AHDB HORTICULTURE

Grower Summary

CP 117

Investigating the cause and potential treatment of coriander yield decline

Final 2016

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The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

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Before using all pesticides check the approval status and conditions of use.
Read the label before use: use pesticides safely.

Further information

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Project title:	Investigating the cause and potential treatment of coriander yield decline
Project number:	CP 117
Project leader:	Kate Fraser, Newcastle University
Report:	Final Report (Year 2) October 2016
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Key staff:	Prof. Ian Singleton Prof. Anne Borland
Location of project:	Newcastle University
Industry Representative:	Dr T M Davies, Malvern View Herbs
Date project commenced:	01 October 2014
Date project completed (or expected completion date):	31 March 2017

GROWER SUMMARY

Headlines

- Coriander yield decline has been successfully induced in two commercial coriander varieties (Santos and Cruiser) in one soil type and a compost.
- A reproducible system was developed to generate yield decline-inducing soils allowing further in-depth study.
- In coriander pot experiments, yield decline was evident as a significant decrease in above ground biomass with no obvious signs of disease or reduction in root biomass.
- Soils in close association with the roots (rhizosphere) of plants exhibiting yield decline symptoms were found to have different microbial communities compared to the rhizosphere of healthy plants but no obvious microbial cause was found.

Background

Coriander (*Coriandrum sativum* L.) is an annual herb that is of high value with sales accounting for over 25% of the fresh herb market. Since the 1970s coriander has been grown commercially in the UK, however, production has been hindered in recent years by yield decline. Growers have reported yield losses of over 50% due to decline and indicate that the issue can persist for up to eight years, impacting negatively on the UK herb market. There are many factors that can cause yield decline such as toxic root exudates (autotoxicity), poor soil quality, poor soil management practices and soil microorganisms. Since coriander yield decline can persist for up to 8 years, autotoxicity is probably not the cause, as over time root exudates will degrade and bind with the soil matrix. Furthermore, preliminary work during this project showed that yield was not affected when coriander was grown in soil containing chopped coriander roots. From available evidence, it is considered that coriander yield decline most likely has a soil microbiological basis.

Summary

While growers reported coriander yield decline, the phenomenon needed experimental confirmation and had to be reproduced under controlled conditions to allow subsequent in-depth studies. The aim of this project was to determine whether yield decline could be induced in different soils and coriander varieties and to assess the impact of coriander cropping on soil microbial communities, using an Illumina Next Generation Sequencing (NGS) technique.

The following hypotheses were tested during the project:

1. Coriander yield decline can be induced in two commercial coriander varieties in soil and compost.
2. Coriander cropping causes a marked change in the soil microbial community, with bacterial communities in rhizosphere soil (soil in close association with roots) differing from those in bulk (the surrounding) soil, in soils planted with a single coriander crop.
3. The bacterial community of rhizosphere soil samples obtained from healthy coriander is different to that of rhizosphere soil obtained from coriander exhibiting yield decline symptoms.
4. The rhizosphere bacterial community obtained from yield decline plants grown in different soils is the same.

Establishing coriander yield decline in an agricultural soil

An experiment was conducted to determine if coriander yield decline could be induced under controlled conditions. This pot experiment involved two treatments: (1) coriander grown in a soil with no history of coriander cropping (sandy soil from Cockle Park Farm, Northumberland, UK); (2) coriander grown in the same soil type buy planted with coriander once before. A single coriander variety Santos was used. Plants from both treatments were harvested nine weeks after sowing for the collection of yield data.

Coriander plants grown in control soil with no history of coriander cropping, had significantly higher above ground weights (fresh weight, p=0.001; dry weight, p=0.01) compared to plants grown in previously planted soil (Figures A and B). Root fresh weight was also significantly higher in control soil (p=0.008).

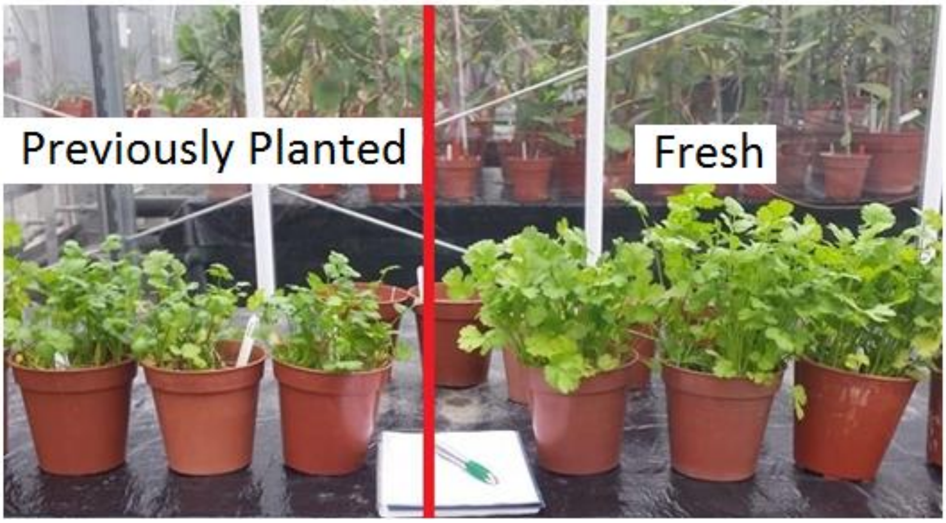

Figure A. Comparison of observable difference in yield between coriander var. Santos plants grown in control soil and soil planted with coriander once before.

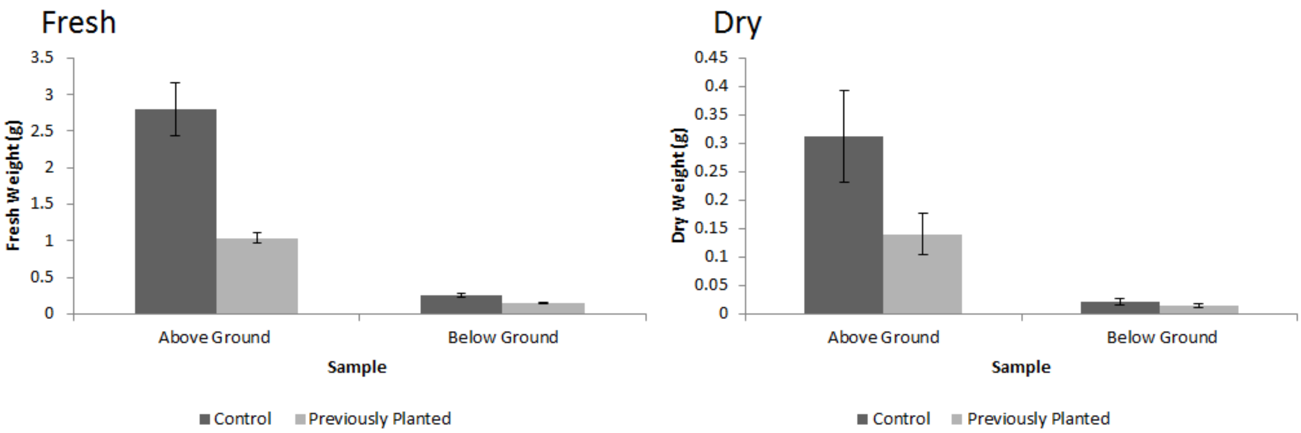

Figure B. Comparison of mean fresh and dry weights of coriander var. Santos plants grown in control and previously planted Cockle Park soil. Weights for above ground (shoot and leaf) and below ground (roots) are shown. Values plotted are ±1 Standard Error.

Inducing yield decline in compost with more coriander varieties

In a second pot experiment, John Innes No. 2 (JI) compost was used, as it could be expected to have consistent properties and have an entirely different microbiota to Cockle Park soil. Two coriander varieties, Cruiser and Santos, were each grown in both control JI compost and in JI compost sown with coriander once before. Plants were harvested eight weeks after sowing for the collection of yield data.

Both coriander var. Cruiser and Santos plants grown in control JI compost had a larger visible biomass compared to those grown in previously planted JI compost but the difference in total fresh biomass was not significant ($p>0.05$). However, for coriander var. Santos, shoot dry biomass was significantly reduced ($p>0.05$) in compost previously planted with coriander.

These results confirmed the occurrence of the yield decline phenomenon and that this could be demonstrated in a reproducible pot assay. Results demonstrated that yield decline occurred in both an agricultural soil and a compost, and with two coriander varieties. Further work will be required to investigate the occurrence of yield decline in more soil types and coriander varieties.

Investigating soil bacterial communities using Illumina NGS

The next focus of the work was to assess the impact of coriander cropping on soil microbial communities using an Illumina Next Generation Sequencing (NGS) technique. After harvesting coriander from pot experiments with Cockle Park soil and JI compost, pots were sampled for rhizosphere soil / compost (in close association with roots) and the surrounding bulk soil / compost. DNA was subsequently extracted from the soil / compost samples and sequenced using the Illumina MiSeq platform at NU-OMICS Ltd, Northumbria University. This work focussed on sequencing and analysing the bacterial communities but fungal community analysis was also carried out (A summary is provided in Appendix 2 of the Science Section of the full report). Data received following Illumina MiSeq sequencing were processed and the bacterial species composition of each soil was analysed.

A. Comparing bacterial communities of coriander rhizosphere soils to corresponding bulk soils

For this comparison, DNA was extracted from both rhizosphere and bulk samples taken from Cockle Park soil cropped once with coriander and containing healthy plants.

Results clearly showed that rhizosphere and bulk samples from Cockle Park soil (planted with a single coriander crop) had different bacterial community compositions. The top five abundant species in bulk soil samples were *Chitinibacter* spp. (~1.7%), *Thermacetogenium* spp. (~1.6%), *Desulfovibrio* spp. (~1.4%), *Mucilaginibacter* spp. (~1.3%), and *Pyramidobacter* spp. (~1.3%). Whereas in rhizosphere soil samples, *Pseudomonas* spp. (~2.2%) replaced *Chitinibacter* spp. as the most abundant species and *Chitinibacter* spp. was no longer within the top twenty most abundant species. In rhizosphere soil, the next most abundant species after *Pseudomonas* spp. were *Lysobacter* spp. (~1.5%), *Thermacetogenium* spp. (~1.5%), *Terrimonas* spp. (~1.4%) and *Desulfovibrio* spp. (~1.4%) (detailed data are shown in the Science Section). This suggests that coriander growth has a marked effect on soil microbial communities, with bulk soil samples having a different bacterial community composition to corresponding rhizosphere samples.

B. Analysing the bacterial communities associated with the coriander rhizosphere in previously planted vs. unplanted soil

For this comparison, DNA was extracted from: (1) Cockle Park soil, cropped once with coriander, containing healthy plants exhibiting no yield decline symptoms; (2) previously planted Cockle Park soil, cropped with coriander twice, and containing plants exhibiting yield decline symptoms.

Rhizosphere samples from ‘control’ Cockle Park soil planted with a single coriander crop had different bacterial community compositions compared to Cockle Park rhizosphere samples in which two coriander crops had been grown. The top five most abundant species in control rhizosphere soils were *Pseudomonas* spp. (~2.2%), *Lysobacter* spp. (~1.5%), *Thermacetogenium* spp. (~1.4%), *Terrimonas* spp. (~1.4%), and *Desulfovibrio* spp. (~1.3%). In previously planted rhizosphere soil, *Pseudomonas* spp. was the most abundant (~2.5%)

however it was not significantly ($p<0.05$) more abundant compared to control soils. The next most abundant species were *Sphingomonas* spp. (~2.5%), *Mycoplasma* spp. (~2.2%), *Halothiobacillus* spp. (~2.0%) and *Sphingobacteriaceae* spp. (~2.0%) (detailed data are shown in the Science Section).

Plants grown in previously planted soil exhibited symptoms of yield decline; therefore, it could be that a significant change to the microbial community is associated with yield decline; however, more work will be required to pursue this theory.

C. Establishing whether coriander yield decline has the same microbial causal agent in different soil types

To establish a potential causal agent of coriander yield decline, DNA was extracted from the following soils: (1) previously planted Cockle Park soil, cropped with coriander twice, and containing plants exhibiting yield decline symptoms; (2) previously planted JI compost, cropped with coriander twice, and containing plants exhibiting yield decline symptoms (three replicates per soil type).

Comparisons between the two soil types show that previously planted Cockle Park rhizosphere soil had a different microbial community composition compared to previously planted JI rhizosphere compost. The top five most abundant species in previously planted Cockle Park rhizosphere soils were *Pseudomonas* spp. (~2.5%), *Sphingomonas* spp. (~2.5%), *Mycoplasma* spp. (~2.2%), *Halothiobacillus* spp. (~2.0%) and *Sphingobacteriaceae* spp. (~2.0%). In previously planted JI rhizosphere compost, *Flavobacterium* spp. (~2.5%) was more abundant compared to Cockle Park rhizosphere soils. The next most abundant species were *Escherichia/ Shigella* spp. (~4.0%), *Vibrio* spp. (~2.0%), *Cytophaga* spp. (~1.7%) and *Flavobacterium* spp. (~1.7%) (detailed data shown in Science Section).

Since yield decline was obtained in soil and compost with different bacterial communities then it could be that the phenomenon is not linked to a specific causal agent. Instead yield decline could be induced by a change in the microbial community (or in microbial species not detected using the current methods) that is able to impact on coriander growth due to an overall functional change. Therefore, it should be noted that the yield decline phenomenon is very complex with different microbial communities having a similar negative impact on coriander crops.

Financial Benefits

The results suggest that coriander yield decline can be induced in soil and compost. Results from the Illumina NGS sequencing indicate that coriander cropping leads to a change in the soil microbial community composition. Hence rhizosphere soil has a different microbial community compared to surrounding bulk soil. However, current findings indicate that no single bacterial species is implicated in yield decline and it is possible that the phenomenon results from a change to the overall function of the microbial community present. This suggests that practices such as tilling after coriander growth, or adding soil amendments could help to alleviate decline by 'resetting' the soil microbial communities to change their overall function. Such remedies require further research but could potentially deliver financial benefit to the UK herb industry.

Action Points

No clear change of practice can yet be recommended.