Nitrogen Management and the Effects of Compost Tea on Organic Irish Potato and Sweet Corn

by

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Thesis submitted to the faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Horticulture

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April 30, 2008
Blacksburg, Virginia

Keywords: organic production, cover crops, Irish potato, sweet corn, nitrogen management, compost tea

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Abstract

Supply and synchronization of plant-available nitrogen (N) to the soil is a major challenge for organic farmers, especially when growing crops in soils that are in transition from conventional to organic systems. This research evaluated the effects of site produced cover crops and application of soil amendments on N uptake and crop yield of organic Irish potato (*Solanum tuberosum*) and sweet corn (*Zea mays*). Cover crops were crimson clover (*Trifolium incarnatum*) and forage radish (*Raphanus sativus*). Soil amendments included in-row application of commercially produced dehydrated compost tea absorbed on charcoal (Soil Biology Innovations) and post-plant sidedressing with organic N fertilizer. Irish potato and sweet corn were grown at the Kentland Agricultural Research Farm near Blacksburg, VA in an organic transition soil during the summers of 2006 and 2007. Nitrogen uptake and crop yield were not affected by cover crop species in either year. SBI increased yield of sweet corn, but not Irish potato for both years; SBI had no effect on N uptake of either crop. Post-plant N sidedressing increased N uptake and crop yield of Irish potato and sweet corn in 2007, but had no effect on crop yield in 2006, presumably because pre-plant organic fertilizer was applied at planting in 2006, but not in 2007. This study shows that the combination of site produced cover crops and applied soil amendments may be required to produce high marketable yields of organic Irish potato and sweet corn in the transition soil used in these experiments.

Acknowledgements

I would like to first thank my advisors, Dr. Ron Morse and Dr. Alex Niemiera for all of their support. Dr. Morse mentored me and showed me how to conduct efficient and productive research. His presence in the field each day was a tremendous asset to me. Dr. Niemiera guided me through my coursework and academic procedures as well as helped me to prepare my seminar. I would also like to thank Dr. Roger Harris for serving on my committee. I wish to thank the following for all of their help out in the field with my research plots: Brinkley Benson, Daniel Schellenberg, Jon Weekley, Cal Wilson, Kara Tourje, Caroline Grist, John Wooge, and the entire Kentland Farm Crew. Finally, I would like to express my gratitude and appreciation for all my close friends and family, especially my parents, for their unwavering support in my academic endeavors.

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1. Literature Review

1.1 History/Background

Organic agriculture has been described by USDA National Organic Standards Board as "an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity" (Gold, 2007). It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony. Organic agriculture has existed since the beginning of farming. Conventional agriculture started as a result of World War I ammunitions with the introduction of inorganic fertilizers and synthetic insecticides (Delate, 2003). Only recently has organic agriculture been described and marketed as an alternative to conventional methods which include using synthetic fertilizers and pesticides. Organic agriculture, both production and sales, has been on a steady increase since the early 1990's. In fact, consumer demand for organic produce has grown 20% each year since 1990 (Greene, 2000). In 1996 retail sales of organic products was $3.5 billion and increased to $9 billion in 2001 (Greene and Kremen, 2002). The appeal for increased profits has enticed farmers to begin adopting organic agriculture, especially organic vegetable production (Thompson, 2000). In the early 1990s only seven percent of all organic products were sold in conventional supermarkets in comparison to 2001, where organic products were sold in 73 percent of conventional supermarkets (Dimitri and Greene, 2002). Organic agriculture is also attractive to consumers because it provides a product that has been grown without the use of potentially harmful synthetic pesticides. The potentially harmful health and environmental effects of synthetic pesticides are among several reasons why people choose to purchase organic products. For example, the use of synthetic fertilizers and synthetic pesticides in conventional farming may adversely affect biological aspects of soil such as arthropods and microbial diversity (Ngouajio and McGiffen, 2002). Soil organic matter, soil microbial diversity, and a wide range of arthropods are all vitally important factors in a productive organic system. Consequently, the degradation of these important factors would result in a much less efficient organic system (Scow et al., 1994). In addition, the recent debates and concerns over genetically modified organisms have led to an increase in consumption of organic foods (Treadwell et al., 2003). Organic vegetable production also incorporates significant aspects of sustainability such as soil and water conservation that have been proven to have significant environmental benefits (Shennan et al., 2004). Organic agriculture research is especially important in the state of Virginia as it ranks third in the nation in total acreage of certified organic vegetable production (USDA, 2005).

1.2 Cover Crops

Nitrogen Management- Soil N is one of the most limiting factors in yields of organically grown crops (Clark et al., 1999a). If N is properly managed, organically-grown crops can produce yields equal to that of conventional systems (Clark et al., 1999b; Delate et al., 2003; Kramer et al., 2002). Supplemental N in organic systems is more difficult to manage because N is mainly available in slow release forms (animal and green manures, composts) compared to immediately available forms (inorganic fertilizers) in conventional systems (Cavero et al., 1996; Kramer et al., 2002). Synchronizing soil N availability with crop demand in organic systems is crucial to successful yields. Optimizing soil organic matter, managing soil microbes and C:N ratios are all critical aspects in providing sufficient N to crops (Morra, 1999; Veenstra et al., 2006). In some cases, additional N sources such as animal manures, feather meal, and sodium nitrate may be needed to provide enough N to the system (Tesi and Lenzi, 2005).

Cover crops play a significant role in the supplication of nutrients, in particular N, to cash crops. Mineralization of N in the organic system from decomposing cover crops is becoming increasingly important because other N sources in organic systems such as fresh animal manure are becoming more limited due to the high costs of transportation, potential pollution problems, and possible crop injury (Gaskell et al., 2000). Legumes constitute the largest group of plants used as cover crops for N supplication in cover crop systems and are a major source of N in organic systems. Legumes, in a symbiotic relationship with bacteria, are able to convert atmospheric N (N_2) into a plant available form, and thus provide more N than non-legumes (Cline and Silvernail, 2001). Legume cover crops require little to no supplemental N yet return large amounts of N to the soil (Sorensen and Thorup-Kristensen, 2003). Legume cover crops fix more N_2 when less soil N is available therefore reducing the need for N fertilizers (Giller and Cadisch, 1995). Cover crops are killed when approximately half of the stand has entered anthesis using various mechanical methods or herbicides. The cover crops are then either laid onto the soil surface or incorporated into the soil. Cover crops can then be decomposed by soil microbes and converted into plant available N via mineralization. Cover crops are also vital because they improve N use efficiency (Rayns et al., 2000).

Costs – Decomposing residue from cover crops, are beneficial because they provide N to the soil at a much lower price than other sources (Tonitto et al., 2006). If managed properly, cover crop costs will only account for a small percentage of crop production costs (Wyland et al., 1996). Studies have shown that crops planted into cover crop mulches are able to produce higher yields with less N input than black plastic mulches(Abdul-Baki et al., 1997b). In addition, the overall production cost of a system with cover crop mulches is much less than a system using black plastic mulches because less supplemental N is needed and weeding control costs are lower

(Abdul-Baki et al., 1996). By increasing the level of soil N released by cover crops, growers reduce their inorganic fertilizer use and fertilizer expenditures.

Cover Crop Mixtures - Mixtures are the use of two or more cover crop species in the same field. Mixtures have been and continue to be a popular practice in cover crop systems (Larsson, 1999). Appropriately managed, mixtures can be an extremely beneficial practice in cover cropping. Researchers are still trying to determine the appropriate mixes of cover crop species for different temperature zones (Creamer et al., 1997). The major issues with these mixtures are 1) maximizing their ability to provide enough N for the following crop, and 2) simultaneously managing the cover crop species to optimize total biomass and weed suppression.

Mixtures of approximately 50 percent grass and 50 percent legume cover crops similar amounts of N fixed compared to a legume monocrop, and thus grass/legume mixtures have been proven to be ideal (Teasdale and Abdul-Baki, 1998). When considering mixtures it is important to know the C:N ratios of each crop. Optimizing soil C:N ratios is important as high C:N ratios results in N immobilization of the N produced by the cover crop (Creamer and Baldwin, 2000).

Life Cycles - Cover crop life cycles are another area of importance. The timing of both planting and killing of cover crops is essential to a successful organic system (Wallace and Bellinder, 1992). Cover crops can be grown anytime during the year but a majority of cover crop species are seeded in the fall and grown through the winter. Annuals are killed by freezing temperatures. The timing of winter cover crop planting is crucial due to fall precipitation and soil temperature aspects. Precipitation levels and soil temperatures have a significant effect on the establishment of winter cover crops (Burket et al., 1997). Cover crops that are grown during the winter take up N which would otherwise be lost if the soil were bare (Di and Cameron, 2002). A healthy full stand of cover crops can be important to an organic system because it not only assists in erosion control but can aid in the prevention of nitrate leaching (Flach, 1990; Olesen et al., 2004; Rosolem et al., 2002; Williams and Tregurtha, 2002). In comparison to bare soil, cover crops result in less nitrate leaching into the groundwater (Wyland et al., 1996). Cover crops can also aid in the control of soil compaction by increasing soil porosity and making it easier for roots of the cash crop to explore the soil system (Williams and Weil, 2004). Cover crops can also aid in soil water retention and increased nutrient availability to the cash crop (Carrera et al., 2004).

Weeds - Along with N management, weeds constitute one of the most limiting factors in terms of crop yields. Weeds can cause severe yield reductions in all types of agricultural systems especially organic systems (Hutchinson and McGiffen, 2000). Cover crops aid in weed control during and after cover crop growth as most herbicide use is prohibited in organic production (Abdul-Baki et al., 1997a). Cover crops shade out or smother weeds or weed seeds. Cover crops can control weeds to the extent that the yield is not reduced compared to conventional methods of controlling weeds (Abdul-Baki et al., 1997a; Teasdale, 1996). Cover crop mixtures have been shown to optimize both N supply and weed control (Creamer et al., 1997). Mixtures tend to control weed growth because they create the ideal architecture that produces maximum canopy closure over the soil surface. Along with canopy closure cover crops such as rye have been shown to control weeds through allelopathic effects (Creamer et al., 1996; Dhima et al., 2006).

1.3 Compost Tea

Compost applications are a commonly used practice in agriculture; however the concept of compost tea is becoming increasingly popular in organic agriculture. Compost tea is simply a liquid solution form of compost that has been soaked in water. The solution produced from the soaking contains nutrients and is known as compost tea. The concept of compost tea is relatively new and there are very few research reports documenting its effectiveness. Research has documented that compost teas suppress diseases in organic systems (Haggag and Saber, 2007; Hibar et al., 2006). Although undocumented, compost teas are also thought to increase the microbial activity in the soil. Other benefits of compost tea are the stimulation of root and vegetative growth (Hibar et al., 2006). Compost teas have been also found to increase crop yields and produce quality(Haggag and Saber, 2007). More research is needed to validate the effect of compost teas on crop yields so that organic growers may have additional options when it comes to increasing crop yields.

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2. Nitrogen Management and the Effects of Compost Tea on Organic Irish Potato and Sweet Corn

2.1 Introduction

During the process of transitioning from conventional agriculture to organic agriculture several factors can cause severe reduction in overall crop yields. Inadequate soil N is the most important factor during this process (Clark et al., 1999a). Many organic farmers make a pre-plant application of manure and compost but do not supplement with fertilizer applications during the crop growing season. The lack of N applications as well as synchronizing available N with crop demand for N is essential to maximizing yields (Pang and Letey, 2000).

In conventional agricultural systems, most N is supplied in an inorganic form that is readily available to plants (Kramer et al., 2002). Organic systems rely heavily on slow-release forms such as green and animal manures and compost (Cavero et al., 1996). Since these slow release N forms take much longer to become available to the crop than synthetic forms it is very important to synchronize N supply with crop demand (Pasakdee et al., 2006).

Cover crops are a key factor in organic agriculture systems. Cover crops are commonly grown before the crop is planted and killed so that the residue remains as a mulch or green manure. Growing cover crops add N to the system through release as plant materials decay in the soil as well as aid in weed control by shading out competing weeds (Abdul-Baki et al., 1997a; Gaskell et al., 2000; Teasdale, 1996). Cover crops with low C:N ratios are the most ideal as crops with high C:N ratios immobilize more N in the soil system once they are killed (Creamer and Baldwin, 2000). Cover crops are also essential in managing N because they can take up and use N during the winter when N would normally be lost to leaching in a fallow system (Olesen et al., 2004; Williams and Tregurtha, 2002).

Compost teas are becoming an increasingly popular soil amendment in organic systems. Compost teas, being the resulting solution of mixing water and composts, are thought to have beneficial effects such as crop disease suppression, root growth stimulation, and increased and higher quality yields (Haggag and Saber, 2007; Hibar et al., 2006; Sanwal et al., 2006).

The objectives of this study were to 1) ascertain the effects of supplemental N soil amendments on organic sweet corn (*Zea mays* L.) and Irish potato (*Solanum tuberosum* L.) yield, 2) examine the ability of crimson clover (*Trifolium incarnatum* L.) and forage radish (*Raphanus sativus* L.) to contribute N to the soil system, and 3) assess the influence of dehydrated compost tea absorbed on charcoal (Soil Biology Innovations) on marketable crop yield.

2.2 Materials and Methods

Experiments were conducted in summers of 2006 and 2007 at the Virginia Polytechnic Institute and State University, Kentland Agricultural Research Farm, near Blacksburg, Virginia. All field plots were grown in the third year of an organic transition. The soil was a silt loam soil having a Hayter loam (fine-loamy, mixed, mesic, Ultic Hapludaf) pH of 6.4, with medium to high levels of phosphorus, potassium, calcium and magnesium. In July of 2003, a 2.4-ha field was set aside for organic research at the Kentland Agricultural Research Farm. The experimental plots used in these 2006-2007 studies were located in this 2.4 ha organic transition field, to which no inorganic fertilizers or pesticides had been applied, and the plots had been continuously covered using a rotation of cover crops and vegetable crops. Both experimental plots had been managed similarly before being used in these studies; the soil had been continuously covered using a rotation of cover crops→ broccoli→cover crops→cover crops (crimson clover and forage radish→ potato and sweet corn.

The experimental design each year was a randomized split-block (Lentner et al., 1993) . The research field plots in both years were divided into four replications (65 m long) consisting of four raised beds (1.85 m center to center, and 15 cm high) (Figures 3 & 4). Bed width was approximately 85 cm, and the alleyways between beds (bed shoulders and bottoms) were 100 cm. Main plots were cover crops (two beds, 65 m long). In early September preceding each cropping year (6 Sept. 2005 and 18 Sept. 2006, Table 1), a Tye drill (Agco Cooperation, Duluth, GA) was used to seed bed tops (grow zones) of two beds in each replication with foraged radish (‘Colonel’, at 20 kg/ha) and two beds with crimson clover (‘Dixie’, at 23 kg/ha), and seed alleyways between beds with cereal rye (*Secale cereale* L., variety unknown, at 134 kg/ha). Zone drilling (seeding grow zones and alleyways with different cover crop species) was accomplished in one pass by portioning the seed hopper of the Tye drill, thus enabling seed separation and simultaneous drilling of two cover crop species. Subplots (two beds, 23 m long) were in-row placement of Soil Biology Innovations granules at planting—control (no SBI) and SBI applied at 22-33 kg/ha (see Irish potato and sweet corn sections for different rates applied). SBI is a proprietary product (Bio-Char Group, Asheville, NC), composed of dehydrated compost tea absorbed on charcoal. Sub-subplots (two beds, 11.5 m long) were nitrogen (N) sidedress fertilizer—control (no sidedress N) and nitrogen applied at 56-112 kg/ha (see Irish potato and sweet corn sections for different rates applied). The sidedress N fertilizer was a hand mixed blend of 20 percent N from sodium nitrate and 80 percent from feather meal (ground up poultry by-products).

Forage radish was frost killed at approximately -6.7 °C and crimson clover and rye over-wintered. In mid April (Table 1), bed tops were flail mowed and the residues were shallow incorporated (5-8 cm deep) with a rototiller. In 2006, but not 2007, all beds were fertilized using

896 kg/ha of 8N-1P-5K organic fertilizer (composed of feather meal, bone meal, soybean and potassium sulfate) (Renaissance Fertilizers, Rowley, MA) (Table 7). The organic fertilizer was precision placed in-row and incorporated to a depth of 13-15 cm deep in grow zones located 51 cm apart on top of the raised beds. Grow zones are the designated row areas on raised beds where vegetables were seeded.

Irish potato - Whole seed potatoes (‘Chieftain’ in 2006 and ‘Kueka Gold’ in 2007) were cut into 57 g seed pieces, treated with an organic fungicide (OxiDate, BioSafe Sytems, Glastonbury, CT) for 5 minutes (15 April 2006 and 5 May 2007, Table 1), stored in a shed at 18-20 °C for 1-2 weeks and planted by hand in 2006 (19 April) and using a potato seeder in 2007 (9 May, Table 1). Seed pieces were set 25-30 cm apart and 13-15 cm deep in the two grow zones on each bed. Prior to planting in 2006, SBI granules (33.6 kg/ha) were hand applied to subplots (two beds, 23 m long) in the grow zones and incorporated to a depth of 8-13 cm with a wheel hoe (20 April, Table 1). Two weeks after shoot emergence, potato plants in untreated subplots (no SBI) were sidedressed with an organic fertilizer by hand at the rate of 67 kg N/ha (13.4 kg N supplied by sodium nitrate and 53.6 kg N from feather meal). Plants in the SBI-treated (+SBI) were not sidedressed. In 2007, SBI granules (22.4 kg/ha) were applied (after planting potato seed pieces with the seed planter) in the grow zones and incorporated (2-3 cm deep) with a hand hoe (10 May, Table 1). Each year, the remaining row area (42 m long) of each row was left untreated, of which the middle 19 m was designated as a buffer zone separating the SBI-treated (+SBI, 23 m) from the untreated (no SBI, 23 m). All treatments received an application of 22.5 l/ha kelp growth regulator (SeaCrop16™ Liquid Plant Growth Regulator, North American Kelp, Waldoboro, ME) (17 July, Table 1) to prolong plant death. Colorado potato beetles (*Leptinotarsa* *decemlineata*) were hand removed on regular scouting walks. Stand counts of potatoes were made and tubers were harvested in late September of both years using a two-row potato digger.

In 2007, each subplot was further divided into two equal sub-subplots (one bed, 23 m long) received 18.7 l/ha of liquid fish 3N-3P-0.3K fertilizer (Organic Gem Liquid Fish Fertilizer, Advanced Marine Technologies, New Bedford, MA) and a second adjacent bed received no fish concentrate (i.e., control). Each sub-subplot was further divided into two equal sub-sub-subplots (one bed, 11.5 m long) one-half of each sub-subplot received 90kg N/ha (13 June, Table 1) as a hand applied sidedress fertilizer and the other half received no sidedress fertilizer (i.e., control). Plots were drip irrigated and hand weeded as needed throughout the growing season. Weeds in the grow zones were removed by hand, stirrup hoes, push hoes, and a multivator. Weeds in the alleyway were controlled and prevented from going to seed by push mowing. In 2007, leaf-N concentration of potato plants was determined by harvesting 20 most recent fully developed whole leaflets from plants in each treatment plot at mid-tuber growth staged (1 August, Table 1). Leaves were dried for 7 days at 70°C, ground with a cyclone mill and analyzed for total N, using the Kjeldahl method (Baker et al., 1964). Potato tubers were dug using a 2 row potato harvester, placed in plastic crates, washed, and air dried for 1-2 days, graded and weighed (10 Sept. 2006 and 3 Sept. 2007, Table 1).

Sweet corn - Sweet corn seed (‘Spring Treat’ in 2006 and ‘Sugar Queen’ in 2007) was planted (13 June 2006 and 31 May 2007, Table 1) with an EarthWay Precision Garden Seeder (Model 1001-B, EarthWay Products Inc., Bristol, IN) in two rows (51 cm apart, 65 m long) of the raised beds. Immediately before seeding in both years, SBI granules were applied (12 June 2006 and 29 May 2007, Table 1) in two rows per bed (51 cm apart) in the +SBI subplots. In 2006, SBI granules (22.4 kg/ha) were hand applied and incorporated to 2-3 cm deep with a wheel hoe. In

2007, SBI granules (33.6 kg/ha) were applied using the Earthway Seeder to a depth of 2-3 cm. The remaining area (42 m long) of each bed was left untreated, of which the middle 19 m was designated as a buffer zone, separating the SBI-treated (+SBI, 23 m) and the untreated (no SBI, 23 m) sections. Five weeks after planting, sweet corn plants of both +*SBI* and no-*SBI* subplots were divided into three sub-subplots (8 m long) and were sidedressed with organic fertilizer by hand (0, 56 or 112 kg N/ha, supplied by a mixture of sodium nitrate and feather meal). Plots were irrigated and hand weeded as needed throughout the growing season. In 2007, corn leaf-N concentration was determined by harvesting 10 most recent fully developed whole leaves per treatment at the early ear development stage (6 August, Table 1). Leaves were dried for 7 days at 70°C, ground with a cyclone mill and analyzed for total N, using the Kjeldahl method (Baker et al., 1964). Sweet corn ears were harvested during the last two weeks of August of both years (Table 1) by hand and weighed in the field. Culls were considered any ear less than 13 cm in length. In 2007, subplots were further divided into sub-subplots and sub-sub-subplots, as described for Irish potato. An application of biological insecticide containing *Bacillus thuringiensis* (DiPel DF, Valent USA Corporation, Walnut Creek, CA) at a rate of 10 milliliters per ear was applied using the Zea-Later II sprayer (Johnny Selected Seeds, Winslow, ME) (4 August 2006 and 8 August 2007, Table 1).

Statistical analysis was performed using the program JMP 7.0, a SAS produced product (SAS, Cary, NC). Significant statistical differences between treatments and interactions between treatments were determined at the $P<0.10$ level. Analysis was done on interactions between treatments(data not shown) and upon finding no significance were analyzed individually as advised by statistics professionals (Dr. Golde Holtzman, Professor, Dept. of Statistics, Virginia

Tech). Linear regression analysis was used to compare leaf-N concentration and crop yield across all treatments and leaf-N concentration and SBI rate.

Table 1. Dates of important cultural practices.

Cultural practice	2006	2007
Seeded cover crops	Sept. 6 (2005)	Sept. 18 (2006)
Applied preplant fertilizer	Mid April	------
Flail mowed cover crops	April 15	May 5
Cut and Oxidated Potatoes	April 15	May 5
Planted Irish potato	April 19	May 9
Applied SBI to potato	April 20	May 10
Applied SBI to sweet corn	June 12	May 29
Planted Sweet corn	June 13	May 31
Applied N sidedressing—Irish potato*	May 24	June 13
Applied N sidedressing—sweet corn	July 18	July 2
Applied kelp to potatoes	------	July 17
Took leaf samples for potatoes	------	August 1
Took leaf samples for corn	------	August 6
Applied Bt to corn ears	August 4	August 8
Potato harvest	September 10	September 3
Corn Harvest	Aug. 18-Sept.1	Aug. 20-Sept.3

*Only untreated (no *SBI*) potato plants were sidedressed (67 kg N /ha) in 2006.

2.3 Results and Discussion

Statistical analysis of crop yield data showed no significant interactions between treatments. Effects of individual treatments on crop yield are shown in ANOVA Tables 2 through 5. Irish potato and sweet corn yield response to cover crops can not be discerned due to the lack of a control treatment (no cover crop).

Effect of cover crops—There was no yield response to cover crop species for Irish potato or sweet corn in either year (data not shown). Although not determined for these experiments, estimated plant-available N in residues of crimson clover and forage radish would be approximately 80 and 40 kg/ha, respectively in 2006 and 20 and 10 kg N/ha, respectively in 2007 (SAN, 2007). Growth and yield of cover crops were severely curtailed in 2007 because of delayed seeding in 2006, drought, and poor plant stands. Although both cover crops grown immobilize N during their growth cycle, the immobilization process is quite different. Since crimson clover is a legume, it fixes atmospheric N, mediated by rhizobial bacteria. Crimson clover grows sparingly in the fall, but over winters and grows rapidly in the spring, producing 3.9-6.2 t/ha of dry-weight biomass and 78-146 kg N/ha. Forage radish does not fix atmospheric N, but it grows rapidly in the fall, producing 4.5-7.8 t/ha dry-weight biomass and scavenging 56-224 kg N/ha from residual N remaining in the soil from the previous crops (SAN, 2007). Forage radish winterkills at around -7 C, and both aerial and root tissues decompose rapidly in late winter–early spring, releasing N back into the soil.

In this study, four days before planting potato seed pieces each year, all plots were flail mowed and the residues were incorporated to a depth of 8-10 cm. Since, there was no difference in yield response to cover crops for Irish potato or sweet corn, either the plant-available N was similar in all plots or there were differences in non-N effects such as pest (weeds, insects, disease pathogens) suppression that counter-balanced (masked) any significant differences in plant-available N. Forage radish is know to exhibit pest suppressiveness and increase yields of subsequent grown crops (SAN, 2007). Although incidence of pests was not measured in this study, there was no visual evidence that pest pressures were different in cover crop plots either year. Based on these results and data from previous research (SAN, 2007), both crimson clover and forage radish could serve equally well as an N source for production of organic vegetables.

Effect of SBI—Marketable sweet corn yield was highest in SBI-treated plots for both years (Table 6). SBI had no effect on Irish potato yield (Table 6).The lack of SBI effect on Irish potato may be related to SBI placement. SBI granules were placed in close proximity to sweet corn seed in 2006 and 2007; in contrast, direct potato seed piece interaction with SBI did not occur in 2007 due to shallow incorporation of SBI granules(1-2 cm) and deep placement of potato seed pieces (12-15 cm below the soil surface). In 2006, SBI-seed piece contact with potatoes was adequate; however, yield response to application of SBI granules was confounded because the untreated control (no SBI) potato plants were sidedressed with 67 kg N/ha, while the SBI-treated plants were not sidedressed.

The reason for SBI enhanced growth of corn, compared to the control, can not be ascertained due to the proprietary nature of SBI composition. Unreplicated observations have indicated that SBI granules (applied at proper concentration, placement and timing) can improve absorption of plant-available soil moisture, and/or improve rate of mineralization (release of plant-available N) (unpublished data—Jon Nilsson, East Coast Compost, Asheville, NC—2004 and 2005). Drip irrigation was applied uniformly to all plots both years; hence, the water absorbing advantage would not be manifested in a non-water limiting situation. In these experiments, linear correlation analysis ($R^2 = 0.03$, for both crops) showed no relationship between application of SBI and leaf-N concentration, indicating that the quantity of plant-available N was not influenced by application of SBI.

Effect of N sidedressing and liquid fish fertilizer—In 2006, applying organic N (3N-3P-0.3K) to sweet corn as a hand-applied sidedressing had no effect on yield (Table 7), indicating that either N was not limiting or the N sidedressing was applied too late (Table 1) to produce a yield response. Perhaps, the cover crop biomass and the in-row applications of Renaissance 8N-1P-5K (at 72 kg N/ha) was sufficient for ‘Spring Treat,’ which is a low-growing, early maturing sweet corn cultivar. However, ‘Spring Treat’ plants developed silks and tassels soon after N sidedressing and nutrient release rate from the slow release organic fertilizer was too slow to produce a measurable growth effect.

In 2007, since no fertilizer was applied at planting and little cover crop biomass was produced, a large yield response occurred to the N sidedressing (90 kg N/ha) for both Irish potato and sweet corn (Table 7). Likewise, a smaller but significant response occurred to in-row application of liquid fish concentrate for Irish potato (Table 8).

The crop yield data (Tables 7 and 8) showed that N availability was a yield-limiting factor in the organic transition soils used at the Kentland Agricultural Research Farm in 2007 for both crops studied, but not for either crop in 2006. This difference in crop yield response to post-applied N fertilizer can be attributed to an adequate amount of mineralized N from *in-situ* produced cover crop biomass and a pre-plant fertilizer application in 2006 (Pasakdee et al., 2006, Schellenberg, 2007). There was no pre-plant fertilizer application in 2007 and cover crop biomass was minimal. Since there likely were inadequate amounts of plant-available N in 2007, N sidedressing increased yield of both crops. In 2007, leaf-N concentration was highly correlated with crop yields in both Irish potato ($R^2 = 0.512$) and sweet corn ($R^2 = 0.808$) (Figures 1 and 2)

(Schellenberg, 2007). In 2006, yields of Irish potato and sweet corn were similar to average yields of these crops grown under conventional chemical-based systems (VAS, 2000). In 2007 in plots receiving sidedress N, yield of sweet corn equaled that in 2006; however, yield of Irish potato was reduced by 47%, compared to 2006 (Table 7). Reduced Irish potato yield is attributed to suboptimal soil conditions (compacted subsoil) of the field site chosen in 2007, resulting in slow and stunted growth of potato plants throughout the growing season. Leaf N concentration in both unfertilized (control) and sidedressed potato plants were in the low to deficient range (Figure 1; Jones et al., 1991), indicating that N uptake by potato plants was inadequate, even in the N sidedressed plots. Leaf N concentration in sweet corn plants was in the sufficient range for plants receiving sidedress N, but was in the low to deficient level for control unfertilized plants (Figure 2; Jones et al., 1991). Apparently, soil compaction had a greater constricting effect on uptake of organic sidedress N for Irish potato than sweet corn because the surface applied organic N was more accessible to the shallow roots of the sweet corn than the deeper rooting system of the potato.

2. 4 Conclusions

This study shows that, during transition from conventional to organic crop systems, multiple sources of N fertilizer may be needed to maximize crop yields. After years of building soil quality by keeping the soil covered with cover crop-vegetable rotations and application of soil amendments, reliance on sidedress N applications should be lessened as more plant-available N is accumulated in the labile fraction of the accumulated soil organic matter. Compost teas, such as SBI, can increase crop yields, especially if placed in close proximity to the seed. Additional studies should investigate the comparative effectiveness and efficiency of using SBI 1) as an adsorbed seed inoculant, 2) mixed with seed at planting, and 3) placed in close proximity to the seed at planting. Hopefully, these experiments will encourage organic farmers to consider applying multiple N fertilizers as well as different compost teas to improve supply and synchronization of N and increase crop yields.

Table 2. Potato 2006 ANOVA

Source	df	Sum of Square	Mean Square	F Ratio	P Value
SBI	1	136.89	136.89	0.125	0.731
Rep	3	2635.74	878.58	0.804	0.741
Cover Crop	1	809.40	809.40	0.741	0.410
Model	5	3582.03	716.41	0.655	
Error	10	10931.19	1093.12		
C. Total	47	14513.22			

Table 3. Corn 2006 ANOVA

Source	df	Sum of Square	Mean Square	F Ratio	P Value
SBI	1	287.83	287.83	5.292	0.027
Rep	3	236.49	78.83	1.449	0.243
N rate	2	11.34	5.68	0.104	0.901
Cover Crop	1	40.88	40.89	0.752	0.391
Model	7	576.54	82.37	1.514	
Error	40	2175.61	54.39		
C. Total	47	2752.15			

Table 4. Potato 2007 ANOVA

Source	df	Sum of Square	Mean Square	F Ratio	P Value
SBI	1	192.17	192.17	2.054	0.157
Rep	3	818.51	272.84	2.916	0.042
N rate	1	3052.56	3052.56	32.620	< 0.001
Cover Crop	1	225.38	225.38	2.408	0.126
Fish	1	514.16	514.16	5.494	0.023
Model	7	4802.78	686.11	7.332	
Error	56	5240.39	93.58		
C. Total	63	10043.17			

Table 5. Corn 2007 ANOVA

Source	df	Sum of Square	Mean Square	F Ratio	P Value
SBI	1	180.43	180.43	3.141	0.082
Rep	3	160.28	53.43	0.930	0.432
N rate	1	18658.19	18648.19	324.789	< 0.001
Cover Crop	1	0.09	0.08	0.002	0.969
Fish	1	105.47	105.47	1.836	0.181
Model	7	19104.46	2729.21		
Error	56	3217.04	57.45		
C. Total	63	22321.50			

Table 6. Effect of application of *Soil Biology Innovations* (SBI) on marketable organic crop yield.

Vegetable crop	2006 Yield (t/ha) No *SBI*	2006 Yield (t/ha) *SBI*	2006 Sign.	2007 Yield (t/ha) No *SBI*	2007 Yield (t/ha) *SBI*	2007 Sign.
Irish potato	21.2*	20.5	ns	9.9	9.2	ns
Sweet corn	10.4	12.0	0.05	6.8	7.5	0.10

*In 2006, untreated (no *SBI*) potato plots received 67 kg N/ha as a sidedressing;
SBI-treated potato plots were not sidedressed.
ns = not statistically significant at p = 0.10

Table 7. Effect of nitrogen fertilizer sidedressing on marketable organic crop yield of Irish potato and sweet corn.

Vegetable crop	**2006** N rate (kg/ha)	**2006** Yield (t/ha)	**2007** N rate (kg/ha)	**2007** Yield (t/ha)
Irish potato	-----	-----	0	8.2
	-----	-----	90	11.0
			Sign.	0.001
Sweet corn	0	11.4	0	3.5
	56	11.0	90	10.6
	112	11.2		
Significance		ns		0.001

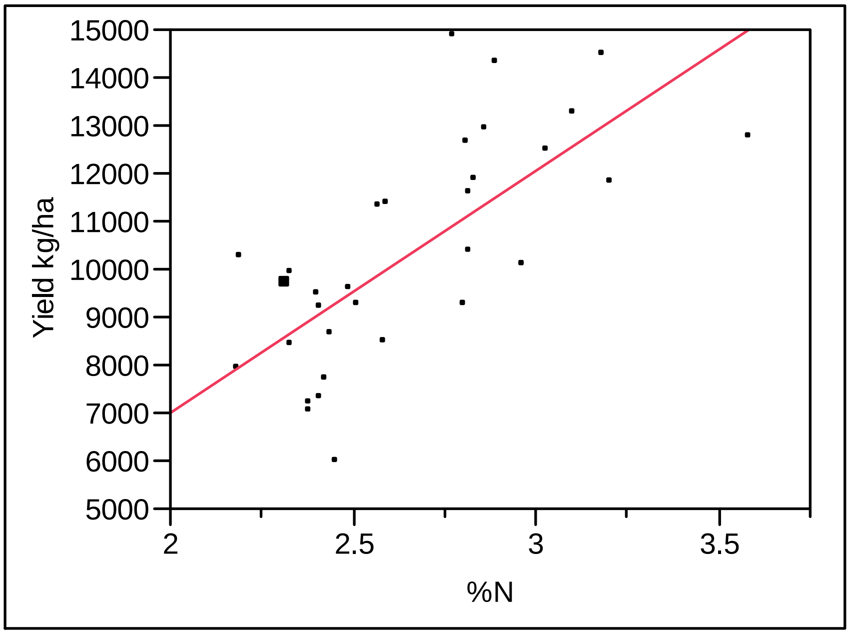
ns = not statistically significant at p = 0.05.

Table 8. Effect of liquid fish concentrate applied in row at planting on marketable organic crop yield of Irish potato and sweet corn, 2007.

Liquid fish (l/ha)	Yield (t/ha) Irish potato	Sweet corn
0	9.0	6.8
18.7	10.2	7.4
Sign.	0.05	ns

ns = not statistically significant at p = 0.05.

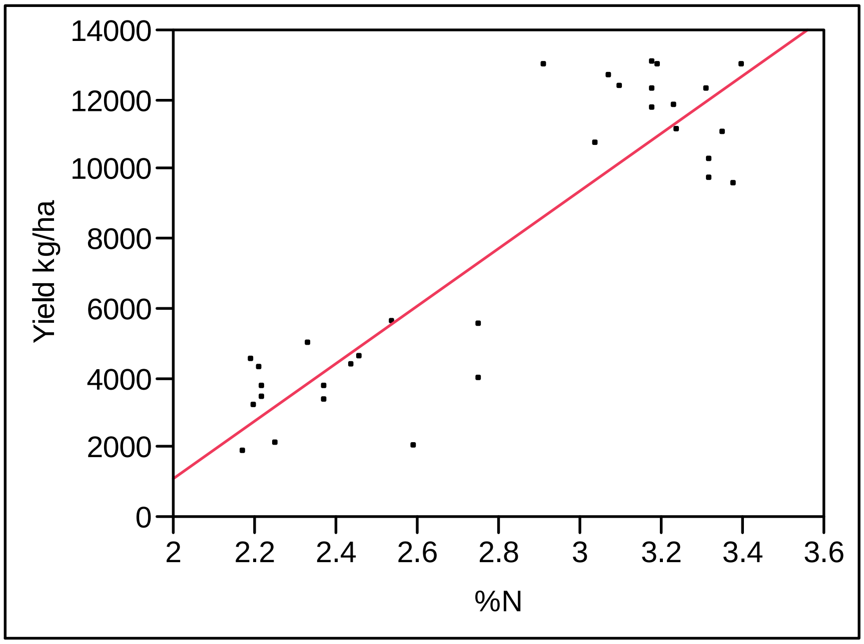
Figure 1. Regression of Leaf %N and Yield of Irish Potato



Linear $R^2=0.512$

Yield kg/ha = -3059.67 + 5038.06*%N

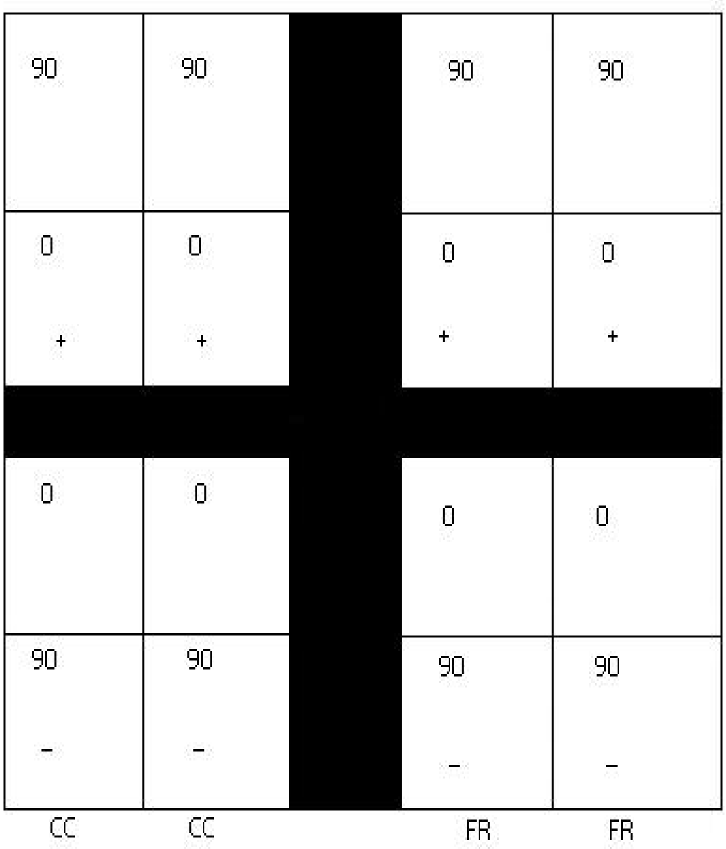
Figure 2. Regression of Leaf %N Leaf and Yield of Sweet Corn



Linear R^2=0.808

Yield kg/ha = -15430.60 + 8273.65*%N

Figure 3. Diagram of a Replication 2006



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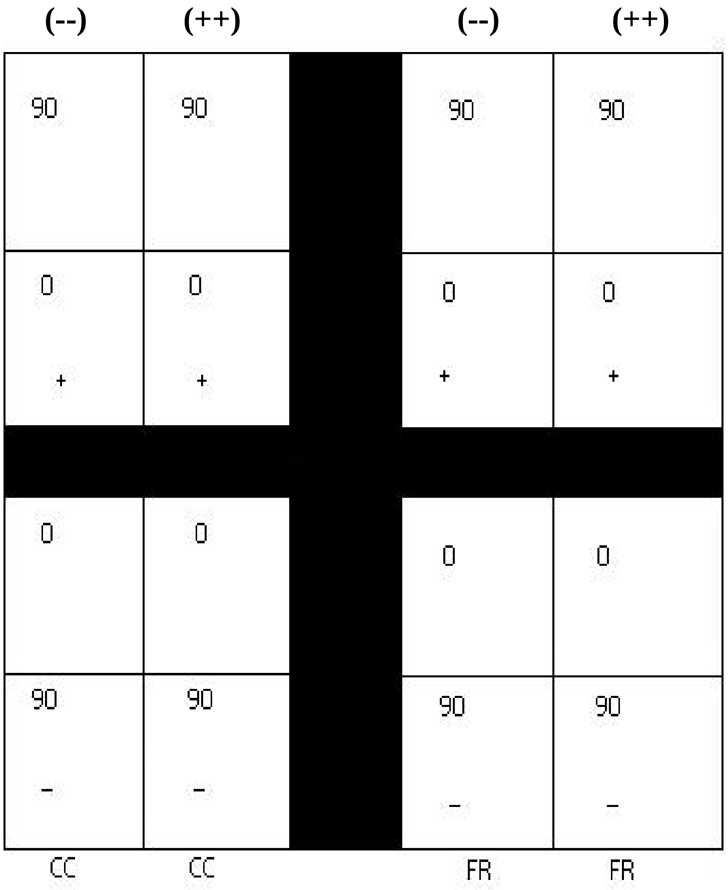
0 and 90 = N rates (kg/ha)

CC and FR = Cover crops: Crimson Clover (CC) and (FR) Forage Radish

+ and - = With (+) and Without (-) SBI

Black= Guard Rows

Figure 4. Diagram of a Replication 2007



0 and 90 = N rates (kg/ha)

CC and FR = Cover crops: Crimson Clover (CC) and (FR) Forage Radish

+ and - = With (+) and Without (-) SBI

(--) = Without Fish and (++) = With Fish

Black= Guard Rows

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