Models for the Future Apple Plots: Benefits of Pre-plant Bio-remediation[1]

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Summary
Two years of bio-remediation with rotation crops during the establishment of demonstration apple plots suppressed nematodes and improved soil health. The pre-plant bio-remediation practices were evaluated and Dagger nematodes were decreased to the zer- tolerance level, and several soil health indicators were improved. Tree growth and fruit yield in the treatment plots were also higher than in control plots.

Following two years of rotations with bio-fumigant cover crops, apple trees were planted into strips of killed sod between middles of well-established endophyte-enhanced fescue. Photo: Tara Baugher, Penn State

Introduction

Penn State Extension is partnering with tree fruit growers in a *Models for the Future* project to provide on-farm demonstrations for new, young, and minority farmers. The *Models for the Future* apple plots are serving as living classrooms where Penn State educators and growers learn from each other. We extend special appreciation to our grower cooperators—Jake Scholl, Brett Saddington, Michael and Jesse King, David Deardorff, and Arturo Diaz. This project looked at plant parasitic nematodes, which can cause tree decline and death in a new apple planting. Dagger nematodes transmit viruses, such as tomato ringspot virus that causes union necrosis and decline, and lesion nematodes feed on tree roots, which can result in stunted tree growth.

Four M*odel for the Future* apple plots were established in 2017 at orchards across Eastern and Central Pennsylvania. From east to west, sites were established at Bedminster Orchard in Bucks County, Scholl Orchards in Berks County, Twin Springs Fruit Farm in Adams County, and the Rock

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Springs Orchard at the Russel E. Larson Ag Research Center near State College. The model orchards were planted with two apple scab resistant cultivars, GoldRush and CrimsonCrisp. All trees are on the dwarfing rootstock G.11, with the exception of the Rock Springs site that planted CrimsonCrisp on M.9 Nic 29.

Prior to planting the trees, all sites were planted in cover crops, including sorghum sudangrass and rapeseed. The cover crops selected have been shown to suppress plant parasitic nematodes and to maintain soil health during the rotation between orchard plantings. In 2015 sudangrass was seeded as a summer cover, and it was followed by rapeseed as a winter cover in late August/early September. The rapeseed was incorporated in April 2016, and a second rapeseed crop was planted for the summer.

Between each planting, the sudangrass and rapeseed covers were mowed with a flail mower, incorporated, and cultipacked. The varieties used ("Pioneer 877F" sudangrass and "Dwarf Essex" rapeseed), have high concentrations of bio-fumigant compounds, and were chosen for this project to help decrease nematode pressure within the plantings. Following two years of bio-remediation, a slow growing endophyte-enhanced fescue mix was planted in fall 2016. The well-established sod out-competes broadleaf weeds that may serve as reservoirs for viruses associated with tree decline.

Nematode comparisons before and after two years of cover crops

Nematodes were sampled before and after the cover crops were incorporated. After two seasons of cover cropping the model plot sites, populations of dagger nematode were zero (Table 1). Several nematodes that feed on roots were also reduced to zero. During the final sampling, two replant sites adjacent to the Scholl Orchard and Rock Springs model plot sites that remained fallow were also sampled for nematodes (data not shown). These adjacent fields each contained high numbers of dagger nematodes.

Table 1. Nematode assay results for "Models for the Future" apple plots following removal of previous orchard/crop and at various stages following bio-remediation with the cover crops sorghum sudangrass and rapeseed. Note: The tolerance level for dagger nematodes is zero.

Nematodes per 100cc of soil.

Model plot	Date	Dagger	Lesion	Spiral	Lance	Ring	Pin	Stunt
Bedminster	Apr-2015	10	0	5	10	5	0	0
	Oct-2016	0	0	0	0	0	0	0
Rock Springs	Apr-2015	4	8	4	4	0	16	0
	Sep-2016	0	0	10	10	0	0	10
Scholl	Apr-2015	0	0	5	10	5	0	0
	Sep-2016	0	0	0	0	0	0	0
Twin Springs	Apr-2015	12	0	0	4	0	0	0
	Sep-2016	0	0	0	0	0	0	0

Soil health comparisons before and after two years of cover crops

Soil health is the ability of a soil to provide an environment that sustains and nourishes plants, soil microbes, and beneficial insects (Natural Resources Conservation Service – USDA-NRCS, 2013). A healthy soil needs to have good soil tilth, soil depth, and water holding capacity, while still draining well. Healthy soils should have adequate nutrients, low amounts of pathogenic organisms, and many beneficial organisms. The Cornell Soil Health Test examines many soil health parameters, and educators submitted samples for the Cornell Soil Health Test before and after two years of rotations with cover crops (Moebius-Clune et al., 2016).

The orchard soils in the Model for the Future plots started out with good to excellent soil health with a couple of exceptions (Table 2). Aggregate stability, organic matter, and active carbon started low and were improved by preplant cover crops at the Bedminster orchard site. Organic matter started very low at the Rock Springs site but was not improved after two years. The average biomass added to each model plot, based on weights of 5-subplot samples, was 15,600 lbs per acre.

Since soil health indicators improve slowly following bio-remediation, we assessed soil health again a third year following the first sudangrass cover crop. Soil organic matter finally improved at the Rock Springs site, and percent organic matter increased further at the Scholl and Twin Springs model plots. Soil health indicators that improved at all sites were surface hardness, subsurface hardness, and pH, while water capacity, aggregate stability, soil protein index, and respiration fluctuated from year to year, even though we collected samples during the same timeframe each season (early June). Overall soil health score improved from sub-optimal to excellent in the Bedminster and Rock Springs plots and from excellent to optimal in the Scholl and Twin Springs plots.

We conducted a separate study in 2017 to compare soil health from the bio-remediated model plots to the following treatments in commercial orchard sites: 1) no rotation, 2) fallow for two years, 3) agronomic crops (corn, soybeans) for two years, or 4) compost prior to planting (4 sites each). In this broader study, organic matter in the model plots was higher than in the "no rotation" or fallow plots. Compost sub-surface hardness was lower than all but the agronomic treatment. Compost soil protein index was equal to model plot levels but higher than the index of the other treatments. The soil protein index is an indicator of chemical and biological health of the soil, and is well associated with overall soil health. The findings are similar to other independent studies; however, statistical evaluations of multiple studies have shown a universally positive effect of cover crops on soil microbiome.

Prior research on soil health in orchards indicates two of the best indicators of improved soil health are early tree growth and yield. Comparisons of the model plot trees that received bio-remediation and control trees that were planted the spring following orchard removal showed that tree height, trunk diameter, yield, and crop load (yield/trunk cross-sectional area) were significantly greater as a result of bio-remediation. Yield in the second leaf increased by 34%, an approximate increase in net return of $2000 per acre.

Table 2. Soil health results for "Models for the Future" apple plantings at the beginning of site preparation and following incorporation of various cover crops and recommended soil amendments. Soil health samples were collected in early June of each year.

Orchard	Year	AWC g/g	Surface Hardness psi	Sub-surface Hardness psi	AS %	OM %	ACE Value	SR mg	Active C ppm	pH
Bedminster	2015	0.27	198	289	23.2	3.6	-	-	383	5.4
	2017	0.33	230	300	77.1	5.2	10.0	0.4	661	5.9
	2018	0.25	90	200	48.9	4.2	6.1	0.4	532	6.7
Rock Springs	2015	0.19	200	300	17.7	2.3	-	-	382	5.7
	2017	0.21	208	228	15.2	2.4	4.1	0.5	385	7.1
	2018	0.25	123	188	12.5	2.9	4.2	0.3	380	6.9
Scholl	2015	0.23	-	-	60.9	6.5	-	-	710	5
	2017	0.26	133	281	42.6	5.2	9.8	0.9	527	6.1
	2018	0.19	117	203	65.8	6.2	7.5	0.6	688	7.0
Twin Springs	2015	0.34	266	300	62	6	12.7	0.68	878	5.8
	2017	0.29	243	250	50.1	5.3	13.0	0.63	711	6.1
	2018	0.23	193	243	71.6	6.2	13.7	0.60	792	6.3

Key to Index Values

Available Water Capacity (AWC)

A measure of porosity of the soil. It is measured by the amount of water held by the soil sample between field capacity and wilting point by applying different levels of air pressure. It is an indicator of how well crops will fair under droughty conditions.

Surface Hardness

A measure of compaction in the top 6 inches of soil as determined with a penetrometer. It is an indicator of physical and biological health of the soil. High surface hardness can severely restrict the ability of roots to penetrate the soil.

Subsurface Hardness

Similar to surface hardness, except at a depth of 6-18 inches. High subsurface hardness can prevent deep rooting in soil.

Aggregate Stability (AS)

A measure of how well soil holds together under rainfall or other rapid wetting stresses. It is measured as the percentage of soil aggregates (or crumbs) that hold together under a simulated rainfall. Good aggregate stability helps prevent crusting, runoff, and erosion, and facilitates aeration, infiltration, water storage, seed germination, and root and microbial health.

Organic Matter (OM)

A measure of carbonaceous material in the soil that is biomass or biomass-derived. OM provides a slow-release pool for nutrients, and promotes resistance to drought and extreme rainfall.

ACE soil protein index (ACE Value)

Measures autoclave citrate extractable proteins in the soil, which acts as an index for total proteins in the soil. It is an indicator of chemical and biological health of the soil, and is well associated with the overall soil health.

Soil Respiration (SR)

A measure of carbon dioxide released by the soil, which indicates the level of metabolic activity of the soil microbial community. This influences organic matter accumulation, as well as aggregate formation and stabilization.

Active Carbon (Active C)

Measures the portion of soil organic matter available as a food source for soil microbes. High active carbon is associated with a large population of soil microbes, which can help maintain disease resistance, nutrient cycling, aggregation, and many other essential soil functions.

Additional Benefits of the *Model for the Future* Living Classrooms

Using grower records from this project, Lynn Kime developed interactive budgets for making decisions on orchard replant practices . For example, the reduction of dagger nematodes to the zero tolerance level resulted in an economic savings of $1000 to $2000 per acre based on the cost of nematicides, and the addition of organic matter represented a potential economic benefit of $1030 per acre based on the costs of compost and application.

Additional cover cropping and pre-plant practices are discussed in a Penn State Extension video. If you are in New York and would like to learn more about this work or orchard soil health in general, please reach out to Mike Basedow at mrb254@cornell.edu or 518 410 6823.

USDA United States Department of Agriculture National Institute of Food and Agriculture

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