New and Effective Plant Protection Product & Mode of Delivery to Control Tree Pests & Diseases

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Trees – Why We need Them – Why We Like Them – Why We Value Them

Trees are integral to our lives;

Trees are keystone organisms that play a fundamental role in the terrestrial ecosystem upon which humans depend, (Meffe & Carroll 1997; Fralish 2002);

In short humans could not survive without trees.


The Benefits of Urban Trees

All trees are vital to human health; they produce oxygen, absorb carbon dioxide; they sequester or lock carbon; and they absorb particulate air pollution down to 2.5 microns ($PM_{2.5}$), and much more.

A recent study by the U.S. Forest Service revealed that between 2002 and 2007 the Midwest Region has lost over **100 million** ash trees to emerald ash borer (*Agrilus planipennis*) [EAB].

Linked to the loss of ash trees there was a significant increase in mortality rates over 'normal' rates from cardiovascular and lower respiratory tract illness in the areas where the ash trees have been lost.

The marginal effect of EAB was found to be **16.7** additional deaths per year per 100,000 adults giving a total of **15,080** additional deaths between 2002 and 2007. [Donovan *et al* (2013) Trees and Human Health. Am. J. Preventative Medicine 44 (2):139-145]

The Benefits of Urban Trees

The US Forest Service has put a **US$3.8 billion** value on the air pollution annually removed by urban trees.

In Washington DC, trees remove nitrogen dioxide to an extent equivalent to taking **274,000 cars** off the traffic-packed motorway, saving an estimated **US$51 mil**lion in annual pollution-related health care costs.

Another study in the USA has found that the ability of trees to absorb particulate air pollution across a number of US cities including Atlanta, Baltimore, Boston, Chicago, Los Angeles, Minneapolis, New York City, Philadelphia, San Francisco and Syracuse NY, translates to a saving of at least one life per city per year.

The greatest effect was evident in NY City where trees were found to save up to eight lives per year.

The Benefits of Urban Trees

There is a direct correlation between lives saved, population size and tree removal rates.

Put simply, trees make our cities healthier places to live.

"What we are doing to the forests is but a mirror reflection of what we are doing to ourselves". (Mahatma Ghandi)

When the trees are attacked by Pests & Diseases we need to find solutions!

What We've Got in the UK

Indigenous / Native / Naturalised

* Ash decline (*Chalara fraxinea*)
* Horse chestnut bleeding canker (*Pseudomonas syringae* pv *aesculi*)
* Horse Chestnut Leaf Blotch, (*Guignardia aesculi*)
* Massaria disease of plane (*Splanchnonema platani*)
* Anthracnose of London Plane, (*Apiognomonia veneta*)
* Anthracnose of Willow (*Drepaniopeziza sphaeroides)*
* Tar Spot on sycamore (*Rhytisma acerinum*)
* Dutch elm disease (*Ophiostoma novo-ulmi*)
* Pine red-band needle blight (*Dothistroma septosporum*)
* *Phytophthora ramorum* on oak and now Larch; and*, P. austrocedrae*, *P. lateralis* other *Phytophthora* species, and
* Cypress Aphid (*Cinara cupressi*)

Chalara fraxinea is in both indigenous and invasive sections because its sexual stage *Hymenoscyphus pseudoalbidus is similar to a genetically distinct strain called Hymenoscyphus albidus which occurs in Britain and seems to be less aggressive.*

What Has Come Into the UK

Invasive / Introduced

* Ash decline (*Chalara fraxinea*)
* Oak processionary moth, (*Thaumetopoea processionea*), [OPM]
* Great Spruce bark beetle (*Dendroctonus micans*),;
* Horse chestnut leaf miner (*Cameraria ohridella*), [HCLM]
* Sweet chestnut blight (*Cryphonectria parasitica*)
* European gypsy moth (*Lymantria dispar*)
* Pitch pine canker (*Gibberella circinata)*
* Asian longhorn beetle (*Anoplophora glabripennis*), [ALB]
* Brown spot needle blight of pine

Existing Threats

Possible future introductions

* Emerald ash borer (*Agrilus planipennis*) [EAB]
* Spruce bark beetle (*Ips typographus*)
* Citrus longhorn beetle (*Anoplophora chinensis*) [CLB]
* Plane wilt disease, (*Ceratocystsis platani*)
* Pine processionary moth (*Thaumetopoea pityocampa*) [PPM]
* Pine Wood Nematode (*Bursaphelencus xylophilus*) [PWN]

What has come into Mainland Europe

Pine Wood Nematode (*Bursaphelencus xylophilus*) [PWN]

Red Palm Weevil (*Rynchophorus ferrugineus*) [RPW]

Palm Borer Moth (*Paysandisia archon*) [PBM]

Oak Processionary Moth - OPM

Found in Britain in 2006 –
Richmond, West London;
Also confirmed in Pangbourne,
Hertfordshire.

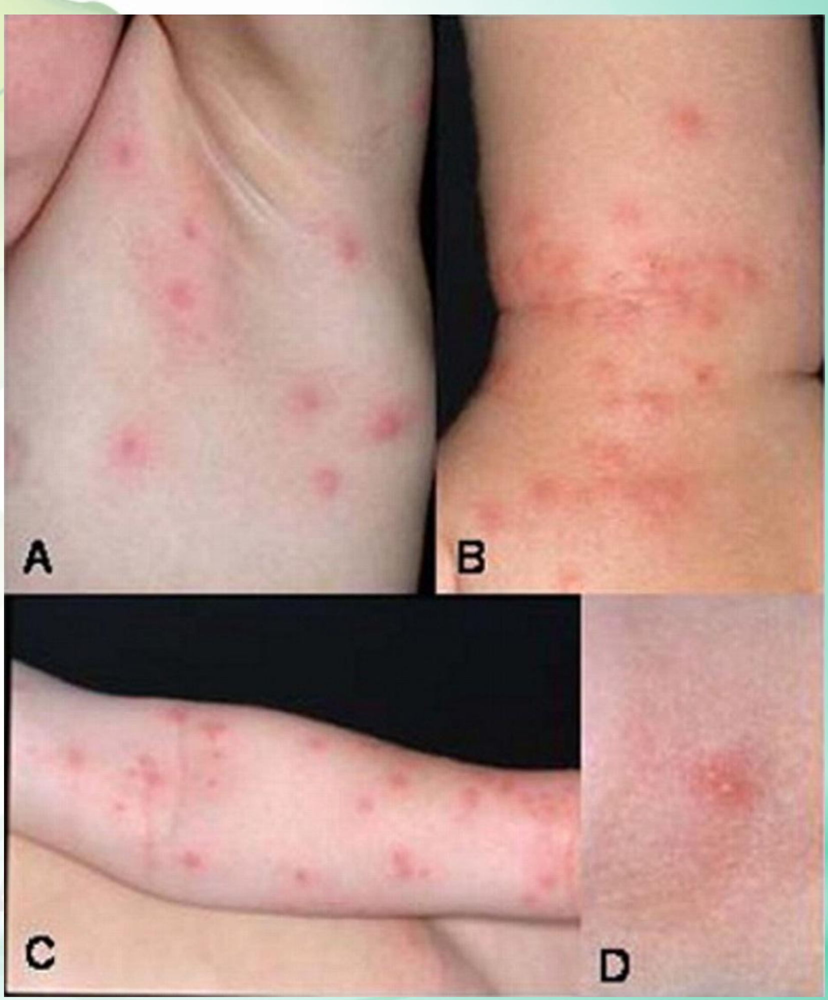
Adults Fly July to September

Eggs laid July - September

Larvae present April to June

Pictures from the Forestry Commission

OPM is a Risk to Human Health



Full PPE is essential as exposure to the OPM toxin is sensitising i.e. the more exposure the worse the effect.

Nests and larvae should be treated with extreme caution!

Horse Chestnut Leaf Miner - HCLM

Horse Chestnut Leaf Miner - HCLM

Severe Leaf Damage
(<u>Not just a cosmetic issue!</u>)

Early Leaf Fall – July

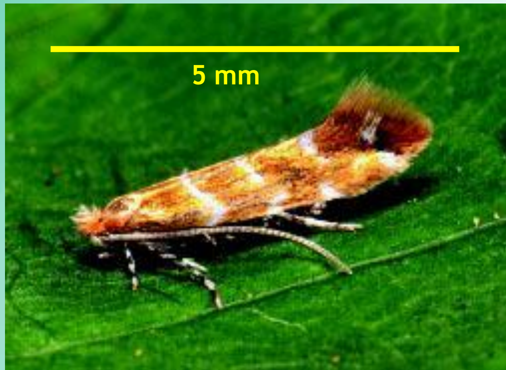
Reduced number of seeds

Seeds smaller than average

Up to 25% of seed not viable

Energy Reserves Reduced (40%)

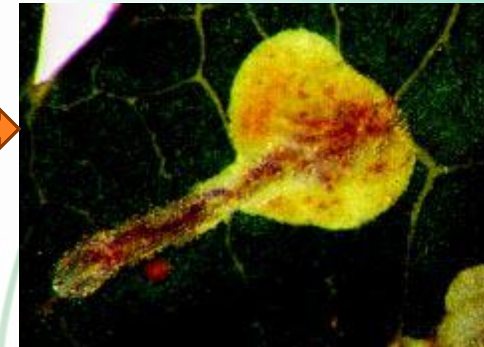
Trees less able to deal with other infections such as *Phytophthora* or *Armillaria*.



Adults Present from April Onwards

Eggs laid May to August

Newly Hatched Larva



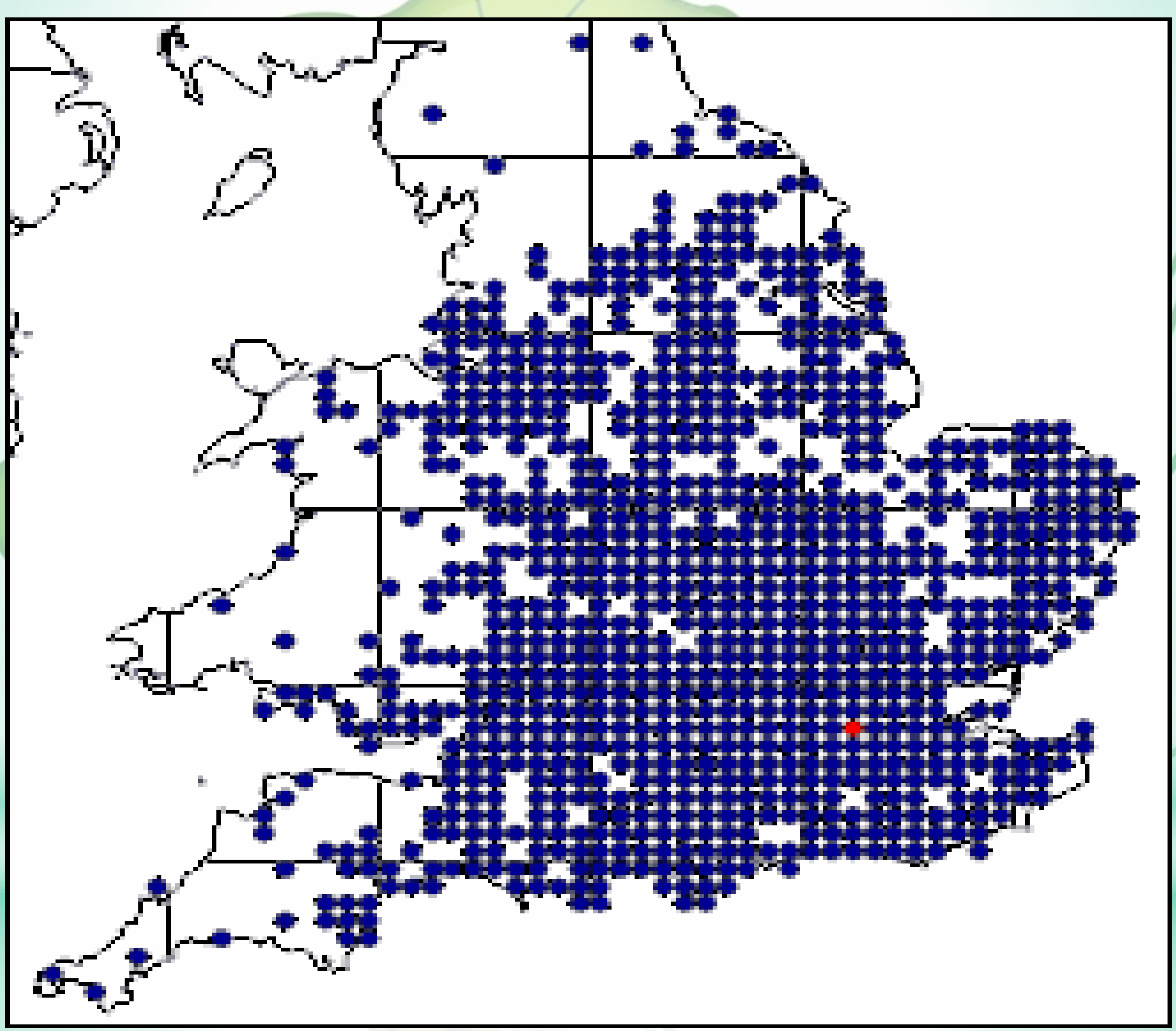
HCLM can have up to 5 overlapping Generations per year

5 Larval Instars (4 Weeks)

Pupa in a Silk Cocoon (2 Weeks)

Pictures from the Forestry Commissions

HCLM Spread Since Introduction in 2002



www.forestry.gov.uk

Controls – Tree Protection

<u>What have we got</u>? <u>What is Available</u>?

1. Chemical & Biological Controls

2. Integrated Pest Management (IPM)
   (a) Attract & Kill
   (b) Allee Approach

Chemical Controls in IPM programmes is the best way for trees in the short to medium term.

Very long term – Tree Breeding

Tree Protection - Soil Injection

Rainbow Treecare Soil Injection System® - a Completely Closed System for Soil Injection

Tree Protection - Foliar Spray

Foliar Spraying on Palm Trees

Tree Protection – Systemic Injection

Pressurised Capsules

Tree Protection – Systemic Injection

ArborJet® System

Syngenta Tree Micro-Injection (TMI) System®

Tree Protection - Systemic Injection

There are many other systems available and these include, but are not limited to:

Pressurised Capsules;

Mauget®; Tree-Tech Capsule System ®

Pressure Injection:

ArborJet®; Viper®; Wedgle Direct Injection System®; Rainbow Q-Gun®, Q-Connect ®& IQ Infuser® ; BITE® (Blade Infusion); GEA Endotherapy for Trees®; and Syngenta TMI®.

For a Review of some of the available systems see:
Parker, Patrick (2014), 'The Current State of Tree Injection Methods and Materials'. Tree Care Industry (TCI) Volume XXV, No. 5, May 2014, Pages 8 to 14

Tree Protection

Biological Control

Biological controls involve the use of live organisms such as parasites, parasitoids, predators or pathogens. All biological control methods involve human intervention and management. Essentially there are three biological pest control strategies:-

Importation: Sometimes called 'classical biological control' – introduction of natural enemies from the pest or disease's locality of origin.

Augmentation: Natural enemies are already present but not in sufficient numbers and more are released to try and get more control.

Conservation: This involves the management of existing natural enemies in the tree environment. They are already adapted to the environment and the pest, and the objective is to manipulate the habitat to increase numbers.

Tree Protection

Nematodes, fungi, bacteria and viruses have all been used at one time or another to control insect pests. They are relatively pest specific and **density dependent**, i.e. they increase in numbers as the density of the pest increases.

There are comparatively few examples of biological controls for tree pests and diseases but research is ongoing:

1. RBG Kew researching natural enemies of HCLM
2. Defra is funding research into OPM control using

-Nematodes;
-*Bacillus thuringiensis* (BT) – In use against OPM in Holland;
-Entomophagous fungi;

Tree Protection

Combined Methodologies

Controlling pests and diseases is not a straight forward process;

Often the only effective way to control pests and diseases is by **'integrated pest management'** (IPM)

Sometimes the use of natural enemies is effective, other times pesticides work, in severe outbreaks of damaging pests a combination of the two is required; e.g.

Emerald ash borer (EAB) has killed and continues to kill tens of millions of trees in the USA. Natural enemies have been found in China where EAB is indigenous and some have been released in the Mid West of the USA.

There is a systemically injectable insecticide that is very effective against EAB, but it is not practical or commercially viable to inject every ash tree, but it is cost effective when used in an IPM approach.

A combination of natural enemies released into the wider environment, coupled with systemic injections for the high value amenity trees provides some control.

It is the approach to control that is most important, as a proper IPM programme enhances the contribution of the different elements

New Plant Production Product – Revive ®

Revive® is Emamectin Benzoate. Derived from the naturally occurring avermectin insecticide.

Refined into a highly effective targeted option.

Revive® is a formulation specifically developed for Tree Micro Injection allowing for: -

- Low pressure injection;
- Very small volumes of product; applied;
- Very small injection holes required
- Very fast injection.

Revive® moves rapidly into the leaf and crown and targets pest activity.

•

New Plant Protection Product - Revive®

Approved for use in Switzerland for *C. ohridella* (HCLM)

Recently (April 2014) Approved in France and Emergency Approval in Spain for Red Palm Weevil and Full Approval in Portugal for Pine Wood Nematode

Currently with CRD for Approval for use in the UK for control of OPM and HCLM – Target date Q1 of 2015

Research trials of its efficacy against OPM and HCLM in Britain have been ongoing for 3 years.

*Thaumetopoea processionea (*OPM) Trials at Barnes Common in London 2012, 2013 & are Ongoing in 2014

Trials undertaken by the Bartlett Tree Research Lab at Reading University

Trees injected with Revive at various doses & formulations.

OPM Trials at Barnes Common in London

Two formulations of EM tested at 4 different levels of active ingredient, (ai);

Untreated control
Water treated control

16297A 0.02 g ai/cm DBH
16297A 0.04 g ai/cm DBH
16297A 0.08 g ai/cm DBH
16297A 0.16 g ai/cm DBH

19308A 0.02 g ai/cm DBH
19308A 0.04 g ai/cm DBH
19308A 0.08 g ai/cm DBH
19308A 0.16 g ai/cm DBH

Each individual plot (treatment) consisted of 1 tree. Trial consisted of 4 replicates (40 trees in total).

Barnes Common OPM Trials

Influence of insecticide formulations A16297A and A19308A applied by ArborJet trunk injection on Oak Processionary Moth nest number and viability over two years.

	Year 1		Year 2	
Treatment	Mean No OPM nests per tree	Percent mortality of OPM larvae	Mean No OPM nests per tree	Percent mortality of OPM larvae
Control (no injection)	0.5b	0	6.0c	0
Water injected	1.0c	0	6.8c	0
A16297A 0.02g	0.0a	-	0.0a	-
A16297A 0.04g	0.0a	-	0.0a	-
A16297A 0.08g	0.0a	-	0.0a	-
A16297A 0.16g	0.0a	-	0.0a	-
A19308A 0.02g	0.5b	0	1.0b	0
A19308A 0.04g	0.0a	-	0.0a	-
A19308A 0.08g	0.0a	-	0.0a	-
A19308A 0.16g	0.0a	-	0.0a	-

Barnes Common OPM Trials

Cameraria Trials at Greenwich
2011 - 2013 & ongoing

Two formulations injected at various doses using the ArborJet® system.

Cameraria Trials at Greenwich

Untreated Control
Water injected control

A16297A (0.02 g ai cm DBH)
A16297A (0.04 g ai cm DBH)
A16297A (0.08 g ai cm DBH)
A16297A (0.16 g ai cm DBH)

A19308B (0.02 g ai cm DBH)
A19308B (0.04 g ai cm DBH)
A19308B (0.08 g ai cm DBH)
A19308B (0.16 g ai cm DBH)

The treatments, 1 non-injected tree, 1 water injected control, 4 A16297A, 4 A19308B were applied in 4 randomized complete blocks with a single tree as the experimental unit i.e. 10 trees per block, 40 trees in total.

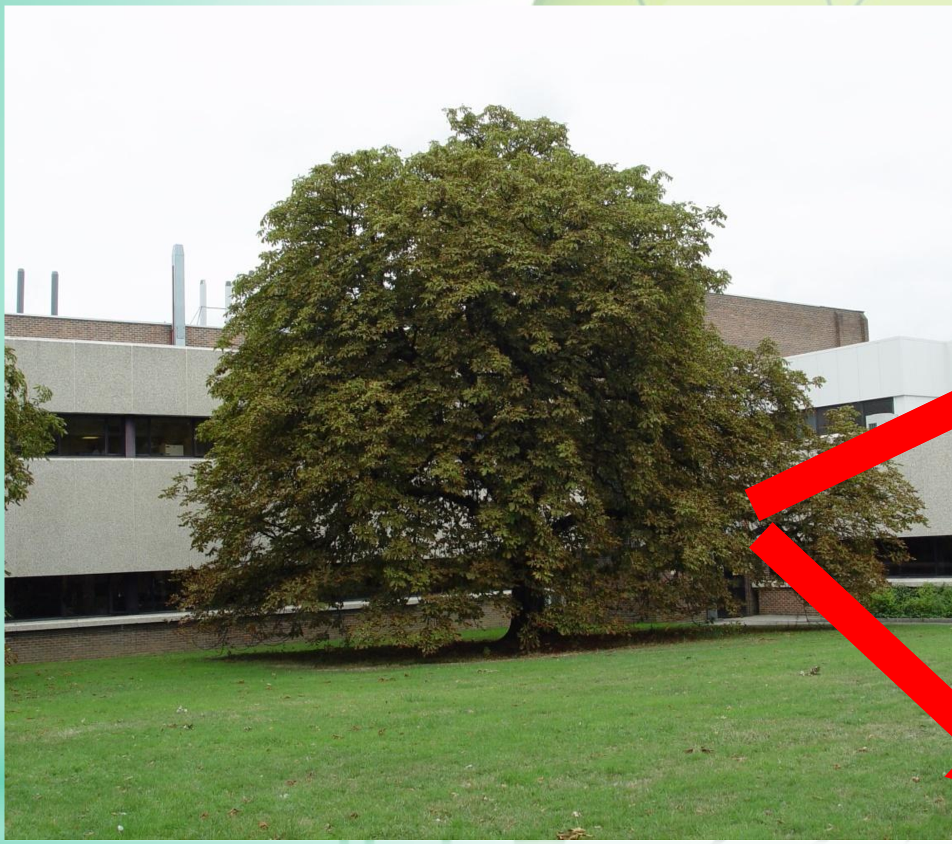
Cameraria Trials at Greenwich

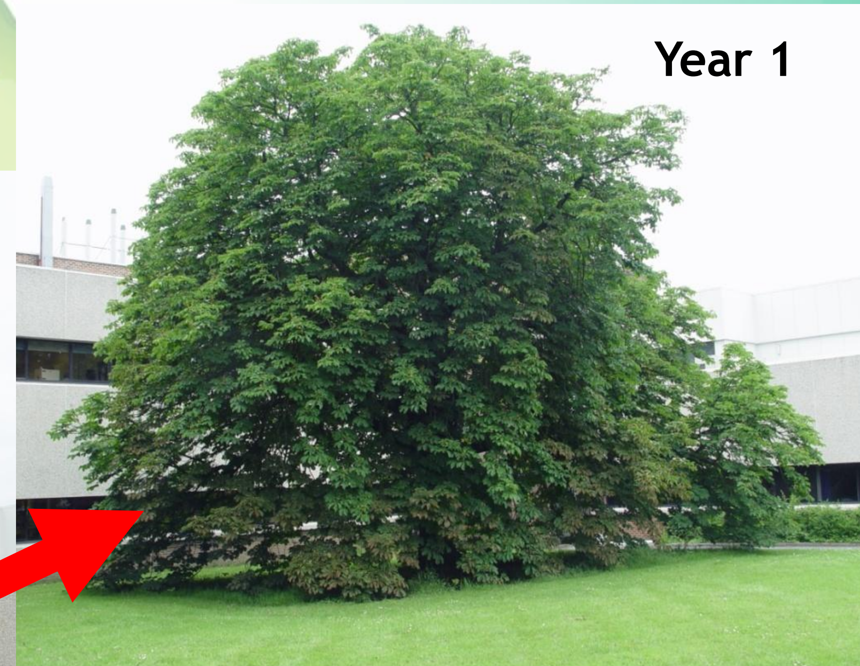
Influence of Revive® applied by ArborJet trunk injection on HCLM infection severity. **(* = Significant at <0.5%)**

	Year 1	Year1	Year 2	Year 2
Treatment	No. Mines/Leaf	%Mortality of Larvae/Pupae	No. Mines/Leaf	%Mortality of Larvae/Pupae
Control	9.25	10.9	8.0	9.4
Product A 0.02g	5.30*	12.5	4.1*	42.0*
Product A 0.04g	3.65*	13.0	2.3*	33.0*
Product A 0.08g	3.85*	18.9*	0.0*	-
Product A 0.16g	2.05*	14.4*	0.0*	-
Product B 0.02g	3.60*	13.8*	0.0*	-
Product B 0.04g	5.55*	16.0*	0.1*	100*
Product B 0.08g	2.25*	14.9*	0.0*	-
Product B 0.16g	1.45*	22.5*	0.0*	-

Cameraria Trials at Greenwich

Horse Chestnut Leaf Miner Control





Revive® Applied by Injection

Royal Holloway University of London

Trees Treated on 13 May 2014 – Post Treatment Photos Taken 23 June 2014

Trials against *Rhynchophorus ferrugineus* (RPW) - Elche (Alicante), Spain

Results from the Elche trials in Spain (Valencia Region) show that Revive is effective in controlling RPW in Canary Island Palm (*Phoenix canariensis*) and Research in ongoing on the Date Palm (*Phoenix dactylifera*). Trials against *Paysandisia archon* are planned.

Syngenta Tree Micro-Injection (TMI)

Side Effects of Tree Injection

Drilling the injection holes causes wounds – entry points for decay organisms
Drilling could breach CODIT Barriers in Broadleaves and Conifers

A balanced decision has to be made based on the health and vitality of the tree and the severity of the pest / disease infestation / infection.

Other side effects include:

- Suppurating Wounds
- Phytotoxicity
- Negative effects on non-target species
- Possible environmental, human and animal

Product Label - Revive®

The **label** carries all relevant information about the product(s) including but not limited to:

- The trade name of the product, e.g. Revive®
- The active ingredient (AI) and the percentage in the product
- Approval No. for example MAPP No.
- The colour, odour and viscosity of the product
- Pack size (total volume of fluid in the container)
- Manufacturer's name and emergency details
- Statutory conditions of use – the pests and/or diseases for which the product can be used
- Directions for storage, transportation and use
- Application rates
- Safety and first aid information
- PPE requirements
- Disposal of surplus and waste material and packaging
- Directions for cleaning the equipment

As well as the label be aware of and know how to obtain and understand the information on the Manufacturers **Safety Data Sheet** (SDS).

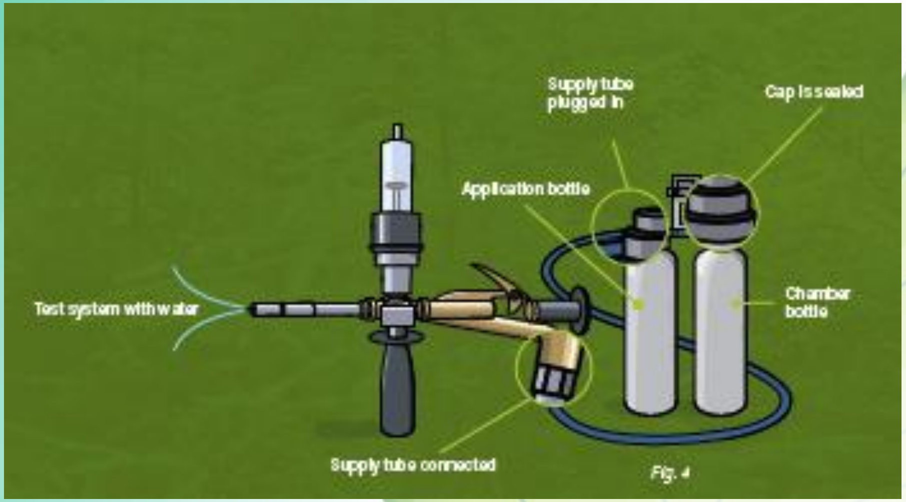
Personal Protective Equipment (PPE)

Calculating the Dose; Example calculating the dose for Horse Chestnut Leaf Miner using 'Revive'.

Dose is based on DBH at approximately 1ml per 1cm DBH injected in 5ml doses. Therefore the number of injection points is the DBH in cm divided by five. Revive is applied at 5cm increments.

DBH in CM	No. of Injection Points	ML of product applied	DBH in CM	No. of Injection Points	ML of product applied
30	6	30	65	13	65
31	6	30	66	13	65
32	6	30	67	13	65
33	6	30	68	13	65
34	6	30	69	13	65
35	7	35	70	14	70
36	7	35	70	14	70
37	7	35	70	14	70
38	7	35	70	14	70
39	7	35	70	14	70
40	8	40	70	14	70

Preparing the equipment for work
Mark 1 Device



The product bottle is filled and the system pressurised to 8 bar.

The dose chamber on the injector unit is charged to 2-3 bar for broadleaves and 4 bar for conifers

Revive® - TMI Steps

1. Drill Holes 1 per 5cm dbh

2. Syngenta Plugs (Biodegradable)

3. Plug Setter

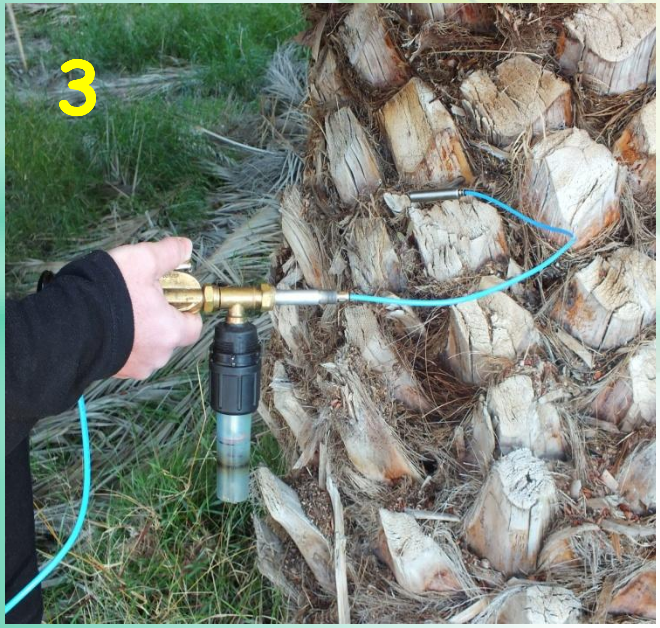
4. View of Set Plug

5. Inject - Revive


The TMI Plug is set such that a small ring of Xylem is exposed

Revive® – TMI Steps – Final Injection

TMI of Palm Trees – The Final Delivery is Different



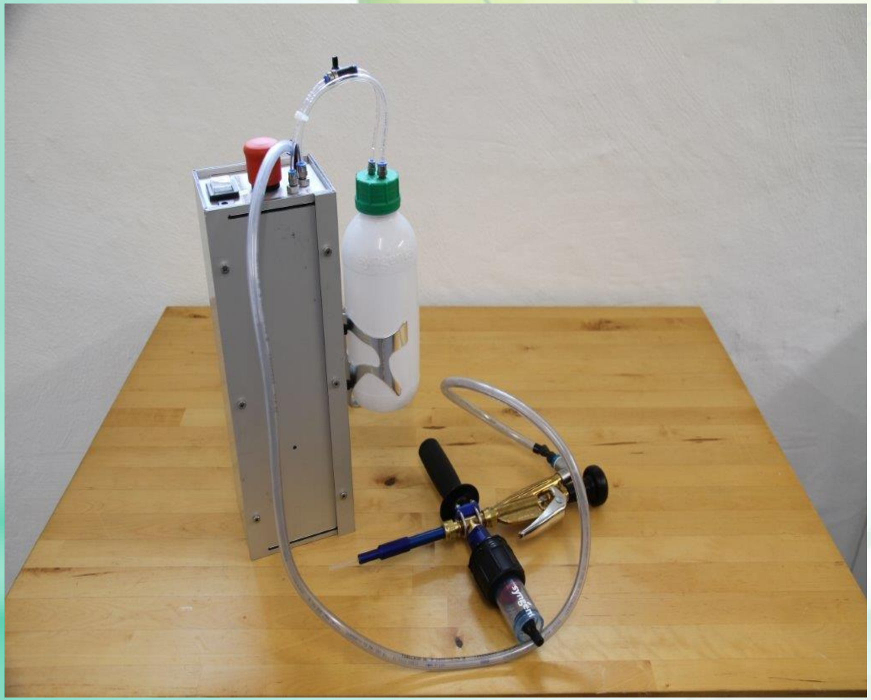
1. Drill 4 holes 20cm-25cm deep but no more than 1/3 of the stem diameter
2. Insert the custom designed injector head
3. Deliver 2 x 6ml doses to each hole
4. Cap the holes when complete

5. Cap the Injection Point to Seal ... Because?

Palms are monocots and don’t compartmentalise!

Second Generation Revive Application Device: Closed system

Functional Mark 2 TMI Kit – Approved by CRD



- An battery powered electric pump sucks the product from product bottle
- The pump continuously drives the product into the injector unit
- The equipment is very compact. It can be placed in a small back pack
- Several injectors can be connected for parallel injection in case of high dose rates
- The battery is rechargeable, and one battery load sufficient to treat 50-100 trees
- Fast and easy cleaning of system

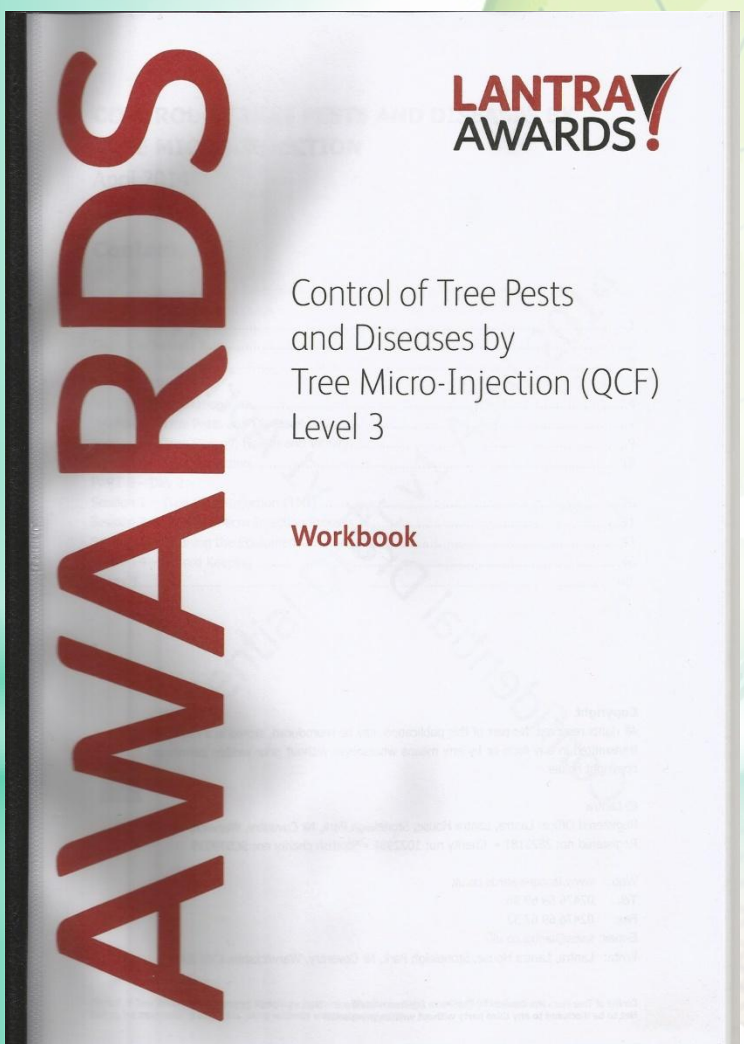
Mark 2 Prototype

Delivery to the tree is the same as the Mark 1

External Demonstration

TMI Requires a New Competency

In order to be able to obtain the TMI Equipment and Revive you must hold the new Lantra Level 3 Award in TMI

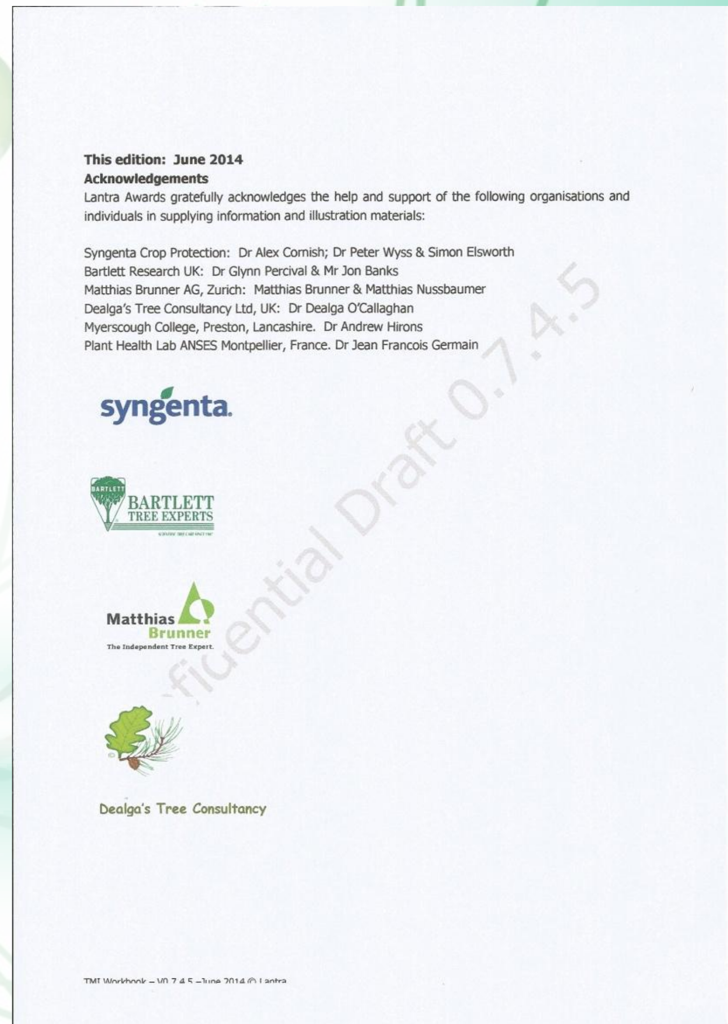


AWARDS

LANTRA AWARDS

Control of Tree Pests and Diseases by Tree Micro-Injection (QCF) Level 3

Workbook



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syngenta

BARTLETT TREE EXPERTS

Matthias Brunner
The Independent Tree Expert.

Dealga's Tree Consultancy

Lantra Level 3 Award in TMI

Prerequisites

Must be over 18 years of age and hold The Safe Use of Pesticides and Hand Held Applicators (in or near water) qualification or equivalent, i.e. NPTC PA6A.

Must demonstrate that they are able to identify a wide range of native, naturalised and introduced tree species (both broadleaf and coniferous) in the landscape, forest, urban forest and woodland; in both summer and winter.

Should also have undertaken training in VTA, (visual tree assessment) and/or the Lantra Awards Professional Tree Inspection and be aware of how to assess trees for risk.

Ideally should be working in Arboriculture or Forestry

Lantra Level 3 Award in TMI

The Award requires attendance at a two day training course

<u>Part A Day1</u>
Session 1 Legislation
Session 2 Indigenous & Invasive Tree Pests and Diseases, Specifically Horse Chestnut Leaf Miner and Oak Processionary Moth
Session 3 Tree Biology, Health & Vitality
Session 4 Tree Protection

<u>Part B Day 2</u>
Session 1: Tree Micro-Injection
Session 2: The Tree Micro-Injection Process (including the Process for Palm Trees)
Session 3: Cleaning the equipment
Session 4 Record Keeping

PART A - Session 3 – Tree Biology, Health and Vitality

Purpose and aim

To provide knowledge on the anatomy of wood and how trees grow and defend themselves. To be able to recognize the signs of stress and strain in trees; to be able to differentiate between the concepts of stress and strain; and the equipment that is available to measure stress in trees.

Learning outcomes

On completing this session, you will be able to:

•Describe the anatomy of wood; differentiate between diffuse, and ring porous woods, and conifer woods.
•Understand compartmentalisation of decay in trees (CODIT)
•Recognise the signs of stress and strain in trees and use existing equipment and methodologies to test the levels of stress in trees
•To be able to decide when trees should and should not be treated;

PART A - Session 4 – Tree Protection

Purpose and aim

To understand the history of tree protection; to differentiate between chemical and biological methods of protection; and to describe the various methods of treatment for tree pests and diseases; for example, foliar sprays, soil drench / injection, stem paints, and tree injection including TMI.

Learning outcomes

On completing this session, you will be able to:

- Describe and critically compare the methods, their efficacy and tools available for the protection of trees from pests and diseases
- Describe the Attract and Kill Concept
- Understand the Allee effect / approach

Control / Eradication of OPM & HCLM in the UK?

The Allee Effect is based on population dynamics. It holds where the population density is low.

Newly established populations when detected at low density are most susceptible to eradication.

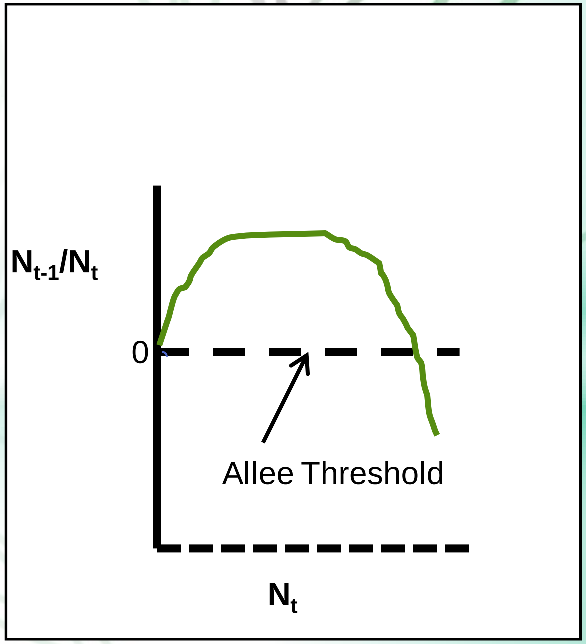
Individuals within a species generally require the assistance of others for more than simple reproductive reasons in order to persist. The level at which this happens is termed the **Allee Threshold**.

Applying the **Allee** population dynamics to pest control, means that not every individual in the pest population has to be killed in order to achieve eradication of the pest population.

Control / Eradication of OPM & HCLM in the UK?

All pest populations require a minimum number of individuals in order to be viable and therefore it follows if a pest control programme can drive the population below this Allee threshold, eradication of the pest is possible without having to track down and kill every last individual.

A strong Allee effect where the change in population density $\mathbf{N_{t+1}/N_t}$ is plotted against the initial population $\mathbf{N_{t.}}$ (Source; Suckling *et al.* 2012)



Control / Eradication of OPM & HCLM in the UK?

Given the relatively low OPM population levels in London and Pangbourne it might be possible to eradicate this pest using a process that would drive the population levels below the Allee threshold and effectively eradicate it.

The **Allee effect** can be achieved using an IPM approach and a discussion of these can be found in:

Suckling, D M, Tobin, P C, McCullough, D M and Herms, DA (2012): *Combining Tactics to Exploit Allee Effects for Eradication of Alien Insect Populations*. Journal of Economic Entomology 105 (1): 1-13.

Eradication of HCLM is not really possible given the severity of the outbreak in Britain; but control is possible by treating high value amenity trees and in the longer term combining this with biological controls in the wider environment.

Control / Eradication of OPM & HCLM in the UK?

Allee Implementation in SLAM (Slow Ash Mortality)[1]

An evaluation of the potential of a recently developed systemic insecticide to protect ash trees in the urban population as a component of the SLAM approach. Over a 10 year time period, the simulations showed that the survival of ash was variable and depended on:

(1) how soon the insecticide treatment began after EAB was detected;
(2) the proportion of trees treated; and
(3) the distribution of treated trees relative to the location where EAB was introduced.

It was found that by treating **20%** of ash trees each year, this protected **99%** of the ash trees annually over 10 years. Significantly the cumulative costs of pesticide treatment were significantly lower than the cost of removing dead or declining trees.

The effects of treating 20% of the ash trees with insecticide had the effect of driving the EAB population below the Allee threshold such that it was effectively eradicated

[1]McCullough, D & R Mercader (2012) Int. J. Pest Management 58: 9-23

Control / Eradication of Tree Pests?

<u>Two Success Stories</u>:

In 2012 a breeding population of Asian Long Horn Beetle (ALB) was found near Maidstone, Kent, England.

Rapid action by the authorities involved the survey of 4,700 potential host trees and the removal of 2,166 trees

66 trees were infected

No other trees have been detected since then

The discovery was made before the adult ALB emergence period

Control / Eradication of Tree Pests?

Boston, USA

ALB was recorded in Worcester, Massachusetts in 2008 and 34,000 tree were destroyed

In 2010 it was recorded opposite the Arnold Arboretum in Boston posing a severe threat to the collection and other trees in the area

Using the Allee approach; injecting strategic trees with Revive and selective tree removal; ALB was declared eradicated in May 2014

www.news.harvard.edu/gazette/story/2014/05/beating-the-beetles

New and Effective Plant Protection Product & Mode of Delivery to Control Tree Pests & Diseases

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