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

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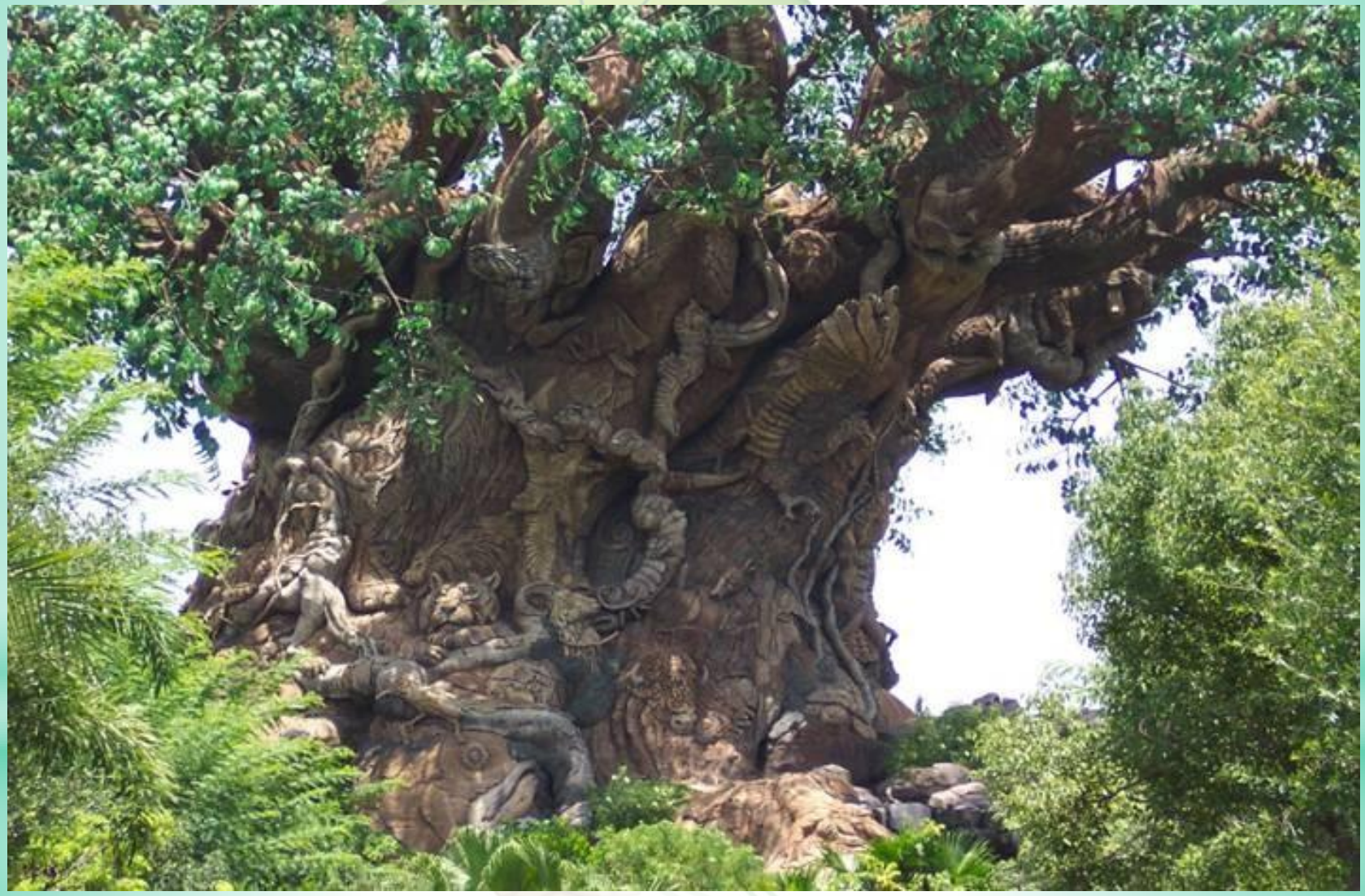
Trees - Why We Need Them - Why We Like Them - Why We Value Them

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.

Some People Worship Them



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 value of **US$6.8 billion** on the air pollution that trees remove annually, (Nowak *et al*. 2014).

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 million** in annual pollution-related health care costs.

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 Pests & Diseases attack our trees 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]

Existing Threats

Possible future introductions

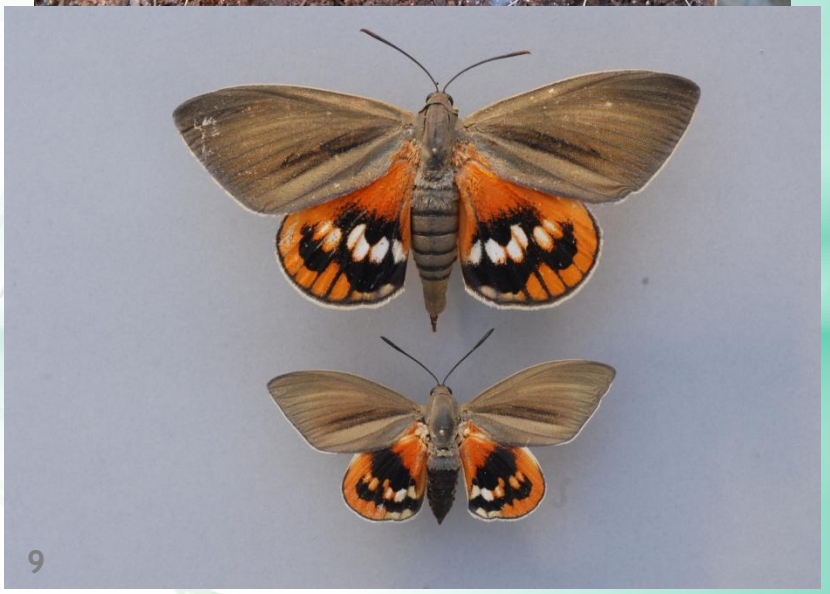
* **Emerald ash borer** (*Agrilus planipennis*) **[EAB]**
* **Spruce bark beetle** (*Ips typographus*)
* **Citrus longhorn beetle** (*Anoplophora chinensis*) **[CLB]**
* **Plane wilt disease** (*Ceratocystsis platani*)
* **Pine processionary moth** (*Thaumetopoea pityocampa*) **[PPM]**
* **Pine Wood 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 in Richmond, West London;
Also confirmed in Pangbourne, Berkshire; in 2014 it has spread to the buffer zone around the epicentre in Richmond.

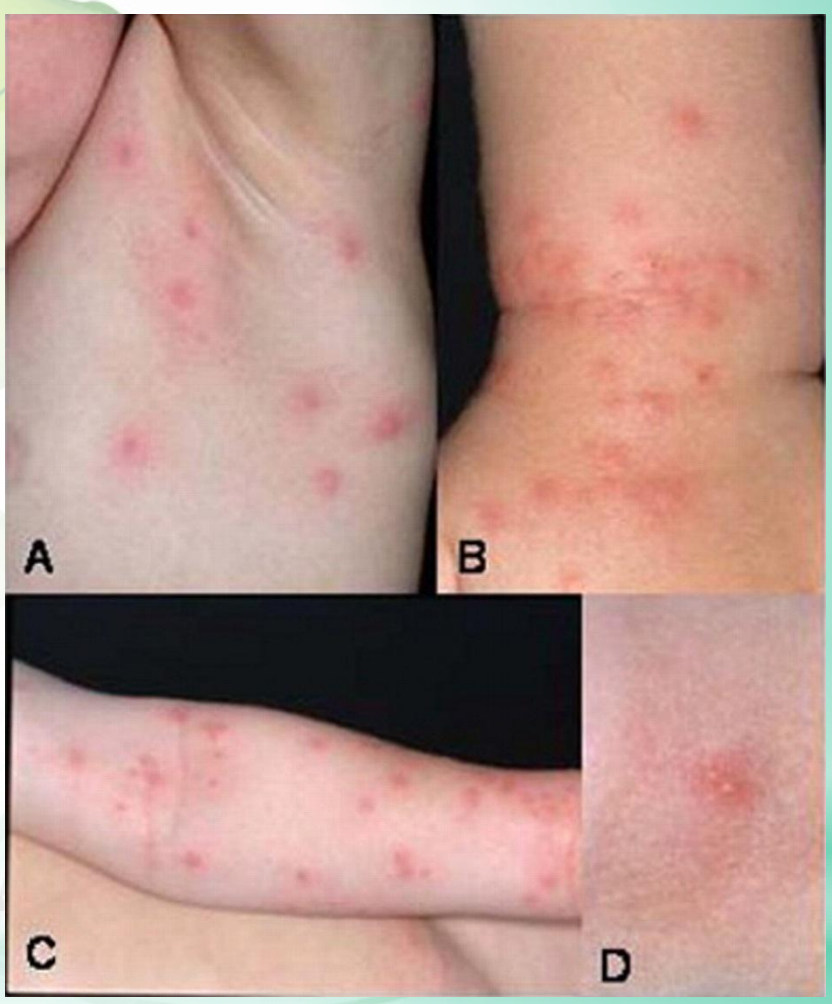
Adults Fly July to September

Eggs laid July - September

Larvae present April to June

Pictures from the Forestry Commission

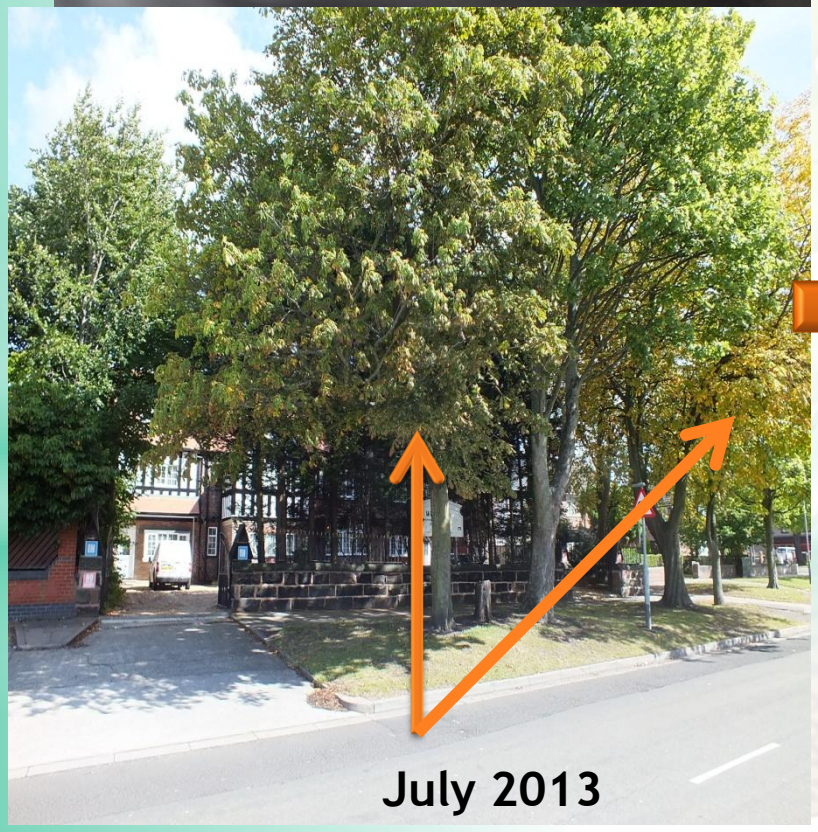
OPM is a Risk to Human Health



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
(Not just a cosmetic issue!)

Early Leaf Fall – July/August

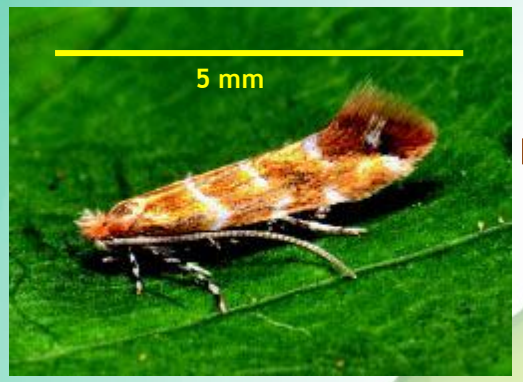
Reduced number of conkers

Conkers smaller than average

Up to 25% of conkers not viable

Energy Reserves Reduced (40%)

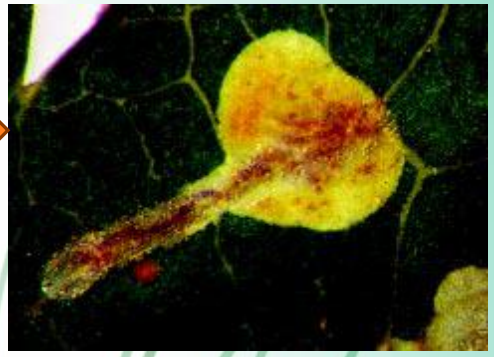
Trees less able to deal with other infections such as bleeding canker; *Phytophthora* or *Armillaria*.



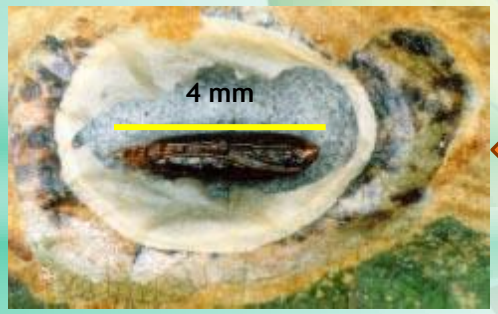
Adults Present from April Onwards

Eggs laid May to August

Newly Hatched Larva



5 Larval Instars (4 Weeks)

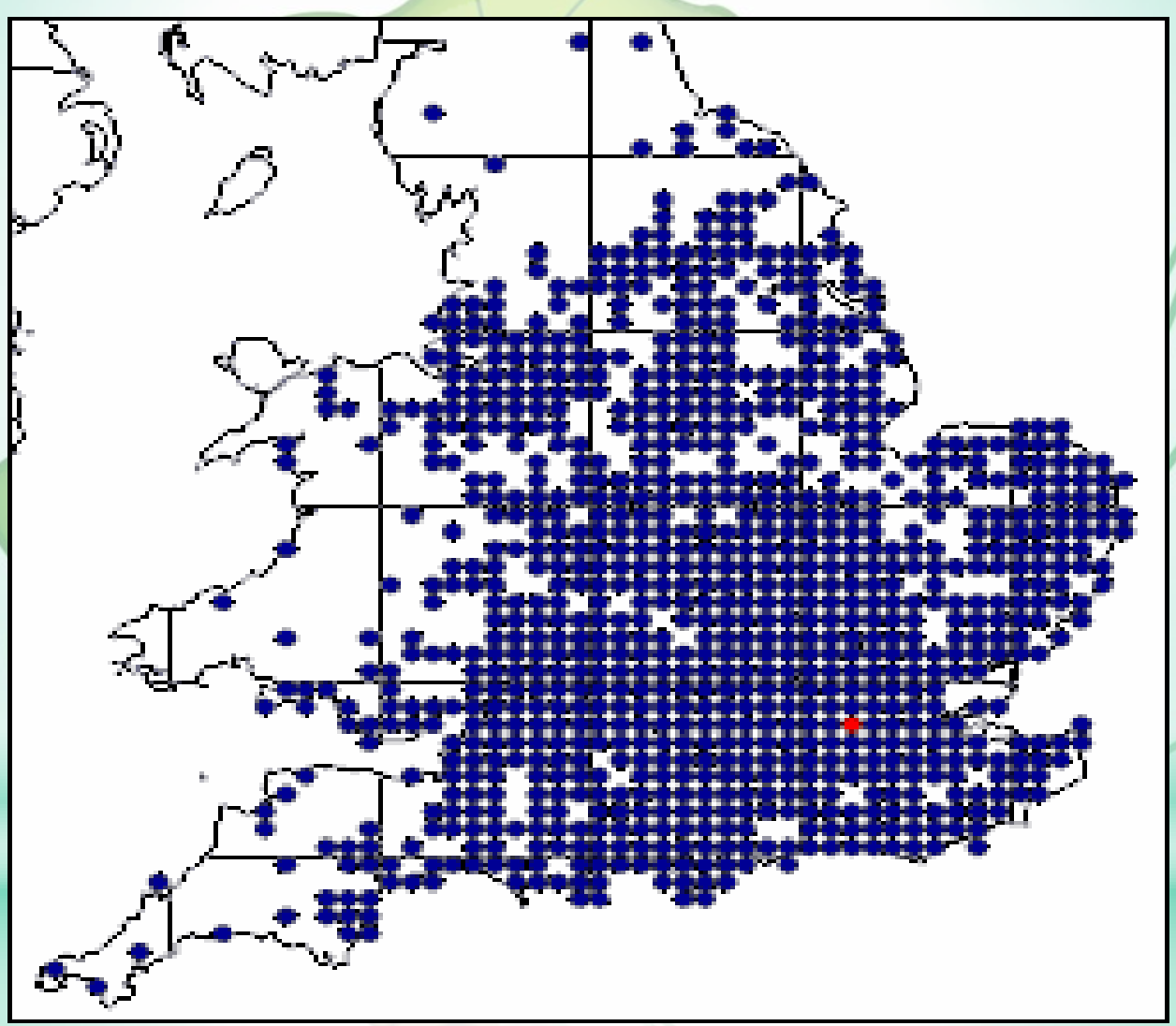


Pupa in a Silk Cocoon (2 Weeks)

HCLM can have up to 5 overlapping Generations per year

Pictures from the Forestry Commissions

HCLM Spread Since Introduction in 2002



www.forestry.gov.uk

Controls - Tree Protection

What have we got? What is Available?

1. Chemical & Biological Controls

2. Integrated Pest Management (IPM)
   (a) Attract & Kill
   (b) Natural enemies?
   (c) Biological Pesticides
   (d) Chemical Pesticides

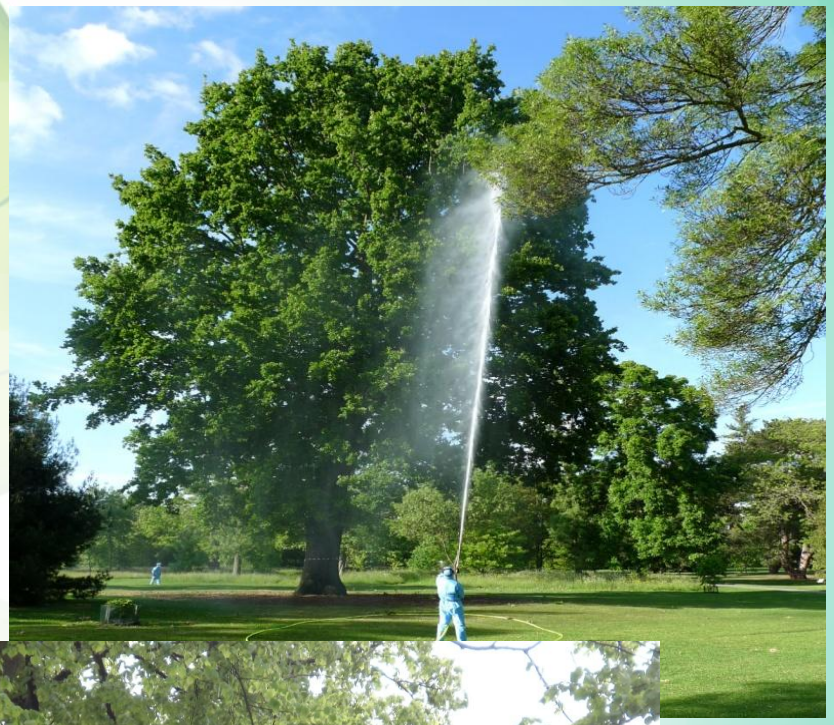
Chemical Controls in IPM programmes is the best way for trees in the short to medium term.

Very long term – Tree Breeding

Tree Protection - Soil Injection

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

Loss of some product to the soil – possible groundwater contamination



Tree Protection - Foliar Spray

Tree Protection – Systemic Injection

Pressurised Capsules
Here applying a Fungicide

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**.

Nematodes, fungi, bacteria and viruses have all been used at one time or another to control insect pests.

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;
- Dipel DF *Bacillus thuringiensis* – In use against OPM in Holland;
- Entomophagous fungi;
- Diflubenzuron and Deltamethrin.

Combined Biological & Chemical Control Measures – **Integrated Pest Management**

A New Plant Production Product

Emamectin Benzoate (EMB)
Derived from the naturally occurring avermectin insecticide.

Refined into a highly effective targeted option.

The formulation is 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.

EMB moves rapidly into the leaf and crown and targets pest activity.

Approved for use in Switzerland for *C. ohridella* (HCLM) in 2012

Recently (April 2014) Approved in France and Emergency Approval in Spain for Red Palm Weevil; Approved in Portugal in 2013 & Japan for Pine Wood Nematode; Approved in the USA for Emerald Ash Borer

Currently with CRD for Approval for use in the UK for control of OPM and HCLM

Research trials of its efficacy against OPM and HCLM in Britain have been ongoing for 3 years under an experimental licence from CRD.

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 emamectin benzoate at various doses & formulations.

OPM Trials at Barnes Common in London

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

Untreated control
Water treated 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

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

Barnes Common OPM Trials

Influence of EMB formulations A16297A and A19308B 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	-
A19308B 0.02g	0.5b	0	1.0b	0
A19308B 0.04g	0.0a	-	0.0a	-
A19308B 0.08g	0.0a	-	0.0a	-
A19308B 0.16g	0.0a	-	0.0a	-

HCLM 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.

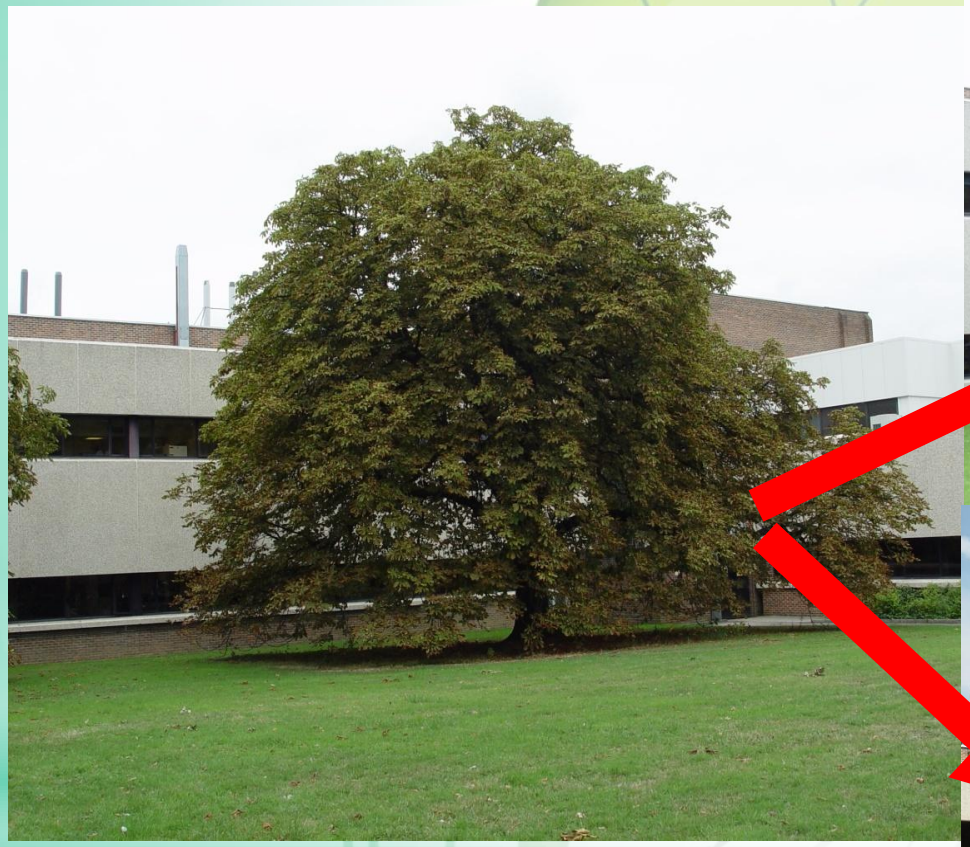
Cameraria Trials at Greenwich

Influence of EMB 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



EMB 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 EMB 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.

Tree Injection - Concerns

Potential Side Effects of Tree Injection

Drilling the injection holes causes wounds – entry points for decay organisms;
Drilling could breach existing CODIT Barriers in broadleaves and conifers;

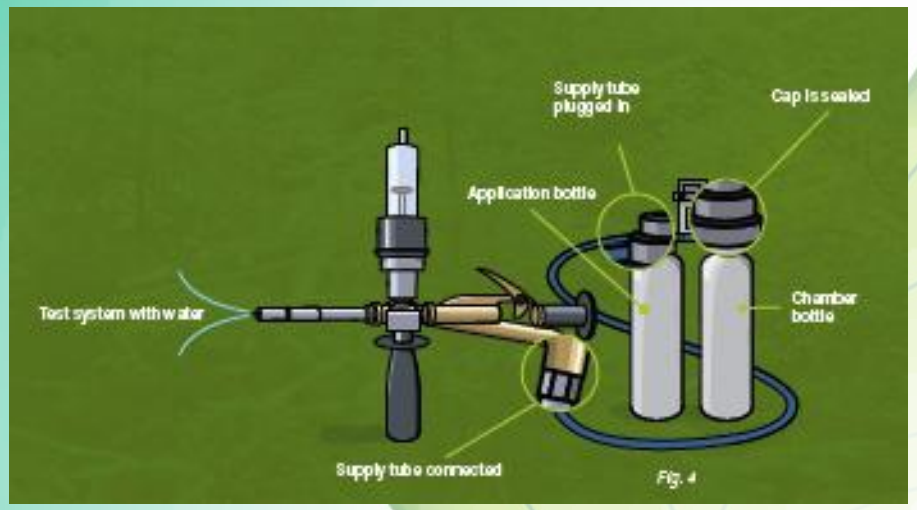
A balanced decision has to be made based on the health and vitality of the tree and the severity of the pest / disease infestation / infection.

Other potential side effects include:
- Suppurating Wounds
- Phytotoxicity
- Negative effects on non-target species
- Safety, Health & Environment

Suppurating wounds and Phytotoxicity should not occur unless the product is applied in the wrong concentration or applied incorrectly

This emphasises the need for proper training in tree injection

These and all other safety, Health and Environment (SHE) concerns are addressed by the Regulatory Authorities prior to granting approval for a plant protection product



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

Tree Micro-Injection (TMI®) - Steps

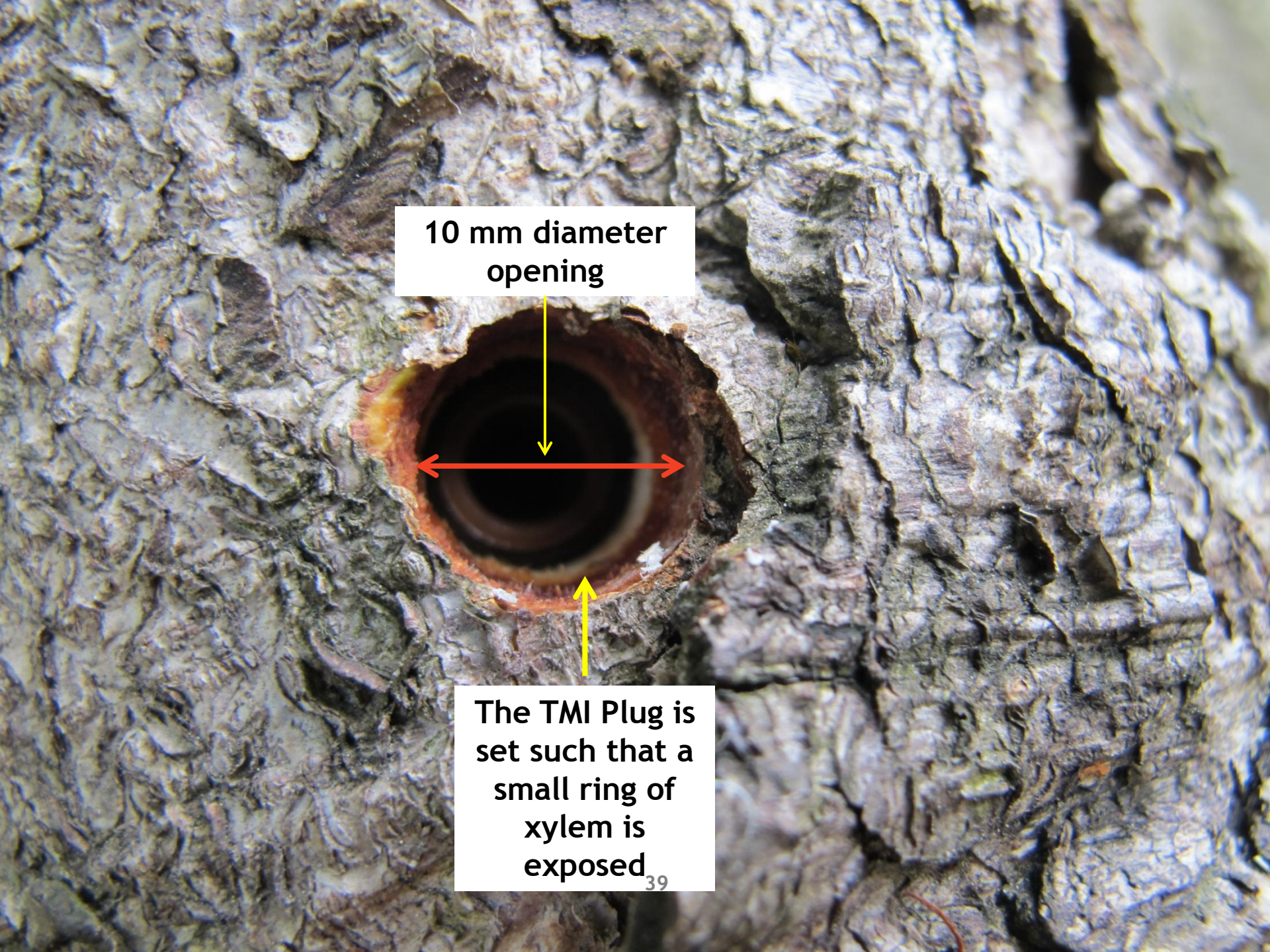
1. Drill injection points 1 per 5cm dbh; 2.5-4cm deep

2. Syngenta Plugs (Biodegradable)

5. Inject the Product

3. Plug Setter

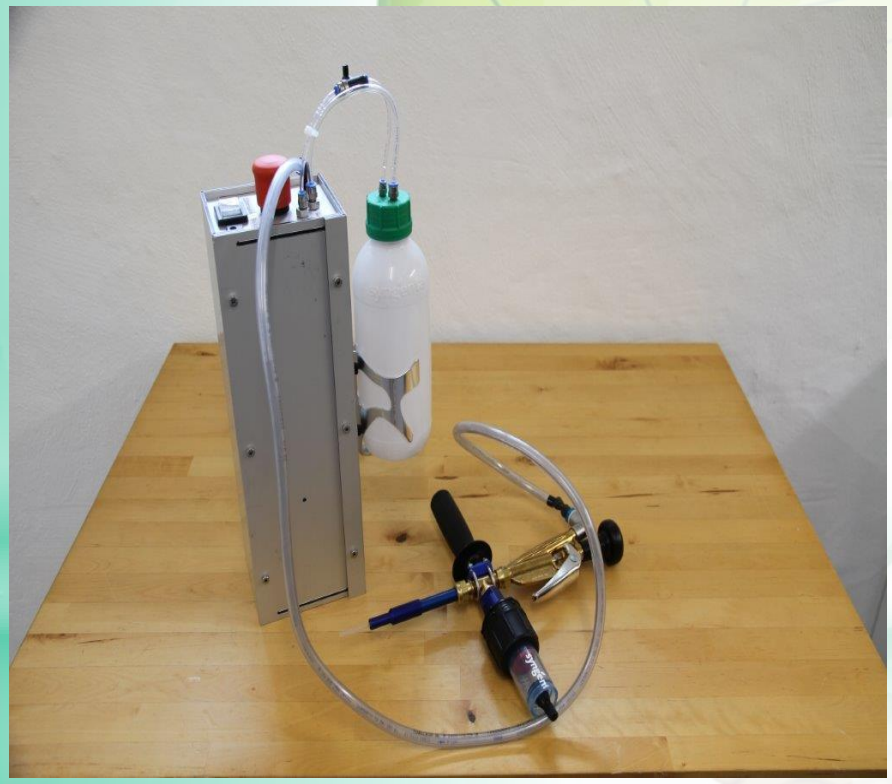
4. View of Set Plug


10 mm diameter opening
The TMI Plug is set such that a small ring of xylem is exposed

EMB – TMI® Steps – Final Injection

Second Generation EMB Application Device: Closed system

Functional Mark 2 TMI Kit



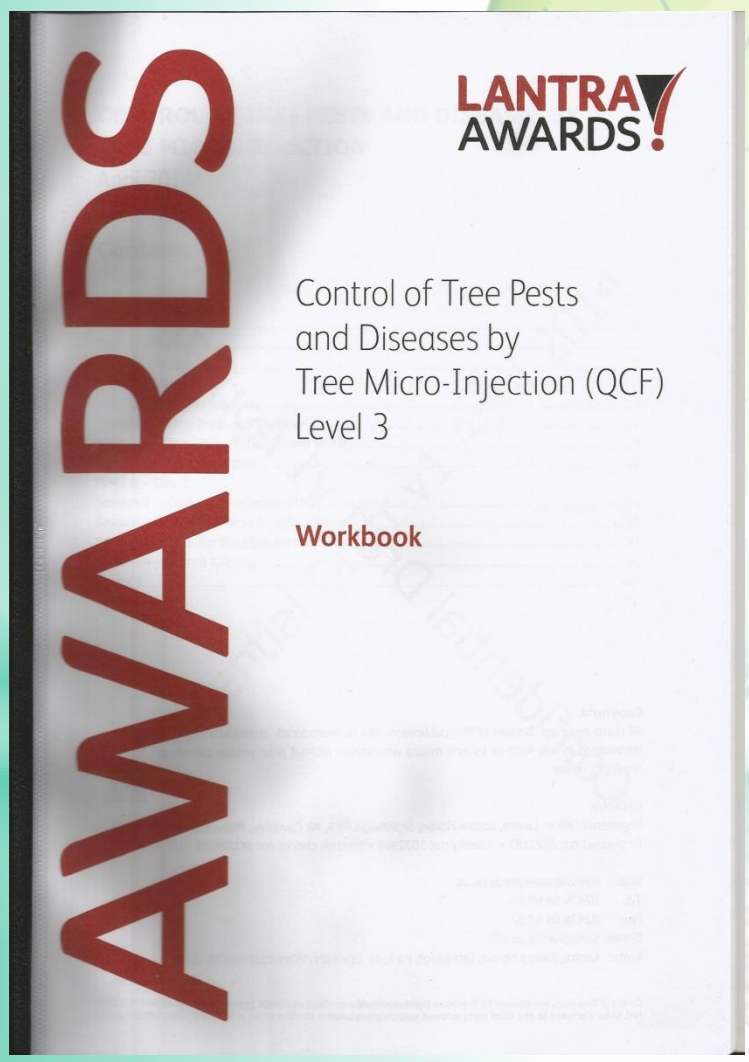
- A battery powered electric pump sucks the product from product bottle
- The pump continuously drives the product into the injector unit
- The equipment is very compact. It can be placed in a small back pack
- Several injectors can be connected for parallel injection in case of high dose rates
- The 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

TMI® Requires a New Competency

In order to be able to obtain the TMI Equipment and EMB you must hold the new 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

Part A Day1

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

Part B Day 2

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

Control / Eradication of OPM & HCLM in the UK?

Control of OPM is certainly possible using an IPM approach that would involve the use of BT and systemic injection of selected trees;

All affected oak trees would not, indeed could not be treated; but those of high amenity value and in closest proximity to locations used by the public could be treated effectively;

Similarly trees that become infected in the 'buffer zones' could be treated quickly and efficiently;

This would reduce population to some degree – one application of EMB provides control of OPM for a minimum of 2-years;

Using Dipel DF *B. thuringiensis* to treat trees in the heavily infested areas would assist in population reduction;

BUT this means that a planned coherent IPM approach is required!

Control / Eradication of OPM & HCLM in the UK?

Control of HCLM is possible but only on high value amenity trees in parks, open spaces, street trees, private gardens etc;

One application of EMB provides control for a minimum of 3-years and this would have an impact on the HCLM population;

It is not practical or cost effective to treat all the chestnuts in the wider environment;

However, if RBG Kew identifies natural enemies that could be introduced to the UK **safely** – then the combination of selective injection of the high value amenity trees and biological control by natural enemies in the wider environment, would provide a measure of control and reduce the pest population;

As with OPM a planned coherent IPM approach is required.

Control / Eradication of Tree Pests -Successes

Maidstone, Kent:

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 found to be infected

No other trees have been infected since then

The discovery was made before the adult ALB emergence period

www.forestry.gov.uk

Successful Control / Eradication of Tree Pests

Boston, Massachusetts:

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

In 2010 it was recorded opposite the Arnold Arboretum in Boston (50km east of Worcester) posing a severe threat to the collection in the arboretum and other trees in the area

Using a strategic target approach of selective felling of infested trees and injecting strategically selected trees with a systemic insecticide; ALB was declared eradicated in May 2014

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

Interestingly the arboretum staff did not want to use any chemical insecticide but the ALB eradication policy of the US Department of Agriculture (USDA) compelled them to do so, which proved to be the correct approach

Anything is possible when you have a coherent planned IPM Programme!

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

Acknowledgements

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Matthias Brunner
The Independent Tree Expert.

Matthias Brunner
Matthias Nussbaumer

Institute of Chartered Foresters
Registered Consultant

Expert Witness

ISA

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