Effects of field management practices on plant health and rhizosphere microbial community structure

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Abstract

Farming practices can have profound effects on soil properties including physical, chemical and biological characteristics. In this study, we characterized the influence of soil management practices on soil borne disease suppressiveness and soil microbial population structure in an organic cropping system. Four transitional management strategies, with and without compost amendments, were considered: mixed hay, tilled fallowing, open-field vegetables and high tunnel vegetables. The effects of compost addition on soil characteristics varied with transition strategy, with the greatest effects being observed in the soils coming from the mixed hay and high tunnel treatments. The effects of treatments on plant health were assayed in growth chambers using Edamame soybean (cv. Sayasume). In general, disease severity increased with the addition of the compost amendments, and the mixed hay treatment was less conducive to disease development. In addition, tilled fallow and vegetable cropping systems had the highest disease. Microbial populations are being studied through culture-dependent and culture-independent strategies. In Edamame soybeans, compost amendments led to higher rhizosphere colonization rates of various *Pseudomonas* spp. under all cropping strategies. In addition, soil and rhizosphere bacterial community profiling using terminal restriction fragment length polymorphism (T-RFLP) revealed at least seven terminal restriction fragments specifically associated with different cropping systems. Characterization of selected ribotypes would lead to the identification of novel microbial populations associated with disease suppressiveness in these fields.

Results

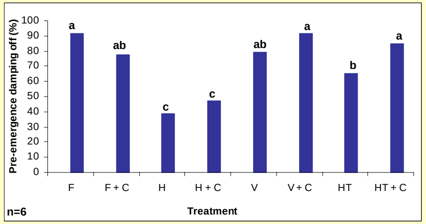
1. Soil characteristics

Treatment	pH		N%		C%		P		K		Ca		Mg		Mn		Zn	
							Nutrients (ug/g)											
F	6.1	f	0.1	c	1.0	d	42	d	88	e	998	f	191	g	185	d	4.6	d
F +C	6.6	d	0.2	b	1.6	c	91	c	219	d	1374	d	249	e	196	cd	5.7	c
H	6.4	e	0.1	c	1.2	d	38	d	81	e	1243	de	188	g	208	bcd	4.1	d
H +C	6.7	d	0.2	b	2.3	b	127	b	327	b	1850	b	332	b	191	cd	10.1	ab
V	6.5	e	0.1	c	1.0	d	40	d	93	e	1175	e	220	f	215	b	3.5	e
V +C	6.9	c	0.2	b	1.7	c	121	b	282	c	1575	c	308	c	202	bcd	6.7	bc
HT	7.0	b	0.1	c	1.1	d	47	d	84	e	1539	c	290	d	239	a	4.0	e
HT+C	7.2	a	0.3	a	3.4	a	222	a	1707	a	2328	a	589	a	198	bcd	14.9	a

- Soil carbon and mineral nutrient content increased with compost application
- Greatest effect observed in high tunnel vegetable cropping system

2. Suppressiveness assay

2a. Suppression of damping-off



3b. Eubacterial community profiles

Mean relative abundance of individual terminal restriction fragments (TRF) associated with rhizosphere and bulk soil fractions, expressed as peak fluorescence intensity,

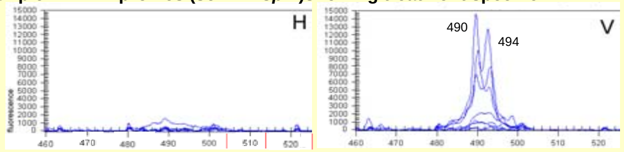
Rhizosphere – *Msp I*

Treatment	TRF TF104		122		141	
F	0	b	0	b	1091	b
FC	111	b	206	b	311	de
H	0	b	0	b	2174	a
HC	0	b	0	b	487	cd
V	0	b	65	b	582	cd
VC	0	b	516	a	642	bc
HT	0	b	902	a	1169	b
HTC	410	a	352	a	0	e

Soil – *Msp I*

Treatment	TRF 103		127		137		141		204		302		401		490		494	
F	278	b	1006	a	187	c	340	b	0	cd	380	a	651	ab	1664	b	2185	b
FC	134	c	778	b	177	c	234	b	57	bcd	131	bc	581	bc	1399	ab	1201	bc
H	145	c	213	cd	1321	a	1384	a	278	b	57	bc	1023	a	193	e	0	e
HC	29	c	0	e	622	b	947	a	0	d	0	c	162	d	204	de	0	e
V	69	c	1015	a	251	c	435	b	2242	a	51	bc	339	c	4074	a	3597	a
VC	99	c	379	bc	274	c	356	b	435	a	61	bc	294	c	1628	bc	2400	bcd
HT	199	c	361	bc	320	c	150	b	291	bc	55	bc	86	d	1409	bc	1505	cd
HTC	491	a	118	de	93	c	231	b	351	bcd	355	a	310	c	730	cd	451	de

Sample T-RFLP profiles (soil – *Msp I*)showing treatment specific TRF



Introduction

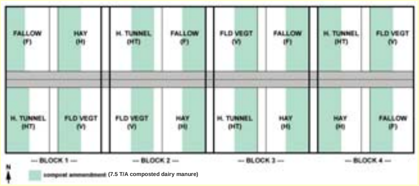
➢ Different management practices could be used during the transition from conventional to organic agricultural systems.
➢Farm management practices have significant impact on soil characteristics, including soil microbial populations.
➢Disease-suppressive soils are soils in which natural microbial populations protect plants from soil-borne pathogens (Weller et al., 2002).
➢ Native populations of *Pseudomonas* spp. are associated with disease suppressiveness (Weller et al. 2002).

Objective

➢ To determine the impact of management practices on soil borne disease suppression, and related microbial populations, during the transition from conventional to organic farming

Methods

The Peri-Urban Field:



Field soil sampling → Suppressiveness assay → Plant measurements / Microbial community analysis

- Edamame soybean (cv. Sayasume)
- Added pathogen inoculum: *Pythium ultimum* and *Phytophthora sojae*

- Rhizosphere colonizing *Pseudomonas* and 2,4-diacetylphluoroglucinol producing *Pseudomonas* (*phlD*+) (McSpadden Gardener et al. 2001. Phytopathology 91:44-54)
- T-RFLP profiling of eubacterial 16S rDNA from soil and rhizosphere DNA samples (McSpadden Gardener and Weller. 2001. Applied and Environmental Microbiology 67:4414-4425; Bankhead et al. 2004. FEMS Microbiology Ecology 49: 307-318)

2b. Effect on seedling vigor

Treatment	Fresh weight/ plant (g)		# of plants at V1*	
F	0.47	e	0.2	c
F +C	0.76	de	0.3	c
H	2.16	ab	2.8	a
H +C	2.42	a	2.3	a
V	1.33	cd	0.5	bc
V +C	0.67	de	0.2	c
HT	1.51	bc	1.1	b
HT+C	1.11	cde	0.4	bc

*V1 stage: first true leaves fully expanded

➢ Hay treatment significantly reduced percent damping-off and promoted plant vigor
➢ Trend: compost application increased damping-off and reduced vigor, except for tilled fallow treatment

3. Microbial community analysis

3a. Abundance and incidence of total and *phlD*+ pseudomonads

Treatment	*Ps.**	*phlD*+ *	% *phlD*+	> log 3.4	> log 4.5
F	7.3 b	4.6 a	4.1 a	50	50
F + C	8.0 a	3.1 a	0.0 a	25	25
V	7.8 a	5.8 a	2.3 a	20	20
V +C	7.9 a	6.8 a	8.2 a	100	100
H	7.0 c	5.9 a	8.2 a	87.5	87.5
H +C	7.8 a	6.3 a	2.3 a	75	75

* Mean population of total *Pseudomonas* or phlD+ *Pseudomonas* expressed as log CFU

➢ Compost application generally increased the abundance of rhizosphere colonizing pseudomonads
➢ The field vegetable cropping system supports higher abundance of total pseudomonads
➢ Amended and non-amended mixed hay cropping system support high abundance and incidence of *phlD*+ bacteria
➢Compost amendment in field vegetable system increased incidence of roots colonized by high levels of *phlD*+ bacteria

➢ Management strategies influenced the relative abundance of individual TRFs associated with rhizosphere and bulk soil fractions
➢ Dominant TRFs differ in relation to cropping system
➢ TRFs significantly associated with hay, field vegetables and high tunnel systems, were identified for both soil and rhizosphere communities

Discussion

➢ We hypothesized that cropping systems influences soil disease suppressiveness and microbial populations possibly linked to suppression.
➢ We observed that damping-off suppressiveness was greater in hay treatments, while tilled fallow soils did not significantly suppress disease.
➢ In general, for all treatments, increased fertility resulted in lower stand and plant vigor.
➢ Transition strategy and compost amendment influenced eubacterial community structure and the abundance and incidence of beneficial rhizosphere colonizing *Pseudomonas* populations (*phlD+)*
➢Higher incidence of phlD+ *Pseudomonas* on Edamame roots was observed in treatments associated with high (VC) and low (H, HC) disease severity.
➢ Specific TRFs associated with cropping strategy could represent candidate member(s) of the eubacterial community involved in disease (e.g. 204 soil) or disease suppression (e.g. 141 roots).
➢Further characterization of selected TRFs is needed to identify soil bacterial strains associated with each transition strategy.

References

➢Bankhead, S.B., Landa, B.B., Lutton, E., Weller, D.M. and McSpadden Gardener, B.B. 2004. FEMS Microbiology Ecology 49: 307-318.
➢McSpadden Gardener, B. B. and Weller D.M. 2001. Changes in populations of rhizosphere bacteria associated with take-all disease of wheat. Applied and Environmental Microbiology 68: 3226-3237.
➢Weller, D.M., Raaijmakers, J.M., McSpadden Gardener, B.B., and Thomashow, L.S. 2002. Microbial populations responsible for specific soil suppressiveness to plant pathogens. Annual Review of Phytopathology 40:309-348.