A whole orchard approach to managing apple canker

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BAPL – Niab: Apple and Pear Technical Day, 10 Feb 2026

Agenda

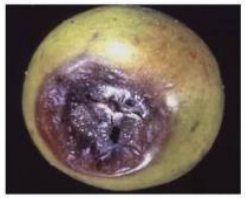
- Canker management overview
- Soil physical and chemical properties linked to canker severity?
- Soil beneficial microbes reducing canker impacts in the orchard?
- Take home messages and questions

(European) Apple canker

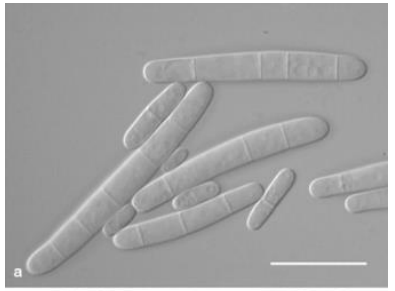
- Caused by fungal pathogen ***Neonectria ditissima***
  - Worldwide distribution - all apple growing regions
  - Broad host range: Malus, Pyrus, Acer, Fagus, Prunus, Sorbus, Quercus,…

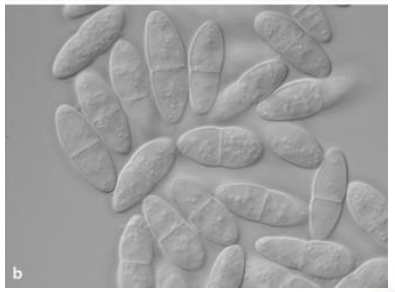
- **Conidia** and **ascospores infecting wounds**:
  - **Branch dieback / Killing trees** <u>- up to 30%</u> of newly planted orchards
  - **Reducing yield, quality and orchard longevity**
  - Causing **postharvest fruit rot**

Eye rot in orchard



Nectria rot in store





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

Apple canker – management challenges

- **<u>Inoculum and wounds present all year around</u>**
  - Manmade: Pruning wounds / Picking wounds / …
  - Natural: Petal scars/ Growth cracks / Lenticels / Leaf scars / …
    - In UK climate: 1 canker in orchard will result in 100% trees with canker 6-7 years if left completely unmanaged

Photo: M. Papp-Rupar

- **Commercial apple cultivars are highly susceptible.**
  - **Variation in susceptibility** (Gala, Jazz > Braeburn > Golden delicious)
  - <u>High density of planting</u>
  - <u>Often ineffective chemical products</u>
    - Difficult to target sporulation / wound protection
    - Product removal
  - <u>No effective biocontrol products</u>
  - <u>Inoculum removal in the most effective,</u> expensive and labour intensive

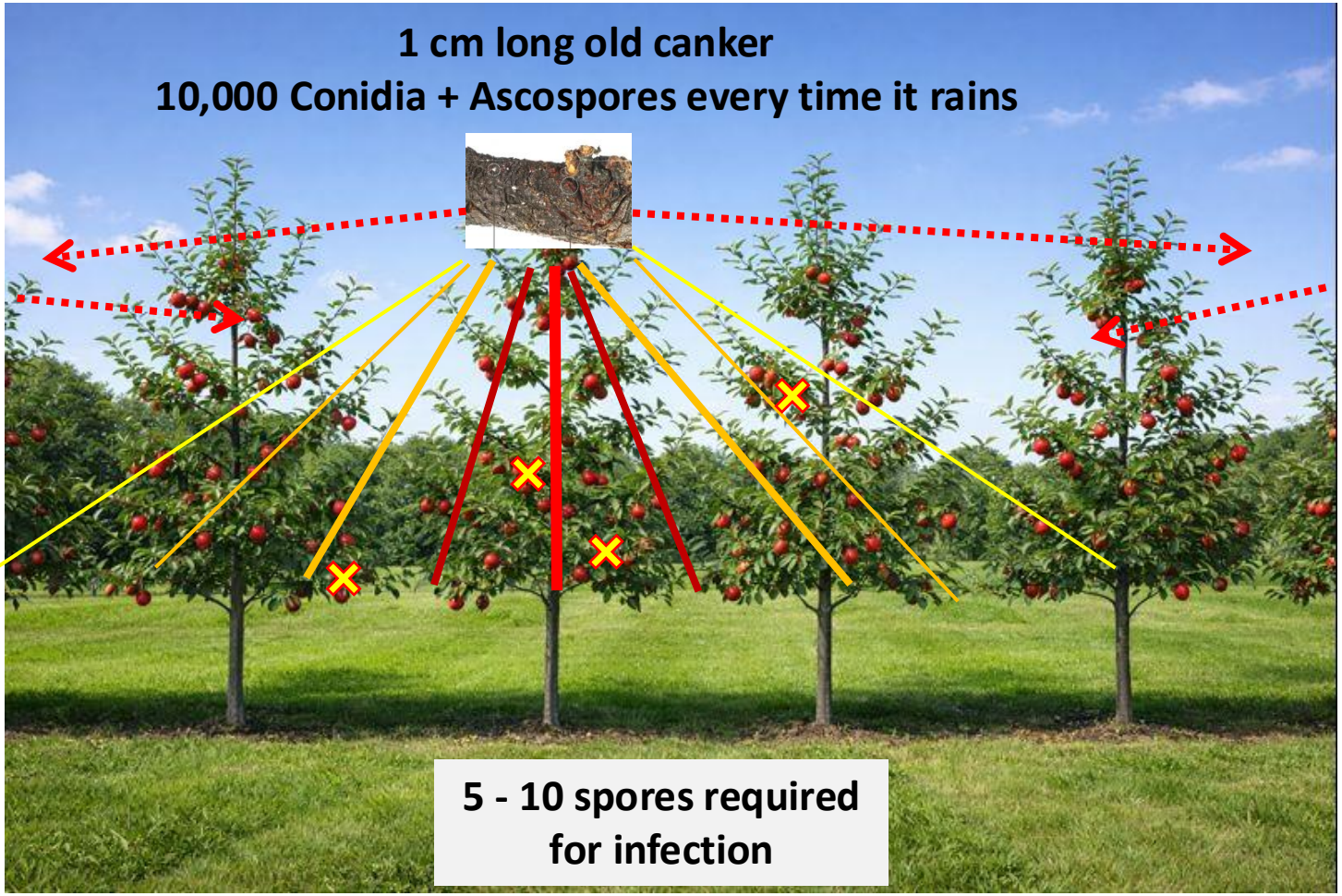
- Multi-locus, quantitative canker resistance (GxE, tissue/age specific)
  - No major R-genes → challenging breeding of resistant varieties

Inoculum removal for canker management

- **YOU CAN NOT SPRAY CANKER AWAY**
  - No spray can kill canker lesions or stop them sporulating
    - 1 mm of canker = 1000 potential infections
  - Leaf scar protection is possible with Captan/Tebuconazole only if:
    - Good coverage / high water volumes (800-1000l/ha); AND
    - Timed correctly (20, 50 80% leaf fall) – orchard access / ground; AND
    - Low inoculum load AND fungicide availability
  - Scab sprays may partly control petal scar infections
  - Picking and pruning wounds are impossible to target and protect
- Experiments in NZ commercial orchards:
  - **Double the spray** effort → reducing the rate of canker spread
    - The same % of trees with canker
  - **Double the pruning** effort→ reducing canker prevalence
    - Cleaner orchard with less cankers

Photo: M. Papp-Rupar

European apple canker – infection **spread**

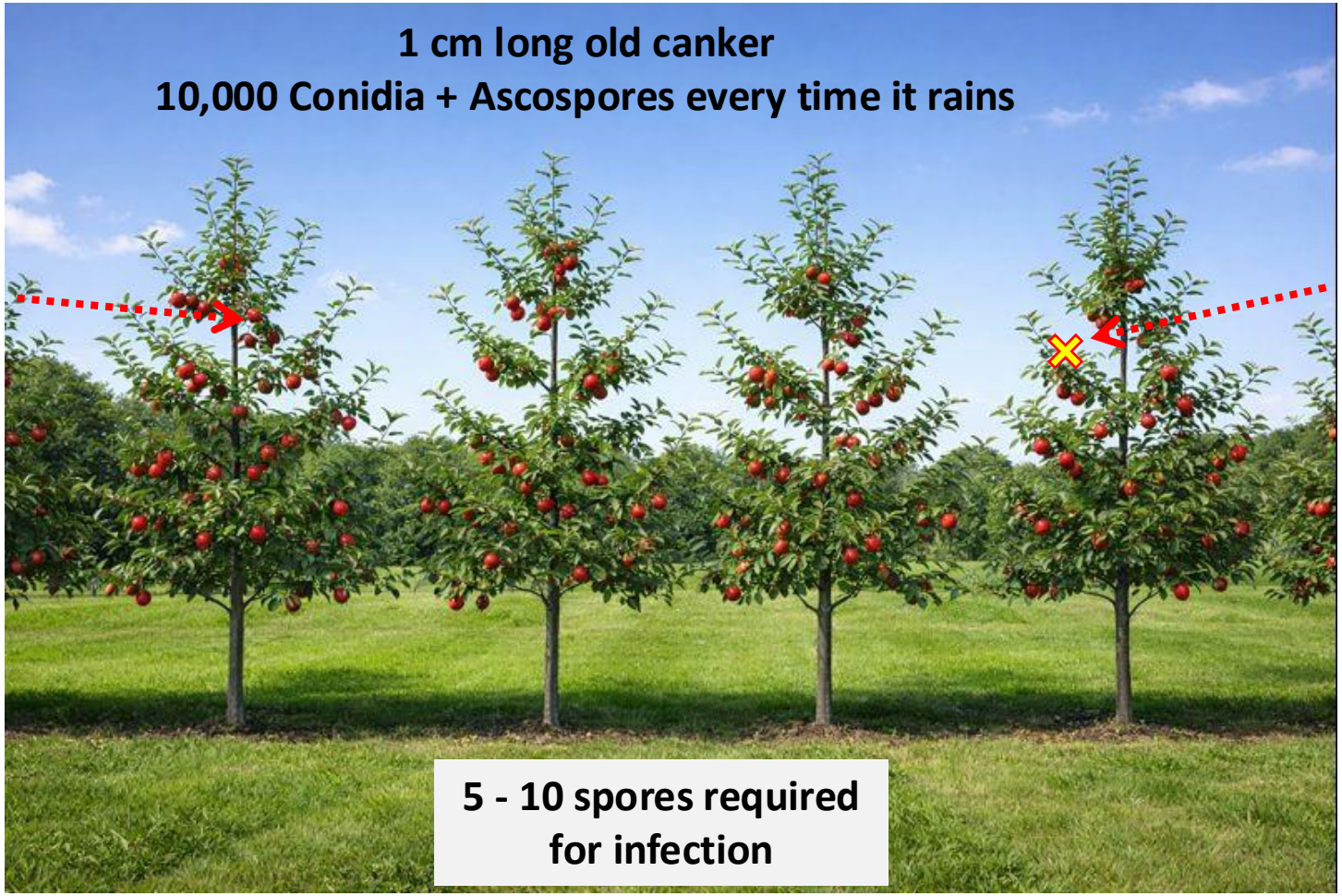


Protection with spraying only – canker not removed:

- Spray fungicide after every rain event
  - Products?

- Cover all wounds:
  - Pruning wounds, Petal scars, Growth cracks, Lenticels, Picking wounds, Leaf scars
  - Continuous battle

European apple canker – infection **spread**



All Cankers removed:

- Not much difference in inoculum load between 1 - 5 cankers per tree
- Huge difference between 1 and 0

Only ascospore inoculum from outside / windbreaks

No inoculum, no problem

WHEN to remove cankers – new orchard

- **Any sunny day – never in the rain.**
- Warmer season → faster healing → lower infection success
- **Monitor young orchards:**
  - **The first 12 -18 months is the most important**
    - **Nursery infections**
    - **Infection of wounds created during lifting, transport, planting**
  - Remove trees with rootstock/mainstem cankers ASAP
  - Reduce the **canker numbers to 0**
    - Below 1-3 % of trees with canker is maximum
  - **Canker Champions / Canker bounty / Hot spot marking**

WHEN to remove cankers – mature orchard

- **Any sunny day – never in the rain.**
- Warmer season → faster healing → lower infection success

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

1) Pre harvest / during harvest (late Aug-early Oct)

- Removes inoculum for picking wounds, leaf scars, pruning wounds and winter cracks
- Fast healing

2) After harvest / pre-leaf fall (Oct-Nov)

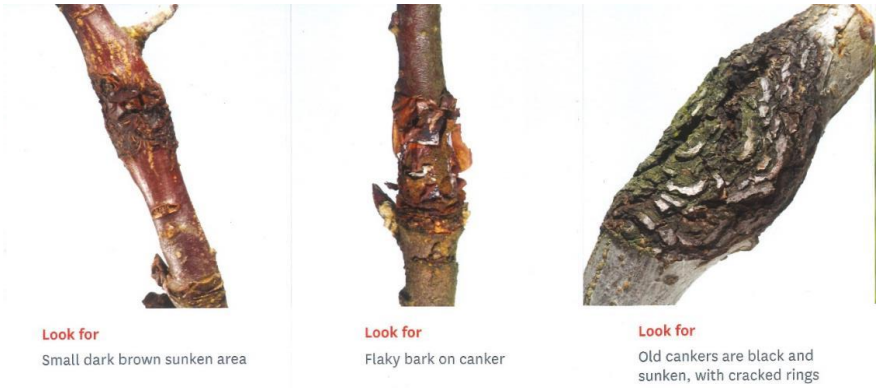
- Removes inoculum for leaf scars, pruning wounds and winter cracks
- In combination with leaf fall sprays for increases efficacy

3) Winter tidy up

- Identify hot spots for spring walk, 3 strikes you're out → replant
- Use Pruning Paints to protect every cut → cold / wet → long healing and lots of inoculum

4) Spring clean

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



New Zealand Apples & Pears

HOW to remove cankers?

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

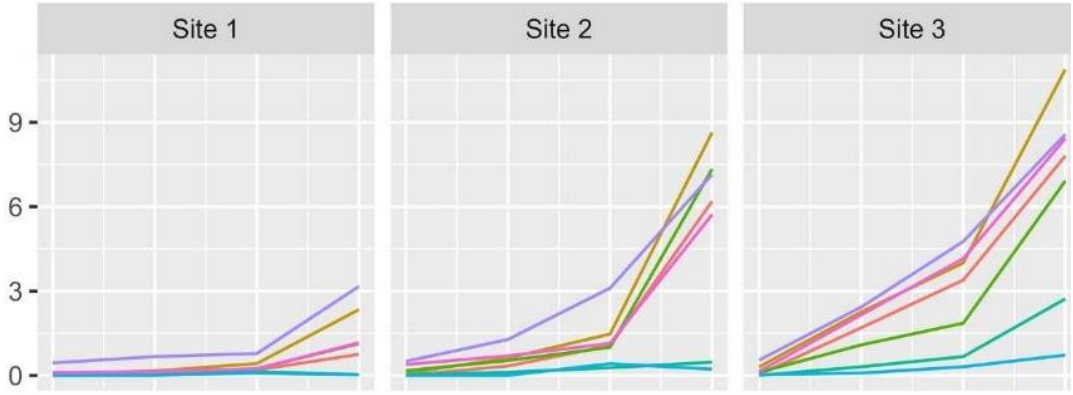
New Zealand Apples & Pears

Canker overview – discussion

- **Inoculum is produced by canker lesions**, infected fruit, infected windbreaks every time it rains
- Spraying only = constant battle to protect the wounds against inoculum
  - Pruning wounds, Petal scars, Growth cracks, Lenticels, Picking wounds, Leaf scars
- **Remove cankers from the trees/orchards → <u>reduce inoculum</u>**
  - Prune in the dry weather
  - Prune to clean wood / protect the cuts
  - <u>Remove trees with mainstem cankers</u> early
  - <u>Remove and destroy all cuttings</u> (and fallen fruit)
- **Monitor**, especially young orchards:
  - Hot spot marking / Canker champions / Canker bounty

Introduction: Soil nutrition - canker

- Hints from a previous Niab trial:
  - Uniform tree source, canker inoculation and management of 7 apple cultivars over 3 sites Kent, UK
  - Significant different incidence of mainstem and peripheral cankers between sites and within blocks on the same site
  - Could variability in soil chemistry explain observed differences?



- Nutrition and apple canker
  - Dryden et al. (2016) - NZ – post harvest N applications increase canker – orchard trial
  - Vorster et al. (2021) – NZ – all N sources increase canker – potted trial

Aims & Methods

- AIM: To investigate the possible **links between soil physiochemical properties and canker**
  - Can **soil properties** explain canker variability **within orchard / between orchards**

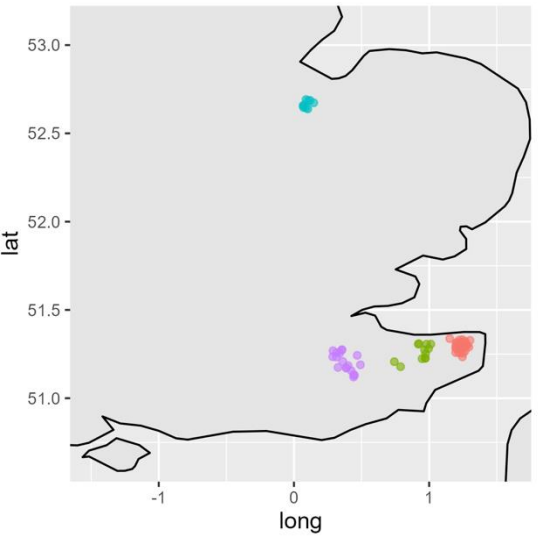
- Methods:
  - Grower engagement – diverse candidate orchards – many thanks to participating growers
    - location, orchard age, cultivar, canker score (good / bad / really bad), previous soil data

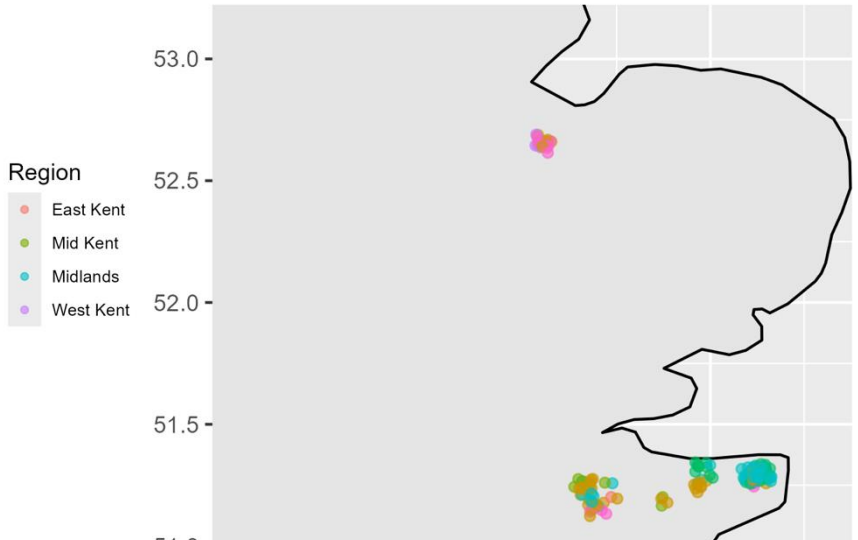
  - Orchard assessment – Gala, Cox, Braeburn, Jazz / 2012-2022 planting
    - Mainstem / peripheral **canker count** (GRID:~every 15th tree in every 5th row)
    - **2 soil samples** per orchard (3 soil cores per tree, 5-20 cm deep)
      - **Low canker**: pool of 5 trees with the lowest canker in each per orchard
      - **High canker**: pool of 5 trees with the highest canker counts in each orchard
    - **Soil analysis**: macro nutrients, micronutrients, % sand/silt/clay

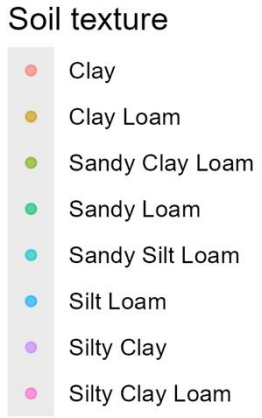
  - Data analysis: Factors (co)relating with canker counts
    - PCA
    - Pearson / Spearman (univariate)
    - LASSO = Least Absolute Shrinkage and Selection Operator (multivariate)
    - Random Forest (importance)

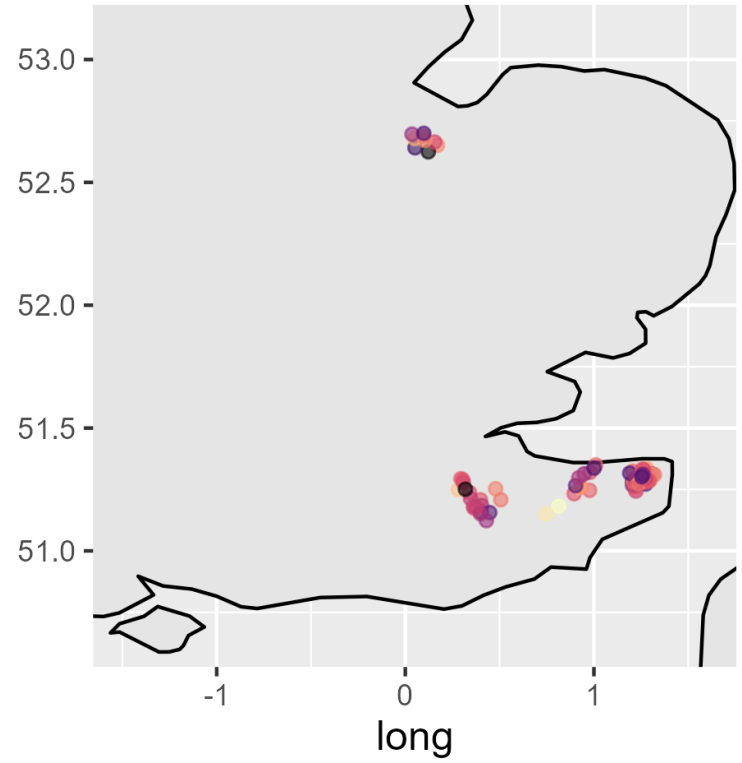
Data overview

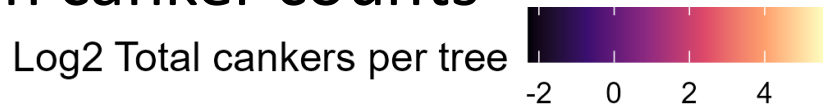
- 72 orchards / 144 soil samples / 4,099 trees / 25,190 cankers
  - 14 farms, 4 regions, 8 soil types, large variability in canker counts
  - 25 predictors (23 soil + dist. to sea + altitude)





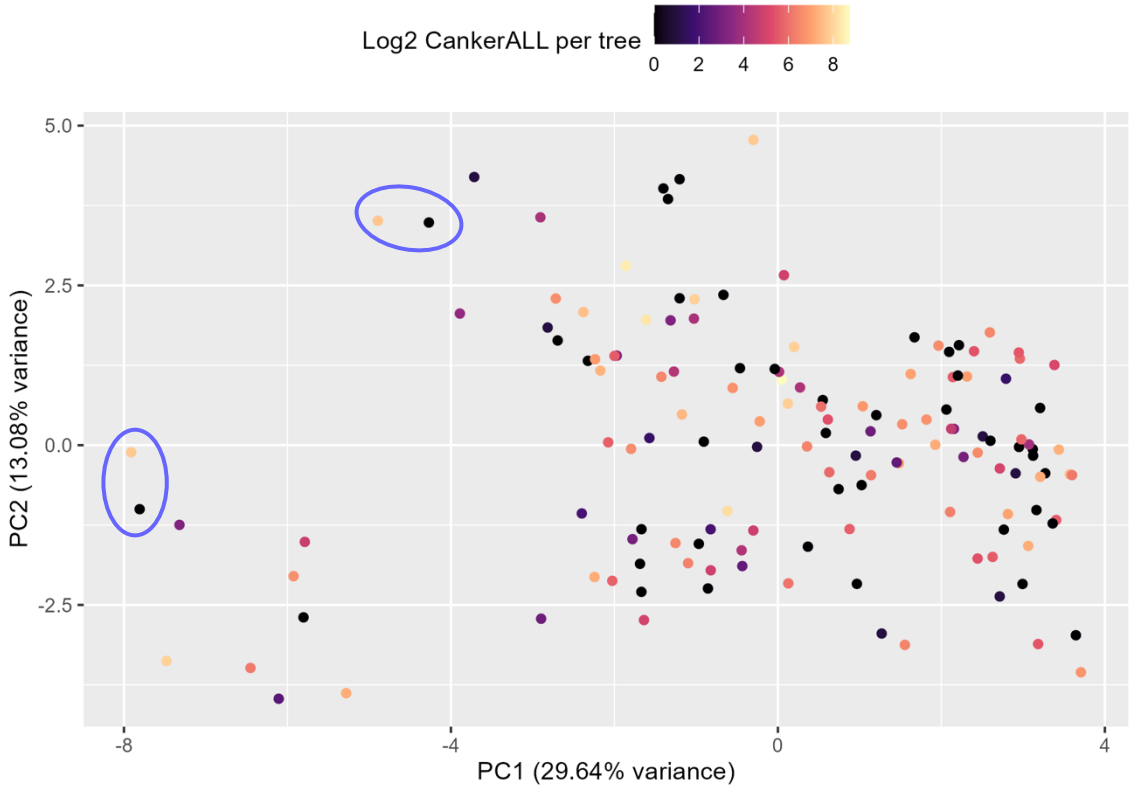


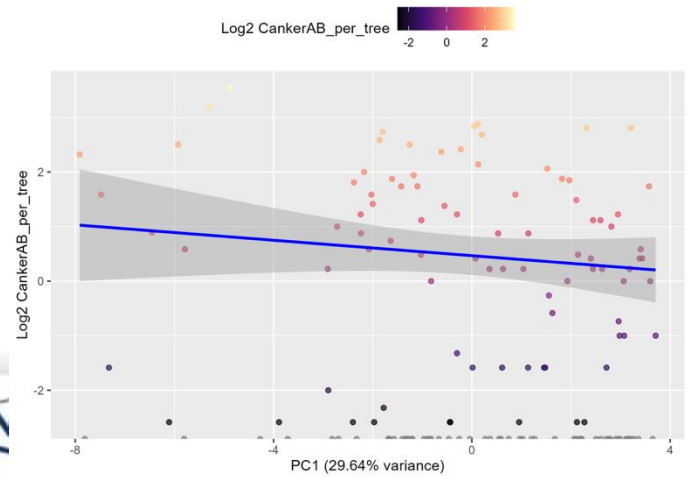


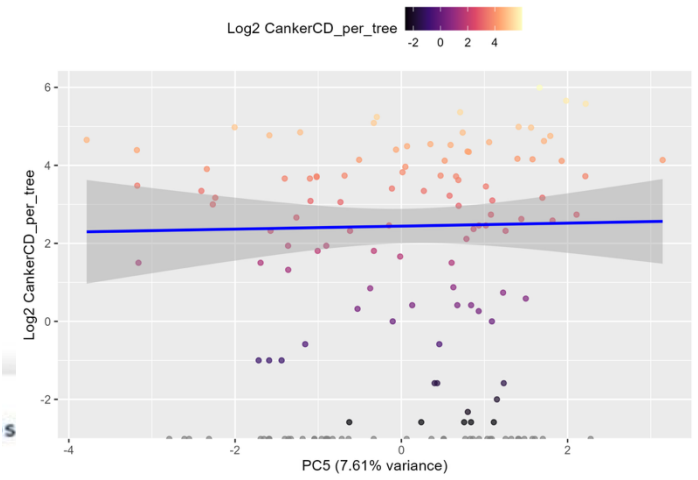


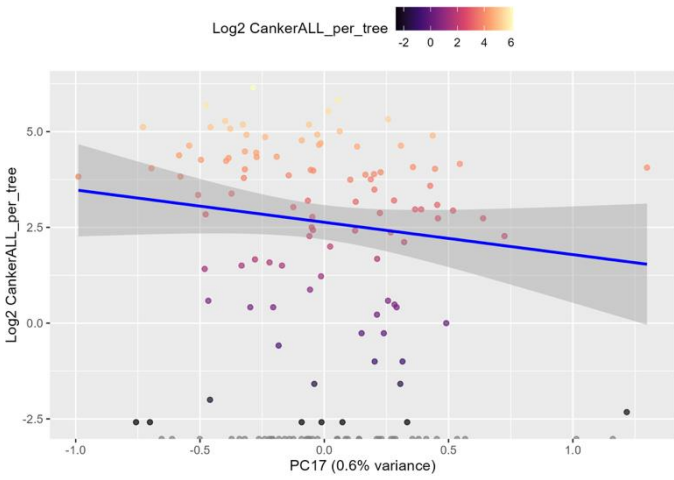
Results – Within orchards - PCA

- Low / High canker count samples
  - 5 best / 5 worst trees assessed in orchard
- Low / no corelations between canker and soil parameters within orchard
  - Large differences in canker
  - Small differences in soil properties
  - Variables with tentative importance:
    - Organic matter, total N, total C, Ca, CEC









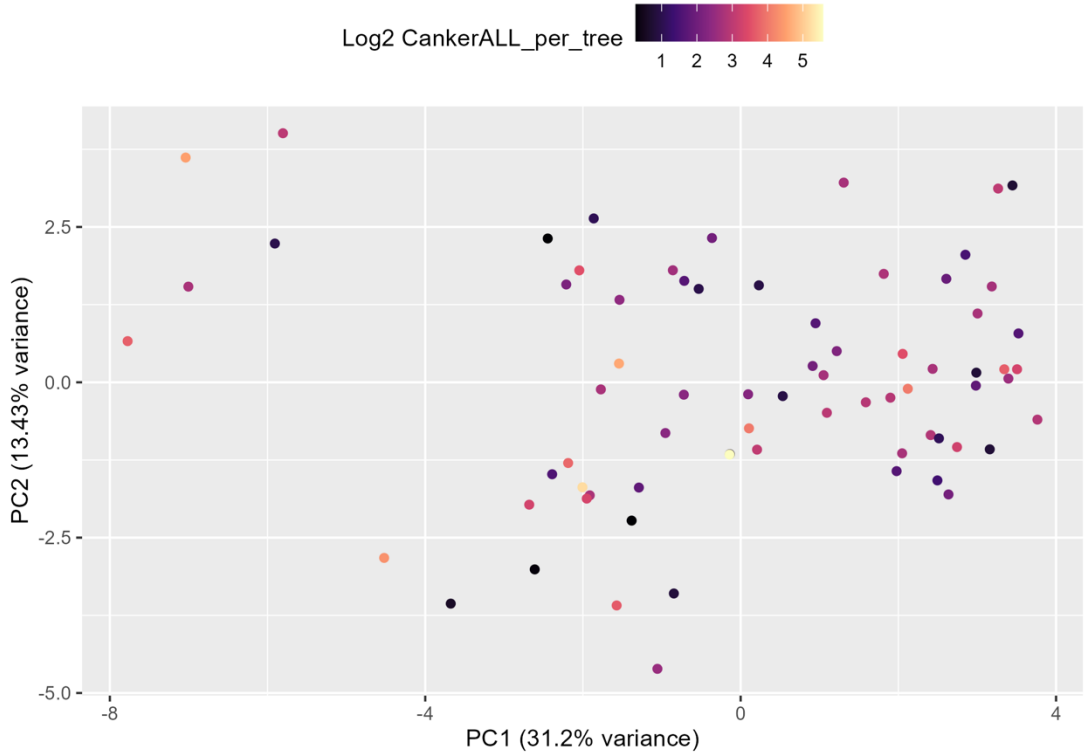
Results – Within orchards

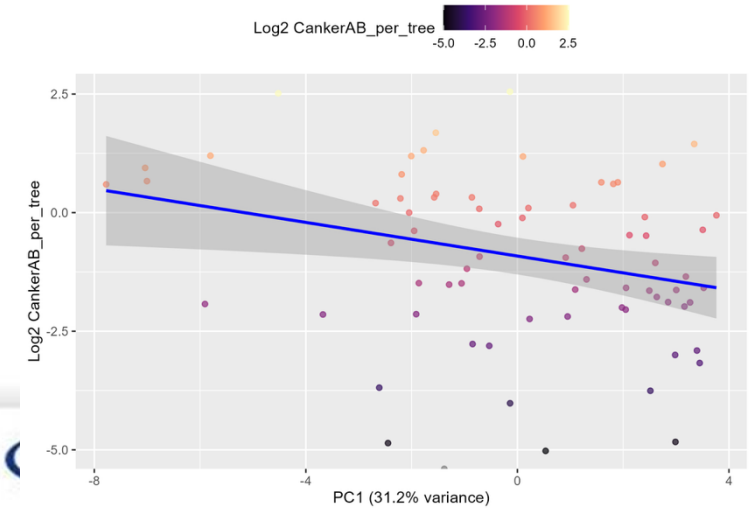
	Total cankers				Mainstem cankers				Peripheral cankers				DMR trees			
	Corr		Lasso	RF	Corr		Lasso	RF	Corr		Lasso	RF	Corr		Lasso	RF
Predictor	Spear	Pears	coef.		Spear	Pears	coef.		Spear	Pears	coef.		Spear	Pears	coef.	
CEC_meq_100g	0.18	0.19	0.20	2.04	0.18	0.19	.	4.32	0.17	0.19	.	3.99	0.18	0.17	.	2.21
Ca (mg/l)	.	0.18	.	4.11	0.15	0.19	.	5.19	.	0.17	.	4.25	0.24	0.20	.	3.17
oC %	.	.	.	1.02	0.14	0.18	.	1.96	.	.	.	2.32	0.19	0.26	.	5.23
tC %	.	.	.	1.59	0.14	0.17	.	1.56	.	.	.	2.02	0.21	0.27	.	6.72
Fe (mg/l)	.	-0.18	-0.005	4.67	.	.	.	3.55	.	-0.18	.	5.39	.	.	.	5.43
OM_LOI %	.	.	.	2.75	.	0.17	.	2.42	.	.	.	.	0.24	0.29	0.01	8.50
pH	.	.	.	2.43	.	.	.	2.13	.	.	.	1.78	0.17	.	.	3.63
tN %	.	.	.	3.72	.	0.17	.	.	.	.	.	3.19	0.21	0.27	.	4.69
SO4 (mg/l)	.	.	.	1.58	.	0.16	.	1.76	.	.	.	.	0.21	.	.	4.04
Silt %	.	.	.	2.86	.	.	.	.	.	.	.	3.21	-0.20	.	.	3.11
K (mg/l)	.	.	.	.	.	.	.	4.17	.	.	.	.	0.18	0.16	.	3.92
Clay %	.	.	.	.	.	0.19	.	.	.	.	.	2.08	0.17	0.17	.	.
. (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	0.18	0.18	.	5.27
P (mg/l)	.	.	.	.	.	.	.	1.68	.	.	.	.	.	.	.	4.47
Zn (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	0.16	0.25	.	6.24
Co (mg/l)	.	.	.	.	.	0.18	.	.	.	.	.	.	.	.	.	1.04
Cu (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	.	0.20	.	12.29
Mg (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.18
Mn (mg/l)	.	.	.	.	.	.	.	2.74	.	.	.	.	.	.	.	.
Sand %	.	.	.	.	.	.	.	.	.	.	.	1.87	.	.	.	.
Mo (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	-0.17	.	.	.
iC %	.	.	.	.	.	.	.	.	.	.	.	.	0.23	.	.	.
oC_tN_ratio	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

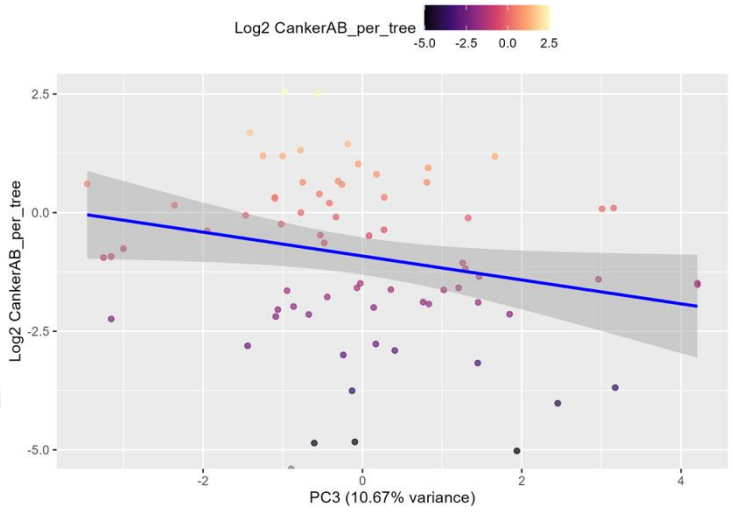
- High **CEC, Ca** in the soil → more canker
- High **Fe, Silt %, Mo** in the soil → less canker

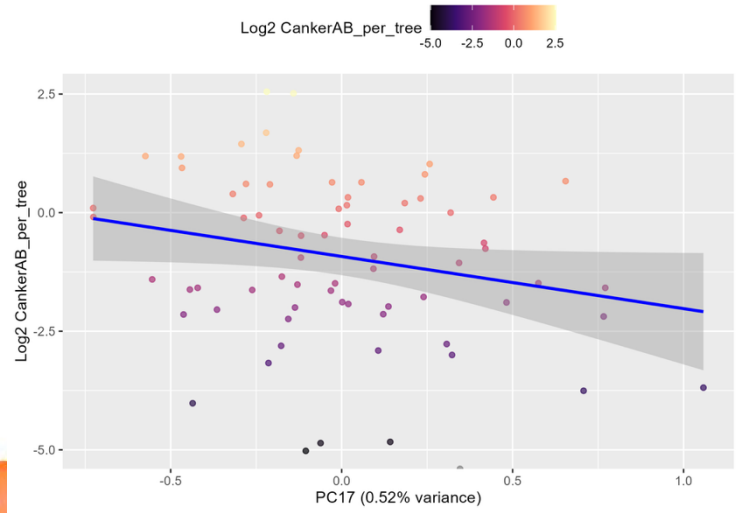
Results – Between orchards - PCA

- Average soil parameters in the orchard
- Average canker across all assessed trees
- Variables with influence on canker:
  - High OM, tC, tN, CEC, Cu → more canker
  - High K, P, SO4, Zn, Mn, Mo→ less canker









Results – Between orchards

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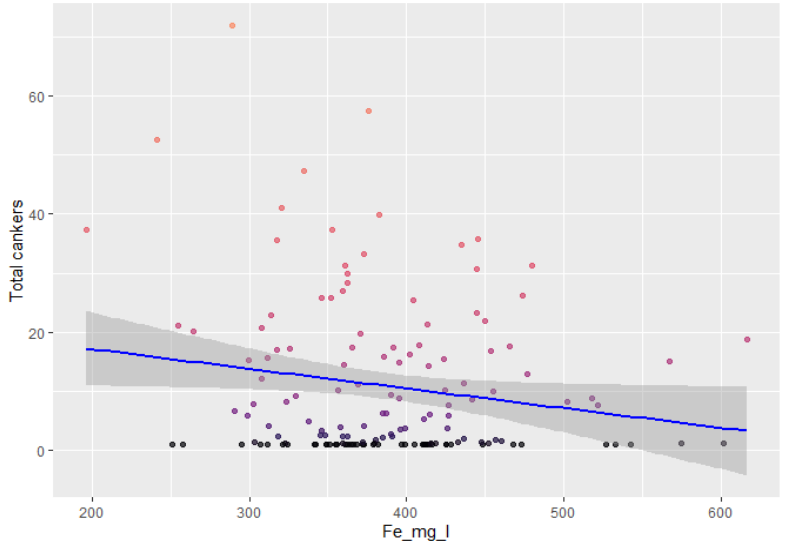
	Corr		Lasso	RF	Corr		Lasso	RF	Corr		Lasso	RF	Corr		Lasso	RF
predictor	Spear	Pears	coef.		Spear	Pears	coef.		Spear	Pears	coef.		Spear	Pears	coef.	
Ca (mg/l)	0.25	0.35	0.00	3.30	0.34	0.36	.	3.99	0.21	0.33	0.00	2.23	0.38	0.35	.	7.07
CEC_meq_100g	0.25	0.30	.	2.96	0.30	0.31	.	3.05	0.21	0.29	.	3.68	0.27	0.33	0.01	7.82
Fe (mg/l)	.	-0.28	-0.01	10.58	.	-0.25	.	3.58	-0.20	-0.28	.	11.16	.	.	0.00	2.34
OM_LOI %	.	0.21	.	4.22	0.29	0.31	.	2.23	.	.	.	3.79	0.44	0.52	.	7.16
Silt %	.	-0.22	-0.04	2.15	.	.	.	1.41	.	-0.22	.	1.91	-0.23	.	0.00	2.31
tC %	.	0.21	.	2.90	0.36	0.33	.	5.13	.	.	.	2.70	0.34	0.53	.	11.21
tN %	.	.	.	3.40	0.29	0.26	.	4.31	.	.	.	2.63	0.33	0.52	0.72	10.61
Clay %	.	0.20	.	1.53	0.27	0.32	.	.	.	.	.	2.49	0.36	0.25	.	3.60
oC %	.	.	.	2.58	0.35	0.31	.	5.21	.	.	.	2.38	0.33	0.53	.	10.54
iC %	.	0.20	.	3.49	.	0.20	.	.	.	.	.	4.16	0.35	.	0.05	3.76
altitude (m)	.	.	.	3.93	.	0.23	.	7.77	.	.	.	2.11	.	0.32	.	4.15
P (mg/l)	.	.	.	1.07	.	.	.	.	.	.	.	1.17	.	0.20	0.00	3.03
Cu (mg/l)	.	.	.	1.36	.	.	.	.	.	.	.	.	.	0.29	0.008	4.46
Na (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	0.27	0.21	0.00	5.42
Zn (mg/l)	.	.	.	2.77	.	.	.	.	.	.	.	3.90	0.24	0.36	.	.
dis	.	.	.	.	.	.	.	2.64	.	.	.	1.80	.	.	0.00	2.75
K (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	0.24	0.26	.	3.81
Mo (mg/l)	.	.	.	1.32	.	.	.	3.63	.	.	.	.	-0.28	.	.	.
Co (mg/l)	.	.	.	.	.	0.21	.	.	.	.	.	.	.	.	0.03	.
Mg (mg/l)	.	.	.	.	.	.	.	.	.	.	.	2.16	.	.	.	4.36
SO4 (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	0.26	.	.	3.59
oC_tN_ratio	.	.	.	.	.	.	.	2.07	.	.	.	.	.	.	0.02	.
pH	.	.	.	.	.	.	.	.	.	.	.	.	0.22	.	.	3.16
Mn (mg/l)	.	.	.	.	.	.	.	.	.	.	.	1.96	.	.	.	.
Sand %	.	.	.	2.60	.	.	.	.	.	.	.	.	.	.	.	.

- High **CEC, Ca, OM, tC, tN, Clay** → more canker
- High **Fe**, Silt, **Mo**→ less canker

Soil nutrients - Discussion

- High **CEC** and **Ca** related to **higher canker** – unexpected
  - **High CEC – healthy soils**: higher nutrient retention/exchange, pH buffering, less leaching, stable microbiome
  - **Ca involved in defence** signalling, call wall integrity
    - Legacy of CaOH additions in the 'bad orchards' ?
- High **tN, OM/oC** related to **higher canker** – expected
  - Rich soils → more canker (Nitrogen supply)
- High **Fe** related to **less canker** – (un)expected
  - Fe deficiency – stress / enhance resistance (Arabidopsis), low Fe in tissue less disease
- High **Mo** related to **less canker** – expected
  - Mo essential for nitrogen uptake, defence, wound healing
- Study limitations:
  - Low sample size / orchard management / cultivars / age / single time point
  - Soil nutrients vs. tree nutrients vs. nutrients available to *N. ditissima*
  - Nutrient interactions not accounted for
  - Low effect sizes – signals – NOT conclusive for improved soil management programme
    - No nutrient clearly separating top 25% from bottom 25% of orchards (analysis not shown)
- Future work:
  - Nutrient / fertigation manipulation experiments – Fe result validation
  - Available nutrients? / Nutrients in plants rather than soil?



Introduction - Soil beneficial microbes - canker

- **Arbuscular mycorrhizal fungi (AMF)** were found to:
  - Help with tree nutrition and water management
  - Increase drought (Wu et al., 2015) and waterlogging tolerance (Tuheteru & Wu, 2017).
  - Reduce the severity of Botryosphaeria canker in India (Krishna et al., 2010) and Neonectria canker in cider apple in the UK (Berdeni et al., 2018)

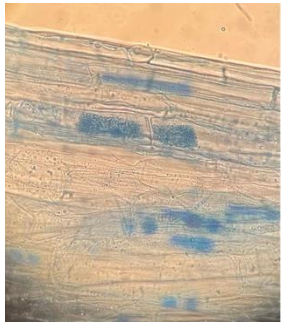
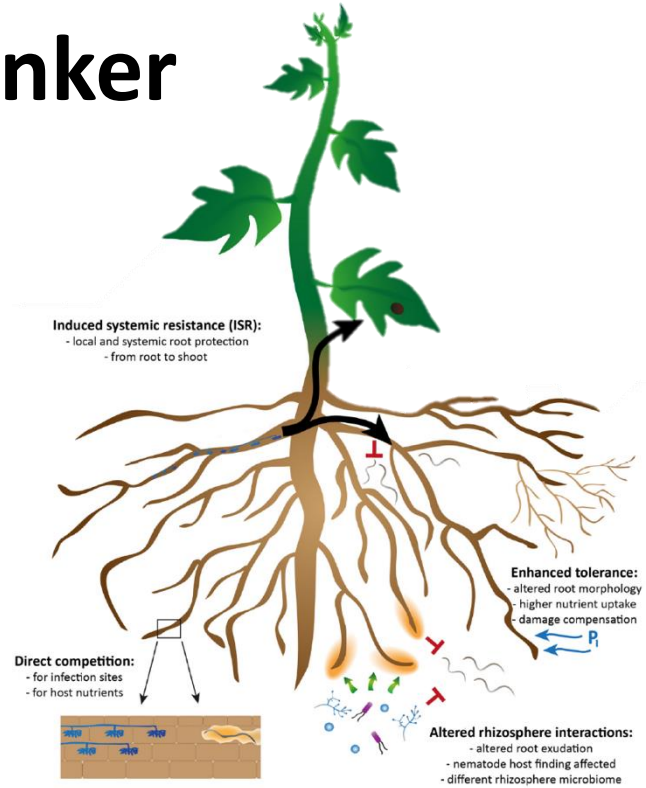
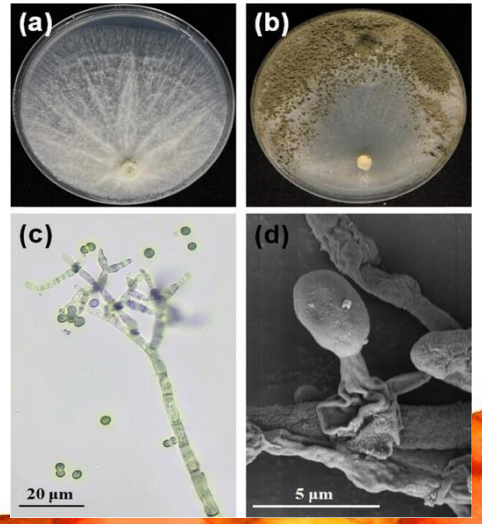


Photo: K. Dagg, L. Boyer



- Trichoderma **spp.** been shown to control almond canker diseases (Holland et al., 2021) and grapevine trunk diseases (Zanfano et al., 2025)



Yuxin Rao, BMC Microbiology, 2022

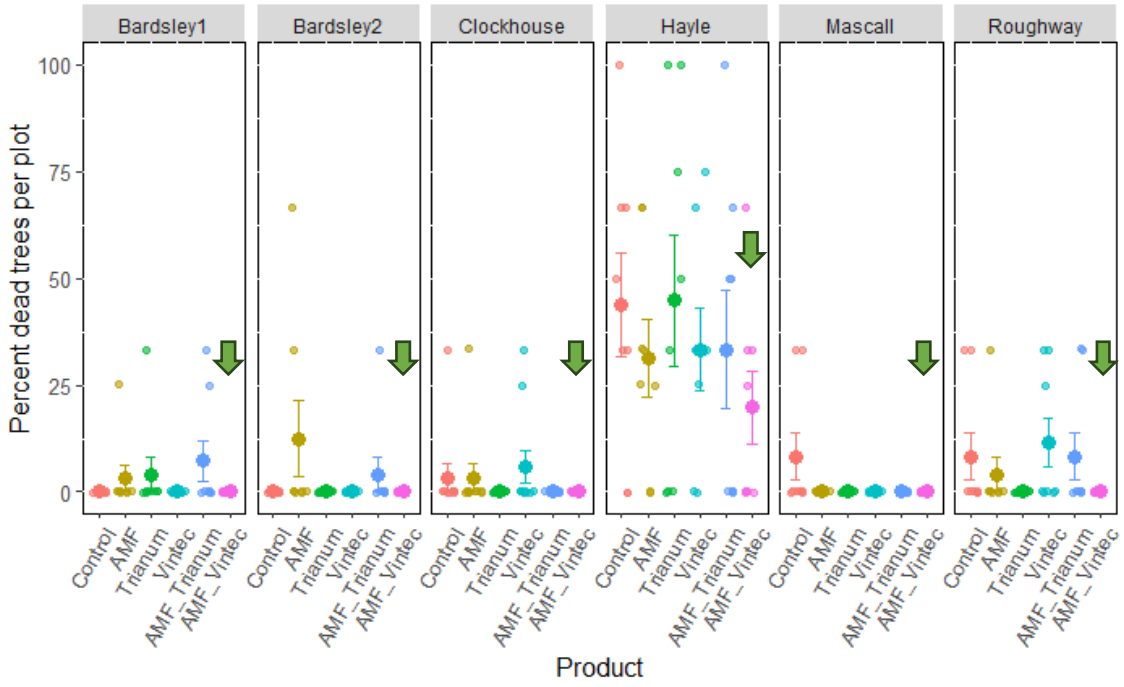
Aims & Methods

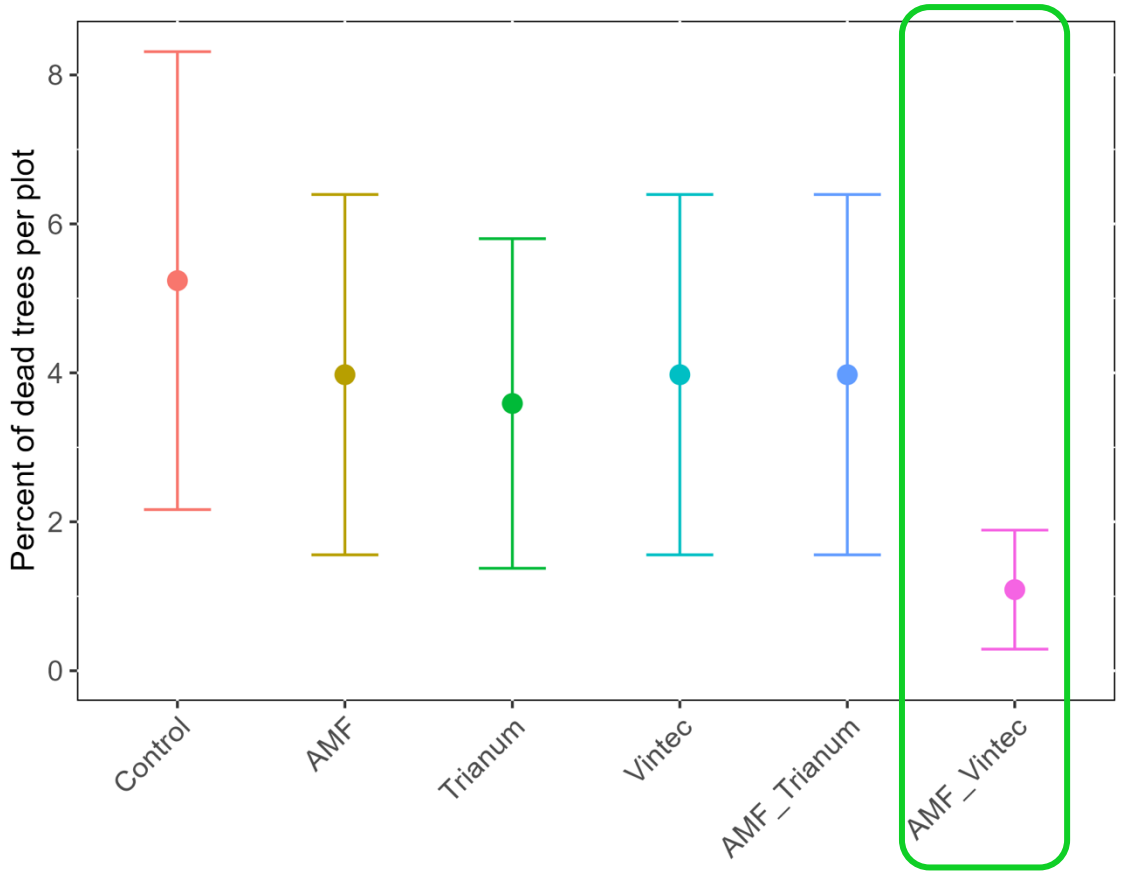
- Aim: To investigate if **soil microbiome amendments at planting** can **improve canker resilience**?
- Methods:
  - Six commercial orchards planted in 2022 (150-200 trees per orchard)
  - Microbial amendment products were applied to the roots of trees at planting
    - Mycorrhiza **(**AMF) (PlantWorks, RootGrow)
    - *Trichoderma harzianum* (Koppert, Trianum-P)
    - *Trichoderma atroviride* (Certis Belchim, Vintec)
  - Six treatments:
    - AMF only
    - Trianum-P only
    - Vintec only
    - AMF + Trianum,
    - AMF + Vintec
    - Control (nothing added)

- Orchards were managed commercially by the growers
- Canker, and tree mortality assessed every year

Results – Soil beneficial microbes

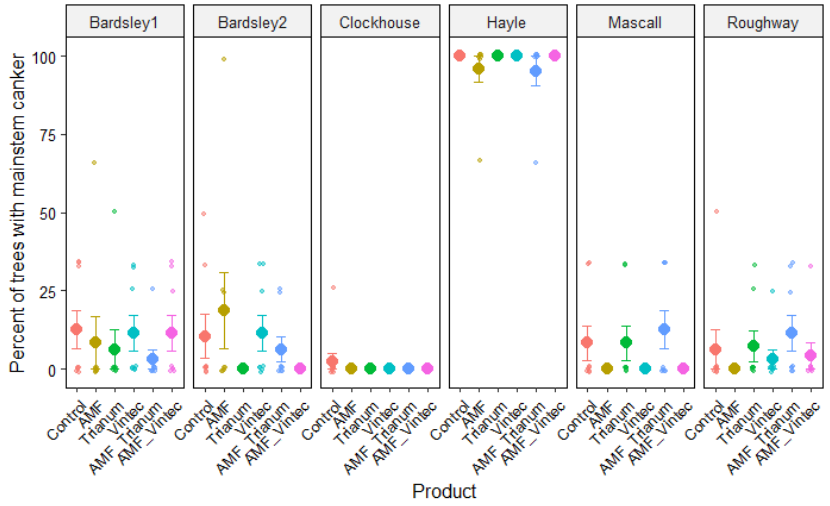
- **Tree mortality**:
  - Reduced slightly by all treatments
  - **Reduced significantly** by combined **AMF + Vintec** treatment
    - 5-fold mortality reduction

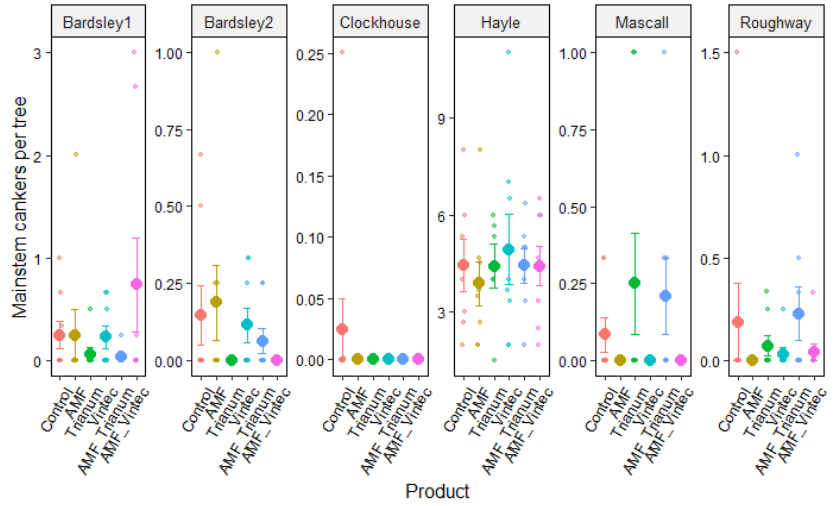


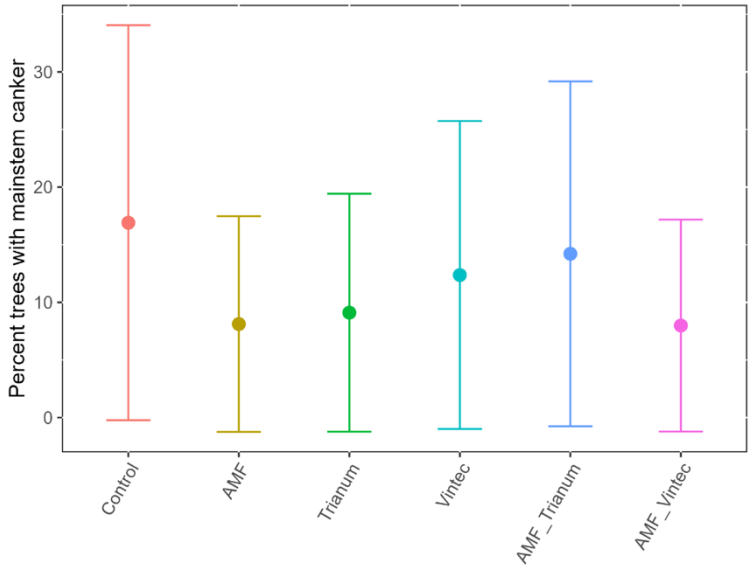


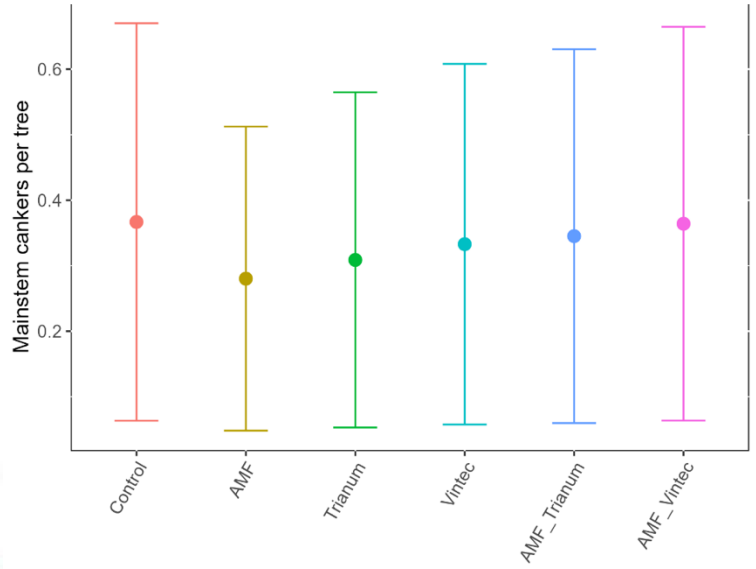
Results – Soil beneficial microbes

- **Mainstem canker – rootstock & mainstem**
  - Not significantly affected by treatments / site variability



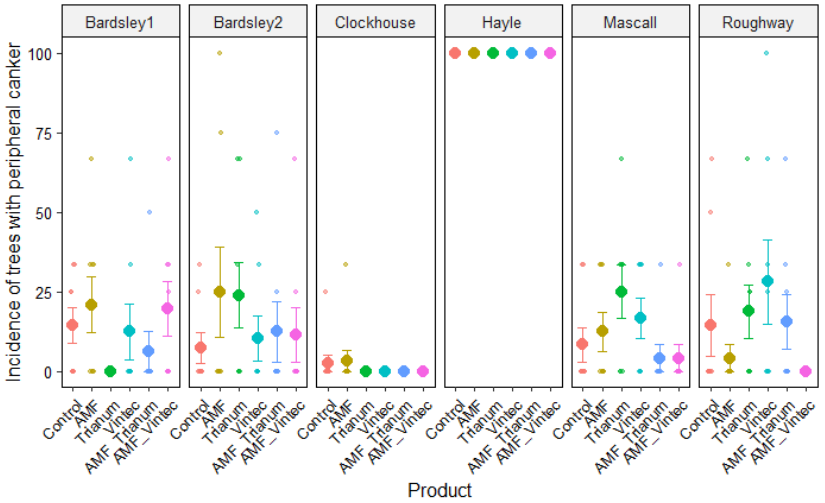


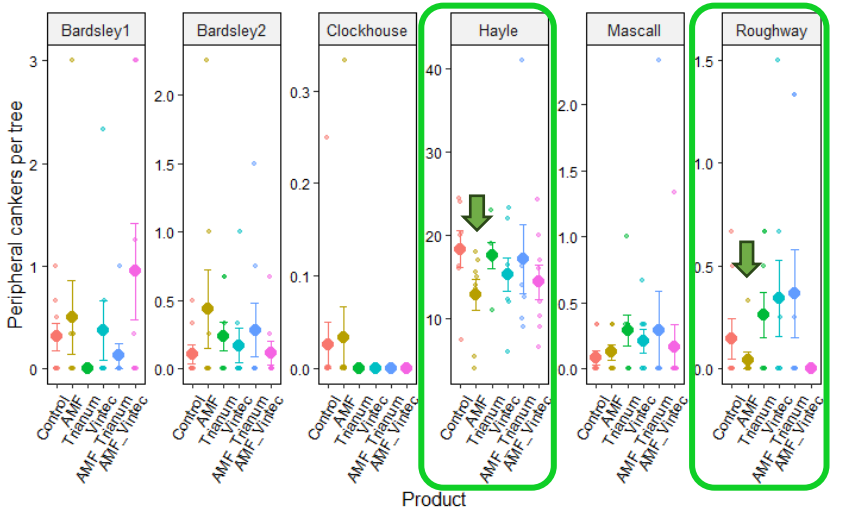


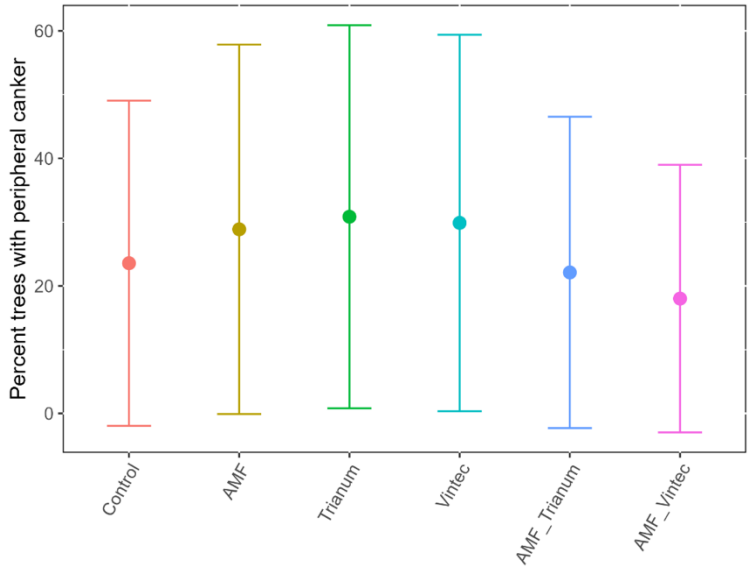


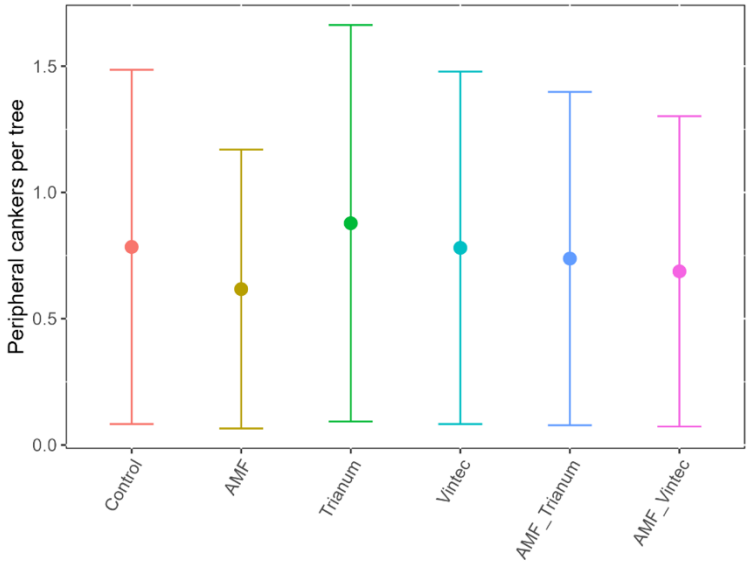
Results – soil beneficial microbes

- **Peripheral canker – branches**
  - Incidence not affected / **Canker numbers reduced by AMF – by 25% on average** (site variation?)



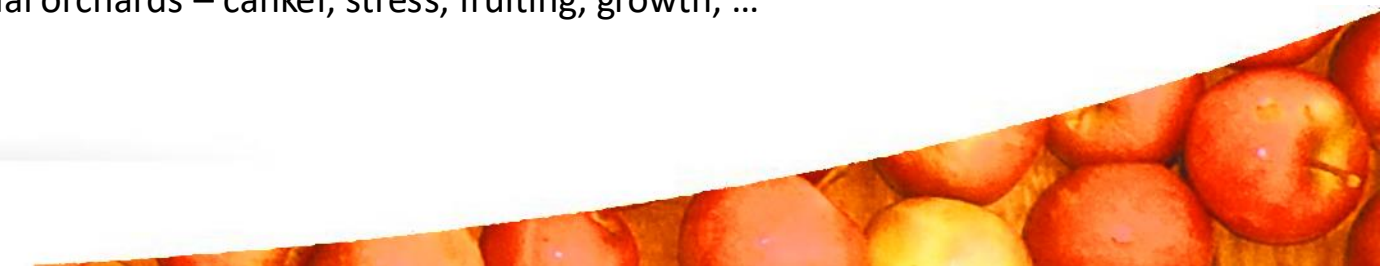






Discussion - Soil beneficial microbes

- **AMF + Vintec significantly reduced tree mortality**
  - In the first 3 years → effect should persist / increase over time
  - Not all trees died of canker / Abiotic Stress tolerance
    - Drought, heat, waterlogging, soil pathogens, …
- **AMF significantly reduced peripheral canker levels**
  - Induced Systemic Resistance / Enhanced nutritional status / Antioxidant and secondary metabolite defence activation / Soil microbiome alteration / Improved vigour
- **Both products available for growers to use***
  - AMF – RootGrow (Plantworks) – 25-50 ml per tree – directly on the wet roots and planting hole
  - Vintec – *T. atroviride* SC1, Certis-Belchim – 0.2 g per tree in 100 ml of water – over the roots and planting hole
    - *EAMU for soil application in progress
- Wildflowers can increase AMF in orchard soil – improve mature orchards (Niab, AM Fresh, Agrovista)
- New and ongoing research on soil beneficial microbes:
  - Measurement of tree growth in progress – to be reported by summer 26
  - New IUK: ADOPT project started – Biochar / AMF / Trichoderma – 2025-27
    - BAPL, AC Hulme, Overy Farm
    - 2 large experiments planted in Dec 2025 in commercial orchards – canker, stress, fruiting, growth, …



Canker management – Take Home Messages

- **Remove / Destroy canker lesions** → reduce inoculum
  - infected fruit, infected windbreaks
- **Spraying only → constant battle** to protect the wounds against inoculum (works only if canker levels 0-3 %)
- **Monitor**, especially young orchards:
  - Hot spot marking / Canker champions / Canker bounty

- Canker and soil chemical properties:
  - **High soil Ca, CEC, OM/C, N** found in orchards with **more severe canker**
  - **High soil Fe and Mo** found in found in orchards with **less severe canker**

- Addition of **AMF and Trichoderma** at planting can **reduce tree mortality** and canker severity
  - Orchard resilience profitability, maintenance, longevity

Acknowledgments

- **Funders:**
  - British Apples and Pears (BAPL)
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  - Growing Kent and Medway – (GKM –IUK)
  - East Malling Trust

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  - **AM fresh**, **Agrovista**, East Kent Fruit Society (EKFS), British Independent Fruit Growers (BIFGA), WorldWide Fruit, …
  - Site access, data, advise, …

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  - Xiangming Xu: Soil nutrient study design and help with analysis
  - Louisa Robinson Boyer: Soil microbes study design and interpretation.
  - Assessments: **Tom Passey**, Jenifer Kingsnorth, Georgina Fagg, Maisie Bickerton, *et. al*

Thank you for listening.

Any questions?