Soil health influences tomato resistance to insect vectors of viruses

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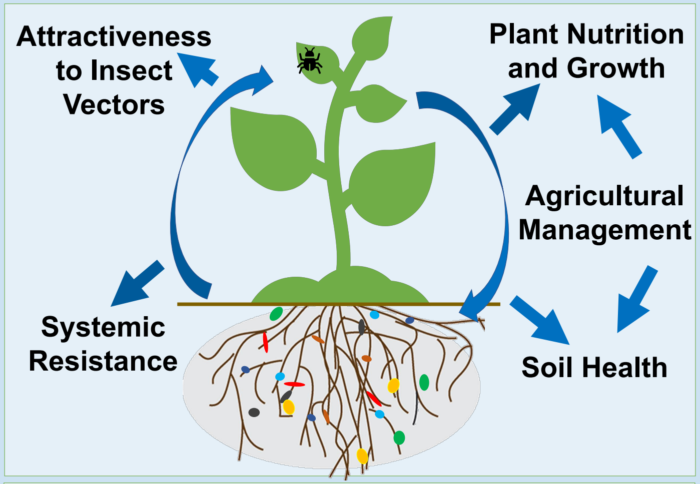
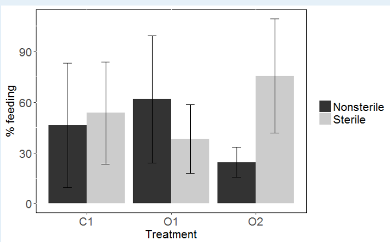
Abstract

Managing multitrophic interactions between soil microbial communities, crops, insect pests, and pathogens has the potential to increase plant health and agroecosystem productivity, resilience, and sustainability. However, the underlying mechanisms are unclear and the impact of soil health-building management practices on pest and virus resistance remains to be quantified in economically relevant crops. Processing tomato (*Solanum lycopersicum*) is a major crop in California, where production is limited by insect-vectored viruses such as Beet Curly Top Virus (BCTV), transmitted by the beet leafhopper (*Circulifer tenellus*). Two greenhouse experiments using field soil from the Russell Ranch Century Experiment representing a soil health gradient investigated the effect of soil health and microbial community composition on plant growth and nutrition, induction of defense compounds, and attractiveness to insect vectors. Results support a key role of microbial communities in multitrophic interactions: management affected fungal and bacterial community composition and soils from organic and conventional management differentially affected plant growth, nutrition, and defense pathways.

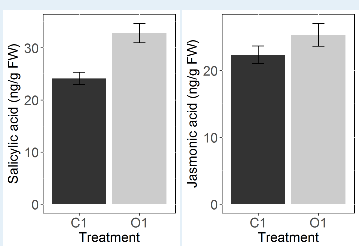


1. Soil microbial communities alone do not affect plant attractiveness to insect vectors of BCTV.



Leafhoppers tended to prefer plants grown in sterilized O2 soil, although the trend was not significant (p>0.05).While microbial communities did not generally make plants less attractive to insect vectors, it should be noted that tomato is not a preferred host for leafhoppers. Error bars indicate standard error. O1=RR organic; O2=PF organic; C1= RR conventional.

2. Management affects microbial mediation of plant defense pathways.



Inoculation with O1 microbial communities increased salicylic acid (SA, left) but not jasmonic acid (JA, right) concentrations as compared to inoculation with C1 microbes. Salicylic acid mediates the systemic acquired resistance response that can make plants more resistant to pathogens[1]. Error bars indicate standard error. O1=RR organic; C1= RR conventional.

Acknowledgements

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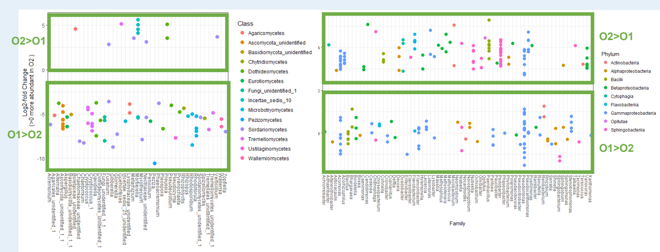
3. The effects of organic management are not uniform.



The abundance of fungal (left) and bacterial (right) OTUs differed between O1 and O2. Each dot represents an OTU and is shown within its genus (fungi) or family (bacteria). OTUs that were more abundant in O2 are above the center; OTUs more abundant in O1 are below the center. O1=RR organic; O2=PF organic.

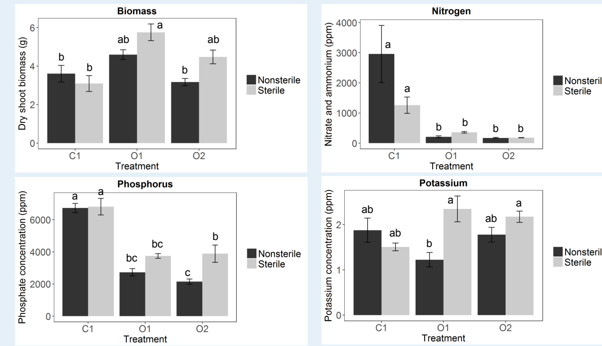
Methods

Field soil was collected from the Russell Ranch Sustainable Agriculture Facility Century Experiment (RR) long-term conventional (C1) and organic (O1) corn-tomato rotation, and an organic tomato field at Park Farming Organics (PF) in Meridian, CA (O2).

Half of the soil from C1, O1, and O2 was sterilized by autoclaving. Tomato seeds were planted in 2L pots in the greenhouse. After 4 weeks, leafhoppers were exposed to two plants/treatment, one grown in sterile soil and one in non-sterile soil (n=30 plants). After three days, feeding damage (# of stipples) was scored on 3 leaf samples/plant. Feeding on sterile vs. nonsterile plants was compared using a X^2 test of independence. At harvest, metagenomic DNA was extracted from rhizosphere soil and fungal and bacterial communities were sequenced using ITS and 16S primers. Reads were assigned to OTUs using 97% sequence similarity. Plants were dried at 60°C and aboveground biomass was recorded, then leaf samples were analyzed for N, P, and K with an acid digest method.

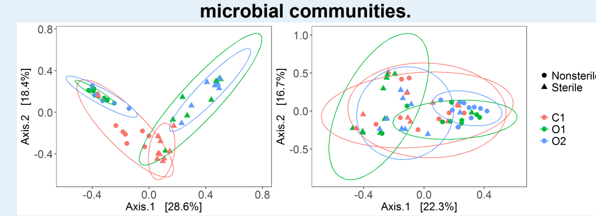
In a second experiment (Figure 2), tomato seedlings grown in sterile potting media were inoculated with soil slurries from C1 and O1 (1 g soil + 5 mL water), half of which had been autoclaved. Slurries were added to tomato plants weekly starting one week after germination. After three weeks, plants were harvested and leaf salicylic acid (SA) and jasmonic acid (JA) levels were measured using LCMS[1].

4. Organic management increases plant biomass and decreases tissue N and P.



Plants grown in organic soils had greater shoot biomass, lower tissue N and P, and tended to have higher tissue K in sterile treatments than plants grown in conventional soil. Plant nutrition affects susceptibility to herbivores and pathogens. Organic management can decrease tissue N, reducing root disease but not herbivory[2]. High levels of K can be protective against bacterial and fungal diseases, but increase susceptibility to viral diseases[3,4]. O1=RR organic; O2=PF organic; C1= RR conventional.

5. Agricultural management shapes rhizosphere microbial communities.



PCoA plots of rhizosphere fungal (left) and bacterial (right) communities, based on Bray-Curtis distances. Communities tended to cluster by management, with organic soils (O1, O2) more similar than organic and conventional soils from the same farm (O1, C1). Soil sterilization reduced the effect of management but did not eliminate differences, perhaps due to selective recolonization. Diversity (Shannon-Weaver and Chao1) was unaffected by management, suggesting that differences are due to changing species composition. O1=RR organic; O2=PF organic; C1= RR conventional.

Conclusions and Future Research

- Rhizosphere microbial communities are affected by agricultural management.
- Different taxa present in organically managed soils may affect plant nutrition, defense signaling pathways, and attractiveness to insect vectors.
- Ongoing research is investigating how management affects relationships between soil biological and physicochemical parameters, virus transmission within plants, and multitrophic interactions at the field scale.
- As tomato cultivation expands into marginal soils, a better understanding of the role of soil health in multitrophic interactions can inform management decisions to improve disease resistance and crop productivity.

References

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