



Sustainable management of apple orchards: canker, scab, replant

Dr Matevz Papp-Rupar,

NIAB, East Malling, ME19 6BJ



Today's Agenda

- **Apple canker** – *Neonectria ditissima*
 - Managing Infection cycle
 - Biocontrol
 - Soil amendments
- **Apple scab** – *Venturia inaequalis*
 - Inoculum sources / reduction practices
 - Novel control programmes
- **Apple replant disease** – multiple causes
 - Planting location
 - Rootstock rotation
 - Soil amendments



European apple canker - *Neonectria ditissima*

- **The problem:**

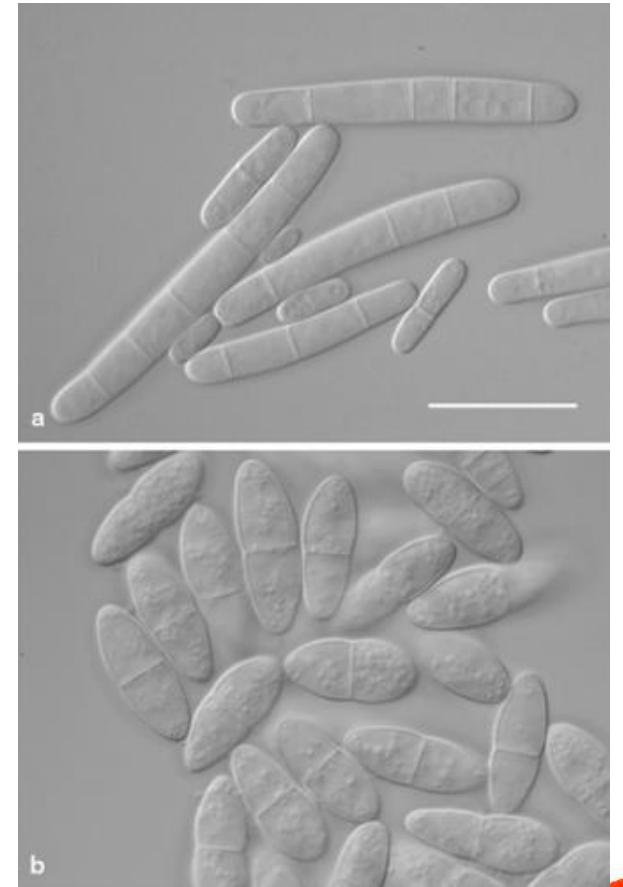
- **Killing trees** - up to 30% in the first 3yrs of newly planted orchards
- **Reducing yield, quality and orchard longevity**
 - Causing postharvest fruit rot

- **Commercial apple cultivars are highly susceptible.**

- High density planting

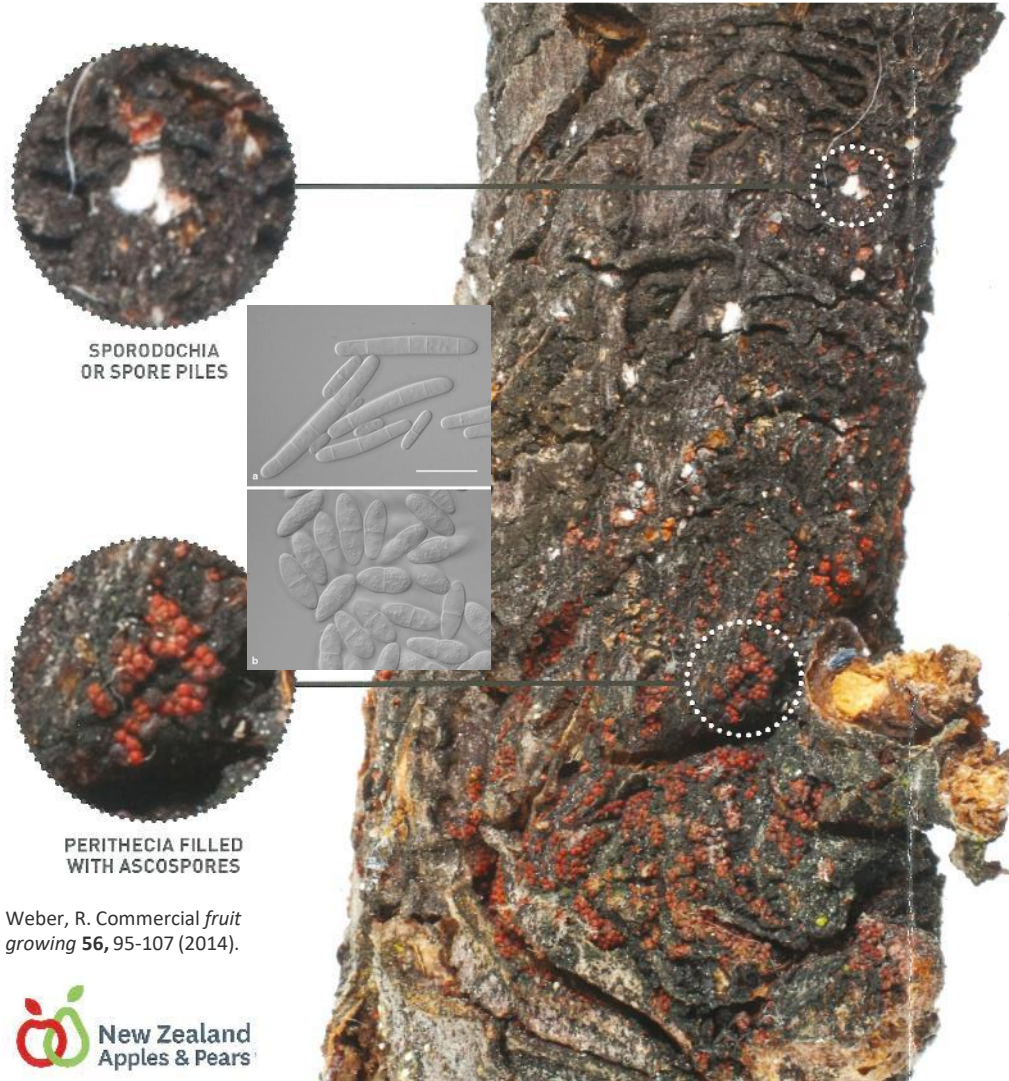
- Difficult to control:

- Reductions and bans of effective chemical products
- Timing issues (**leaf scars, picking wounds, rain...**)
- Orchard hygiene is labour intensive – expensive / unavailable
- Climate change



Weber, R. Commercial fruit growing 56, 95-107 (2014).

European apple canker – infection spread



SPOROCHIA
OR SPORE PILES

PERITHECIA FILLED
WITH ASCOSPORES

Weber, R. Commercial fruit
growing 56, 95-107 (2014).



INFECTION SOURCE = cankers on trees!!!

- **Conidia**

- produced on young and old cankers
- If you see canker → producing spores
- Rain splash dispersed
- Within and between neighbouring trees/rows

- **Ascospores = sexual stage**

- produced on old cankers
- 3-6+ months after infection
- wind dispersed! → long distance spread!

- **In NZ (UK) climate both spores are produced all year around!**

- 30 min of rain (2 mm) = 1000-10,000 spores per mm of canker length
- 5-10 spores required for infection!!!

- **Alternative inoculum sources:**

- Apple fruit, wind breaks, pruning material, nursery

European apple canker – infection spread

- **Infection points are wounds** → **present all year around!**
 - Pruning wounds
 - Petal scars
 - Growth cracks
 - Lenticels
 - Picking wounds
 - Leaf scars
- **Inoculum all year around + wounds all year round = constant chance of infection**
 - In UK climate: 1 canker in orchard will result in 100% trees with canker in 6-7 years if left completely unmanaged
 - Not necessarily true for Sweden



Photo: M. Papp-Rupar



Canker management

- **YOU CAN NOT SPRAY CANKER AWAY !!!!! !!! !!!**
 - No fungicide can kill cankers or stop them sporulating
 - 1 mm of canker = 1000 potential infections
 - Leaf scar protection is possible with Captan/Tebuconazole at high rate and water volumes (800-1000l/ha) if:
 - Timed correctly (20, 50, 80% leaf fall)
 - Low inoculum load
 - Scab sprays may partly control petal scar infections
 - Picking and pruning wounds are impracticable to target and protect



Photo: M. Papp-Rupar



Canker management - **CUT CANKERS OUT!**

WHEN to remove (any sunny day – never in the rain)

FOUR dedicated canker walks a year (in order of importance):

1) Pre-picking / during picking

- Removes inoculum for picking wounds and leaf scars

2) After harvest / pre-leaf fall

- Removes inoculum for leaf scars, pruning wounds and winter cracks
- In combination with leaf fall sprays for increased efficacy

3) Mid-winter tidy up

- Identify hot spots for spring walk
- 3 strikes you're out
- Use Pruning Paints to protect every cut

4) Spring clean

- Autumn infections will start to show at bud burst/flowering
- Can express as late as July



Canker management - **CUT CANKERS OUT!**

WHAT to remove



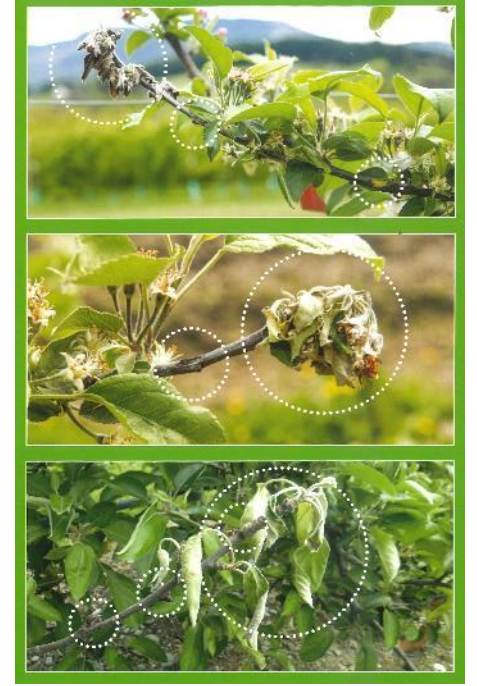
Look for
Small dark brown sunken area



Look for
Flaky bark on canker



Look for
Old cankers are black and sunken, with cracked rings



Extra training / supervision of staff

Canker champions

Hot spots marking

Canker bounty at low canker counts



New Zealand
Apples & Pears



Canker management - **CUT CANKER OUT!**

HOW to remove:



-  You must apply **commercial pruning paint** to all pruning cuts to kill spores
-  Always remove infected wood from orchard and burn. Cover until burnt
-  Routine tool hygiene required if pruning out **European canker**. If pruning out Fire blight at the same time, **you must** follow Fire blight sterilisation rules
-  Don't prune in the rain

- Protect all cuts
- Remove and destroy infected and healthy looking cuttings!!
 - chipping with commercial composting also effective
- Keep cuttings dry to prevent sporulation!
- Remove / grind out trunk cankers.
- Remove trees with more than 2-3 mainstem cankers
- Mark hotspots for easier monitoring

Other known management factors

Nutrition:

- **High nitrogen in the soil or as post-harvest foliar application will lead to increased canker.**
 - Addition of as little as 50kg/ha of urea as soil application will increase canker incidence and lesion size (Harteveld 2021)
 - Any source of nitrogen will make canker worse (NZ)

Nursery infections = mainstem cankers in year 1-3

- NZ data show 2-5% trees come with canker, latent expressions
- Increase monitoring/removing in the first 3 years = canker control
- Stop canker in its tracks!!!



Photo: M. Papp-Rupar

Biocontrol Protection Products: field trial

Treatment code	Active	All rasp wounds		Naturally infected rasp wounds		Artificially infected rasp wounds		Leaf/bud scars		Pruning wounds	
		Canker incidence	SE	Canker incidence	SE	Canker incidence	SE	Canker incidence	SE	Canker incidence	SE
Water	Water	35.0%	4.0%	10.8%	2.4%	51.4%	3.7%	1.9%	0.8%	19.6%	2.6%
Standard	Captan/ tebu. / captan	15.7%	3.1%	1.9%	1.0%	33.2%	3.4%	0.7%	0.5%	13.9%	2.2%
BCA1) (AHDB9788)	Trichoderma	20.1%	3.3%	3.7%	1.4%	39.3%	3.5%	2.3%	1.0%	14.2%	2.2%
BCA2 (AHDB9694)	Aureobasidium	34.7%	4.0%	9.3%	2.2%	53.3%	3.6%	1.8%	0.8%	18.9%	2.5%
BCA3 (AHDB9712)	Clonostachys	23.0%	3.5%	4.3%	1.5%	42.1%	3.6%	1.2%	0.6%	16.1%	2.4%
PE1 (AHDB9712)	Plant oil	27.9%	3.6%	9.3%	2.2%	41.8%	3.6%	1.9%	0.8%	16.0%	2.3%
PE2 (AHDB9852)	Plant extract	25.2%	3.7%	4.4%	1.5%	46.2%	3.6%	1.9%	0.8%	16.9%	2.4%
CF2 (AHDB9862)	New azole product	22.9%	3.9%	2.3%	1.1%	49.6%	3.7%	1.0%	0.5%	17.6%	2.5%

Current biocontrol agents applied at leaf fall / during picking do not control canker

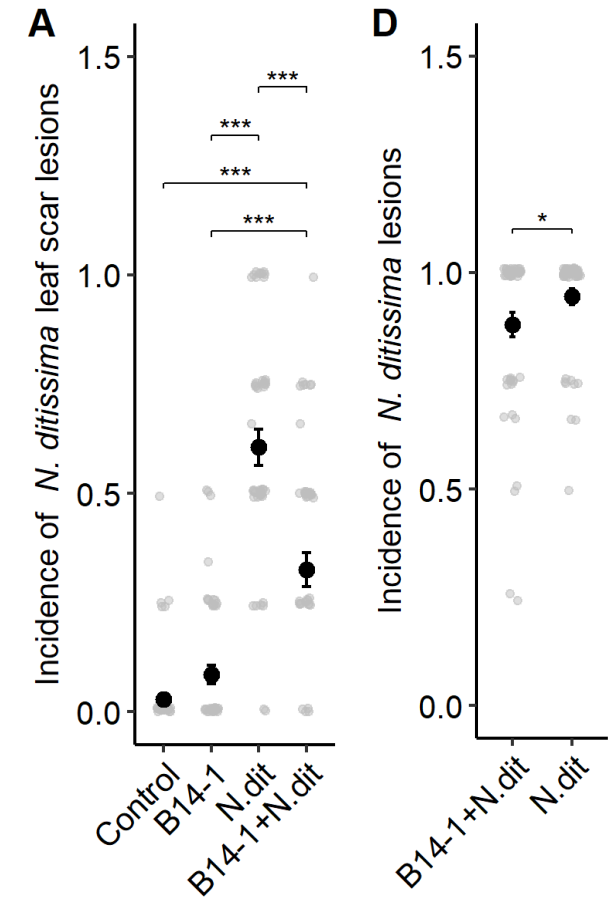
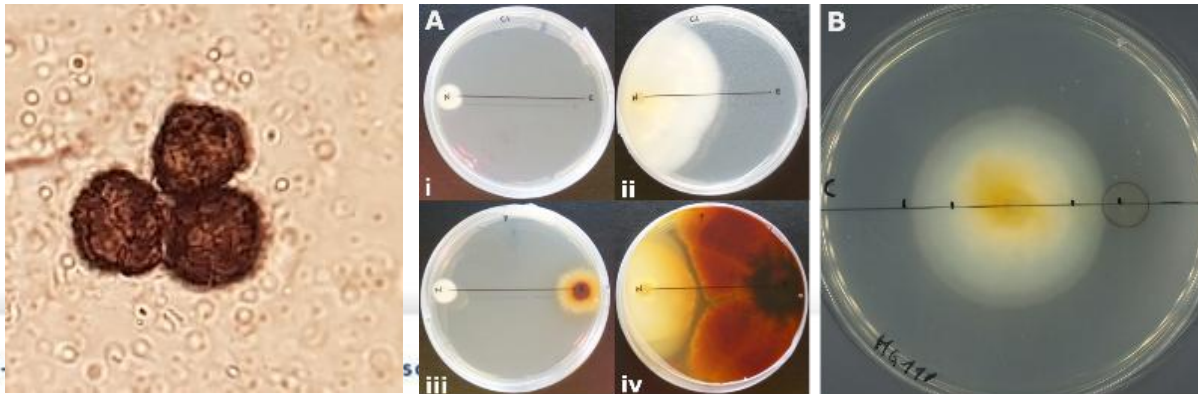
Aligned with evidence from NZ – Walter et al. (2017)

- New Zealand Plant Protection 70: 63-72 (2017)
- Bacillus, Pseudomonas, Trichoderma, Salicylic acid



Novel microbial amendments against canker

- **Apple endophytes – microbes in the trees – a novel strategy to increase the resilience against canker**
- We have found fungal endophyte ***Epicoccum nigrum***:
 - More abundant in resistant apple cultivars
 - **Reduced leaf scar (50%) and pruning wound (5%) infections when co-inoculated in field trial**
 - Transiently colonised apple tissues
 - Not causing growth penalty, nor symptoms on fruit / leaves.
 - Known for biocontrol potential in the literature



Novel microbial amendments against canker

- **Beneficial bacterial endophytes from Sphingomonas genus**

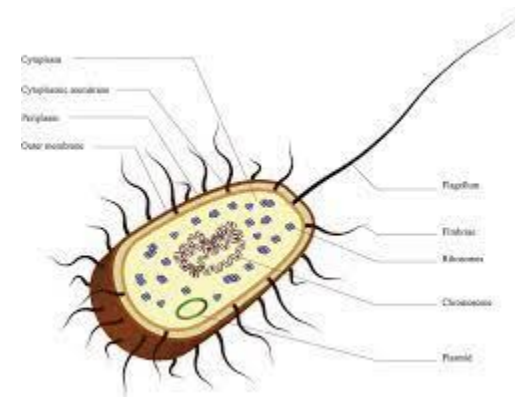
- Bacterial communities in apple are more stable than fungal
 - Changing less in abundance and composition across seasons

- **Sphingomonas strains**

- **Higher abundance in resistant** compared to susceptible apple cultivars
 - Across 2 years and 3 sites in Kent, UK
 - **High Sphingomonas** abundance → **higher canopy health** (less canker)
 - Known to promote plant growth and pathogen tolerance



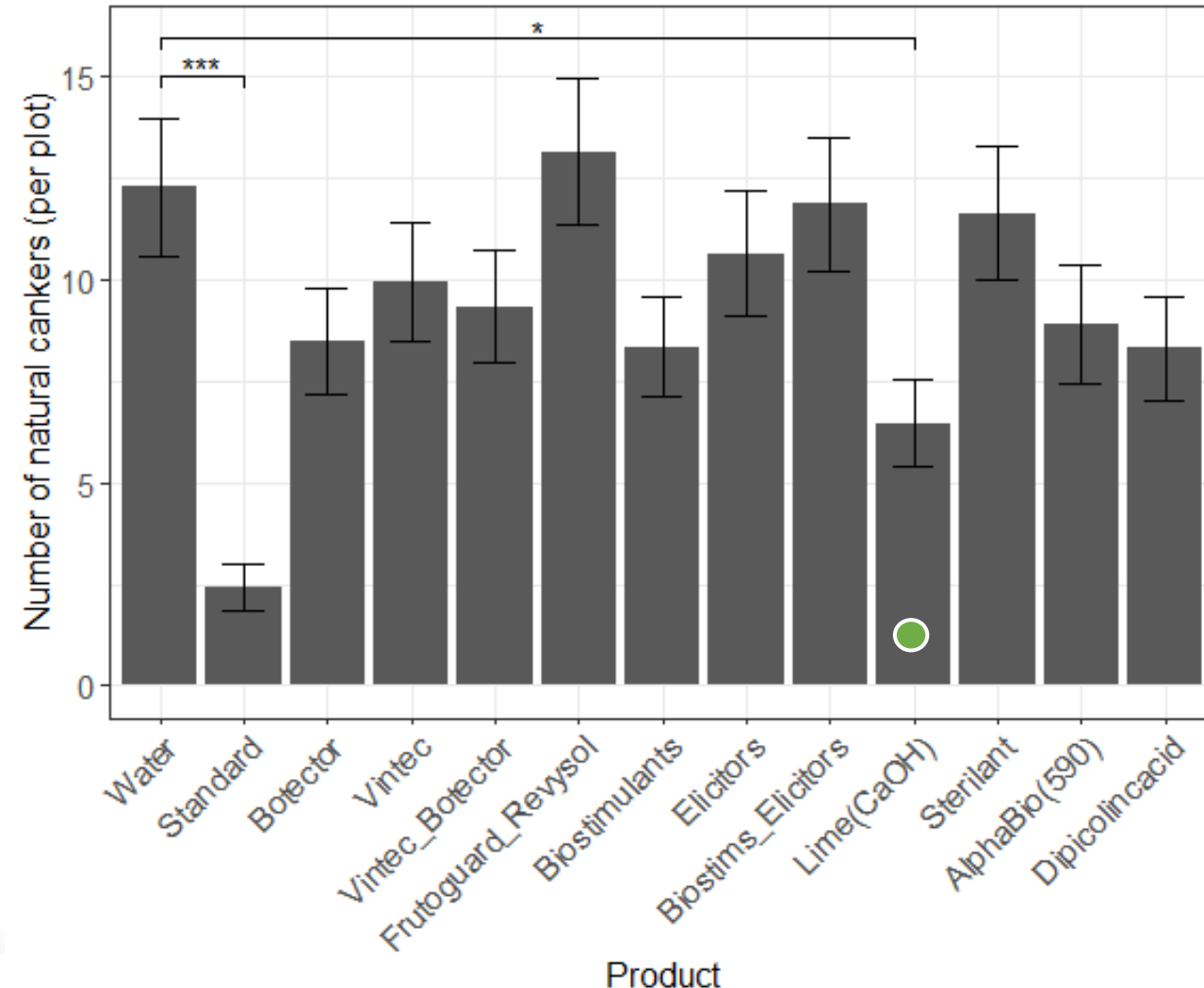
https://upload.wikimedia.org/wikipedia/commons/thumb/5/5b/Sphingomonas_phyllosphaerae_Alan.jpg/375px-Sphingomonas_phyllosphaerae_Alan.jpg



<https://doi.org/10.1016/j.jiid.2010.09.021>

Potential organic spray “product”

- **Hydrated lime (CaOH):**
 - 50 kg/Ha in 300L/Ha (1 year old trees)
 - Building grade hydrated lime
 - 3 sprays applied at 20, 50 and 80 % leaf fall
 - Used in The Netherlands through frost protection sprinklers
 - Used in NZ organics
 - Fresh material essential (**pH 13+**)
- **Protected natural leaf scar infections**
 - Peripheral cankers
- Not protecting larger rasp wounds
- Difficult application / particle size

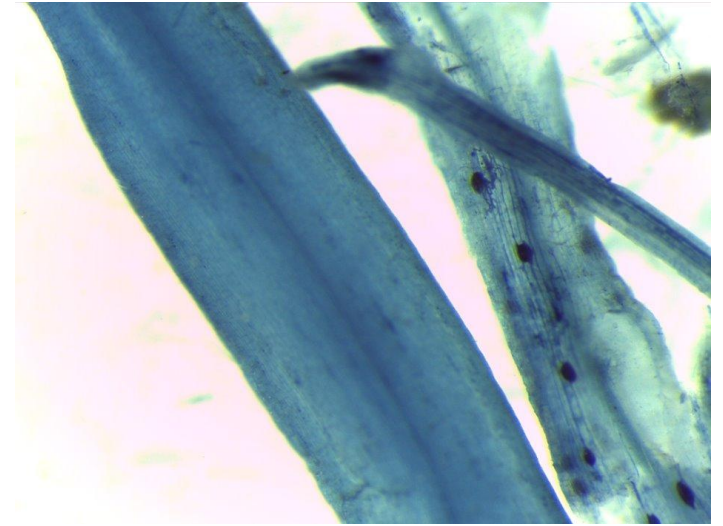


Soil amendments for canker resilience

- Arbuscular mycorrhizal fungi – **AMF** :
 - Improve **drought tolerance** (Wu et al., 2015)
 - **Waterlogging tolerance** (Tuheteru&Wu, 2017)
 - **Reduced the severity of Botryosphaeria canker** (Krishna et al., 2010) and **Neonectria canker** in cider apple (Berdeni et al., 2018).
 - Improve **P uptake** (Peng et al., 2015)
- **Trichoderma** species:
 - Improve plant growth and disease resistance (Szczatba et al., 2019)
 - Control canker on almond (Holland et al., 2021)

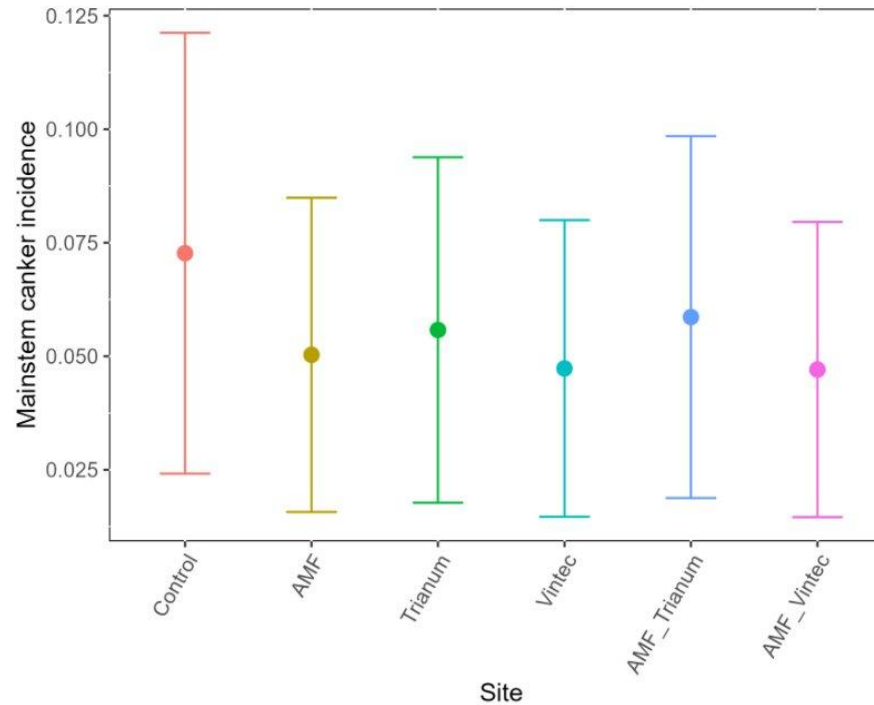
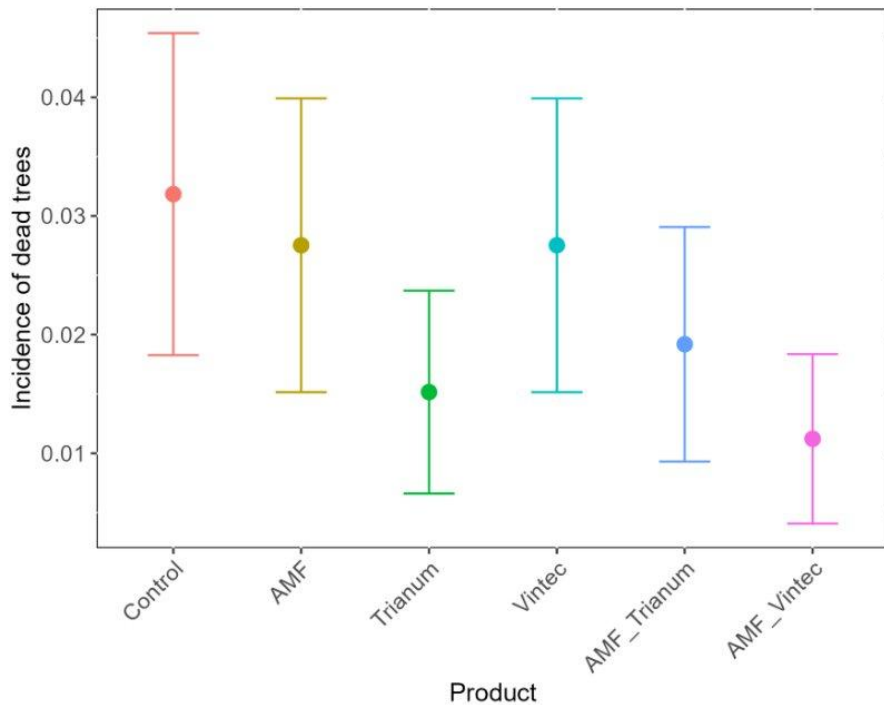
Amendment at planting?

Amendment of mature orchards?



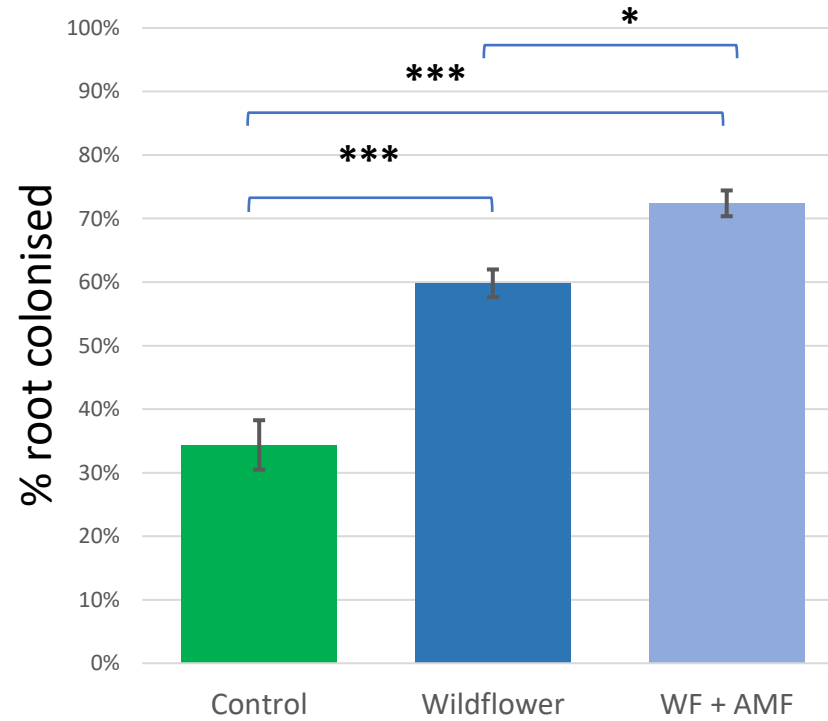
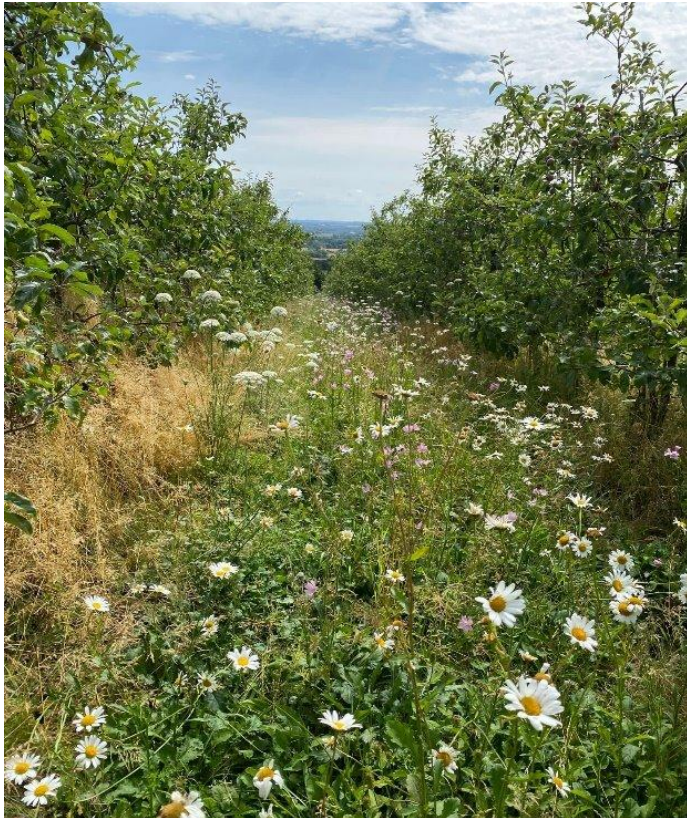
AMF / Trichoderma amendment at planting

- Small (not sig.) positive effect of AMF and Trichoderma across 6 commercial orchards
 - Lower tree mortality
 - Lower mainstem canker



AMF enrichment in mature orchards

- Wildflowers = increased AMF interaction / AMF abundance
- WF seed + commercial AMF = additional benefit



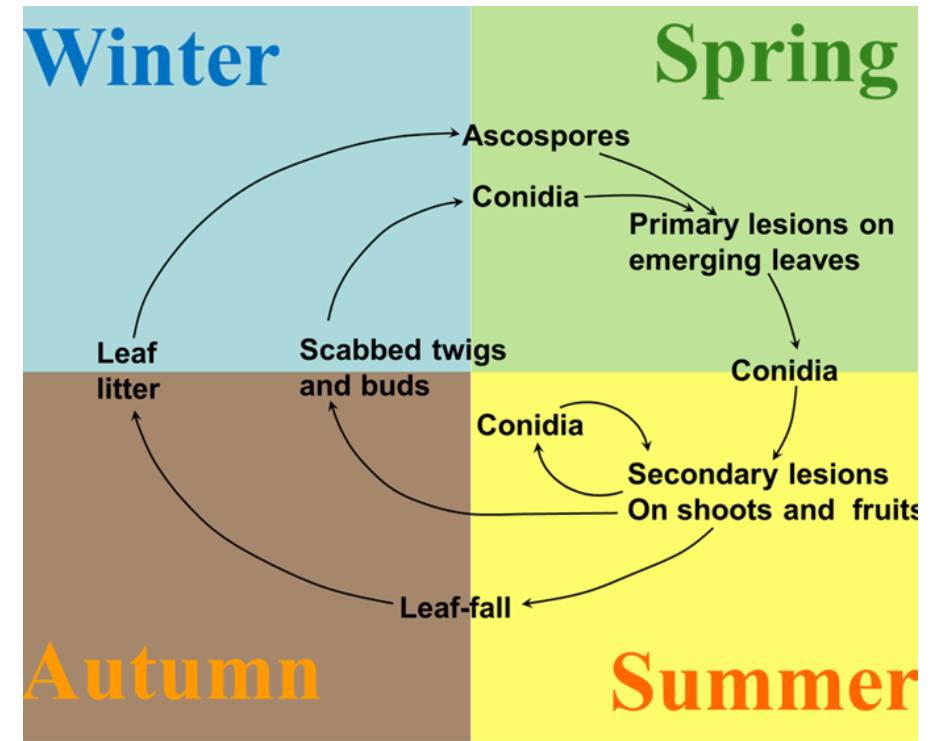
Introduction of wildflowers
or
Wildflowers with additional AMF

Increase AMF in the orchards

Transmission of AMF from WF to
apple roots not confirmed yet

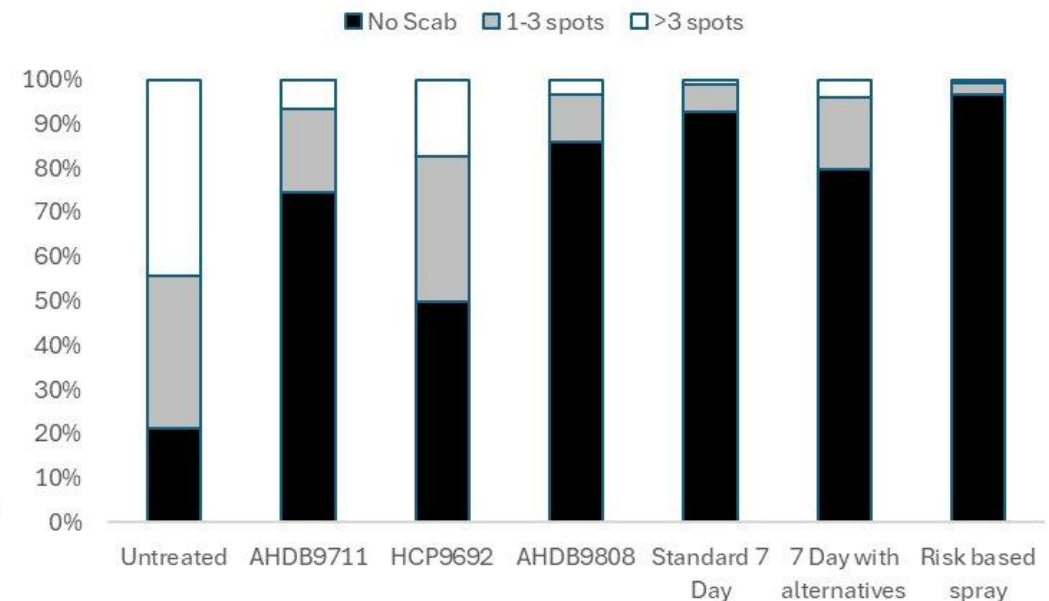
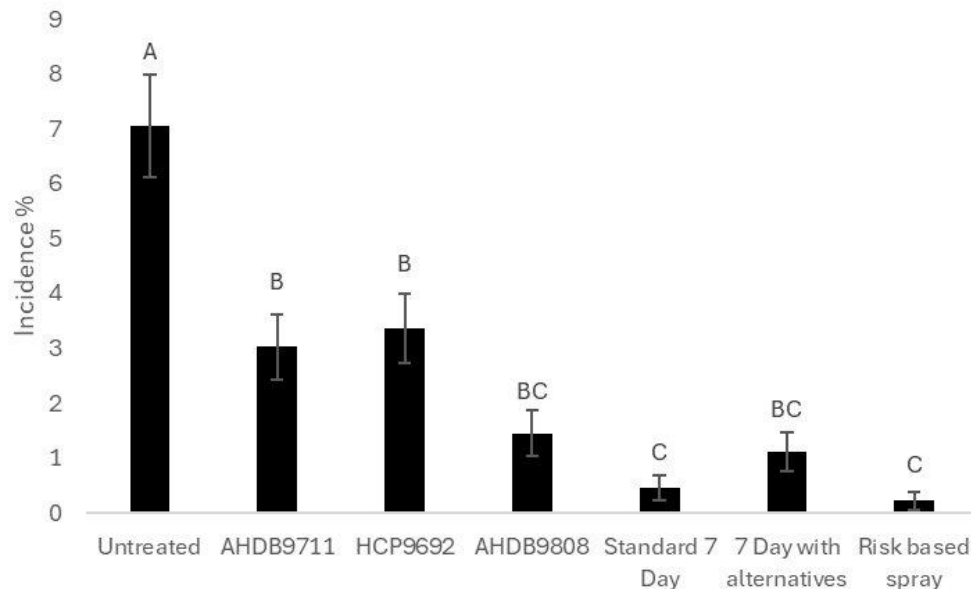
Apple scab

- Inoculum
 - Ascospores - Primary
 - Overwinter in leaf litter
 - Released by water, air dispersal
 - Conidia – Primary/Secondary
 - Overwinter in buds (?)
 - Dispersed by water splash
 - 20-50% contribution to primary inoculum in UK (Passey, 2017)
- Resistant varieties
- Orchard hygiene!
- Leaf degradation
 - Trichoderma
 - Orchard ground cover
- Timed ascospore release in dry weather(?)



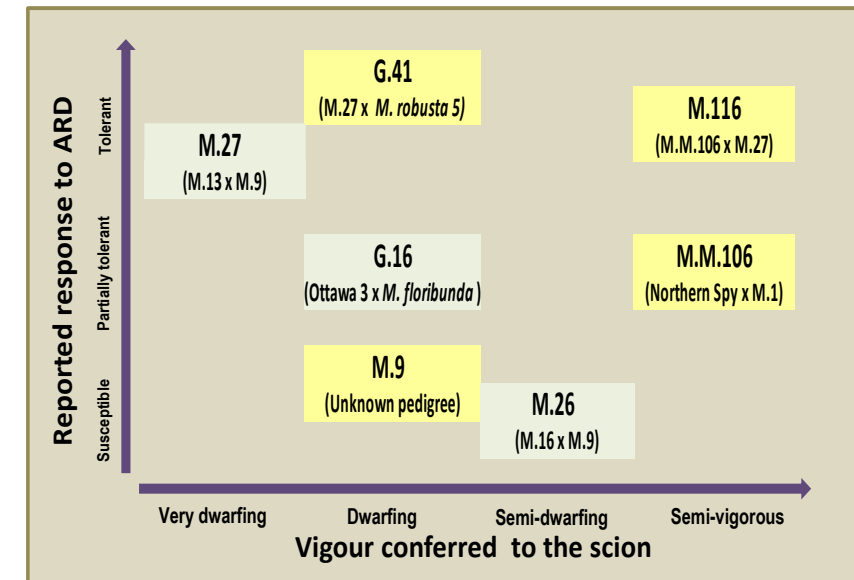
New control programmes against apple scab:

- Conventional scab programme = 15 – 20 spray applications
 - Loss of available chemistry / Resistance break down
- Majority of conventional pesticides replaced by:
 - Elicitor with metal component - AHDB9711
 - Elicitor - HCP9692
 - Inorganic Compound - AHDB9808
- Scab incidence on leaves and fruit comparable to standard
 - 9/12 fungicide applications replaced with alternative products
- Risk based approach (Rimpro) can also help reduce pesticide use (3/12)



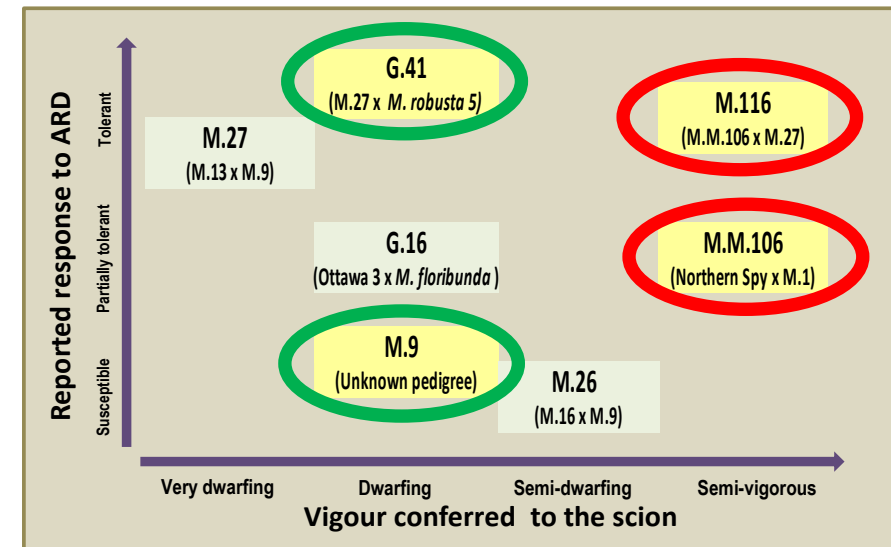
Apple replant disease

- Poor establishment and growth of apple trees in soils where the same (apple), or a closely-related species, has grown previously
- Complex causes:
 - ***Rhizoctonia*, *Cylindrocarpon*, *Phytophthora*** and ***Pythium***
 - Relative importance varies with sites
 - **Nematodes** can exacerbate ARD
 - Rootstocks differ in their susceptibility to ARD
 - **Decreased** prevalence of **beneficial microbes** (including AMF, *Trichoderma* and *Bacillus*)
- ARD trees start bearing fruit up to 2-3 years later
 - yields reduced by up to ~60% during the commercial life
 - Inconsistent in the orchards



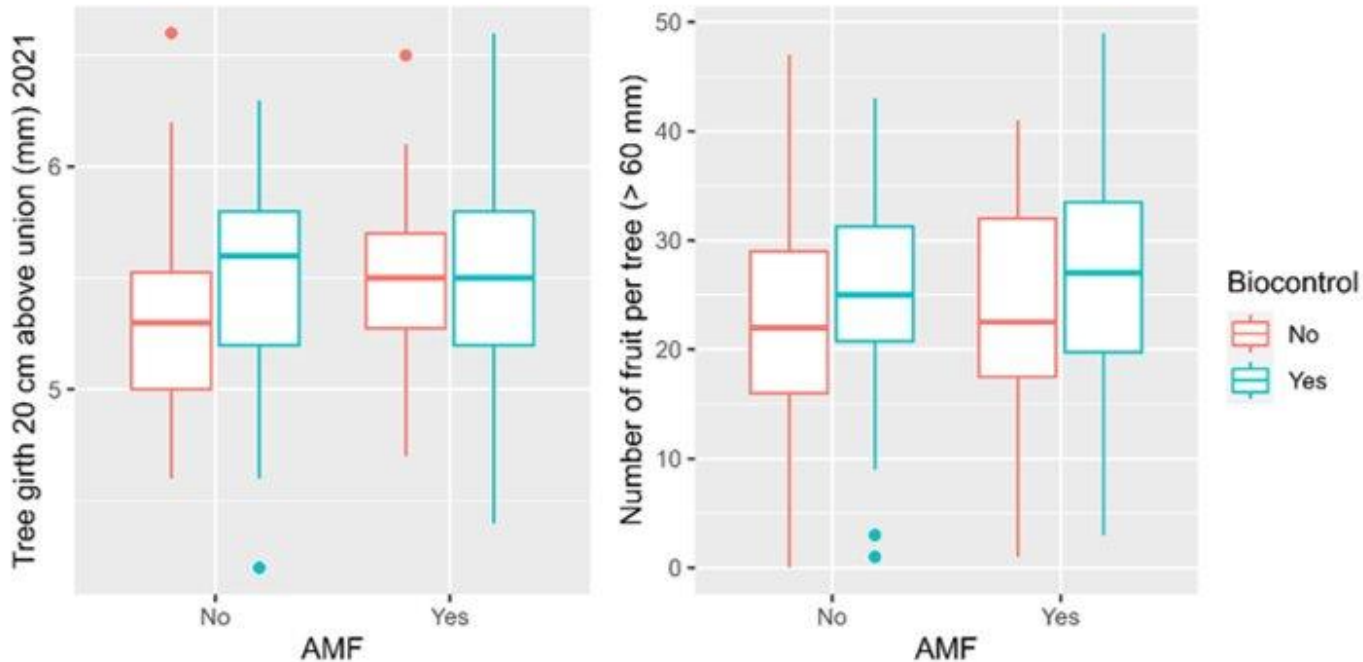
ARD management

- Rotating alleyway / tree row?
 - Different microbiome in the aisle
 - Normal tree growth in the aisle
 - In tree row between planting stations?
- Rotating rootstocks?
 - MM106 orchard replanted by:
 - M9, M26, MM106, M116, M27, G16, G41, EMR01
 - Most severe ARD in MM106 and M116
 - Most related to the previous rootstock
 - Least severe ARD in M9 and G series
 - Less related to MM116



Soil amendments against ARD

- Individual/combinations of beneficial soil microbes to improve tree establishment:
 - **AMF** / Plant growth promoting rhizobacteria (**PGPR**) / **Trichoderma** Biocontrol
 - AMF and Trichoderma but not PGPR can partially mitigate ARD



Take home messages:

- Canker:
 - Remove all infected material → out of the orchard
 - Current chemical and biocontrol agents not effective
 - New biocontrol is being developed
 - Improvement of the soil and orchard ground cover
 - AMF, Trichoderma, Wildflowers
- Scab:
 - Remove / degrade primary inoculum
 - Alternative control with elicitors (etc.) possible
- Replant:
 - Rotate alleyway / tree row planting
 - Rotate rootstock cultivar – rootstock relatedness!
 - Improve soil microbiome
 - AMF and Trichoderma



Acknowledgments

- **Funders:** Growing Kent and Medway, Innovate UK, AHDB, BBSRC, BAPL and apple industry partners.
- **Apple growers** from AM Fresh, Worldwide Fruit, Adrian Scripps and Agrovista.
- Frank P. Matthews **tree nursery**
- Thanks to Louisa Robinson, Xiangming Xu, Tom Passey, Greg Deakin and NIAB Pathology team for trial establishment, monitoring and assessments of trials.

Thank you for listening!

Questions?

