MANAGING SOIL MICROBIAL COMMUNITIES TO ENHANCE GROWTH OF APPLE IN REPLANT SOILS

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Typically, there are few biological impediments to the growth of apple on sites not previously grown to this or related species. In addition, agro-ecosystems in general possess a wealth of biological resources with the potential to be harbored for the control of plant diseases. Thus, the question arises as to what microbial transformations occur in response to planting soil to apple which result in the development of a microbial community capable of inciting replant disease. To address this question, studies were conducted that examined changes in soil microbial communities induced when an orchard was established in soil not previously planted to apple. The study site had been farmed to dryland wheat prior to orchard establishment, and the soil microbial community supported optimal tree growth. That is to say that a substantial elimination of the soil microbiota from non-replant soil did not significantly enhance, or for that matter reduce, growth of apple. A microbial community capable of inducing symptoms of replant disease on apple seedlings developed within two years of orchard establishment, and pasteurization of this 'replant' soil significantly enhanced tree growth. Decreased growth of apple was associated with increases in populations of plant pathogenic fungi belonging to the genera *Cylindrocarpon*, *Phytophthora*, *Pythium* and *Rhizoctonia*. Soil and root populations of plant parasitic nematodes were not altered over time and remained below damage threshold levels.

Significant changes in composition of rhizosphere bacterial communities were also observed. These included dramatic reductions in relative recovery of *Burkholderia cepacia* with prolonged orchard establishment, and transformation of the fluorescent pseudomonad population from one dominated by *Pseudomonas putida* btp B to a population comprised almost exclusively of *Pseudomonas fluorescens* btp C and *Pseudomonas syringae.* Interestingly, the microbial community from non-replant soil was capable of suppressing Rhizoctonia root rot, but soil from the same site that had been in apple production for three or more years was conducive to disease development.

Based on the disease suppressive capability of the microbial community resident to what had been 'wheat-field' soil prior to orchard establishment, studies were conducted to determine the feasibility of a 'phyto-remediation' approach to managing microbial communities for the control of replant disease. In greenhouse experiments, cultivating multiple cycles of wheat in replant soils was found to substantially improve the growth of apple subsequently planted into these soils. However, although the relative growth response was consistent across multiple replant soils, the magnitude of this growth response varied among three wheat cultivars grown prior to planting apple (Table 1).

In subsequent studies we have demonstrated that not all wheat cultivars (11 tested) are capable of eliciting this response, and that prior cultivation of replant soils to other grasses, including annual rye grass, does not enhance apple growth. Preliminary studies suggest that the ability of a specific wheat cultivar to enhance subsequent growth of apple in replant soils is determined by the capacity of root exudates to stimulate activity of specific elements of the soil microbial community. As indicated above, *P. putida* btp B typically dominates fluorescent pseudomonad populations in soils that support optimal growth of apple. *P. putida* strain 2C8 was isolated from the apple rhizosphere and provides biological control of Rhizoctonia root rot of apple. Wheat cultivars, such as 'Penewawa', that enhance growth of apple in replant soils produce root exudates that support growth of strain 2C8 when used as a sole carbon source in minimal media (Fig. 1). In contrast, wheat cultivars, such as 'Edwall' that do not exhibit the ability to enhance subsequent growth of apple or that provide a negligible growth response of apple in replant soils produce root exudates that are incapable of sustaining growth of strain 2C8.

Many research programs are actively examining the use of crucifers in rotation schemes to manage soilborne plant diseases. We have examined the use of canola plant tissue and oil rapeseed meal as a means to directly suppress the fungal complex that incites replant disease. In greenhouse studies, both materials dramatically enhanced the growth of apple in orchard replant soils (Tables 2 and 3). When amended to soil at a concentration of 2%, rapeseed meal was phytotoxic to apple regardless of incorporation date.

Further studies examined the combination of rapeseed followed by a single wheat rotation. The growth response achieved through this integration was superior to that obtained with either wheat or rapeseed alone (Table 2). In addition, a single 20-day wheat planting in soil amended with rapeseed meal at a concentration of 2% significantly reduced phytotoxicity.

The duration of fallow or cover cropping period required to obtain disease control obviously will have a large role in determining whether such a disease management option is economically viable. Experiments being conducted at the CV and WVC orchards are incorporating a time element to all of our wheat and rapeseed cropping trials. Replicated blocks within these orchards have been removed at one-year intervals over the past three years and planted to either 'Penewawa' soft white wheat or 'Dwarf Essex' rapeseed. In addition, each rapeseed block will be split and followed by one planting of wheat. At the time of planting, the orchard will possess replicated plots that have been fallow, cropped to wheat, or cropped to rapeseed for 1, 2 or 2.5 years. The orchards will be planted to 'Gala' on M.26 in the spring of 2000.

TABLE 1. Impact of short-term wheat cultivation in the greenhouse on subsequent growth of 'Gala' apple seedlings in CV and WVC orchard replant soils.

Wheat cultivar[a]	Plant height (cm)	Shoot weight (g)	Root weight (g)
CV Orchard			
None	9.2a[b]	1.04a	0.91a
Eltan	17.4b	2.89b	2.05b
Penewawa	18.2b	3.54b	2.90c
Rely	17.3b	3.25b	1.96b
WVC Orchard			
None	5.6a[a]	0.48a	0.39a
Eltan	11.1b	1.67b	0.99b
Penewawa	14.6c	2.66c	1.45c
Rely	14.0c	2.46c	1.06b

[a]Soils were planted to three successive 28-day cycles of the respective wheat cultivar.
[b]Means in a column followed by the same letter are not significantly (P=0.05) different.

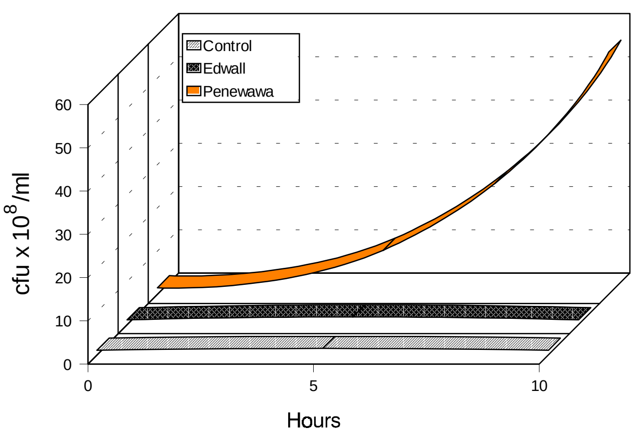

Fig. 1. Growth of *Pseudomonas putida* 2C8 in M9 media (control) or M9 amended with wheat root exudate as the sole carbon source.

Table 2. Impact of soil incorporation of canola leaf tissue and/or wheat cultivation on growth of ‘Gala’ apple seedlings in WVC orchard replant soils.

Treatment[a]	Plant height (cm)	Shoot weight (g)	Root weight (g)
Control	10.8ab[b]	1.35ab	0.74a
Wheat	9.3a	1.19a	0.62a
Canola	11.6b	1.77b	1.08b
Canola+wheat	20.6d	4.32d	1.49c
Pasteurized	16.4c	2.87c	1.13b

[a]’Wheat’ was a single 21-day planting of ‘Penewawa’ wheat. ‘Canola’ treatment involved the incorporation of ‘Dwarf Sussex’ leaf tissue into soil at a concentration of 1.0% (v/v).
[b]Means in a column followed by the same letter are not significantly (*P*=0.05) different.

Table 3. Effect of oil rapeseed meal on growth of ‘Gala’ apple seedlings in WVC orchard replant soil.

Treatment	Plant ht (cm)	Shoot wt (g)	Root wt (g)
Control	7.2a[a]	0.86a	1.12b
Rapeseed meal 0.1%	12.7b	2.59b	1.70c
Rapeseed meal 1.0%	17.0c	4.34c	1.66c
Rapeseed meal 2.0%	9.3a	1.01a	0.36a
Pasteurized	16.0c	3.03b	2.41d

[a]Means in a column followed by the same letter are not significantly (*P*=0.05) different.