MPIC-06-10

Michigan Potato Industry Commission Proposal FY2009

Title: Continuation: Management of Disease Suppression, Yield, and Soil Quality in Potatoes

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Justification. Potato cropping systems present two fundamental challenges: maintaining soil quality and keeping plant diseases below economic thresholds. We believe that these challenges are intertwined and that declines in organic matter and biological function may contribute to increased severity of soil diseases, such as Verticillium wilt (Verticillium dahliae), potato common scab (*Streptomyces scabies*), and Rhizoctonia stem canker and black scurf (Rhizoctonia solani). These diseases are ubiquitous in Michigan potato production systems and their effects on yield or quality can be dramatic. For example, the root-lesion nematode (Pratylenchus penetrans), which is typically present in combination with the Verticillium-wilt fungus, is a major problem in approximately 50% of Michigan's potato acreage and, without the use of appropriate control factors, can result in yield losses of up to 15,000 kg/ha.

Organic amendments, such as compost or manure, can build soil quality and may provide an additional line of defense against disease (Porter et al., 1999; Grandy et al., 2002). Organic amendment applications, especially in sandy soils used to produce potatoes and many other vegetable crops have been shown to suppress a range of common plant diseases (Drinkwater et al., 1995; Abawi and Widmer, 2000; Stone et al., 2003; Everts et al., 2006; Rotenberg et al., 2007). Michigan potato producers have begun using organic amendments (manure and compost) to build organic matter and associated functions but there has, to date, been little research on optimizing application rates, timing, and quality to increase soil health and maximize yields and income. The key to broader deployment of these soil-building practices is to demonstrate their advantages and develop specific, economical recommendations for their use.

Based on our results in 2009, preliminary work by Dr. George Bird (personal communication), and field observations made by our collaborator Mark Otto there is reason to believe that the frequency of amendment applications may be critical. Here we are proposing to use low rates of application typically used by producers. At low rates, temporary stimulation of the microbial community may explain partial disease suppression and changes in soil quality (e.g. Boehm et al. 1996; Cleveland et al., 2007). While annual applications of large amounts of manure have been explored in many other studies, fewer experiments have looked at lower rates (c.f. Snapp et al., 2007). No studies that we are aware of have examined the benefits of low rates of organic amendments applied at different inter- and intra-annual frequencies.

Research to Date

We have received funding from MPIC in 2008 and 2009. In our 2008 MPIC submission we proposed a series of studies to analyze the effects of amendment additions on soil quality and plant disease. We made considerable progress on this work and presented it at the Montcalm Field Day in the summer of 2008 and at the Michigan Potato IndustryWinter Meeting in Grayling, MI. Our three most substantial accomplishments from this proposal include a thorough analysis of the soils in Dr. Sieg Snapp's long-term rotation study, the hiring of a graduate student and several undergraduates to contribute to the potato soil quality program, and the initiation of work to understand links between plant disease and soil quality. We showed that

crop rotations, including the use of clover cover crops and wheat could improve soil quality along with compost additions.

In 2009, after many discussions with industry personnel, producers, and potato researchers at MSU, we initiated a long-term manure rate x timing trial. The objectives of this trial were to determine whether the rate and timing of chicken manure application influences soil quality, potato tuber disease, and crop yield. We made weekly or bi-weekly measurements of soil nitrogen, enzymes, and microbial biomass. We presented the initial results from this study at the 2009 Montcalm Field Day and continue to examine soils from the site. At the end of the growing season we determined tuber yield and disease. A full discussion of our results to date will be reported in our 2009 year end report but we are excited to find strong changes in soil biology, yield, and disease with amendment applications. This study was initially envisioned to run for four years, which would provide us with enough time to explore different rates and timing of amendments over two rotation cycles. After considering our results and consulting with stakeholders at the summer meeting we feel it is important to set up a parallel study on a different site at MRF.

Research Objectives. Our global objective is to to determine how to economically use organic amendments such as compost and manure, as well as crop rotations, to improve soil health and crop yields and enhance environmental quality. Our specific objectives in this study are to: 1) investigate how the timing and frequency of organic amendment additions influences disease severity and soil disease suppression in potato systems; and 2) determine the degree to which the quality (i.e. chemical structure) of organic amendments interacts with the temporal pattern of organic inputs to influence soil quality and disease suppression.

Methods and Procedures. To address objectives one and two we are proposing laboratory and field experiments.

Field studies

Experiment Station Trial Our experiment station trial will be at the Montcalm Research Farm and consist of two parallel experiments with the same treatments. One of the studies was initiated in 2009 and another will be initiated in 2010. Our focus in the experiment station trial will be to evaluate the effects of organic amendment rates and timing on soil quality and disease suppression in a 3-year study. All of our plots will contain potatoes grown in a 2-year potato-corn rotation with rye cover crop planted in the fall. The potato variety that we will use is Snowden, a late-maturing variety many MI producers grow for sale to the chipping industry.

In 2009, we initiated a study investigating 7 different treatments (Table 1). The first set of treatments (treatments 1-3) receives a total of 6.8 tons of amendment C ha^{-1} during the experiment. This C is applied in one (treatment one), two (treatment two), or four applications (treatment three). Treatments 4-6 receive 13.6 tons of amendment C ha^{-1} applied at different frequencies, similar to treatments one through three. The seventh treatment is a control that receives no organic amendments. Plot management conforms to Michigan State University recommendations and the amendment is a chicken manure-based product from Herbruck's, one of the primary suppliers to the MI potato industry. The site that we initiated this experiment on in 2009 has heavy scab pressure. For example, we found a scab rating of 3-4 (with 5 being nearly complete coverage and deep pits) across all of our plots. Although rates tended to be

lower where manure was applied we would like to test these results again in a site with less scab. After consultation with other researchers, Bruce Sackett, and Alan Sackett at the MRF field day we would like to set up a parallel study on a different site at MRF with less scab pressure. This will allow us to test the validity of our first year results on a different site but continue with the initial trial.

Table 1. Organic amendment treatments that we use in the study at the Montcalm Research Farm. The potato variety that we will use is Snowden.

Treatment	Rate of amendment addition	Total number of applications	Timing of amendment applications	Total C addition over entire experiment
	ton C ha^{-1}			ton C ha^{-1}
1	6.8	1	1) Initiation (early spring year 1)	6.8
2	3.4	2	1) Initiation (early spring year 1); 2) after wheat harvest (year 2)	6.8
3	1.7	4	1) Initiation (early spring year 1); 2) after potato harvest (year 1); 3) after wheat harvest (year 2); 4) prior to potato planting (year 3)	6.8
4	13.6	1	same as above for 1 application	13.6
5	6.8	2	same as above for 2 applications	13.6
6	3.4	4	same as above for 4 applications	13.6
Control (7)	0	0		0

Soil quality and disease assessment Soil samples will be collected from both experiments bi weekly to determine pH, and several parameters used to characterize soil quality that are most likely to correlate with disease following changes in management. The biological parameters that we will look at include soil enzyme activities, microbial biomass, microbial substrate use diversity, and microbial community structure. We will use microplate methods in A.S. Grandy's lab to analyze 4 enzymes (β-1,4-N-acetylglucosaminidase, β-1,4-glucosidase, phenol oxidase, and phosphatase) involved in C and N cycling that we have previously found are reliable indicators of management effects on C and N cycling. The physical measurements that we will make are soil water stable aggregates and bulk density; the chemical measurements that we will make include soil pH, macro and micro nutrients, and total soil organic C and N. Grandy is familiar with all of these methods and has published protocols for several. At harvest, we will determine total yield, tuber size, and tuber discoloration and scab infection.

Laboratory studies

The laboratory and greenhouse measurements will allow us to screen the effects of multiple different organic amendments and the timing of their application on plant disease interactions. The first phase of our experiment will be conducted in replicated jars using artificial media consisting of sand and 16 organic amendments. The amendments will include six different manures commonly used in MI cropping systems (turkey, chicken, and cow, each acquired from two different sources) and 10 compost products. The compost products will be acquired from Morgan Composting (Sears, MI) and Herbrucks poultry Ranch and be chosen to represent a range in nutrient availability and C quality. Carbon quality, a term for the chemical structure and biological availability of the C, will be determined in A.S. Grandy's lab by chemical characterization using pyrolysis gas chromatography/mass spectroscopy and by CO_2 respiration during incubation. Jars containing the artificial media will be inoculated with Verticillium dahliae, Streptomyces scabies, and Rhizoctonia. Jars will be maintained at 60% water-filled pore space and capped weekly for CO_2 flux determination, an indirect estimate of microbial enzymatic activity. At the end of weeks two, four and 8, a subset of jars will be destructively sampled and a bioassay used to determine pathogen activity. At the same time, we will use enzyme kinetics (phenol oxidase, peroxidase, β-1, 4-glucosidase, and β-1,4-N-acetyl-glucosaminidase) and community-level physiological profiling (CLPP) to determine the physiological diversity of the soil community. Depending on these results, we will consider additional measurements of microbial community structure using terminal restriction fragment length polymorphism.

After screening a range of organic amendments for their efficacy we will choose three for follow-up studies in two experiments. In the first experiment, we will test the effects of our selected amendments on suppressing diseases on potato. Potato plants (var. snowden) will be grown in 75 L containers (58 cm height and 48 cm diameter) containing artificial media consisting of sand, agricultural soil, and organic amendment following methods outlined in Snapp et al., 2007. Organic matter will be supplied at a rate equivalent to 5 tons C/ha. The total C addition will be identical in all pots but we will vary the timing of application in three treatments: 1) one application (5 tons C/ha), where the equivalent of 5 tons C ha is applied ~15 d prior to potato planting; 2) two applications (2.5 tons C/ha each), where amendments are applied prior to potato planting and at tuber initiation; and 3) four applications (1.25 tons C/ha each), where amendments are applied prior to potato planting, at emergence, at tuber initiation, and ~three weeks after tuber initiation. Containers will be inoculated with Verticillium dahliae, Streptomyces scabies, and Rhizoctonia shortly after potato planting. Throughout the study, we will destructively sample containers to determine potato growth, disease severity, and soil biological properties.

Budget

Budget Item	FY-10
(A.) Personal Wages	
(A1.) Research Associates	
(A2.) Graduate Students	8,000
(A3.) Technical, Shop & Other	
(A4.) Secretarial & Clerical	
(A5.) Undergraduate Students	
(B.) Total Personal Costs	
(C.) Equipment Cost (Attach Explanation)	
(D.) Materials & Supplies	3,500
(E.) Travel	
(F.) Publication	
H. Other Costs (Attach explanation, list of items and individual costs.)	
TOTAL:	11,500

Justification

In this MPIC grant we are seeking funding ($8,000) to help support a graduate student who has been working on potato systems for the past two years in Stuart Grandy's lab. To date, he has been funded from other source. These are no longer available so we are trying to find funding for him through other sources. We are also seeking $3,500 for laboratory and field supplies related to this project.

Budget

Field experiment	$8,000
Technical support	$3,500
Total	**$11,500**

References

Abawi, G.S., and T.L. Widmer. 2000. Impact of soil health management practices on soilborne pathogens, nematodes and root diseases of vegetable crops. Applied Soil Ecology 15:37-47.

Drinkwater, L.E., D.K. Letourneau, F. Workneh, A.H.C. Vanbruggen, and C. Shennan. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California Ecological Applications 5:1098-1112.

Everts, K.L., S. Sardanelli, R.J. Kratochvil, D.K. Armentrout, and L.E. Gallagher. 2006. Root-knot and root-lesion nematode suppression by cover crops, poultry litter, and poultry litter compost. Plant Disease 90:487-492.

Grandy, A.S., G.A. Porter, and M.S. Erich. 2002. Organic amendment and rotation crop effects on the recovery of soil organic matter and aggregation in potato cropping systems. Soil Science Society of America Journal 66:1311-1319.

Porter, G.A., G.B. Opena, W.B. Bradbury, J.C. McBurnie, and J.A. Sisson. 1999. Soil management and supplemental irrigation effects on potato: I. Soil properties, tuber yield, and quality. Agronomy Journal 91:416-425.

Rotenberg, D., A.J. Wells, E.J. Chapman, A.E. Whitfield, R.M. Goodman, and L.R. Cooperband. 2007. Soil properties associated with organic matter-mediated suppression of bean root rot in field soil amended with fresh and composted paper mill residuals. SOIL BIOLOGY & BIOCHEMISTRY 39:2936-2948.

Stone, A.G., G.E. Vallad, L.R. Cooperband, D. Rotenberg, H.M. Darby, R.V. James, W.R. Stevenson, and R.M. Goodman. 2003. Effect of organic amendments on soilborne and foliar diseases in field-grown snap bean and cucumber. Plant Disease 87:1037-1042.