Improving Disease Management and Production of Organically - Grown Tomatoes

Report on 2005 Research Project
Toward Sustainability Foundation
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Abstract:

Tomatoes are an important crop for organic as well as conventional growers on Long Island. Effective control of foliar diseases, especially those caused by bacteria, has been a challenge for all growers. Organic growers are also looking for information on fertility and weed management. One goal of research conducted in 2005 was to evaluate chickling vetch, a new organic mulch that reportedly fixes nitrogen quickly, to determine if planted in early spring it could be a suitable substitute where hairy vetch cannot be sown early the previous fall. Chickling vetch did not grow adequately when no-till seeded on 6 Apr into fall-seeded rye to serve as a nurse crop. Therefore experiments were conducted at LIHREC with tomato no-till transplanted into hairy vetch-rye mulch. The cover crop was chopped at about the same time as for experiments conducted the previous two years; however, the vetch was not adequately killed although it was flowering when chopped, the rye evidently had viable seed, and the quantity of mulch from these cover crops was not as thick as in previous years, consequently weed control was a greater problem than in previous experiments. Another problem that occurred in 2005 was placement of peanut meal side-dressing too close to tomato stems which either damaged the stems enough to kill many plants and/or stimulated growth of fungi that were then able to attack the stems. These problems affected the success of the experiments, but provided valuable information to include in guidelines to growers about these practices. The objectives of one experiment conducted in 2005 was to evaluate benefits of growing tomatoes in a hairy vetch mulch by comparing to

tomatoes grown in rototilled plots and to evaluate AgriLife, a product that reportedly boosts the natural immune system of plants and improves crop yield. Diseases developed naturally. Leaf mold was the only one that developed to a sufficient degree to be assessed. Neither incidence nor severity of leaf mold or yield were significantly different for tomato grown in hairy vetch mulch than tomato grown in bare-ground. There may not have been sufficient hairy vetch biomass to activate defense genes in tomato, a finding that has been published, or to contribute sufficient additional nitrogen to affect yield. Tomato plants treated with AgriLife had less leaf mold. This new product has not yet been reviewed for acceptability for organic production. The objective of the second experiment was to evaluate for foliar disease control applying a copper fungicide (Champion) combined with a botanical oil, Organocide, which is thought to improve control by facilitating movement of copper into the cells of foliar pathogens. This was also examined in a grower's field. This combination did not affect leaf mold in the replicated experiment but it did appear to reduce bacterial speck in an on-farm observational study. No signs of phytotoxicity were observed which was a concern with this combination. In contrast with the situation in the research field, bacterial speck was the main disease occurring at the farm where Organocide + copper was examined. Septoria leaf spot also occurred at this farm as well as at two organic farms examined.

Background and Justification:

Effectively controlling foliar diseases, especially those caused by bacteria, can be challenging in tomatoes, an important crop for both organic and conventional growers on Long Island. Fresh local tomatoes are one of the most popular items during summer at farm stands. Organic growers on Long Island have identified tomato as a high priority for research, therefore it was selected as the research project to be conducted in 2005 in the organic research block at Cornell University Long Island Horticultural Research and Extension Center (LIHREC) in Riverhead, NY. Unfortunately resistant varieties have not been developed for diseases that have been affecting production. In addition to disease management, organic growers often ask for advice on nitrogen fertilization and weed management in tomatoes. The goal of this project is to address research needs identified by organic farmers. Bacterial speck occurs regularly. This pathogen likely is surviving on weeds. Bacterial spot and bacterial canker occur more sporadically. Copper fungicides, the main material used by both organic and conventional growers, are moderately effective. Actigard, a product that stimulates the plant defense system, is an additional option for conventional growers.

A new potential future option for organic growers is AgriLife, a citric acid product that reportedly boosts the natural immune system of plants and improves crop yield by increasing Brix level in plants. It has not yet been reviewed by OMRI, but it is considered sufficiently safe to be exempt from EPA registration under FIFRA Section 25(B). Research is needed to evaluate its activity in vegetable crops.

Based on anecdotal evidence, better disease control can be achieved by combining copper with Organocide and additionally the rate of copper can be reduced. Copper is extremely soluble in Organocide, being comprised mostly of fish and sesame oils, is mostly lipids, which are absorbed into the cell wall of many foliar pathogens fairly easily. This absorption then carries the copper into the pathogen. It does not move through the waxy cuticle covering plant leaves. Organocide also functions as a spreader / sticker for the copper, reducing wash off. Replicated experiments have not been conducted yet to document observations from commercial fields because the company producing Organocide, Organic Laboratories, is too small to have the necessary funds for research. Organocide was shown to be effective for powdery mildew in pumpkin in 2004 at LIHREC through a project funded by the EPA/USDA IR-4 Biopesticide Demonstration Grant Program.

Growing cover crops, an important practice in organic production to improve soil health and also to supply nitrogen when a leguminous type is used, is gaining interest among conventional growers. Organic matter from the cover crop increases microbial activity in the soil, which leads to nutrients being released in forms that crop plants can use and also to improve soil health. Cover crops are preferred over compost by organic growers who strive to minimize off-farm inputs. Conventional growers are becoming more interested in leguminous cover crops because the cost of synthetic nitrogen fertilizer has increased substantially recently and recent research on soil health has documented the negative impact of years of conventional farming.

The leguminous cover crop hairy vetch has been found useful when used as an organic mulch for managing diseases and suppressing weeds as well as supplying nitrogen and improving soil health. Through previous research conducted at LIHREC, a dead organic mulch of hairy vetch provided sufficient nitrogen for tomato and provided partial weed suppression. Yield was not increased by banding peanut meal at 625 lb/A (equivalent to 50 lb/A of N) over the rows. Additional grain straw mulch needed to be added to achieve sufficient weed suppression. Tomatoes grown in hairy vetch mulch were found to be less severely affected by early blight and Septoria leaf spot than tomatoes grown in either bareground or black plastic mulch through experiments conducted over several years in MD (Mills et. al., 2002). It was initially concluded that foliar disease reduction was due to reduced splash dispersal and reduced leaf wetness. Through subsequent research, a molecular basis was identified that accounted for the disease tolerance and delayed leaf senescence observed in the tomatoes grown in hairy vetch mulch (Kumar et. al., 2004).

Chickling vetch (*Lathryus sativus)* has the potential to be a good substitute for hairy vetch as a mulch in tomatoes for situations where hairy vetch cannot be seeded the previous fall or frost-seeded during late winter. Organic seed is available of the variety AC Greenfix from Johnny's Selected Seed company. Chickling vetch can be seeded in early spring. This annual legume grows more quickly than hairy vetch. It was developed as a fertilizer alternative. It can fix nitrogen in just 45 days, which is earlier than sweet clover. An average of 80-100 lbs N/acre has been produced in just 8-10 weeks. It is actually a flatpea, closely related to sweet pea (*Lathryus odoratus*). Like hairy vetch, it will die when mowed at flowering. If mowed before flowering it could be used as a living mulch since it has indeterminant growth. Thus it could be used as a living mulch between rows as well as a dead organic mulch in the row. A living mulch provides weed suppression and a means to grow a cover crop while also producing a crop. The physiological means by which hairy vetch promotes disease defense and enhances longevity in tomatoes has been identified and is expected to operate with other leguminous mulches including chickling vetch.

A two-acre field at LIHREC has been designated to be used exclusively for applied research in cultural practices and pest management within an organic farming framework.

The block was in alfalfa/timothy/orchardgrass for eight years before planting a fall/winter cover of Japanese millet plus buckwheat in August 2000, then research was started in 2001. The block is divided into four sections with a small swale left untilled as a diversity strip and drainage area that runs diagonally through the field. Each year since 2001 research has been conducted in some sections while the others have been planted to cover crops.

Objectives:

1. Evaluate chickling vetch by comparing with bareground in terms of disease suppression, yield, and nitrogen level in tomato plants.
2. Determine whether Organocide combined with copper fungicide can improve control of foliar diseases.
3. Examine Organocide combined with copper fungicide in a commercial operation.

Procedures:

Experiments were conducted in a field of Haven loam soil at LIHREC that has been assigned to research on organic vegetable production.

Chickling vetch. Following correspondences with Ila Krause, Dakota Frontier Seeds, Ltd., ND, who was involved with development of the variety AC Greenfix, it was mixed with inoculant and then no-till seeded at about 80 lb/A into fall-seeded rye in one section of the Organic Research Field on 6 April 2005 (Figure 1). Chickling vetch is recommended planted at 50-70 lb/A with a grain nurse crop such as oats. Ila felt no-till seeding into fall-planted rye as soon after winter as soil permitted would be successful and was a better approach than tilling in the rye and preparing the field for seeding the vetch plus oats, but he hadn't heard of anyone who had done this. Rye was 4.5–7 inches tall. By 23 May, very few chickling vetch plants had grown and those that were living were only 8-11 inches tall (Figure 2). At this time the rye was 4.5-5 feet tall and was starting to flower.

The section of the field planted to chickling vetch was abandoned and the section of the field that was fall-seeded to hairy vetch and rye was divided into two separate experiments.

Cultural practices for experiments at LIHREC. Hairy vetch (40 lb/A) and rye (2 bu/A) had been seeded on 8 Oct 04 in another section of the field. On 28 May when the vetch was flowering and the rye had headed, the field was flail chopped to form a mulch layer (Figures 3-4).

All tomato transplants were propagated and transplanted in the same manner for both experiments. Non-fungicide-treated tomato seed was hot-water treated at 50°C for 25 minutes to control seed-borne bacterial pathogens and then seeded in an organic soil-less mix on 2 May 05 in a greenhouse. Seedlings were put outside to harden on 31 May and were no-till transplanted on 7 Jun with Neptune's Harvest Benefits of Fish (2-4-1 N-P-K) as a starter fertilizer. A tractor equipped with a fluted coulter and an S-tine was used to cut 4 inch deep strips through the field. Seedlings were placed in these holes by hand (Figure 5). There were 10 plants spaced 2 ft. apart in each single-row plot and the individual plots were spaced five feet apart. A randomized complete block design with four replications was used for both experiments. Drip irrigation tube was laid on the soil surface next to the plants and the field was irrigated as needed.

Peanut meal was applied at 625 lb/A (equivalent to 50 lb/A of N) and straw was placed around the base of plants (1/2 bale/plot) in all plots on 27 June. In addition to the straw, weeds were managed throughout the growing season by mowing between plots and hand weeding in the planted rows. Plants were pruned, staked, and trellised. Entrust was applied to all plots to help control Colorado potato beetle and fruit worms on 8 and 25 Aug.

Experiment 1: Evaluation of hairy vetch mulch and AgriLife for controlling foliar disease. The objective of experiment 1 was to evaluate hairy vetch plus rye mulch used alone or combined with applications of AgriLife for control of foliar diseases of tomato that occurred naturally by comparing these treatments to tomatoes grown in bare-ground.

On 3 Jun, before transplanting, plots receiving the bare-ground treatment were prepared by raking away the vetch/rye mulch then using a hand-held rototiller. Bare-ground plots were rototilled again on each side of the planted row on 27 Jun after transplanting.

Nitrogen and other nutrients were monitored in soil and plants for the vetch mulch and rototilled plots. Soil was collected for PSNT (pre-side-dress nitrogen test) analysis on 23 June. Leaf samples were collected on 11 Aug. Analysis was done by the Cornell Nutrient Analysis Laboratory in Ithaca and the Brookside Laboratories, Inc. in Ohio, respectively.

AgriLife was applied to the ground early in plant growth as well as to foliage throughout the growing season. It was applied using a CO_2-pressurized backpack sprayer with a single flat-fan nozzle boom. Each side of the planted row was treated with the boom held sideways to obtain thorough coverage of foliage, then a second pass was made around the plot with the boom directed on the soil on each side of the plot. AgriLife was applied at 1:200 on 13, 21, 28 Jun, 5, 12 Jul, as well as on 1, 8, 16, 23, and 30 Sep. In the middle of the season AgriLife was applied at a higher rate of 1:100 on 19, 22, 27 Jul, and 1, 5, 8, 16 Aug.

Plants were scouted routinely for evidence of foliar disease. Leaf mold developed naturally and was first observed on tomato foliage on 6 Sep. Leaf mold incidence (percentage of plants infected per plot) and severity (percentage of leaf tissue infected per plot) were rated on 15, 27 Sep, 3, and 17 Oct. Canopy condition including defoliation was assessed on 23 Sep.

Red fruit and those turning red were harvested five times on a weekly basis from 10 Aug to 5 Oct. Fruit was graded by size, counted, and weighed. Green fruit with insect feeding damage were removed and combined with culls. Culls were categorized as damaged by insect feeding, diseased, and physiological (eg blossom-end-rot).

Experiment 2: Evaluation of Organocide for controlling foliar disease. The objective of this experiment was to compare two fungicide programs with OMRI-approved products for their control of foliar diseases of organically-produced tomatoes. The products tested were Champion (77% copper hydroxide) and Organocide (5% sesame oil). Organocide was applied alone and also in combination with Champion to determine whether disease control was improved and whether there were any phytotoxic effects from combining the two fungicides. Organocide combined with a copper fungicide was observed to provide good control of foliar diseases, better than obtained with copper alone, under farm conditions. A replicated experiment was needed to confirm this observation and to address the concern that combining copper with an oil could be phytotoxic to the tomato foliage.

The three treatments evaluated were Organocide applied alone, Organocide combined with Champion, and a nontreated control. Fungicides were applied using a CO_2-pressurized backpack sprayer with a single twin jet nozzle boom. Applications were made on 8, 16, 23 and 30 Sep.

Plants were scouted routinely for evidence of foliar disease. Leaf mold developed naturally and was first observed on tomato foliage on 6 Sep. Leaf mold incidence (percentage of plants infected per plot) and severity (percentage of leaf tissue infected per plot) were rated on 15, 28 Sep, 3 and 17 Oct. Canopy condition including defoliation was assessed on 23 Sep.

Red fruit and those turning red were harvested four times on a weekly basis from 10 Aug to 20 Sep. Fruit was graded by size, counted, and weighed. Green fruit with insect feeding damage were removed and combined with culls. Culls were categorized as damaged by insect feeding, diseased, and physiological (eg blossom-end-rot).

On-Farm Observation Study: Organocide + Champion applied for bacterial speck and other foliar diseases in tomato. A section of the first tomato planting at Sang Lee Farms was sprayed with Organocide + Champion by owner Fred Lee beginning on 20 July. The rest of the planting was sprayed with just Champion. Plants were examined several times during the season to assess disease severity and look for symptoms of phytotoxicity.

Observations of foliar diseases in tomato at organic farms. Tomatoes were examined at Garden of Eve Organic Farm and Golden Earthworm Farm.

Results and Discussion:

Chickling vetch. Inadequate growth of chickling vetch for a mulch and source of nitrogen was obtained when it was no-till seeded into standing rye as early in the growing season as possible (Figure 2). Growth may have been better if the vetch had been seeded with oats after incorporating the rye. At the time, no-till seeding into the rye cover crop was viewed as a better option.

Experiment 1: Evaluation of hairy vetch mulch and AgriLife for controlling foliar disease. Rye plus vetch did not produce as good a straw mulch as in previous years (Figures 6-10, 14) and several plants died early in the season due to stem rot following inappropriate placement of peanut meal fertilizer in contact with the stem (Figures 11-13). The fertilizer was applied to the soil around the base of the plant, with some in direct contact with the stem (Figure 12), rather than spread in a band across the planted row. The peanut meal appeared to either burn the stem and/or stimulate fungal growth around the tomato stems (Figure 13). In one week's time many of the tomato plants had developed a stem rot and died resulting in an uneven number of plants per plot (Figures 11, 14, 15). Although this experiment consequently was not as successful as previous ones, valuable information was gained from the experience. The vetch stand was not as dense as in previous years when seeding was done about 1 month earlier in the fall (6-12 Sep). When the cover crop was mowed, evidently the vetch was not sufficiently in flower to completely kill it and the rye had some mature seeds, consequently the cover crops became weeds (Figures 7-8). It was valuable to learn that peanut meal can either damage young tomato stems and/or stimulate fungal growth resulting in stem rot sufficient to kill the plant.

Nitrate, phosphorous, and organic matter levels for soil in the vetch mulch plots were numerically higher but not significantly different from the rototilled plots on 23 June, which was a few days before peanut meal fertilizer was applied (Table 1). All nutrients except phosphorous and potassium were numerically higher for leaves from vetch mulch plots than leaves from the rototilled plots, but these differences were not statistically significant (Table 2).

Foliar diseases developed naturally. Leaf mold was the only foliar disease that developed to a sufficient degree to be rated. Symptoms were first observed in the field on 6 Sep. Bacterial speck, powdery mildew, and Septoria leaf spot developed on tomato grown in this research field in previous years. Neither incidence nor severity of leaf mold were lower for tomato grown in hairy vetch mulch than tomato grown in bare-ground (Table 3). Hairy vetch mulch has suppressed disease in other experiments and been shown to activate defense genes in tomato. Tomato plants treated with AgriLife had numerically lowest disease ratings at all assessments with incidence on 27 Sep being significantly lower than the other treatments. There were no significant differences in yield among treatments.

In this experiment there may not have been sufficient hairy vetch biomass to activate defense genes or to increase soil nutrient levels, in particular nitrogen, since it was grown with rye plus the vetch stand was not as dense as in previous experiments when seeded earlier. Vetch is commonly grown with rye as a winter cover crop because rye protects the vetch when it is young and serves as a support for the vetch to grow up on. Additionally, vetch biomass may not have been adequately removed from the rototilled plots for these to serve as an appropriate comparison with the vetch-mulch plots.

Analysis has not been completed yet of the leaves sent to Dr. Autar K. Mattoo at the USDA in Belsville, MD. He is determining if plant defenses were stimulated as he has documented for tomatoes grown in hairy vetch.

Experiment 2: Evaluation of Organocide for controlling foliar disease. As occurred in Experiment 1, early in the season many of the plants in Experiment 2 died due to a root and stem rot presumably resulting from inappropriate application of peanut meal fertilizer. The best plots were selected and three planned treatments were not tested: Champion alone, Organocide + half rate of Champion, and applications of Organocide + Champion initiated after disease detection.

Leaf mold developed naturally and was first observed in the field on 6 Sep. No significant differences were found in the levels of control of leaf mold or yield for any of the treatments (Table 4). No phytotoxicity was found for any of the products tested and defoliation was not significantly different between treatments. Therefore Organocide tank-mixed with Champion appears to be a safe combination for tomato. Additional testing is needed on efficacy for disease control and impact on yield because the plant stand was inadequate in this experiment to make definitive assessments.

On-Farm Observation Study: Organocide + Champion applied for bacterial speck and other foliar diseases in tomato. Just before the first fungicide application on 20 July, symptoms of bacterial speck were observed scattered throughout the first tomato planting at Sang Lee Farms (Figure 17). The section of this planting that was sprayed with Organocide + Champion by owner Fred Lee appeared to have less severe symptoms than the rest of the planting that was sprayed with just Champion. There was a lot of variation in disease severity in this planting which made it challenging to quantify the treatment impact. A lot of the variation appeared to be due to differences in disease susceptibility among varieties and plant types. There were 40 varieties of cherry, plum, beefsteak and Heirloom tomato types in this planting. Just beyond one end of the tomato rows was an area with dense natural growth including trees, which may have resulted in environmental differences across the field. The amount of variation in disease severity unrelated to the treatment was surprising. No signs of phytotoxicity were observed in the tomatoes treated with Organocide + Champion.

Observations of foliar diseases in tomato at organic farms. Septoria leaf spot was the primary disease affecting tomatoes examined at Garden of Eve Organic Farm and Golden Earthworm Farm in 2005 (Figure 18). Bacterial speck was also present. Powdery mildew was at one farm (Figure 19).

Literature Cited:

Kumar, V., Mills, D. J., Anderson, J. D., and Mattoo, A. K. 2004. An alternative agriculture system is defined by a distinct expression profile of select gene transcripts and proteins. PNAS 101(29): 10535-10540.

Mills, D. J., Coffman, C. B., Teasdale, J. R., Everts, K. L., and Anderson, J. D. 2002. Factors associated with foliar disease of staked fresh market tomatoes grown under differing bed strategies. Plant Dis. 86:356-361.

Conclusions and Project Impact:

Information was obtained on production practices, disease occurrence and disease management for organically-produced tomato, an important crop, through this project.

Chickling vetch did not grow adequately when no-till seeded on 6 April into fall-seeded rye to serve as a nurse crop. This cover crop should be re-evaluated seeded conventionally with oats at a similar time to assess whether the rye was too competitive.

Importance of proper timing for seeding vetch in the fall and for chopping vetch and rye in the spring to obtain an adequate mulch for no-till tomato was demonstrated through this project. Vetch was seeded after the ideal time, which likely was the reason that it did not grow as well as in previous experiments when it was seeded earlier. Not chopping vetch and rye at their appropriate growth stages resulted in them becoming weedy.

A hairy vetch mulch used for no-till tomato did not affect leaf mold severity or yield based on comparison with rototilled plots; however, the density of vetch mulch was low. Additional research is warranted.

Peanut meal applied as a side-dress fertilizer next to young tomato stems can lead to stem rot and plant death due to either the peanut meal in direct contact with the stem damaging it and/or stimulating growth of fungi that were able to attack the stem after developing on the nutrient-rich peanut meal.

The botanical oil fungicide Organocide tank-mixed with the copper fungicide Champion appears to be a safe combination for tomato. It was not effective for leaf mold but appeared to be effective for bacterial speck. Additional research is warranted to evaluate this treatment for speck as well as for other foliar diseases.

AgriLife, a new product that is claimed to boost the natural immune system of plants, may be a valuable tool for organic growers. It has not been reviewed yet for acceptability for organic production. Additional research is warranted to confirm it is effective for leaf mold and to determine if it is effective for other foliar diseases.

It was valuable to learn that disease occurrence can vary greatly on tomatoes grown in a small geographical area. Leaf mold was the main disease in the research plots. Bacterial speck was the main disease occurring at the farm where Organocide + copper was examined. Septoria leaf spot also occurred here and was the main disease at two other farms. This suggests that important sources of inoculum for these pathogens occur near these farms.

Growers can use this information now.

Table 1. Nutrient analysis results for soil collected on 23 June, 2005.

P (NAOAC)	**OM (LOI)**		**NO_3 (NAOAC)**
Treatment	**mg/Kg**	**%**	**mg/Kg**
No-till Vetch Mulch	19.43	3.03	5.47
Rototilled	18.28	2.93	5.06

Table 2. Leaf tissue nutrient analysis results for tomato foliage collected on 11 August, 2005.

Treatment	**Tomato Leaf Tissue Nutrient Content (Samples collected 11 August)**												
	N (%)	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (%)**	**B (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**Cu (ppm)**	**Zn (ppm)**	**Al (ppm)**	
No-till Vetch Mulch	2.58		0.27	2.41	1.44	0.65	0.58	38.9	202.2	36.6	16.4	14.9	177.3
Rototilled	2.43		0.29	2.61	1.20	0.56	0.54	34.7	195.6	32.9	14.5	14.7	174.2

Table 3. Leaf mold disease ratings and yield of organically-produced tomato evaluated in 2005.

Leaf Mold Disease Ratings[z]						**Yield (lbs/plant)**							
Disease Incidence (%)				**Disease severity (%)**	**2-3 inch fruit**								
Treatment[y]	**12-Sep**						**>3 inch fruit**		**All fruit**	**27-Sep**	**3-Oct**	**17-Sep**	**3-Oct**
AgriLife + Vetch Mulch	43.1	51.9	b[x]	84.7	3.8	10.3	13.9	16.8	30.7				
Rototilled	56.3	84.4	a	100.0	9.6	17.7	10.0	7.5	32.1				
No-till Vetch Mulch	67.5	77.5	a	100.0	15.7	22.9	10.8	22.1	18.3				
Treatment *P*-value	0.2104	0.0020		0.1338	0.0573	0.0639	0.8577	0.0704	0.2417				

[z] Disease Incidence refers the the percentage of plants in each plot that showed symptoms of leaf mold. A plant was considered infected if any part was showing symptoms (leaves, petioles, stems etc). Disease severity refers to the level of infection of each of these plants in the plot.

[y] CropLife 1:200 was applied on 13, 21, 28 Jun, 5, 12 Jul, 1, 8, 16, 23, and 30 Sep. In the middle of the season CropLife was applied at a higher rate of 1:100 on 19, 22, 27 Jul, 1, 5, 8, and 16 Aug.

[x] Numbers followed by the same letter are not statistically different from each other according to Fisher's protected LSD (P=0.05).

Table 4. Effects of organic fungicides on leaf mold incidence and severity as well as yield for organically-produced tomato evaluated in 2005.

Leaf Mold Disease Ratings[z]						Yield (lbs/plant)				
Treatment[y]	Disease Incidence (%)			Disease severity (%)	2-3 inch fruit					
15-Sep	20-Sep	28-Sep				>3 inch fruit		All fruit	28-Sep	3-Oct
Nontreated	70.6	80.0	96.9	19.7	24.1	35.0	8.9	20.6		
Champion	30.8	58.1	69.7	5.6	11.7	36.5	10.8	21.6		
Organocide/Champion	83.7	93.7	89.3	15.8	21.6	36.8	14.2	27.1		
Treatment *P*-value	0.0662	0.1912	0.1184	0.4449	0.3736	0.9501	0.4402	0.4545		

[z] Disease Incidence refers the the percentage of plants in each plot that showed symptoms of leaf mold. A plant was considered infected if any part was showing symptoms (leaves, petioles, stems etc). Disease severity refers to the level of infection of each of these plants in the plot.

[y] Fungicides were applied using a CO_2-pressurized backpack sprayer with a single twin jet nozzle boom and applications were made on 8, 16, 23 and 30 Sep.

Figure 1. No-till seeding chickling vetch into fall-planted rye on 6 April 2005 in the Organic Research Field at LIHREC.
Figure 2. Chickling vetch and rye on 23 May 2005.
Figure 3. Hairy vetch mulch and rye on 23 May 2005.
Figure 4. Hairy vetch mulch and rye on 1 June 2005, 4 days after chopping.
Figure 5. Opening rows for no-till transplanting tomatoes in the Organic Research Field in 2004.

Figure 5. cont,
Opening rows for no-till transplanting tomatoes in the Organic Research Field in 2004.
Figure 6. Tomato plant on 17 June 2004, 16 days after chopping vetch plus rye cover crop and 6 days after transplanting.
Figure 7. No-till transplanted tomato plants on 16 June 2005, 19 days after chopping vetch plus rye cover crop and 9 days after transplanting.
Figure 8. Research field on 20 June 2005.

Figure 9. Tomato plant and weeds in no-till vetch mulch plot on 20 June 2005.
Figure 10. Tomato plant in rototilled plot on 20 June 2005.
Figure 11. Healthy tomato plant (left) and tomato plant with stem rot associated with peanut meal application (right) on 8 July 2005.
Figure 12. Peanut meal fertilizer on tomato stem on 8 July 2005.
Figure 13. Fungal growth on peanut meal fertilizer and damaged tomato stem on 19 July 2005.

Figure 14. Overview of research field on 11 August 2005. Note added straw mulch in tomato rows.

Figure 15. Staked and trellised tomato plants in no-till vetch mulch plot on 11 August 2005.
Figure 16. Tomato plants at Sang Lee Farm on 19 July 2005.
Figure 17. Symptoms of bacterial speck on tomato plants at Sang Lee Farm on 19 July 2005.

Figure 18. Symptoms of Septoria leaf spot.
Figure 19. Symptoms of powdery mildew.