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

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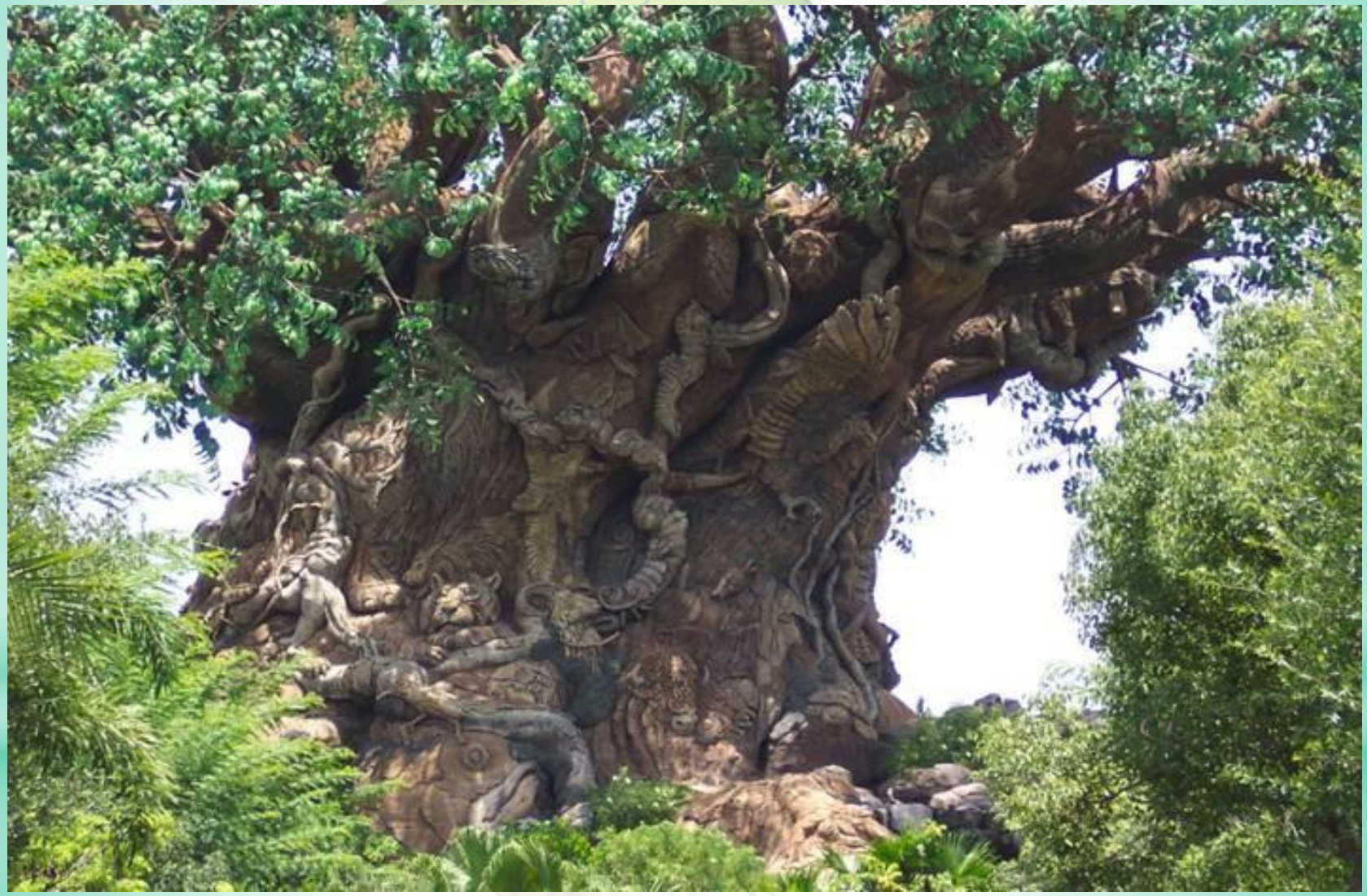
Trees - Why We Need Them - Why We Like Them - Why We Value Them

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

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 - Clear & Present Dangers!

Possible future introductions

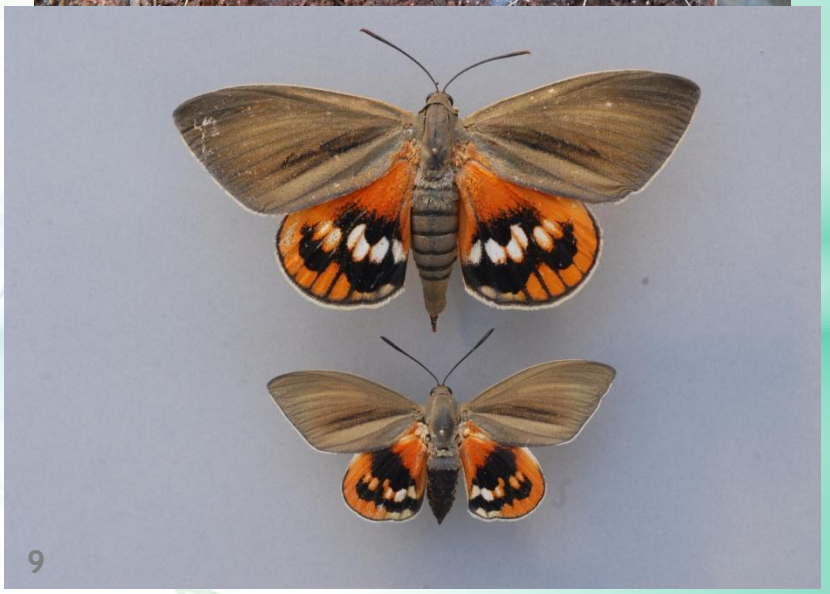
* **Emerald ash borer** (*Agrilus planipennis*) **[EAB]**
* **Spruce bark beetle** (*Ips typographus*)
* **Citrus longhorn beetle** (*Anoplophora chinensis*) **[CLB]**
* **Plane wilt disease** (*Ceratocystsis platani*)
* **Pine processionary moth** (*Thaumetopoea pityocampa*) **[PPM]**
* **Pine Wood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



Immediate Threats to Ireland's Trees

Ireland's Trees enjoy a relatively low level of pests and diseases ...BUT

Oak Processionary Moth – on imported nursery stock + Tourist Introductions

Pine Processionary Moth – Ditto

Pinewood Nematode – Timber (detected on timber from Canada in 2007)

Asian / Citrus Longhorn Beetles – Pallet Wood & Timber

Emerald Ash Borer – Pallet Wood, Timber, Firewood etc.

We should view these as not if, but when?

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.

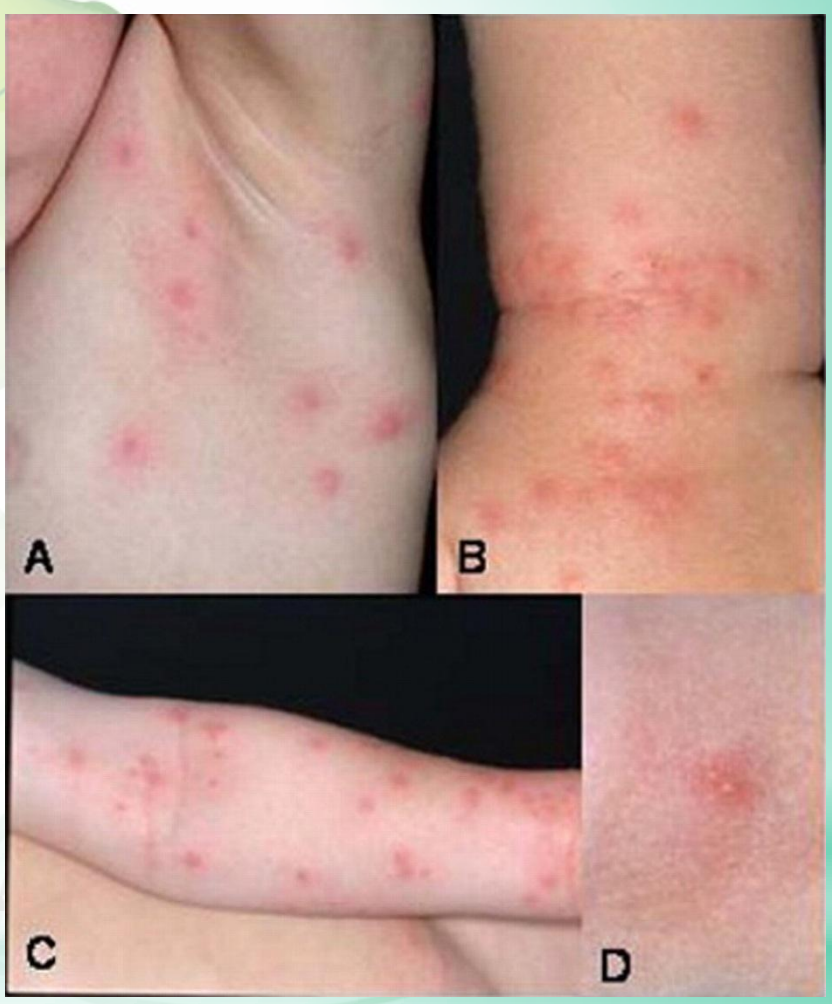
Adults Fly July to September

Eggs laid July - September

Larvae present April to June

Pictures from the Forestry Commission

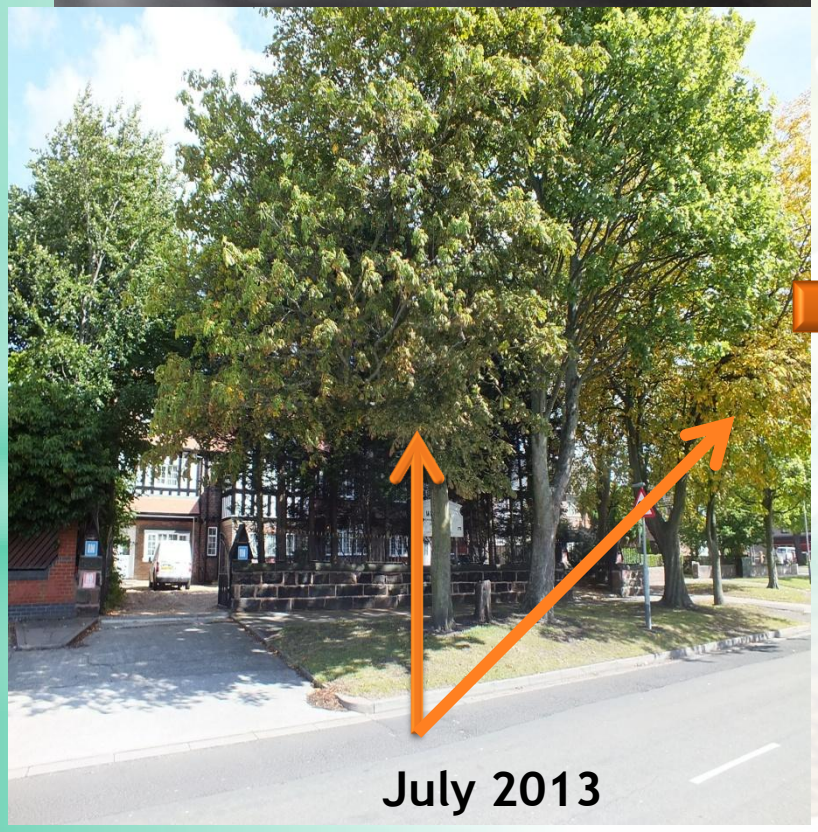
OPM is a Risk to Human Health



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

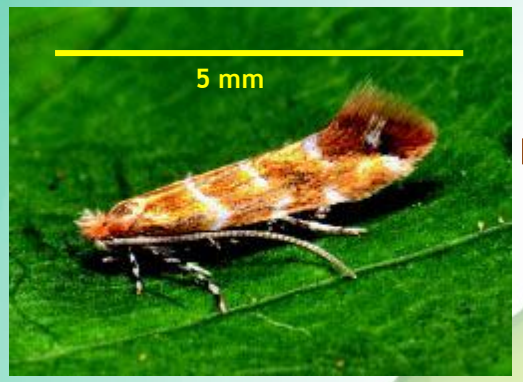
Reduced number of conkers

Conkers smaller than average

Up to 25% of conkers not viable

Energy Reserves Reduced (40%)

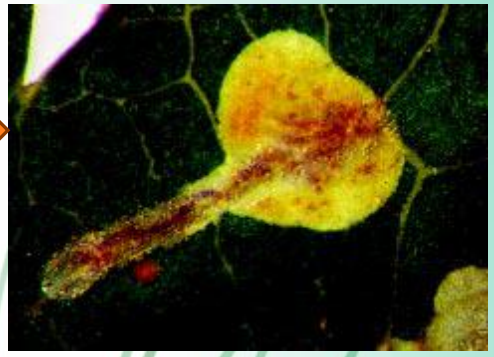
Trees less able to deal with other infections such as bleeding canker; *Phytophthora Armillaria* etc



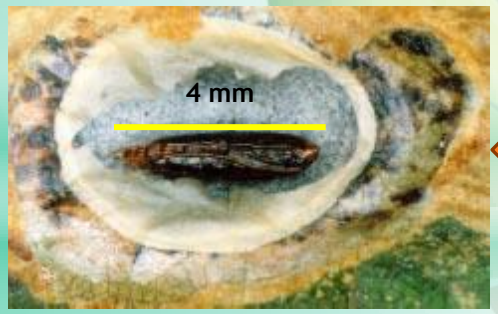
Adults Present from April Onwards

Eggs laid May to August

Newly Hatched Larva



5 Larval Instars (4 Weeks)



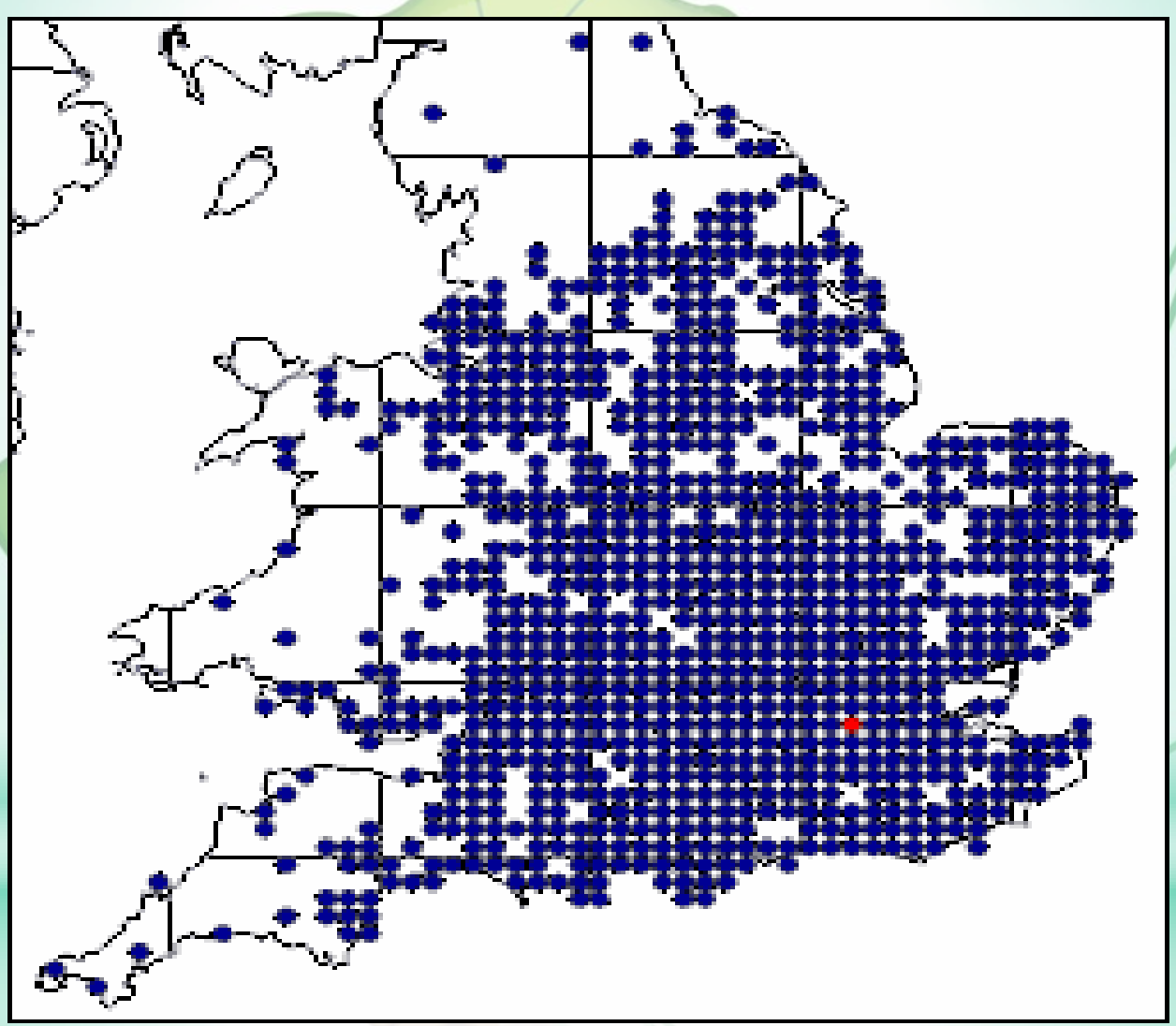
Pupa in a Silk Cocoon (2 Weeks)

HCLM can have up to 5 overlapping Generations per year

Pictures from the Forestry Commissions

Phoenx Park Dublin May 2015

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.

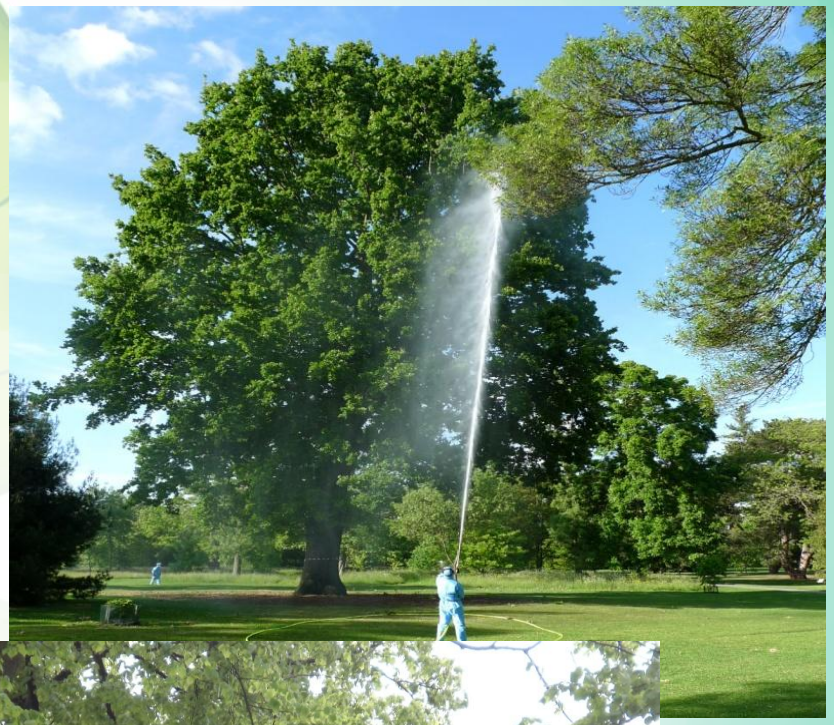
Very long term – Tree Breeding

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

Likely to be banned in the UK & EU



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, 2014 & are Ongoing in 2015

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 - 2014 & 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.

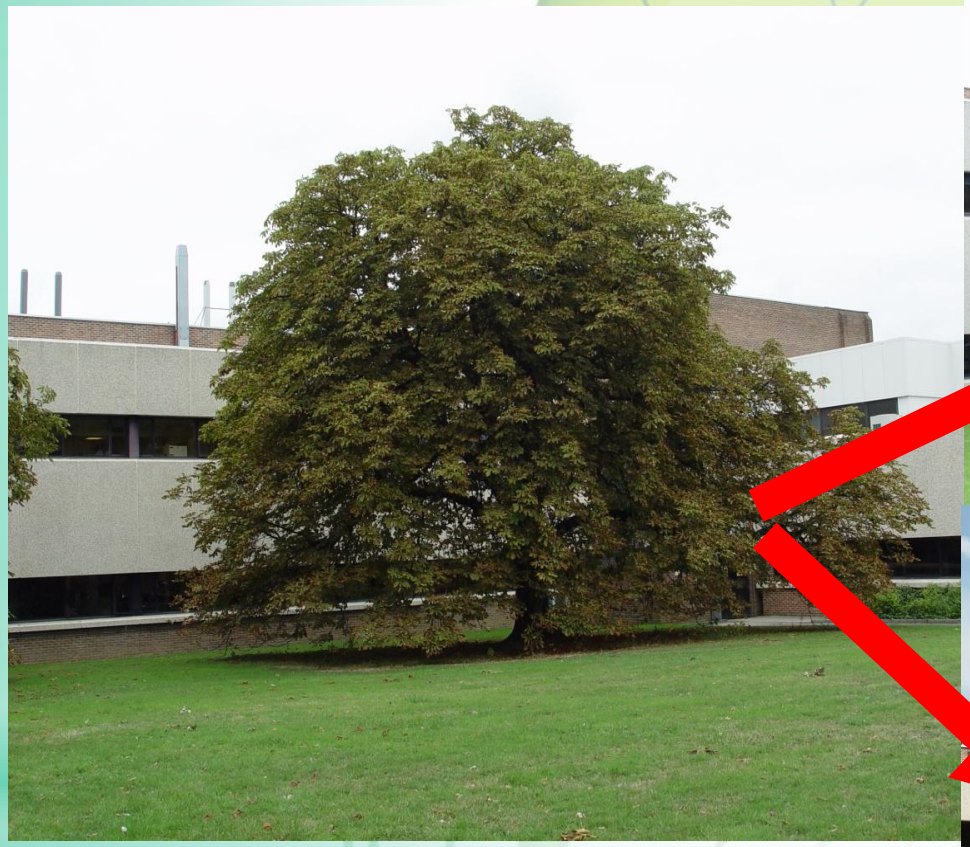
Cameraria Trials at Greenwich

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.

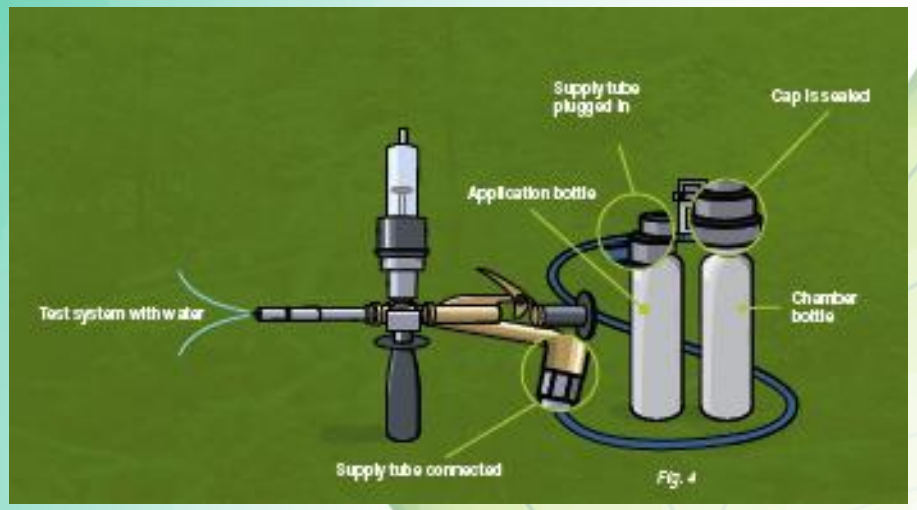
Other potential side effects include:
- Suppurating Wounds
- Phytotoxicity
- Negative effects on non-target species
- Safety, Health & Environment

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

The Syngenta TMI process is a 'closed' system and the dose is pre-set.



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

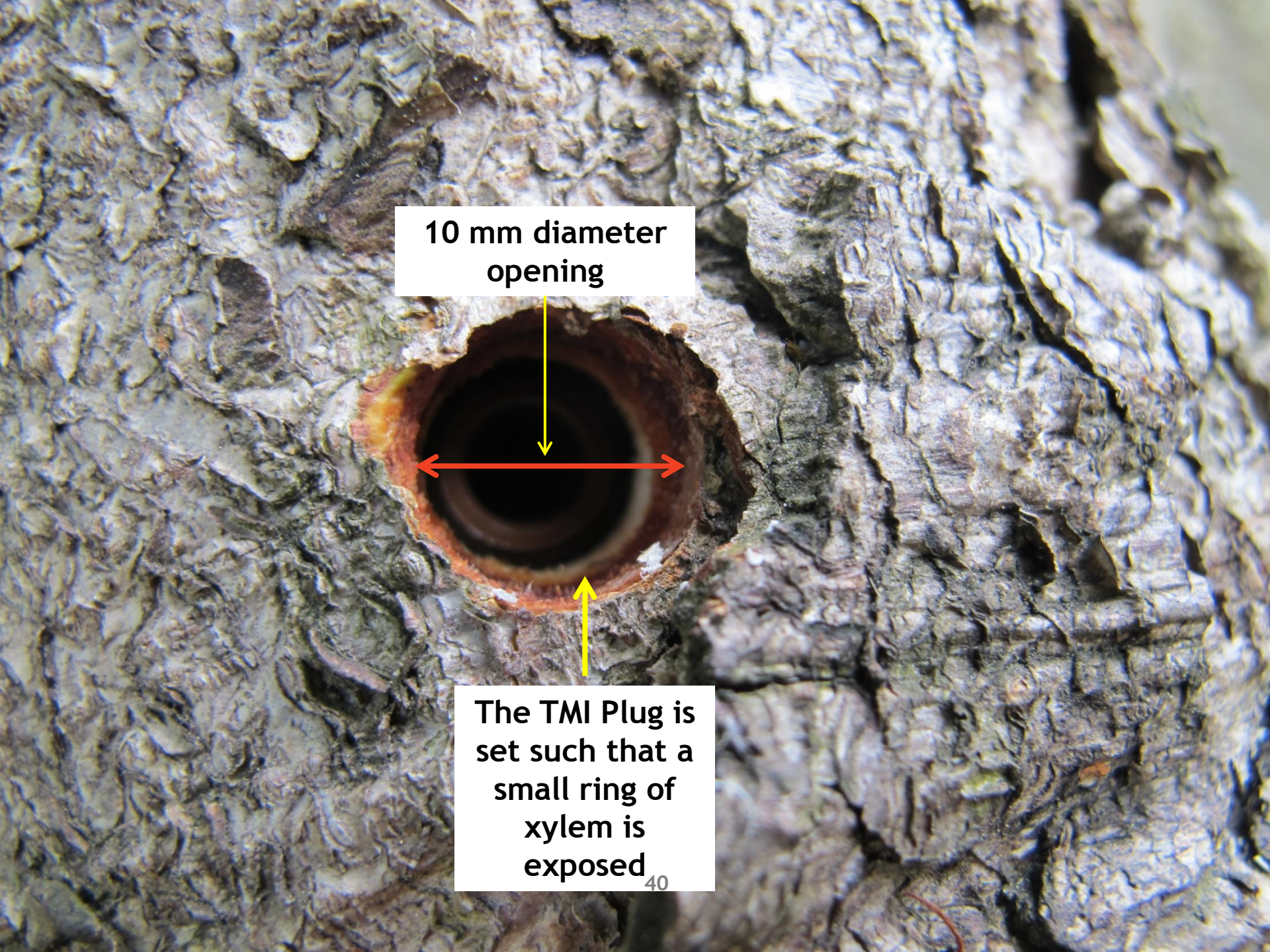
1. Drill injection points 1 per 5cm dbh; 2.5-4cm deep

2. Syngenta Plugs (Biodegradable)

5. Inject the Product

3. Plug Setter

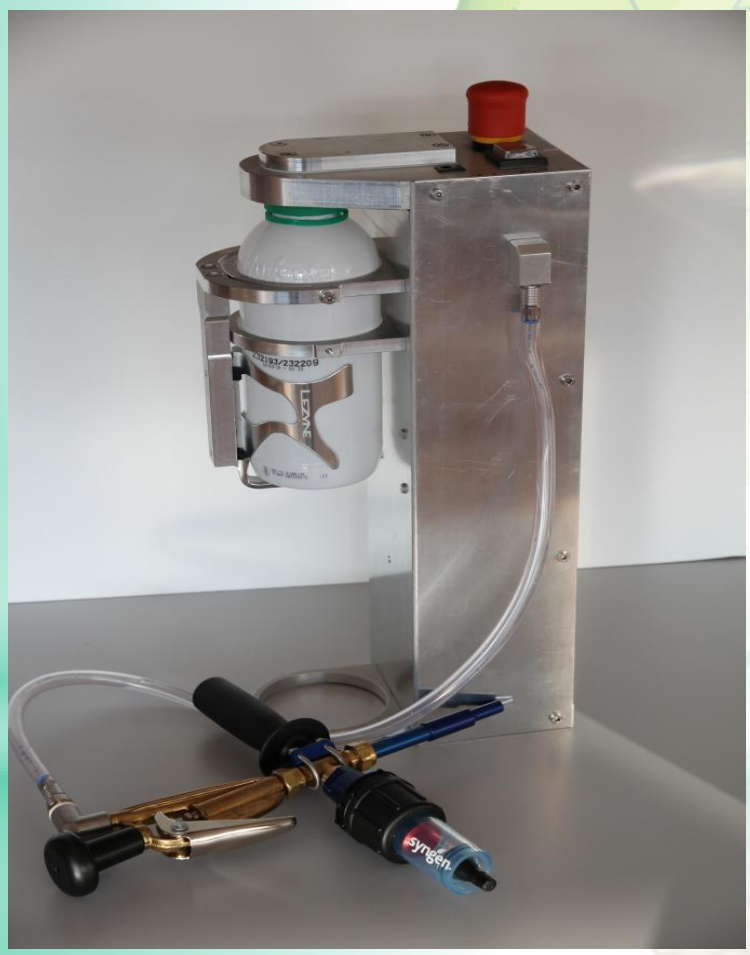
4. View of Set Plug


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

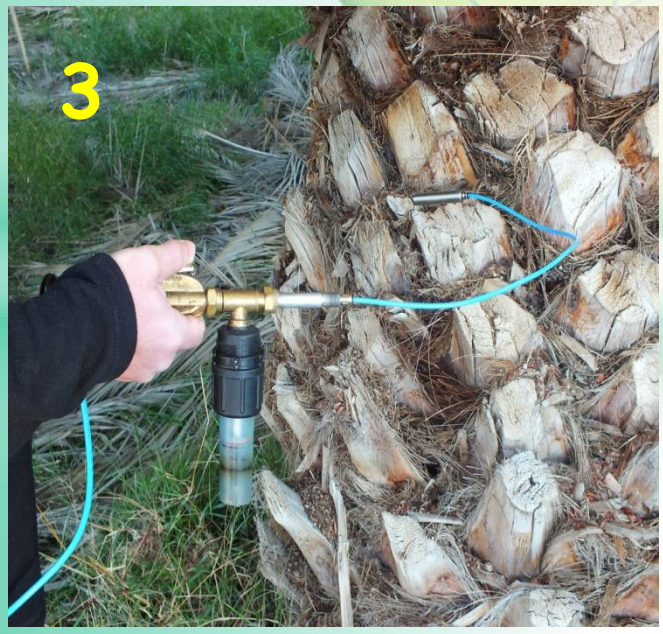

Z32193/232209
syngen


Z32193/232209
syngen

Mark 2 Prototype

Delivery to the tree is the same as the Mark 1

TMI of Palm Trees - The Final Delivery is Different



1. Drill 4 holes 20cm-25cm deep
2. Insert the custom designed injector head
3. Deliver 2 x 6ml doses to each hole
4. Cap the holes when complete

Control / Eradication of OPM & HCLM?

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 the population to some degree – one application of EMB provides control of OPM for a minimum of 3 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?

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

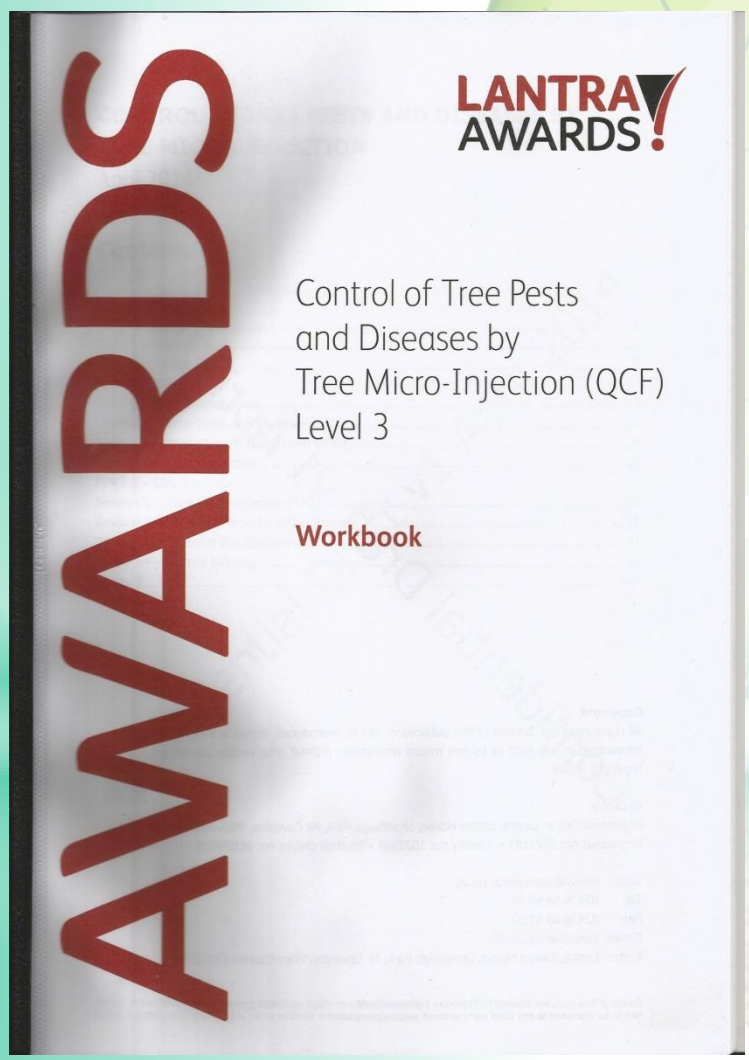
www.news.harvard.edu/gazette/story/2014/05/beating-the-beetles

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!

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



EU Directive 2009/128/EC '*Framework for Community action to achieve the sustainable use of pesticides*' Specifically

Chapter II '*Training, Sales of Pesticides, Information and Awareness-Raising*' of which Article 5 deals with '*Training*' and Annex 1 deals with '*Training subjects referred to in Article 5*'

In the UK this has led to the '*Sustainable use (Plant Protection Products) Regulations 2012*' (SI 2012: 1657)

Training is a legal requirement of the EU Directive across all Member States

Award Structure

The Award consists of two distinct parts:

1. **Science & Knowledge** (Day 1)
2. **Practical Training** (Day 2)

Pre-Requisites:

Before being eligible to train and be assessed for this Lantra L3 Award in TMI learners:

Must be over 18 years of age

Must hold PA1 & PA6a or the equivalent Lantra Awards in application of pesticides.

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

Should also have undergone training in VTA, (visual tree assessment) and be aware of how to assess trees for risk, (Tree Risk Assessment); i.e. the Lantra Tree Professional Tree Inspection (PTI) Award.

Award Structure

Part A Day1

Session 1 Legislation

Session 2 Indigenous & Invasive Tree Pests and Diseases

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

Session 3: Cleaning the equipment

Session 4 Record Keeping

Objectives

The course and the professional training, will give learners the information to be able to:

1. assess tree vitality;
2. diagnose which pest or disease is affecting the tree(s);
3. select the appropriate plant protection product;
4. calculate the dose required; apply the product to the tree using the TMI technique;
5. prepare, maintain and repair the TMI equipment;

All with minimum risk to yourself, colleagues, the general public, and non-target species.

PART A - Session 1 - Legislation (Ireland)

Learning outcomes

* Describe the legislative structure
* Describe the regulations relevant to the use of pesticides
* Be aware of local regulations

Destructive Insect Pests Act 1958 & 1991

EU Plant Health Directive 2000/29/EC

EU Decision 2006/133/EC – Measures to limit the spread of pinewood nematode

EU Directive 2009/128/EC Framework for Community action to achieve the sustainable use of pesticides

EU Directive on The Conservation of Habitats and Species

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

Learning outcomes

* 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 B - Session 2 - The Tree Micro-Injection Process

Learning outcomes

Understand the product label(s)

Check that the product is authorised / licensed for use

Identify if a product is counterfeit

Operator Exposure, Symptoms, First Aid & Emergency Treatment

Calculate the dosage required

Prepare the tree micro-injector(s)

Drill the injection holes and insert the plugs

Operate the tree micro-injector without risk to yourself, other people and the environment

Product Label

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

- The trade name of the product, e.g. Revive®, Pursue®, Tree-age®
- 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).

Authorised Products

In Ireland the Pesticides Registration and Controls division of the Department of Agriculture, Food and the Marine Guidance maintains a list of approved plant protection products on a searchable website

www.pcs.agriculture.gov.ie/products/

Counterfeit Products

If it is suspected that a product is counterfeit it can be checked using the 'PCS' 'product registration database' which contains a list of all authorised products.

Revive® - General safety and environmental information

- ❑WHEN USING THE PRODUCT DO NOT EAT, DRINK, OR SMOKE
- ❑KEEP IT AWAY FROM FOOD, DRINK AND ANIMAL FEEDSTUFFS
- ❑KEEP OUT OF THE REACH OF CHILDREN
- ❑DO NOT CONTAMINATE WATER WITH THE PRODUCT OR ITS CONTAINER.
- ❑DO NOT CLEAN APPLICATION EQUIPMENT NEAR SURFACE WATER
- ❑DO NOT APPLY THE PRODUCT IN EXTREME WEATHER CONDITIONS

Effects of Exposure to the product

Some products can cause serious eye irritation, and may cause damage to organs through prolonged or repeated exposure if swallowed. Refer to the product label and safety data sheet

Personal Protective Equipment (PPE)

Hat/Helmet & clear face shield

Long sleeve work shirt / jacket

Nitrile Gloves

Work trousers

Knee Pads

Work Boots

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

Transport Between Work Sites

Mark 1 - The equipment must be de-pressurised using the three way release valve, before storing for transport.

Mark 2 – Turn the pump off and depressurise the injector lance

TMI Equipment and product bottles must be stored in separate spill proof containers.

Both sealed containers should be placed inside a larger spill proof sealable container in the back of the work vehicle.

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

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