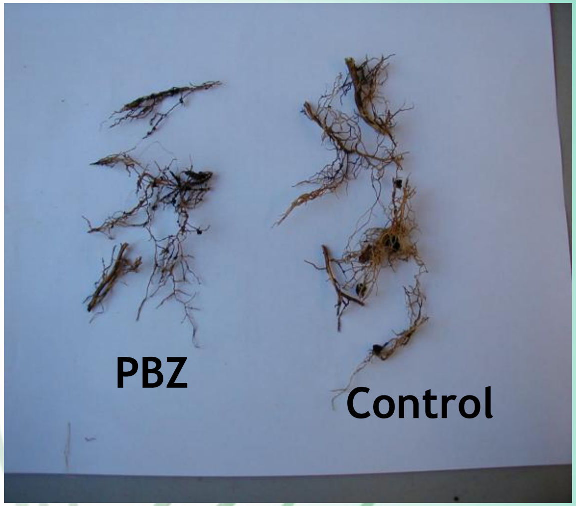
What Is a Tree Growth Regulator?

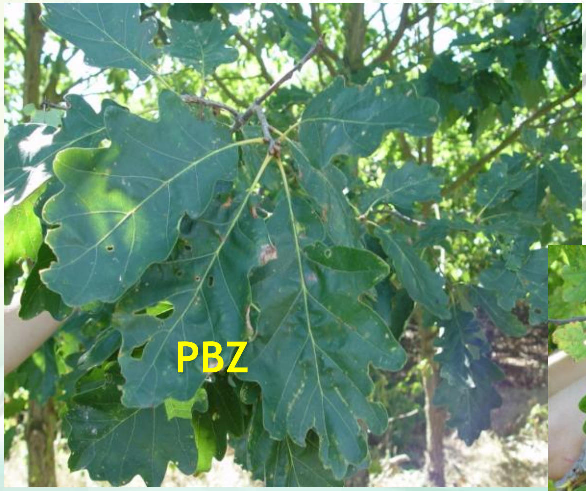
PBZ has been shown to have beneficial effects on treated trees;

it increases drought tolerance, and the production of fine roots;

It enhances chlorophyll production;

it has fungicidal properties that can combat vascular wilt diseases and tar spot on Sycamore for example





UK Trials of PBZ

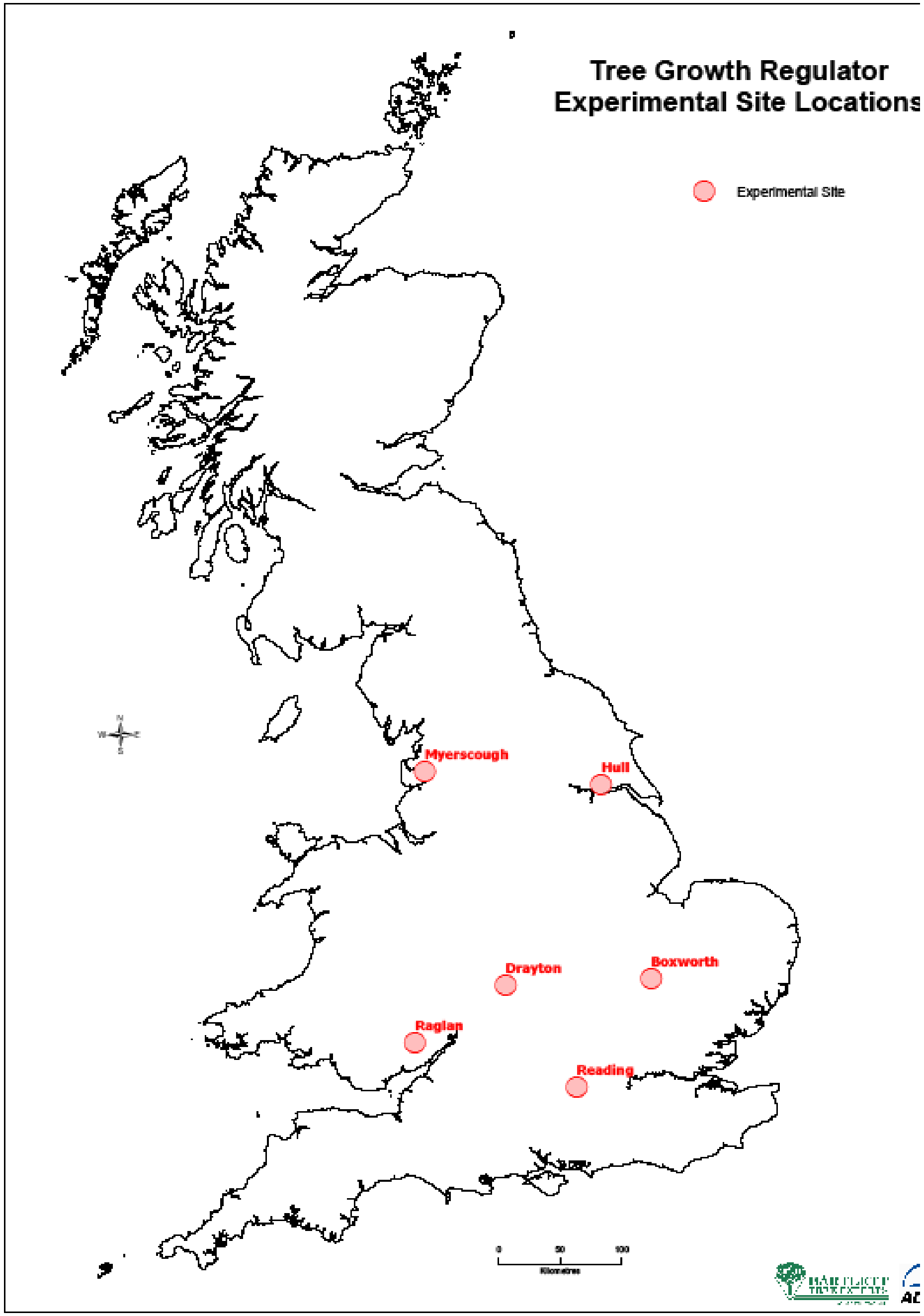
This five year study was financed through the Regulator (Ofgem) Innovation Fund Initiative (IFI); started in 2009 and completed in 2013

Four of the UK Electric Utilities participated, Northern Powergrid; Scottish & Southern Energy; UK Power Networks; and Western Power Distribution which between them control 11 f the 14 Licence Areas.

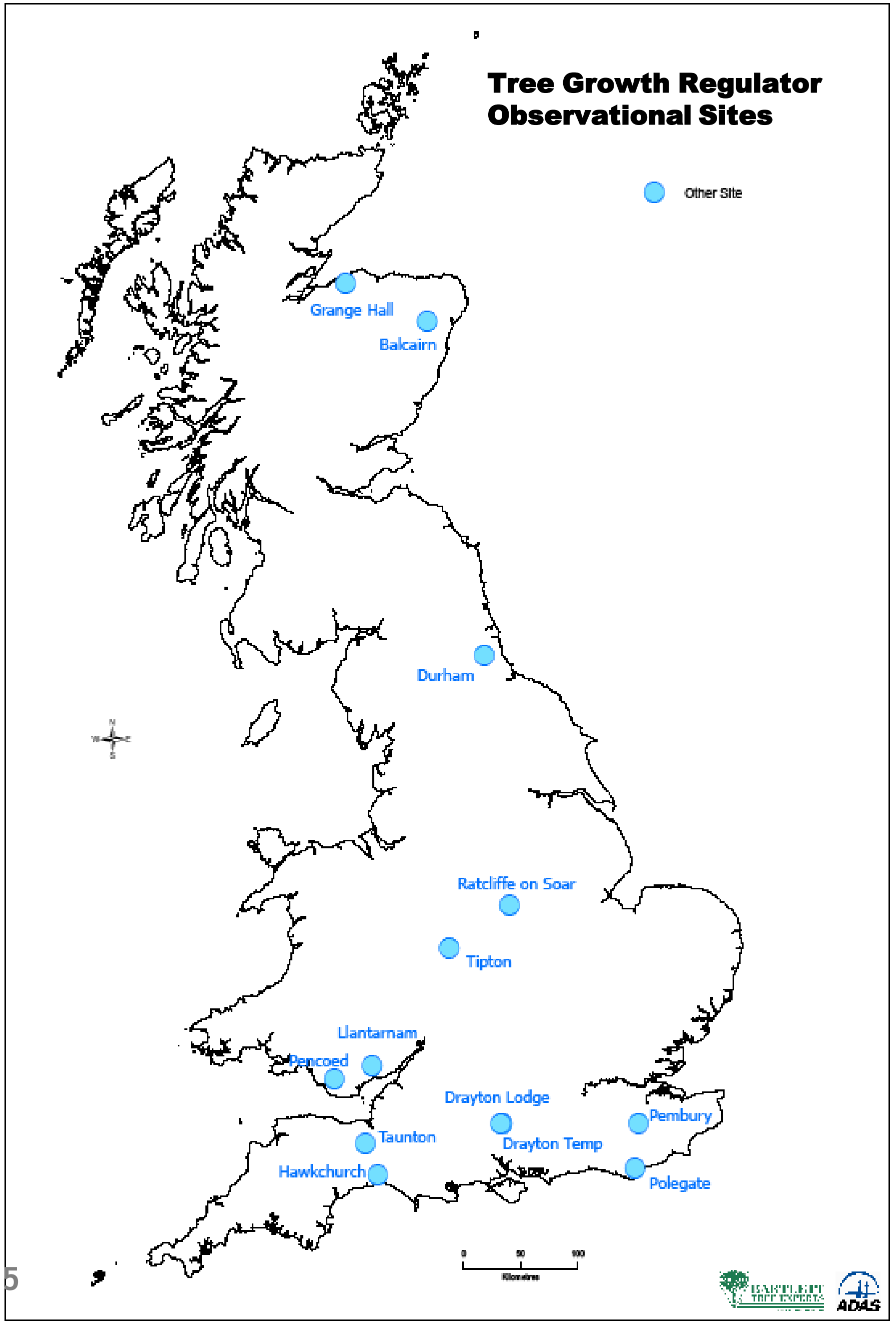
The Research Collaborators were the F A Bartlett Tree Research Lab at Reading University; and ADAS

Objectives of this study were to evaluate the feasibility of PBZ as a TGR for UK DNO purposes using a large number of tree species.

Six field sites throughout the UK were used for experiments supported by thirteen smaller observational sites.



Produced by the ADAS Environment Group, Wolverhampton, WV6 8TQ.



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UK Trials of PBZ - Methods

PBZ was applied using a Rainbow Treecare Soil Injection System based on a 1 x 1 metre spacing to an area three times the diameter of the trunk. One litre per hole was injected to a depth of 20-25cm at a pressure of 2 bar (30 psi).

The quantity of PBZ injected was based on manufacturers recommended rates as determined by tree species and diameter at breast height.

All field and observational sites were treated between late June to early August 2009.

After PBZ application all trees were top and side pruned by 15%

Experimental Design

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.

This experimental design was adopted in line with ORETO guidelines for efficacy testing

The results were analysed as a three randomized complete block design.

In the observational site pairs of trees were identified with one treated and the other as a control.

PBZ	Control	PBZ	Control	PBZ	Control
T1	C	T1	C	T1	C
T1	C	T1	C	T1	C
T1	C	T1	C	T1	C
T1	C	T1	C	T1	C
T1	C	T1	C	T1	C

Analysis

The project assessed the effects of PBZ on two factors;

(1) The effects of PBZ on tree health and vitality; and
(2) The effects of PBZ on tree growth.

The effects on tree health were designed to investigate whether PBZ produced any phytotoxic in the treated trees when compared to controls.

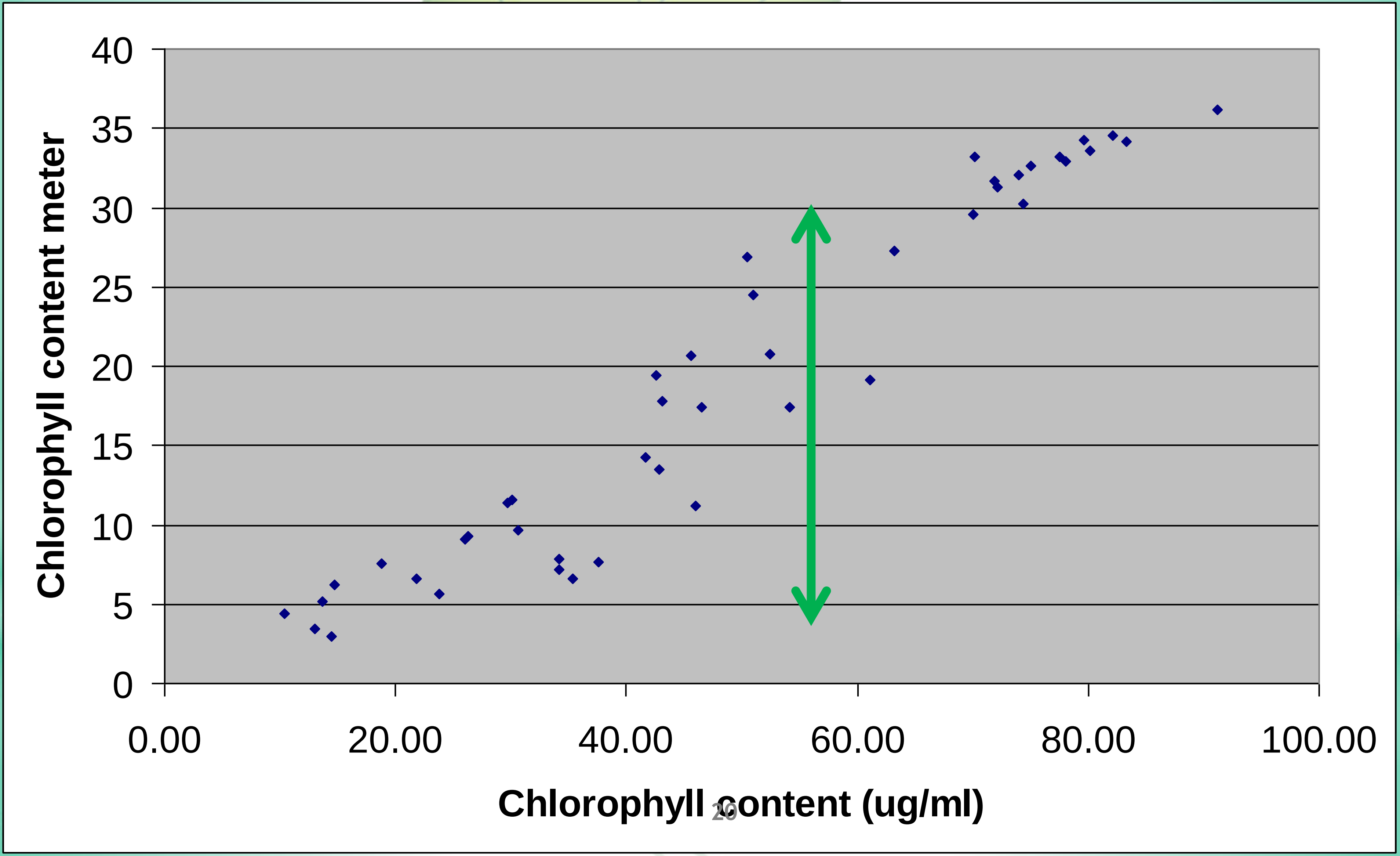
Tree Heath was assessed in three ways

(1) Chlorophyll Content – amount of chlorophyll present or ‘greenness’
(2) Chlorophyll Fluorescence – the efficiency of the chlorophyll
(3) Electrolyte Leakage – a measure of the strength of the cell walls

Chlorophyll Content can be measured electronically in the field using a SPAD meter. This device measures the amount of chlorophyll in a leaf; in other words a measure of the '**greenness**' of the leaf. It is calibrated prior to use and is used to take readings at the mid-point of the leaf next to the main leaf vein

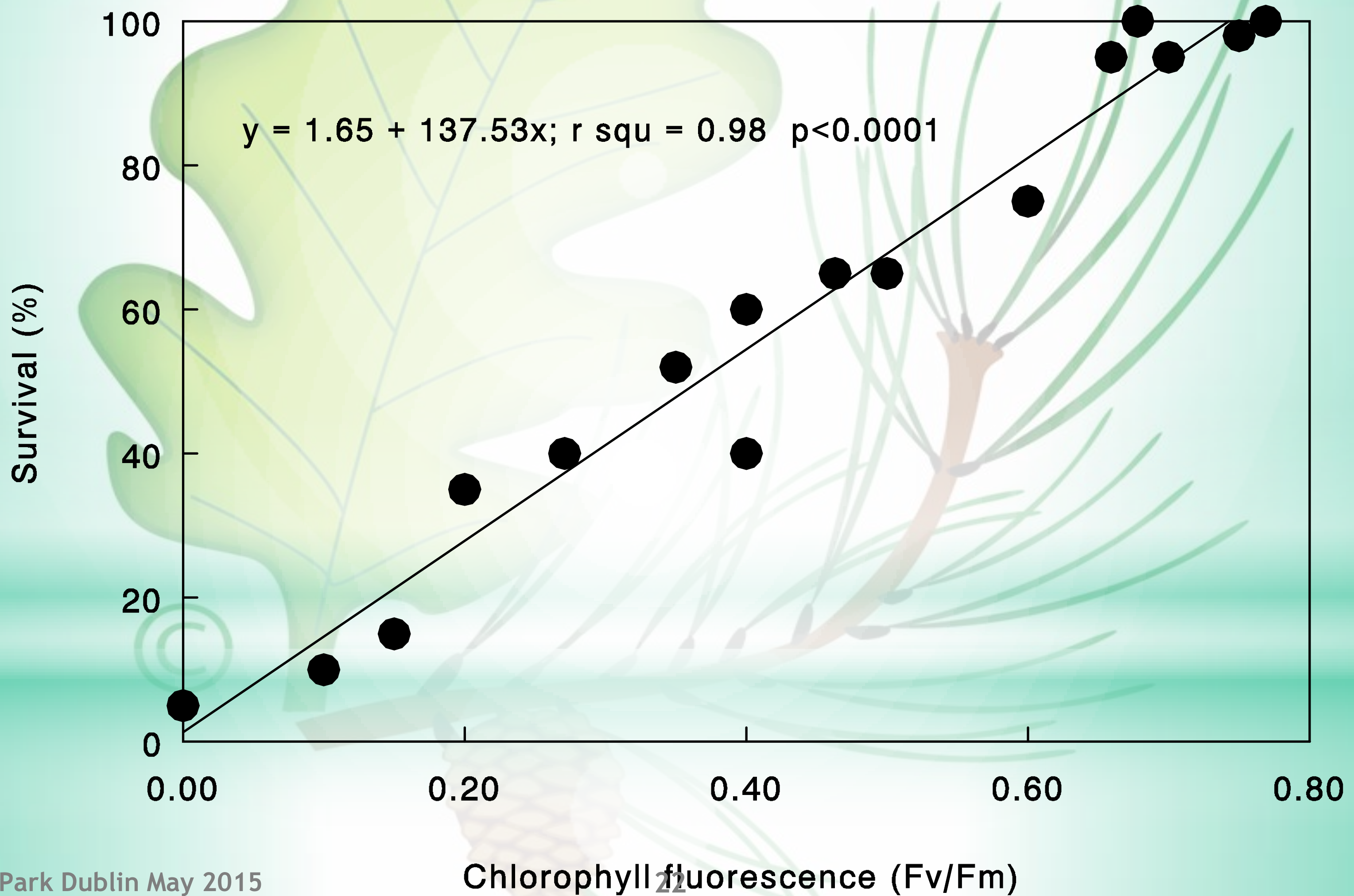
A Minolta chlorophyll meter SPAD-502 being used to measure the chlorophyll content of a leaf arrowed.

Plot of chlorophyll content meter Vs actual leaf chlorophyll content



Photosynthetic Efficiency is measured by **chlorophyll fluorescence** which can be undertaken in the field using a portable fluorescence spectrometer. The ratio of variable fluorescence (Fv = Fm-Fo) to maximum (Fm) fluorescence i.e. Fv/Fm where Fv/Fm is considered a quantitative measure of the maximum or potential efficiency.

Correlation of chlorophyll fluorescence Vs survival of young trees : Maki and Colombo 2001. For. Ecol. Man. 154: 237-249 and Percival 2004. J. Arb 30(2): 80-92)



Electrolyte Leakage is measured in the laboratory. Essentially it is a measure of the health and strength of the cell walls. Leaf samples are taken back to the laboratory where they undergo specific treatment after which the amount of electrolytes that have leaked out can be measured. The higher the leakage; the greater the degree of stress.

Effects of PBZ on Tree Health - Results

No symptoms of leaf burn or reductions in leaf photosynthetic activity caused by PBZ application have been recorded to date. Close to 2000 trees have been treated.

A significant influence of PBZ on vitality was recorded from 2010-2013 i.e. four years after PBZ application. Analysis of individual tree species (PBZ treated Vs non-PBZ treated control) at each field site shows that the influence of PBZ was manifest by

* Increased leaf photosynthetic activity (higher CF values),
* Greener leaves (higher SPAD readings as a measure of leaf chlorophyll content)
* Reduced electrolyte leakage (higher plant cell wall strength).

Statistical Analysis

Significant effects and salient interactions at each field site were determined by both two and one way analyses of variance (ANOVA) after checks for normality and equal variance distributions (Anderson-Darling test) were met.

Differences between treatment means were separated by the Least Significance Difference (LSD) at the 95% confidence level ($P<0.05$) using the Genstat for Windows program.

Trial data that violated the basic assumptions required by ANOVA data were log transformed and then back transformed for presentation in tables.

Due to differences in climatic variables between each field site and for reasons of clarity each field and observation site was analysed independently.

Statistical analysis was checked and verified at the Statistics Department at Reading University.

Results Reading Site (Year 1)

Table 1. P values[z] for tree vitality 2009 (Year 1)

Variable	CF	SPAD	EL
Species (S)	<0.001	<0.001	<0.001
PBZ (P)	0.009	0.961	0.278
S*P	0.027	0.007	0.024

[Z]P<0.05 are considered significant based on LSD.

CF = A measure of photosynthetic efficiency
SPAD = A measure of leaf chlorophyll content
EL (Electrolyte leakage) = A measure of damage to cell membranes

The influence of PBZ on tree vitality of trees growing under field conditions 2010

Species	Treatment	CF	SPAD	EL
English oak	Control	8.27	46.60	2.93
	PBZ	8.08ns	47.12ns	3.06ns
Silver Birch	Control	10.5	43.6	1.98
	PBZ	11.2ns	42.8ns	1.97ns
Poplar	Control	18.5	42.4	5.17
	PBZ	18.5ns	43.5*	4.72*
Beech	Control	6.5	32.8	1.98
	PBZ	6.4ns	33.7ns	1.97ns

ns = not significant from control, * = P≤0.05 using LSD. All values mean of fifteen trees, ten leaves per tree.

Lack of significance between control and PBZ treated trees indicates no leaf phytotoxicity

Effects of PBZ on Stem Extension - Results

Application of PBZ has resulted in reduced shoot extension growth over three years in the majority of tree species tested.

However, data trends indicate greater growth reduction in 2010 and 2011 compared to 2012 and 2013 indicating the effects of PBZ are starting to "wear off" in some, but not all species.

Species	Treatment	2010	2011	2012	2013
English oak	Control	10.60	5.44	18.50	7.30
	PBZ	2.97* (71.9)	4.92^{ns} (9.6)	19.88^{ns} (+7.0)	6.50^{ns} (11.0)
Beech	Control	10.8	9.75	8.55	11.31
	PBZ	6.3* (41.6)	2.17* (77.7)	6.61^{ns} (22.6)	6.20* (45.2)
Apple	Control	16.8	13.72	5.71	4.90
	PBZ	14.5^{ns} (13.7)	3.28* (76.1)	2.34* (59.0)	1.50* (69.8)
Poplar	Control	18.9	8.27	11.58	17.9
	PBZ	14.3^{ns} (24.3)	8.51^{ns} (+2.9)	12.64^{ns} (+8.4)	16.9^{ns} (5.4)

Results Reading Site (Year 2)

The influence of PBZ on tree vitality of trees growing under field conditions 2010

Species	Treatment	CF	SPAD	EL
Apple	Control	8.27	42.77	3.14
	PBZ	11.74*	47.97*	2.66*
Silver Birch	Control	10.1	42.2	2.00
	PBZ	12.3*	42.8^{ns}	2.13^{ns}
Poplar	Control	9.1	32.1	4.48
	PBZ	11.0*	38.9*	3.76*
Beech	Control	6.1	35.4	2.00
	PBZ	8.6*	39.7*	2.13^{ns}

ns = not significant from control, * = P≤0.05 using LSD. All values mean of fifteen trees, ten leaves per tree.

Results Reading Site (Year 3)

Table 3. P values[z] for tree vitality 2011

Variable	CF	SPAD	EL
Species (S)	<0.001	<0.001	<0.001
PBZ (P)	<0.001	<0.001	0.085
S*P	<0.001	<0.001	<0.084

[Z]P<0.05 are considered significant based on LSD.

CF = A measure of photosynthetic efficiency
SPAD = A measure of leaf chlorophyll content
EL (Electrolyte leakage) = A measure of damage to cell membranes

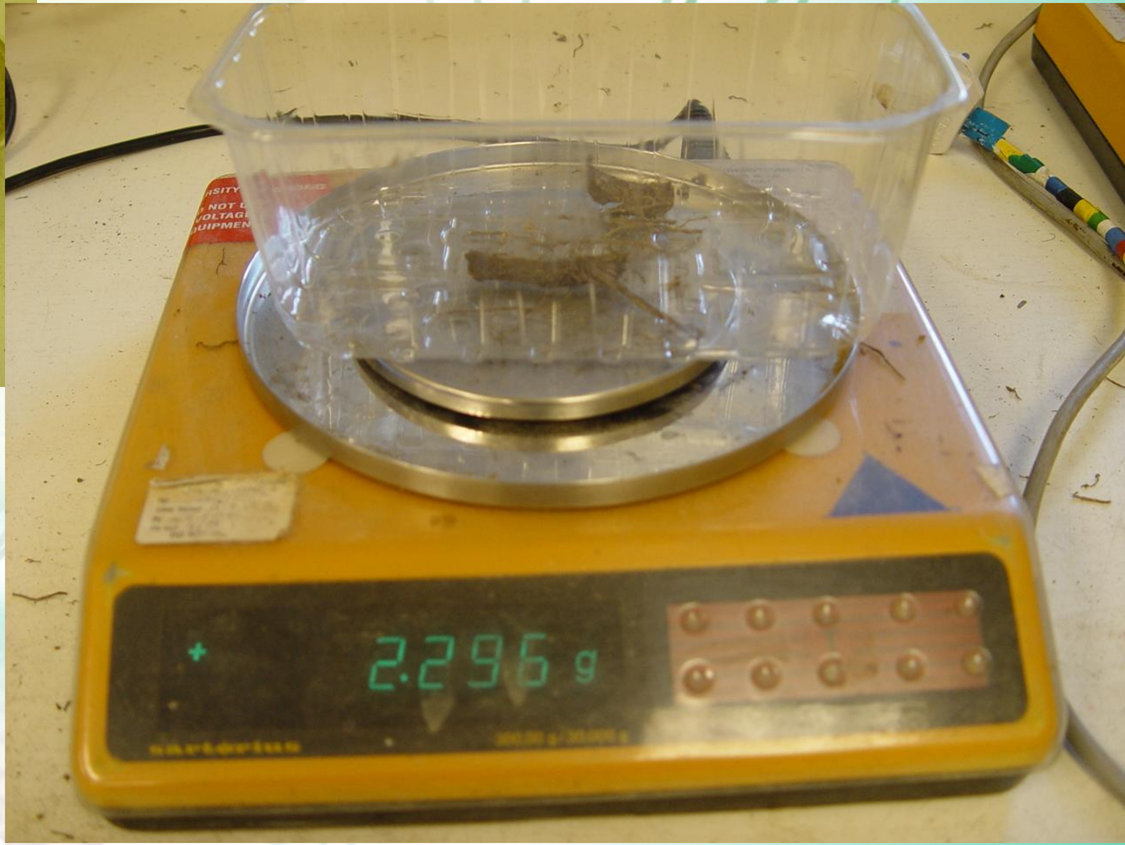
Conclusions (Tree Health & Vitality)

No symptoms of leaf burn or reductions in leaf photosynthetic activity caused by PBZ application have been recorded to date. Close to 2000 trees have been treated.

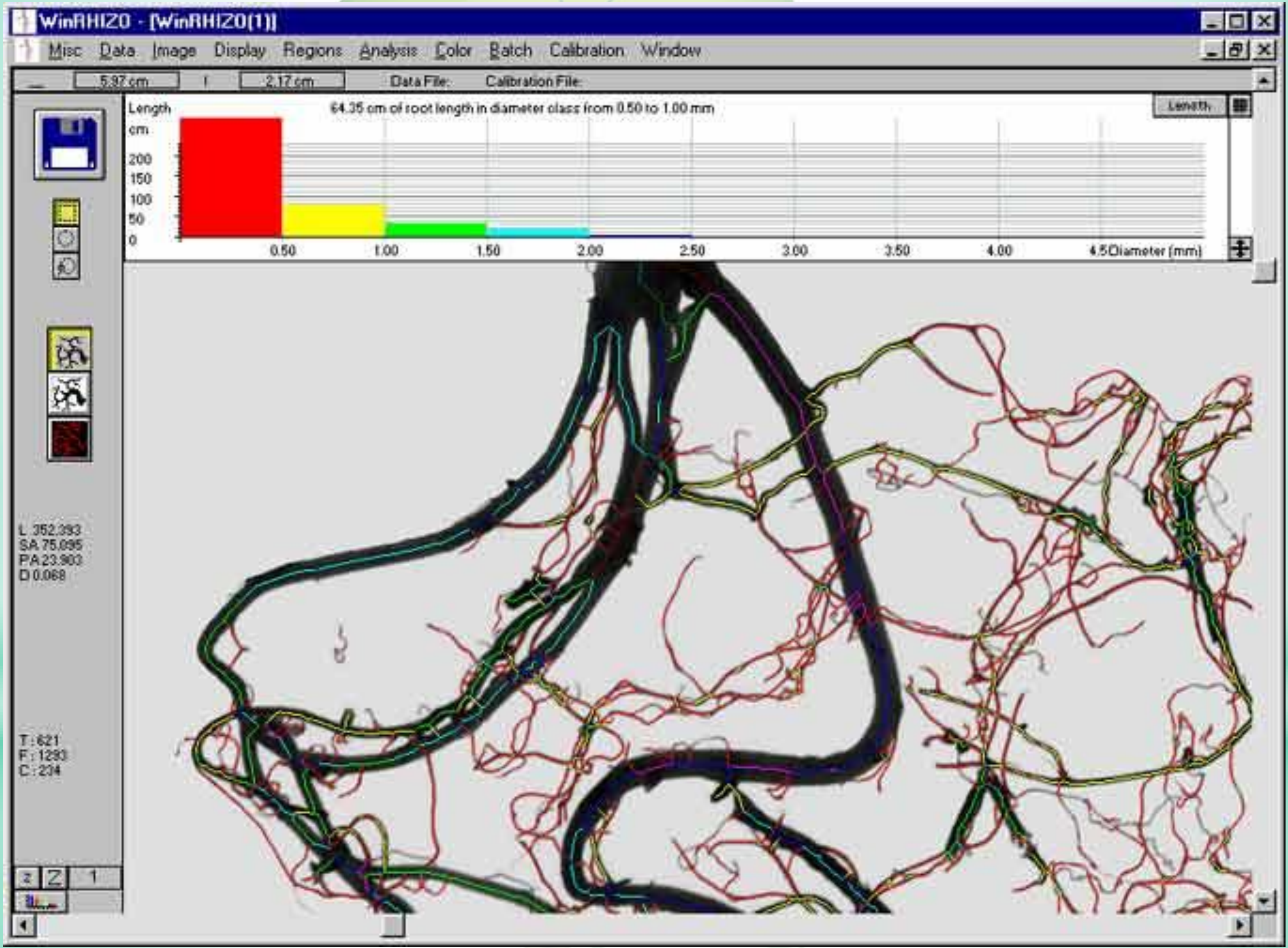
A significant influence of PBZ on vitality was recorded from 2010-2013 i.e. four years after PBZ application. Analysis of individual tree species (PBZ treated Vs non-PBZ treated control) at each field site shows that the influence of PBZ was manifest by

* Increased leaf photosynthetic activity (higher CF values),
* Greener leaves (higher SPAD readings as a measure of leaf chlorophyll content)
* Reduced electrolyte leakage (higher plant cell wall strength).

Root Analysis



Digital Root Analysis



Tree Growth - Measurements

Results Reading Site (Extension Growth)

The influence of PBZ on stem extension (cm) of trees growing under field conditions

Species	Treatment	2010	2011	2012	2013
English oak	Control	10.60	5.44	18.50	7.30
	PBZ	2.97* (71.9)	4.92^{ns} (9.6)	19.88^{ns} (+7.0)	6.50^{ns} (11.0)
Beech	Control	10.8	9.75	8.55	11.31
	PBZ	6.3* (41.6)	2.17* (77.7)	6.61^{ns} (22.6)	6.20* (45.2)
Apple	Control	16.8	13.72	5.71	4.90
	PBZ	14.5^{ns} (13.7)	3.28* (76.1)	2.34* (59.0)	1.50* (69.8)
Poplar	Control	18.9	8.27	11.58	17.9
	PBZ	14.3^{ns} (24.3)	8.51^{ns} (+2.9)	12.64^{ns} (+8.4)	16.9^{ns} (5.4)

parenthesis are % reduction from controls. + = % increase from controls.
± = standard error of the mean.

Results Reading Site - Extension Growth

The influence of PBZ on stem extension (cm) of trees growing under field conditions

Species	Mean reduction in growth over four years
English oak	21.4%
Beech	46.8%
Apple	54.7%
Poplar	4.6%

Results Hull Site -Extension

Table 3. P values[z] for growth

Variable	2010	2011	2012	2013
Species (S)	<0.001	<0.001	<0.001	<0.001
PBZ (P)	<0.001	<0.001	<0.050	<0.001
S*P	0.042	<0.001	<0.101	<0.001

[Z]P<0.05 are considered significant based on LSD.

Results Hull Site - Extension

Table 4. The influence of PBZ on stem extension (cm) of trees growing under field conditions

Species	Treatment	2010	2011	2012	2013
Sycamore	Control	4.77	6.22	8.88	7.1
	PBZ	3.25^{ns} (31.9)	2.72* (56.2)	5.76* (35.1)	6.5 (8.2)
English Oak	Control	13.00	15.20	7.98	8.1
	PBZ	8.00* (38.5)	5.90* (61.2)	7.74^{ns} (3.0)	7.8 (4.3)
Scots Pine	Control	10.69	10.40	11.28	9.1
	PBZ	5.76* (46.1)	4.90* (52.9)	9.91^{ns} (12.1)	8.4 (8.1)
Norway Spruce	Control	5.66	5.25	6.07	4.5
	PBZ	5.68^{ns} (+ 0.35)	5.63^{ns} (7.2)	7.23^{ns} (+16.0)	5.1 (+17.5)

ns = not significant from control, * = P≤0.05 using LSD. Values in parenthesis are % reduction from controls. + = % increase from controls.

Results Reading Site - Extension

The influence of PBZ on stem extension (cm) of trees growing under field conditions

Species	Mean reduction in growth over four years
Sycamore	32.9%
English Oak	26.8%
Scots Pine	29.8%
Norway Spruce	+6.7%

Species	Mean reduction in growth over four years
Quercus robur	21.4%
Fagus sylvatica	46.8%
Malus	54.7%
Populus	4.6%

Conclusions - Extension

* Application of PBZ has resulted in reduced shoot extension growth over three years in the majority of tree species that were tested.

* Data trends indicate greater growth reduction in 2010 and 2011 compared to 2012 and 2013 indicating the effects of PBZ are starting to “wear off” in some, but not all species.

Effects of PBZ on Stem Extension - Site Effect

Species	Location	Stem Extension Reduction (mean of three growing seasons)
Quercus Robur	Hull	34%
	Reading	25%
	Raglan	50%
Acer pseudoplatanus	Boxworth	9%
	Drayton	44%
Fagus sylvatica	Reading	47%
	Raglan	34%
	Myerscough	19%

All stem extension values mean of fifteen trees five stems per tree.

Principal Results

The principal result of the research is that the tree growth regulator (TGR) Paclobutrazol (PBZ) is effective and fit for purpose.

Effects of PBZ on tree growth will vary between sites.

Growth of English oak was reduced by 50% averaged across four growing seasons at the Raglan site and by 25% at the Reading site when averaged across four growing seasons.

Stem extension of sycamore was reduced by 9% averaged across four growing seasons at the Boxworth site and by 44% at the Drayton site when averaged across four growing seasons.

Stem extension of beech was reduced by 47% at the Reading site; 34% at Raglan; and 19% at Myerscough.

Differences in soil conditions may account for these responses.

Effects of PBZ on Stem Extension - Species Effect

Sensitive	Intermediate	Tolerant
Tilia spp (46%)	*Quercus robur* (37%)	*Salix* spp (18%)
Quercus ilex (61%)	*Fagus sylvatica* (33%)	*Populus* spp (4%)
Crataegus monogyna (38%)	*Betula pendula* (26%)	*Picea sitchensis* (+3%)
Malus spp. (50%)	*Acer pseudoplatanus* (35%)	
Alnus glutinosa (41%)	*Pinus sylvestris* (29%)	
	Fraxinus excelsior (28%)	
	Cupressocyparis leylandii (28%)	

the numbers in parentheses represent the mean extension growth reduction over four growing seasons 2010 to 2013 inclusive

Effects of PBZ on Stem Extension – Species Effect

<u>Sensitive</u>: = A minimum of 3 years growth reduction ranging from 30%-60%

<u>Intermediate</u>: = A minimum of 2 years growth reduction ranging from 50%-75% with effects starting to wear off in year 3 i.e. *ca*. 25% growth reduction.

<u>Tolerant</u>: = Little effect of PBZ. Probably not cost effective to treat these trees.

Of the eight genera that make up 77% of trees on the OHPL Networks in Britain

two genera (*Alnus* & *Crataegus*) are 'sensitive' to the effects of PBZ; and

four (*Acer*, *Betula*, *Fraxinus* & *Quercus* are in 'intermediate' in their response to PBZ.

Of the remaining two genera (*Corylus* & *Salix*), *Corylus* was not tested and *Salix* is 'tolerant' to the effects of PBZ,

(*Populus* comprises <2% of the trees on the overhead line networks nationally).

Final Conclusions

1. The TGR Paclobutrazol is effective in controlling the growth of six of the eight genera of tree most commonly occurring on the OHPL networks.

2. Significantly it controls the growth of *C. Leylandii* which is a very common tree on the low voltage network.

3. The effects of PBZ vary between sites possibly due to differing soil conditions.

4. PBZ is 'fit for purpose' to control the growth of commonly occurring trees within UVM programmes.

5. Research is ongoing into the development of a formulation of PBZ that can be applied by trunk injection rather than into the soil and the results to date look promising

6. Further research is planned to investigate if higher doses of PBZ would result in control of the growth of 'tolerant' genera.

Applications to the Amenity & Urban Forestry Sectors

1. Local Authorities with large tree populations could use PBZ on sensitive & intermediate species to extend their pruning cycles;

2. To maintain the size and shape of some trees in more compact forms - pollards for example;

3. Because PBZ stimulates new root growth it is used in parts of the USA to treat trees after underground utility installations in proximity to trees;

4. To increase drought tolerance of trees;

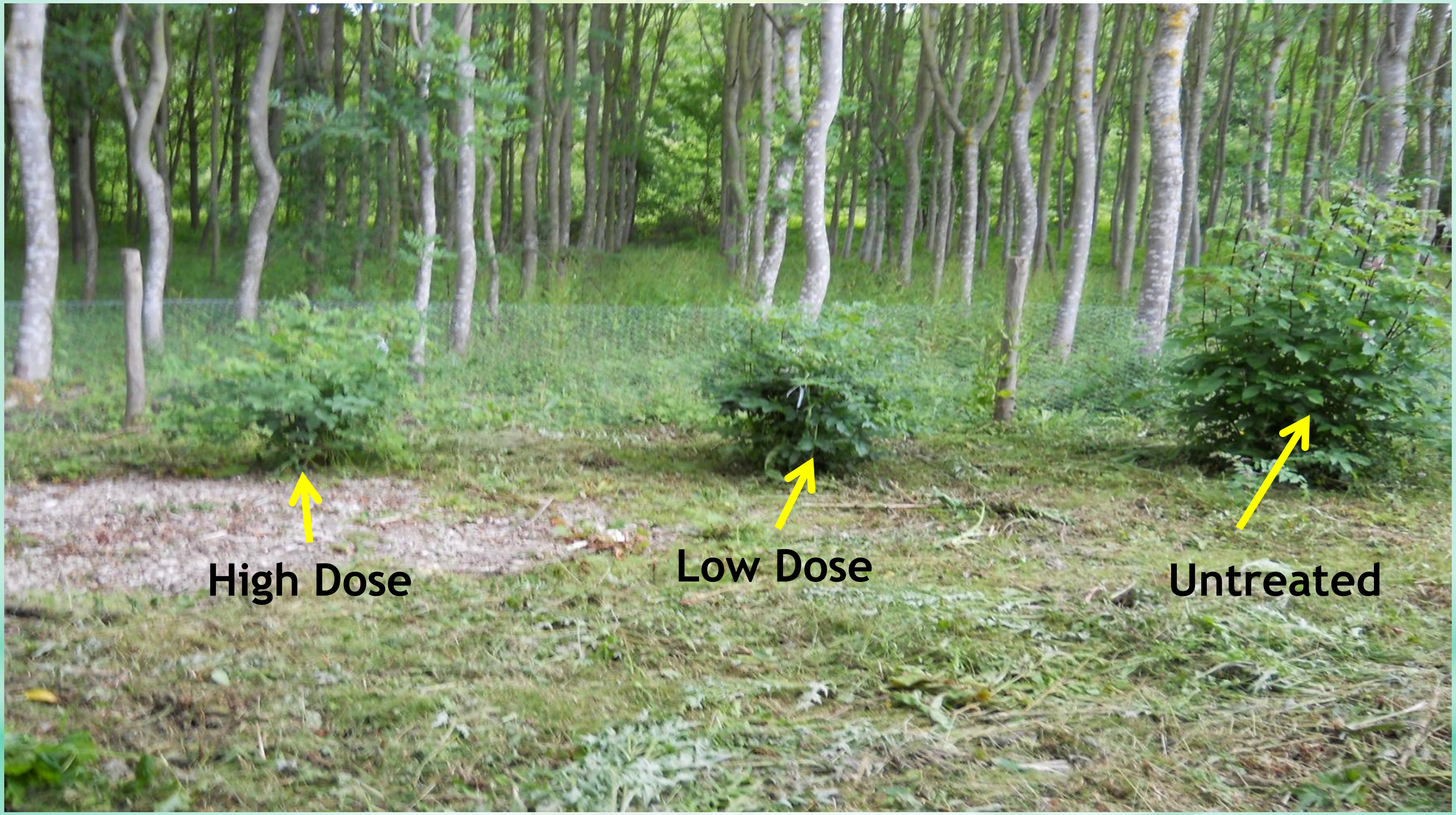
5. To deal with the unsightly/cosmetic tar spot diseases.

Application Methodology

The probable ban on soil injection methodologies at EU Level, PBZ is in a 'Limbo' phase, because current formulations are unsuitable for systemic injection.

Application Methodology

Some development work has been done on an injectable formulation that is looking promising.



ADAS - Boxworth Trials

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