Linking Organic Knowledge
OACC
Organic Agriculture Centre of Canada
oacc.info
Le réseau du savoir biologique
CABC
Centre d'agriculture biologique du Canada
agbio.ca

SOIL HEALTH IN ORGANIC POTATO SYSTEMS

Final Research Report E2008-22

ORGANIC POTATO PRODUCTION

Recently, there has been a growing interest by consumers in certified organic potatoes (*Solanum tuberosum* L.) with an insufficient supply to meet this demand. As production of organic potatoes expands, there is a need to understand the effects of management options on crop yield and quality as well as their effect on soil health. Organic potato production systems are characterized by extended rotations (four years or more) involving leguminous crop green manures. These systems are productive and have the added benefit of reduced risk of losses of soil nitrate to water systems (Lynch et al. 2008). The ability of these rotations to bring the system back to a state of health in potato production has not been well studied.

Soil degradation is difficult to avoid under intensive (short rotation) potato production systems as they return little or no organic matter back into the soil. Recent research (Boiteau 2005, personal communication) suggests biological indices of soil health fail to recover when the frequency of potatoes in rotation is high. Maintenance of soil quality or soil health is a central concept in all sustainable agriculture systems. Soil is a dynamic living system, and agricultural management practices should aim to preserve and protect this nonrenewable resource. Soil health has been defined as 'the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health'.

INDICATORS OF SOIL HEALTH

Indicators used to assess soil health have not been rigidly defined, though major components of the soil such as soil organic matter (SOM) are considered a key aspect in determining soil health. Light fraction (LF) organic matter, comprised mostly of recent plant residues and microbial and microfaunal debris, has been found to be an accurate and early indicator of changes in SOM because of farm management practices. Studies have found that the soil LF content was greater in extended rotations than in continuous crop rotations.

Successful organic potato production depends on good soil health (D. Lynch)

Bioindicators are soil organisms (such as microbes, microarthropods, and earthworms) whose biomass, abundance or diversity responds to changes in management practices and can potentially be used as early warning systems of detrimental conditions. The occurrences of springtails have been found to be greater in organic systems than in conventional production systems. Earthworms play a key role in organic matter decomposition and nitrogen cycling and are considered the most important invertebrate in temperate soils. Monitoring the abundance and diversity of these and other soil organisms in agroecosystems can give us useful information on the sustainability of different soil management systems.

Earthworms were hand-sorted from two 0.75m^2 quadrats in each field (K. Nelson)

WHAT WAS DONE

Sampling to determine the effects of the extended rotations on soil biological, physical and chemical indicators was conducted in 2006 and 2007. Composite soil samples (n=4) from fields in each year of 5-year organic potato rotations were collected from four organic farms, two in PEI and two in NB. Soil from nearby long-term pasture fields at each site was also collected as a reference against which the soil properties could be tested. Long term pasture fields are considered less affected by agronomic activity, therefore soil properties would be suspected to be at their "best". The soil and earthworms were returned to the Nova Scotia Agricultural College where they were analyzed for mineralizable carbon, microbial biomass C, light fraction, bulk density, total organic carbon and nitrogen, pH and earthworm abundance and biomass.

Farm rotation sequences for 2006 and 2007

Farm	Rotation Sequence 2006	Rotation Sequence 2007
Farm 1	P/W/F/F/F	P/W/F/F/F
Farm 2	P/W/F/F/F	P/na/F/F/F
Farm 3	P/B/F/F/F	P/B/F/F/F
Farm 4	P/B/na/F/F	P/B/F/na/F

Rotation crop: P= potato; B= barley; F= forage (predominately timothy/red clover mixtures), na= not available

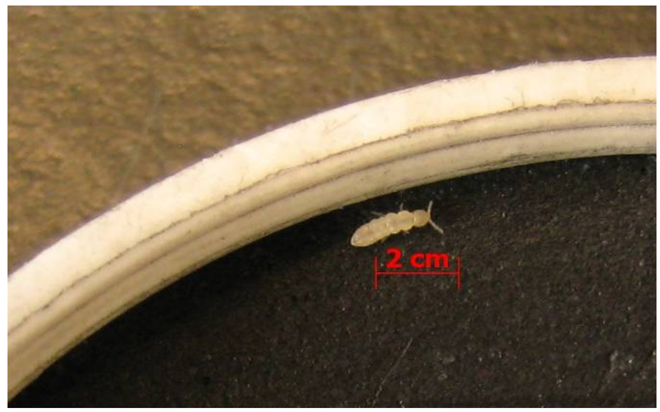
To determine if the springtail, *Folsomia candida,* is a sensitive species to the changes in soil health, we measured growth, reproduction and survival of 1 day olds and 10 day olds on different soil substrates (Table 1). The soil substrates included: pasture soil, forest soil, and two artificial soils, one containing sand alone and the other sand with Baker's yeast, which is considered the standard high quality food for this organism. The first experiment also included composted manure as a test substrate.

Table 1. Characterization of each of the soil treatment substrates for experiment 1 and 2 used for the *Folsomia candida* trials

Treatment substrate	Soil pH	Total Carbon (%)	Total Nitrogen (%)	C/N ratio
Yeast	na	45.7a	5.87a	7.8d
Composted manure	7.22a	23.0c	1.26b	18.3b
Forest	3.88d	33.5b	0.94c	35.4a
Pasture	5.50c	2.1d	0.18d	11.9c
Sand alone	5.95b	0.01e	0.05e	0.3e

Different letters indicate significant differences between treatments ($p<0.05$).

The first experiment (Expt. 1) was conducted with 10 day olds over a 14 day period to evaluate growth (i.e. body length) and survival at the end of the test period. The second experiment (Expt. 2) was conducted with 1 day olds over a 47 day period in which individuals (n=10) from each treatment substrate were measured for growth, reproduction and survival on days: 0, 4, 10, 15, 23, 29, 42, and 47. On each sampling date, vials containing the *Folsomia* were destructively sampled by adding water and allowing the mature individual and any juveniles to float to the surface (their exterior is hydrophobic causing them to float in water).



***Folsomia candida* measured on day 42 using digital camera and image tool software (K. Nelson)**

RESULTS

Use of biological, chemical and physical indicators to assess soil health:

The effect of the rotation on average earthworm abundance and biomass increased as the length of time in the rotation increased (Figure 1 and 2). Earthworm abundance (i.e. number) was significantly reduced during the potato year of the rotation with only 31.2 and 73.5 individuals per m^2 in 2006 and 2007, respectively.

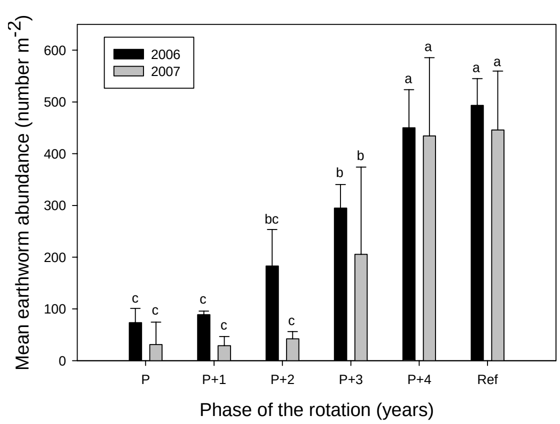


Figure 1. Mean earthworm abundance throughout each phase of a 5-year rotation. Different letters indicate significant differences between treatments (p<0.05).
Table 2. Abbreviations

Abbreviations	Rotation phases
P	Potato phase
P+1	1 yr after potato
P+2	2 yrs after potato
P+3	3 yrs after potato
P+4	4 yrs after potato
Ref	Reference= pasture

Greatest earthworm abundance was obtained in the reference fields (pasture) with 494 and 446 individuals per m^2 in 2006 and 2007, respectively (Figure 1). Four years of rotation after potato cropping was required for earthworm abundance to recover to levels found under the pasture fields.

Earthworm biomass followed a similar trend as earthworm abundance, with significantly decreased levels during the potato year (32.2 and 12.2 g fresh weight per m^2, in 2006 and 2007), and increasing as the time in the rotation increased to levels found under the pasture field at 215 and 158 g fresh weight per m^2 (Figure 2). Earthworm biomass did not reach levels found under the long-term pasture field until 4 years after the potato crop (P+4) in 2006 and 2007.

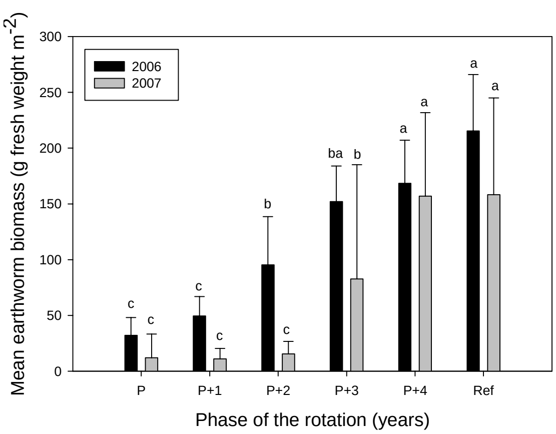


Figure 2. Mean earthworm biomass throughout each phase of a 5-year rotation. Different letters indicate significant differences between treatments ($p<0.05$).

The microbial biomass (i.e. the living fraction of organic matter, consisting of fungi and bacteria) was affected by the rotation in a pattern similar to that found for the earthworm population. The microbial biomass carbon was significantly decreased in the potato year (297 and 218 µg C g^{-1} soil) of the rotation in 2006 and 2007 (Figure 3), with greatest biomass obtained in the pasture fields (at 781 and 622 µg C g^{-1} soil). Microbial biomass C was able to recover to levels found in the reference fields after 4 years in the rotation (P+3) in 2006, however in 2007 biomass levels were unable to reach levels found in the pasture fields.

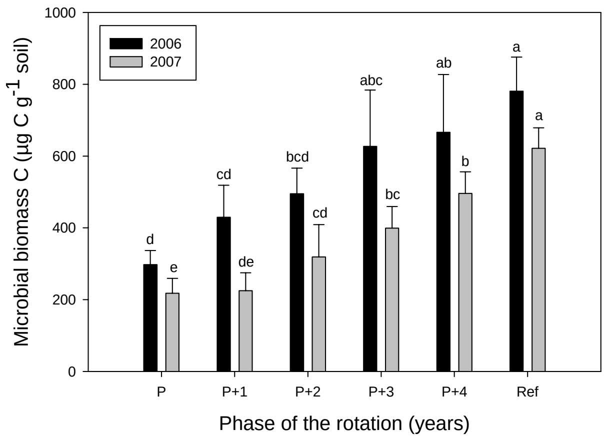


Figure 3. Mean microbial biomass C throughout each phase of a 5-year crop rotation. Different letters indicate significant differences between treatments ($p<0.05$).

The soil biological components (i.e. microbial biomass, and earthworm abundance and biomass) were effective and consistent indicators of change induced by the rotations on these organic farms. Consistently greater amounts were obtained in the pasture fields as they had been relatively undisturbed by cultivation for at least 15 years.

Springtails as an indicator species:

Experiment 1 found that 10 day old juveniles on the sand with yeast treatment obtained greater growth than juveniles grown on the other treatments over the 14 day period (Figure 4). Under this experimental design, *F. candida* was not sensitive enough to clearly separate all the soil substrates and their different soil health characteristics.

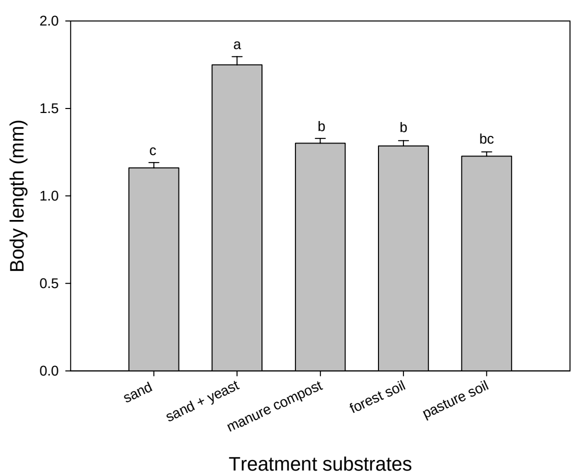


Figure 4. Body length of 27 d old *Folsomia candida* after 14 d exposure to each of the soil substrates

Under Experiment 2, mean body length increased over the 47 day period on all soil substrates tested. The 1 day old juveniles were more responsive to the properties of each of the soil substrates tested than 10 day olds (Experiment 1.)

Effects of each soil substrate on springtail growth were apparent by day 4 with substrates clearly separated by day 10 (Figure 5). The sand with yeast treatment provided the greatest body growth over the 47 day period as was found in experiment 1. Under the second experimental design, the relative health of the substrates studied could clearly be ranked from the lowest to the highest according to body length: sand only, forest soil, pasture soil and sand with yeast. The sand alone treatment resulted in minimal growth during the 47 day period.

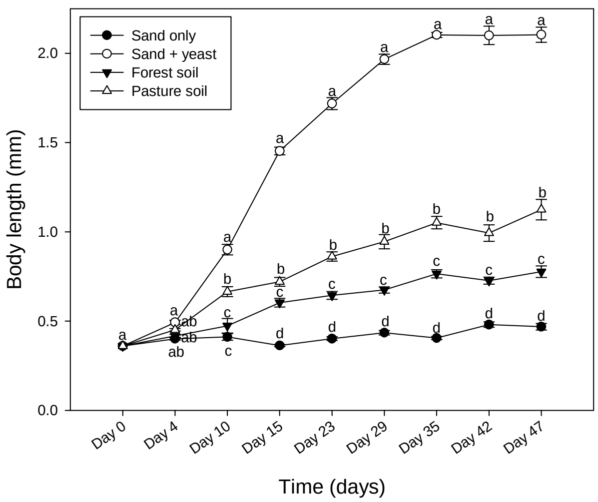


Figure 5. Cumulative changes in body length of 1 d old *Folsomia candida* over 47 day period on four soil substrates

The different reproduction levels or the timing of reproduction on the different substrates could be used to complement body growth in assessing soil health, but survival was not a sensitive enough parameter to be considered in the development of tests with this bioindicator.

THE BOTTOM LINE…

Biological indicators are more sensitive and consistent at detecting effects of organic potato rotations on soil health than chemical and physical properties.

The soil insect, *Folsomia candida,* has potential as a sole bioindicator of soil health. The body growth and the reproduction level of this species are sensitive to soils of differing soil health characteristics. The use of 1 day old juveniles exposed to test soils over 10 – 15 days holds the greatest promise for this test.

ACKNOWLEDGEMENTS

Thanks to:

- Participating farmers: Fred Dollar (Kentdale Farms, PEI), Raymond Loo (Springwillow Farms, PEI) and Pirmin Kummer (Timber River Eco-Farms, NB).
- Research technicians, especially Chris Nelson, Andrea Munroe, Iris Vaisman and Pam MacKinley.

CREDITS

Karen Nelson (graduate student), Derek Lynch (Nova Scotia Agricultural College) and Gilles Boiteau (Agriculture and Agri-Food Canada)

FUNDING

New Brunswick Department of Agriculture and Aquaculture
Prince Edward Island Department of Agriculture
Canada Research Chairs Program
Organic Agriculture Center of Canada

Production of this bulletin was supported by:

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

REFERENCE

Lynch, D.H., Zheng, Z., Zebarth, B.J. and Martin, R.C. 2008. Organic amendment effects on tuber yield, plant N uptake and soil mineral N under organic potato production. Renewable Agriculture and Food Systems 23:1-10.

For more information:
Visit **oacc.info** or contact us at
P.O. Box 550 Truro, NS B2N 5E3
Tel: (902) 893-7256
Fax: (902) 896-7095
Email: oacc@nsac.ca