Wheat varietal selection and annual vs. perennial growth habit impact soil microbes and apple replant disease suppression

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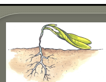


Soil-borne pathogens

- Major cause of yield loss in agricultural systems
- Apple replant disease
  - Caused my a complex of several fungal pathogens and parasites from the genera *Rhizoctonia, Pythium, Phytopthora, Cylindrocarpon and Pratelynchus*
  - Negatively impacts the growth of newly planted apple trees
  - Pre-plant fumigation is the only effective treatment

Suppression via crop rotation

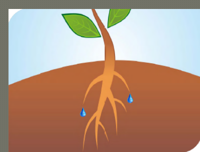
Rotating with cover crops and mixed hay has reduced soil-borne disease (Gu and Mazzola, 2003; Benitez et al., 2007; Larkin et al., 2011)

- Suppression correlated with changes in soil microbial activity & community composition
- Including genera well-characterized as biological control agents
  - ***Fluorescent Pseudomonas, Streptomyces, Burkholderia, Bacillus and Mycorrhiza***

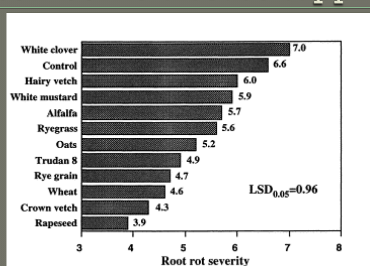
Basis for plant-microbial interactions

Plants support soil microbes via root exudates

- Amount & composition varies by species and genotype (Rengel, 2002)
- Soil microbial community varies with single plant gene mutation (Badri et al., 2009)



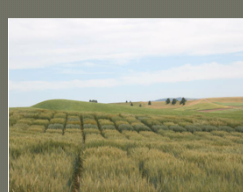
Impact of cover crop species on soil-borne disease suppresion



Effects of cover crops on root rot severity of snap bean. Rated on a scale of 1 (no root rot observed) to 9 (>80% of the roots infected). (Abawi and Widmer, 2000)

Impact of wheat genotype on biological control agents

- Wheat varieties differ in capacity to support biocontrol *Pseudomonas* species (Gu and Mazzola, 2003; Meyer et al., 2012)
- Differences correlated with suppression of apple replant disease in greenhouse studies (Gu and Mazzola, 2003)



Impact of selection conditions on plant-microbial interactions

- Soybean genotypes selected in high-input systems unable to discriminate between efficient nitrogen fixing symbionts (Kiers et al., 2007)

Soybean root nodules

- Selection in low-input systems inadvertently selected for sugarcane genotypes that associate and benefit from native soil diazotroph spp. (Baldini et al., 2002)

Perennial wheat

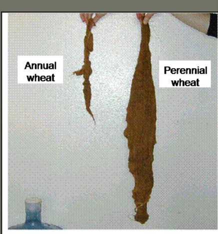


Figure 2. Root systems of annual and perennial wheat grown in hydroponics

- Cross between annual wheat and wheat ancestors (*Thinopyrum intermedium*)
- Deeper and more extensive root systems than annual wheat
- Tolerant of *Rhizoctonia* and *Pythium* (Okubara and Jones; Hoagland et al., unpublished)
- Regrows after cutting

Objectives

- Determine whether selection conditions and a perennial versus annual growth habit impact the ability of wheat genotypes to increase genera characterized as biocontrol agents
- Evaluate the ability of annual and perennial wheat genotypes to suppress apple root pathogens and enhance apple seedling health

Materials and Methods

- Greenhouse trials conducted using field soil from apple orchards with documented pathogen infestation
- Field soil subjected to the following treatments:
  - Control
  - Pasteurized
  - Annual ryegrass
  - One of four annual historic wheat genotypes
  - One of four annual high-input wheat genotypes
  - One of four annual organic wheat genotypes
  - Wheat relative (*Thinopyrum intermedium*)
  - One of four perennial wheat genotypes

Materials and Methods

- Each treatment subjected to three, 28- day wheat growth cycles (5 reps/treatment)

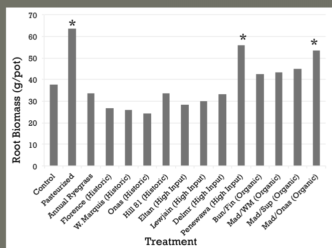
- Following cultivation, planted to three six-week old gala seedlings and harvested after 10 weeks
- One genotype from the perennial, high-input and organic groups with greatest improvement in apple seedling health selected for rhizosphere microbial analyses
- Experiment was repeated

Materials and Methods

- Field studies conducted at two sites (Fuller and Tukey) previously planted to apple with documented pathogen infestation
- Treatments
  - Pasteurized or fumigated with a mixture of *Brassica juncea* and *Sinapis alba* seedmeal
  - High-input annual wheat genotype (cv. Penewawa)
  - *T. intermedium* (cv. Rush)
  - Mixture of perennial wheat genotypes

(*Organic not included due to lack of available seed*

Greenhouse results

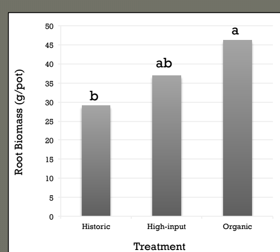


Impact of annual genotypes on apple root biomass in two greenhouse trials
** Different from control (P<0.05)*

- Large differences among genotypes
- Two genotypes improved performance relative to the control
- None improved performance relative to pasteurization

Greenhouse results

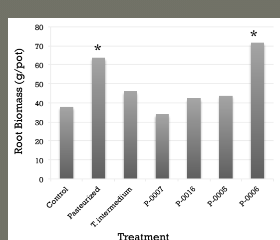
- Selection conditions influence genotype performance



Impact of wheat selection conditions on apple root biomass in two greenhouse trials *(P<0.05)*

Greenhouse results

- High variability within perennial wheat genotypes
- P-0006 improves performance relative to pasteurized treatment



Impact of perennial wheat on apple root biomass in two greenhouse trials
(Significantly greater than control P<0.05)*

Greenhouse results

Improvement in apple seedling health correlated with modification of the soil microbial community

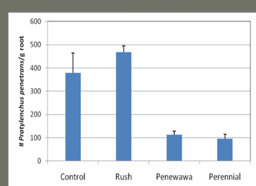
Rhizosphere microbial populations in greenhouse trials (CFU per 0.5g apple root)

Treatment	Fluorescent Pseudomonas	Total pathogens†
Control	31.6×10^8 bc*	58×10^4 a
Pasteurized	6.05×10^8 c	15×10^4 c
T. intermedium (cv. Rush)	93.5×10^8 a	14×10^4 c
Perennial (P-0006)	94.4×10^8 a	32×10^4 b
Organic (Onas/Madsen)	93.9×10^8 a	32×10^4 b
High-input (cv. Penewawa)	70.7×10^8 ab	15×10^4 c

* Means in the same column followed by the same letter are not significantly different ($P < 0.05$; n=10); † *Cylindrocarpon, Pythium, Rhizoctonia*, and *Verticillium*

Field results

- Penewawa reduced soil-borne pathogens and improved apple seedling health
- Perennial wheat mixture reduce pathogens despite poor establishment, but did not improve apple seedling health



Soil populations of *Pratenlynchus penetrans* following cover crop cultivation at Fuller orchard

Conclusions

- Wheat is a valuable crop to include in a crop rotation to help suppress soil-borne pathogens
- Similar pathogen complexes affect various crop plants, thus findings of value across multiple systems

Conclusions

Breeding programs can be designed to exploit beneficial microbial interactions

- Wheat genotypes differ in their ability to support biological control agents
- Wheat genotypes also differ in their ability to associate and benefit from:
  - *Azospirillum* (Hoagland et al., 2008)
  - Mycorrhiza (Herrick et al., 1993; Hilderman et al., 2011)

Conclusions

Selection under organic conditions will enhance selection for positive plant-microbial interactions

- Soil microbial community structure differs in organic and conventional systems (Bullock III et al., 2002; Esperschütz, et al., 2007; Reeve et al., 2010)
- Soil microbes impact plant phenotypic traits (yield, disease resistance, flowering time, nutritional content, etc.)
- Varieties selected under organic conditions are not always top performing varieties selected under conventional conditions (Murphy et al., 2007)

Conclusion

- Continued development of perennial wheat will improve soil-borne disease suppression and bring other broad agronomic and environmental benefits

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Sowing Seeds to Transform Agriculture

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Thank you for your attention