Title: Farm Ecosystem and Management Factors Contributing to Pest Suppression on Organic and Conventional Farms

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Summary:

Many organic farmers report a reduction in pest pressure after a number of years of organic production. Our goal in this project was to identify relationships between farm management practices, soil quality, and pest populations on mixed vegetable farms. We sampled extensively in potatoes and winter squash on four organic and four conventional farms throughout New York to characterize crop management practices, pest and beneficial complexes, a variety of soil characteristics, weed species and density, and field border flora and fauna. We also conducted educational programs for organic vegetable growers, and conducted efficacy trials for pest management materials approved for organic production.

Introduction:

Organic farmers rely mainly on a combination of soil building, cultural practices, and natural ecosystem functions to control pests of their farms, with occasional interventions with approved pest management products. Experienced organic growers report a reduction in pest pressure as their soil quality improves and their farm ecosystem develops. To determine levels of pests and look for relationships between soil and ecosystem factors and pest populations, we sampled potatoes and winter squash fields on four organic and four conventional mixed vegetable farms. Crops were scouted weekly to enumerate pests and beneficials. Beneficials in the field borders were sampled using pitfall traps and sweep samples, and in-field beneficial samples included yellow sticky cards and pitfall traps. The flora in the field borders was characterized once per season. Soils were sampled once at mid-season to determine nutrient estimates, microbial activity, nitrogen mineralization rate, and particulate organic matter fractions, and once just before harvest to estimate root disease severity and pathogenic and beneficial nematodes.

Management systems were compared using t-tests, and relationships between pest and other ecosystem factors were explored using regression analysis. Cooperating growers kept records of labor, equipment, and other inputs used to grow these crops. These records were analyzed to estimate average enterprise budgets for these two crops on organic and conventional farms.

Three-day workshops on organic vegetable production were conducted in 2001 and in 2003. Presenters included university researchers and extension staff, and experienced organic farmers. A proceedings from the 2003 meeting including summaries of academic presentations and transcripts of grower presentations was produced by NRAES (NRAES-165).

Efficacy trials with organically approved pest management products were conducted against several pests identified as high priority by the grower members of the Cornell Organic Program Work Team.

Objectives:

A. Explore the relationships between farm management practices, soil quality, farm landscape, and pest populations in two vegetable crops on organic and conventional farms. Estimate costs of production for the two crops on each cooperating farm.
B. Develop and present educational programs for organic vegetable growers.
C. Research and demonstrate new or unfamiliar pest management techniques and products allowable on certified organic farms.

Materials and Methods:

A. Extensive sampling was conducted in potato and winter squash fields on four organic and four conventional mixed vegetable farms. Two farms (one organic, one conventional) were located in eastern NY, two (one organic, one conventional) were located in western NY and four (two organic, two conventional) were located in south central NY near the Ithaca area. All farms were mixed vegetable operations managing between 2 and 80 acres (see Appendix 1 for brief farm profiles). Farms had been in operation for between eight and thirty five years and grew both winter squash and potatoes as part of their crop mix. Each year farmers were interviewed prior to the growing season to determine the five-year rotation history of the fields that would be planted to squash and potatoes, and detailed production history of those fields during the past two seasons. At the beginning of the project we determined their equipment inventory, and marketing channels. The potato variety "Superior" and the winter squash variety "Waltham Butternut" were determined to be those most commonly grown by the cooperating farmers. Farmers who did not grow those varieties were provided with enough seed to grow at least 200 row feet of that variety so yields could be estimated. Growers maintained logs of all activities associated with their potato and winter squash crops during the growing and marketing season. These logs were used to estimate costs of production for each crop on each farm.

Each field was divided into six sampling areas of approximately equal size. Sampling area size varied greatly from field to field, reflecting field size. Insect and disease pests and beneficial insects were sampled weekly on five plants or a number of plant units in each of the six areas of the field. Samples taken in the "common" varieties were designated as such on the data forms. One yellow sticky card was placed at the height of the top of the crop canopy in each of the six areas of the field during alternate weeks to monitor beneficial insects. To monitor for insects active on the soil surface, one pitfall trap filled with a saturated salt solution was placed in each area of the field. Pitfall samples were collected bi-weekly, with the traps being closed on alternate weeks. Pitfall traps were also installed in non-crop field borders. Insects in non-crop field borders were sampled using an insect net on alternating weeks. Sticky card, pitfall, and border sweep samples were placed in freezers for evaluation during the winter. Crop-specific pests as well as beneficials were enumerated from these samples.

Levels of parasitism for known parasitoids of two major insect pests were estimated. First generation, fourth instar Colorado potato beetles (CPB) were collected from fields with sufficient CPB populations, and reared on potato foliage to determine levels of parasitism by two parasitic flies. Adult striped cucumber beetles were collected from both the overwintering and summer generations and dissected to determine levels of parasitism by two parasitic wasps.

Weed populations were sampled using a 25 x 100 cm quadrat randomly thrown and centered over the crop row. Number and stage of development (vegetative, flowering, seed set) for each weed species in the quadrat area was recorded. Five to six quadrats were sampled in each field three times during the 2000 season; six quadrats (one per sample area) were sampled during the 2001 and 2002 seasons. Weed populations were sampled three times during the growing season: shortly after crop emergence, at flowering in potatoes or vine running in squash, and just before harvest.

The species composition of the non-crop field borders was characterized by recording forb species and estimating percent ground cover, percent grass cover, percent forb cover, and percent bare ground in semicircles with a five meter radius at the edge of the tilled area. The border species composition was sampled every 100-150 ft. along each non-crop edge of the field. The vertical dimension of the border vegetation was not recorded.

Tissue samples were taken from the "common" varieties of each crop for nutrient analysis. Squash were sampled after vine run, when plants had two or more vines with greater than five leaves. The fifth leaf from the meristem was sampled. Potatoes were sampled just before flowering and again, the fifth compound leaf from the meristem was sampled.

Soil samples were analyzed for nutrient status, microbial activity, particulate organic matter (POM) fractions, nematode populations, and disease suppression. Six aggregate samples were taken for all soil analyses except disease suppression at the time of maximum crop growth (late June, early July). In 2001 and 2002 an additional six aggregate samples were taken soon after planting and at harvest for nitrate analysis. Each aggregate sample for nitrate, ammonium, N mineralization, microbial activity, and POM consisted of four cores collected with a bulb planter (6.8 x 15.2 cm). Nitrate and ammonium were determined using 2 M KCl extracts of fresh soil, within 24 h of sampling. At the same time, 7-day anaerobic incubations of soil were set up to determine N-mineralization potential. Soil microbial activity was determined by measuring the rate of hydrolysis of fluorescein diacetate (FDA) (Schnurer and Rosswall, 1982). Particulate organic matter (POM) was separated from the mineral fraction and separated into three size classes (>2000μm, 2000-250μm, and 250-52μm) by wet sieving.

Aggregate samples for a nematode survey and root disease severity bioassay were collected with a trowel and consisted of 10 subsamples taken to a depth of six inches. Soil for the root disease severity bioassay and nematode evaluation was collected just prior to harvest.

Disease severity bioassays were conducted in the greenhouse. Subsamples of soil from each farm were placed in two pots and 7 bean seeds were planted in each. Pots were maintained in the greenhouse for 5-6 weeks at which time plants were harvested and soil washed off the roots. Roots were rated for root disease severity on a scale of 1 (no visible disease) to 9 (>75% of hypocotyls and root tissues diseased) and the pathogens present (Fusarium, Pythium, Rhizoctonia, Thelaviopsis) recorded if discernable.

Pathogenic and saprophytic nematodes were enumerated using the Baerman pan technique. Fifty cc of soil was placed on a paper tissue over a stainless steel screen. The screen with the soil was placed in a shallow pan and sufficient water added to cover the soil. This setup was incubated for four days at 21-24° C after which time nematodes were identified and counted.

At harvest, for potatoes, four 20 ft. sections of the potato variety "Superior" were dug, counted, graded, and weighed. A ten pound sample of tubers from each replicate was returned to the lab for specific gravity determination. These tubers were also examined for tuber defects. In squash, four 10 ft.^{2} areas in the variety "Waltham Butternut" were established in 2000, and 20ft^2, areas were established in 2001 and 2002. All ripe fruit in each area were counted and weighed. Each fruit was examined for symptoms of fruit rotting or cosmetically damaging diseases. Four fruit from each harvested area were returned to the lab to measure the percent soluble solids.

Data summary and analysis: To create a summary data set that allowed us to examine relationships between variables, whole fields were treated as replicates, giving us a total of eight fields of each crop (four organic and four conventional) each year, and a total of 24 fields of each crop (twelve organic and twelve conventional) over the three-year period. For samples that were common across crop we had a total of 48 replicates (24 organic and 24 conventional) over the three-year period. Data for all variables was summarized, if necessary, to create one observation per field per year. To represent insect or disease pressure for the entire season, a modified "area under the disease progress curve" (AUDPC) was calculated for most insect and disease pests. The modified AUDPC was calculated by averaging the weekly field average for each pest (average of the six sampling areas) with that for the following week and multiplying by the number of days between samples. These numbers were summed for the entire season and then divided by the number of weeks the field was sampled. The number of weeks sampled varied 1-2 weeks between fields because of different planting and harvest dates. Other variables were summarized by calculating a seasonal average. Insecticide and fungicide applications were summarized for each field by calculating a field use environmental impact quotient (EIQ) (Kovach et al. 1992) for the natural enemy EIQ component for each pesticide applied.

To compare systems, t-tests were calculated (Proc TTEST, SAS Institute) comparing management systems (conventional and organic) by year and combined over the three years.

To examine relationships between variables, data were analyzed by a general linear model (Proc GLM, SAS Institute) using "year" as a class variable and entering it into the model before the predictor variable of interest. This had the effect of accounting for variability associated with different growing seasons, fields and field histories, and myriad other sources of variability associated with year. Relationships between variables of interest were considered significant if p values associated with slope were ≤ 0.10. R^2 values associated with the relationship are for the entire model including year. As a rough indicator of the correlation between year and the predictor variable of interest we compared the P values for year calculated using the Type I and Type III sums of squares. P values that are similar for each type indicate that year and the variable of interest are orthogonal. P values associated with the Type III sums of squares that are larger than the than those associated with Type I indicate that year and the variable of interest are correlated but the variable of interest accounts for more of the variability in the dependent variable. The converse is true if P values associated with Type III sums of squares for year are smaller than those associated with Type I. Variables with significant relationships were plotted to look for observations with undue influence on the regression. Where those occur they are indicated in the notes column of the appendices and in the narrative.

B. Three-day workshops on organic vegetable production were conducted in February and March 2001 and again in January 2003. A proceedings from the January 2003 meeting including written summaries of presentations by university staff and transcripts of grower presentations has been produced by NRAES (Organic Vegetable Production, NRAES-165). In-field meetings and newsletter articles discussing the overall results of the project will be forthcoming.

C. Because of the lack of efficacy data on many organically-approved pesticides, several trials looking at the efficacy of Organic Materials Review Institute (OMRI)-approved pesticides were conducted. Trials were conducted on grower farms, university research farms, and in greenhouse trials. The pests we chose to conduct trials with were those prioritized by growers attending a Cornell organic advisory committee meeting in December of 2000, and included flea beetles on spring brassicas, thrips on onions, cabbage aphids on fall brassicas, potato leafhopper on potato, fungal foliar diseases of tomato, and Rhizoctonia black scurf on potato tubers. In some cases we arranged to have faculty who regularly conduct efficacy trials in the crops in question to include the OMRI-approved materials in their trials.

Results:

A. The three seasons during which this study was conducted were difficult growing seasons. The 2000 season started out very wet and then turned hot and dry. The 2001 and 2002 seasons were both characterized by a shortage of rainfall. A sampling problem in potatoes that was revealed in the data analysis is the difficulty of distinguishing between early blight foliar infection and hopperburn caused by potato leafhopper feeding. A trial looking early blight would control potato leafhoppers to avoid disease estimation error. On the organic farms, hopperburn was likely inadvertently rated as early blight, especially late in the season when they nearly impossible to distinguish.

Comparisons between organic and conventional systems

T-tests comparing management systems are summarized in Appendices 2-4.

Pests:

In potatoes, populations of Colorado potato beetle (CPB) and aphids were not significantly different between the two farm management types, although average numbers for CPB were higher on the organic farms and average number of aphids was lower on the organic farms. One organic grower used a Bt product one season for CPB control. No other insect management products were applied on the organic farms. Populations of potato leafhopper (adults and nymphs) and flea beetles were significantly higher on the organic farms. Early blight levels were not significantly different between the two management types, although data are confounded with hopperburn ratings as discussed above.

Neither number nor diversity of beneficial insects was significantly different between management types, either when measured on the plants during scouting or on yellow sticky cards or in pitfall traps. Number and diversity of beneficials in the field borders, as measured by border sweeps or border pitfall traps, did not differ between management systems.

Both total and marketable yield of potatoes on organic farms was significantly lower than on conventional farms two of the three sampling seasons, and overall when data from all three years is pooled. A backward stepwise regression (PROC stepwise, SAS Institute) revealed significant negative relationships between yield, and both potato leafhopper populations and the early season weed population. A significant positive relationship was seen between soil total nitrogen and yield. These relationships were present in both the combined and organic data sets. When looking at the conventional farms alone, only early season weed pressure showed a significant (negative) relationship with yield. The initial model included total water (rainfall plus irrigation), bean root rot rating, root knot and lesion nematodes, and mid-season weed pressure.

Bean root rot rating and root knot nematode numbers were significantly lower on the conventional farms when data were pooled over the three years. Root lesion nematodes were significantly lower on the organic farms. Saprophytic nematode numbers were significantly higher on the organic farms.

For data pooled over the three seasons, weed pressure differed significantly between systems only for the early season sample, and was lower on the organic farms. Weed species diversity was not significantly different between systems.

In squash, striped cucumber beetle pressure was significantly higher on the organic farms. Squash bug numbers were generally higher on the organic farms, but the difference was not significant. Aphid numbers and powdery mildew levels were generally lower on the organic farms, but again, differences were not significant. Bacterial wilt levels were very low on all farms, and our sampling plan was not intensive enough to reveal differences between management systems if they did exist. Sampling would have needed to be concentrated on the field edges to detect significant differences for bacterial wilt. Striped cucumber beetle parasitism was higher on average on the organic farms for both early and late season samples, but differences were not significant. As we saw in potatoes, in-field beneficial numbers and diversity did not differ significantly between management systems whether measured directly by scouting, on yellow sticky cards, or in pitfall traps. Similarly, beneficials in field borders in sweep and pitfall samples did not differ between management systems.

Average yield for squash was lower on the organic farms, but differences between systems were not significant. The average sugar content in the fruit was lower on the organic farms all three seasons, but the difference was not significant. Bean root rot ratings were significantly lower on the organic farms in squash, in contrast to what we saw in potatoes, and no significant differences were seen between systems for either root knot or lesion nematodes. The number of saprophytic nematodes was significantly higher on the organic farms. Neither weed number, nor species diversity was significantly different between systems for any sampling period. The organic squash fields had a higher percent of the rotation out of vegetable crops during the previous five seasons.

Soils:

Soils from organic farms had higher soil organic matter and higher concentrations of estimated nitrogen in this organic matter (Table 1). This higher organic matter content from organic farm soils was also reflected in higher levels of particulate organic matter (POM measured via wet sieving method)(Table 2), higher total soil nitrogen and total soil carbon (Table 3). There was no difference in the percent of POM of different size classes among the years or management styles (Table 2).

Higher levels of total soil microbial activity were also measured in organically managed soil (Table 1). Soil microbial activity was determined by measuring the rate of hydrolysis of fluorescein diacetate (FDA)(Schnurer and Rosswall, 1982), which has been correlated with disease suppressiveness (Hoitink and Grebus, 1994). Results from research with composts suggest that FDA values above a threshold of 3.2 ug$\bullet$min$^{-1}\bullet$g^{-1} were suppressive to certain soil borne pathogens (Boehm and Hoitink, 1992). Over three years, organically managed soils had higher levels of microbial activity (Figure 1). This observation of higher soil microbial activity under organic management systems compared to conventional systems has been previously reported (Workneh et al., 1993).

Table 1. Comparison of climate and soil nutrients across years and management st study farms. Crop choice had no significant effect on these measurements.

Variable	Average Rainfall (inches)	Estimated degree days	Length o Season (days)	Soil Organic matter (%)	Estimated N in Soil Organic Matter (lb/a	Average Microbial Activity (ug•min-1•g-
Year						
2000	7.1	1138	111	3.8	68	2.2
2001	16.2	997	118	4.5	100	2.6
2002	15.8	984	113	4.0	93	3.6
Management						
Conventional	12.3	1053	118	3.0	78	1.9
Organic	13.8	1027	109	5.1	97	3.7
			Signficance (Pr>F)			
Year	0.0001	0.002	ns	ns	0.005	0.015
Management	ns	ns	0.05	0.0001	0.05	0.0001
Yr*Mnmt	ns	ns	ns	ns	0.025	0.0266

Table 2. Amounts of three Particulate Organic Matter (POM) Fractions from soils collected on study POM was determined, in duplicate, on 50 gm of air dry soil. Total POM was the sum of the three fra collected. The percent POM was based upon the 50 gm sample. Sizes of POM fractions were either than 2000 um seive size, between 250 um and 2000 um, and between 53 and 250 um per 50 g dr sample. Percent of each POM fraction based upon the total POM collected during the seiving. Crop c had no significant effect on these measurements.

			POM Fractions (g/50 dry soil)			Percent of Tota POM per Fraction		
Variable	Total POM	Percent POM	>2000 um	250-200(um	53-250 um	>2000 ur	250-200 um	53-250 ur
Year								
2000	3.6	7.2	0.1	0.9	2.5	3	27	70
2001	2.9	5.8	0.1	0.5	2.3	4	17	79
2002	2.3	4.6	0.1	0.4	1.8	5	17	78
Management								
Conventional	2.2	4.3	0.1	0.4	1.7	3	19	77
Organic	3.7	7.4	0.2	0.8	2.7	5	22	74
				Signficance (Pr>F)				
Year	0.05	0.05	ns	0.0001	ns	0.05	0.0001	0.01
Management	0.001	0.001	0.0001	0.0001	0.005	ns	ns	ns
Yr*Mnmt	ns	ns	ns	ns	ns	ns	ns	ns

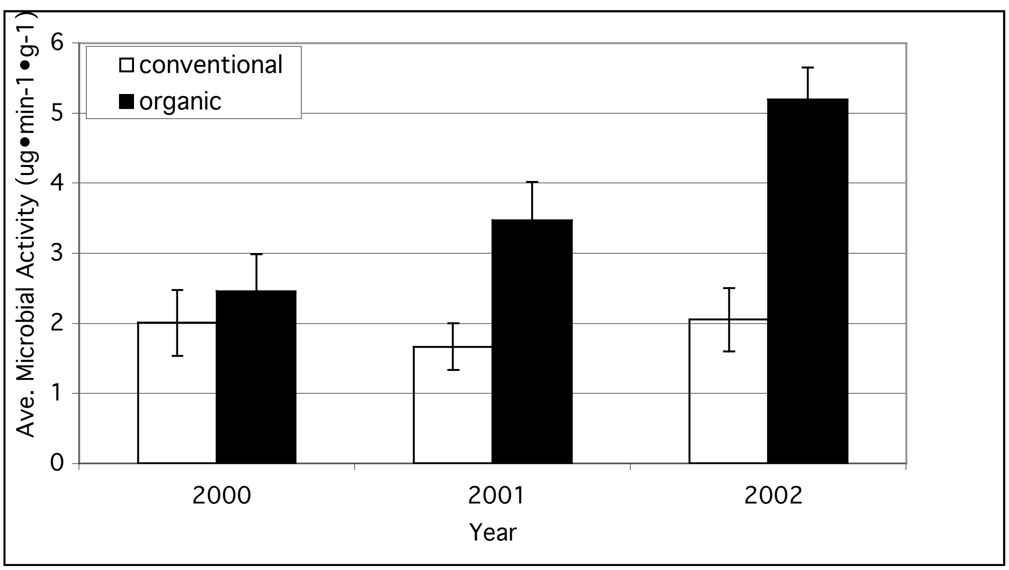


Figure 1. Microbial activity of soils collected on organic and conventionally managed farms i York, 2000-2001.

Soil nitrate nitrogen (NO3N) was measured once in 2000 and three times in 2001 and 2002. Total rainfall and estimated degree days differed by year but not between the two crops or management styles (organic or conventional) (Table 1). The growing season was longer on conventional than organic farms (Table 1), which did occasionally result in later final soil sampling in the conventional farms. Notable is that soil NO3N did not vary by management style or crop (Table 3, Figure 2) which suggests that soil NO3N was not limiting in the organically managed systems. Mid-season nitrate values were highest in the two years with repeated nitrate measurement. Other research on soil nitrate-N adequacy for vegetables (e.g. sweet corn, pepper) has suggested that of 30 to 35 ppm NO3-N (or 60 to 70 lb/a NO3N) measure early to mid-season supports good to excellent productivity of crops.

Table 3. Soil nitrogen, carbon, pH, CEC and electrical conductivity (EC) across years and managemen of study farms. Nitrate-N levels in soil were measured three times during the season (2 weeks after p rapid growth phase, harvest).

Variable	Soil Total N (%)	Soil Total C (%)	Soil C:N ratio	Early Season Nitrate-N (lb/a)	Midseason Nitrate-N (lb/a)	Late Season Nitrate-N (lb/a)	pH	CEC	EC (uS)
Year									
2000	0.19	2.3	12		58		6.3	8.0	
2001	0.20	2.6	14	36	99	16	6.1	9.5	162
2002	0.12	2.3	22	79	165	83	6.2	8.6	230
Management									
Conventional	0.14	2.0	18	67	118	53	5.8	7.8	192
Organic	0.20	2.8	15	48	96	46	6.5	9.5	200
Crop									
Potato	0.15	2.2	18	57	120	54	6.0	8.3	202
Squash	0.20	2.6	15	58	94	45	6.3	9.1	190
				Signficance (Pr>F)					
Year	0.0088	ns	0.0001	0.0001	0.003	0.0001	ns	0.05	0.05
Crop	0.05	ns	ns	ns	ns	ns	ns	ns	ns
Management	0.01	0.007	0.05	ns	ns	ns	0.0015	0.0006	ns
Crop*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Mgt*Crop	ns	ns	ns	ns	ns	ns	ns	ns	ns
Mgt*Year	ns	ns	0.008	ns	ns	ns	ns	ns	ns

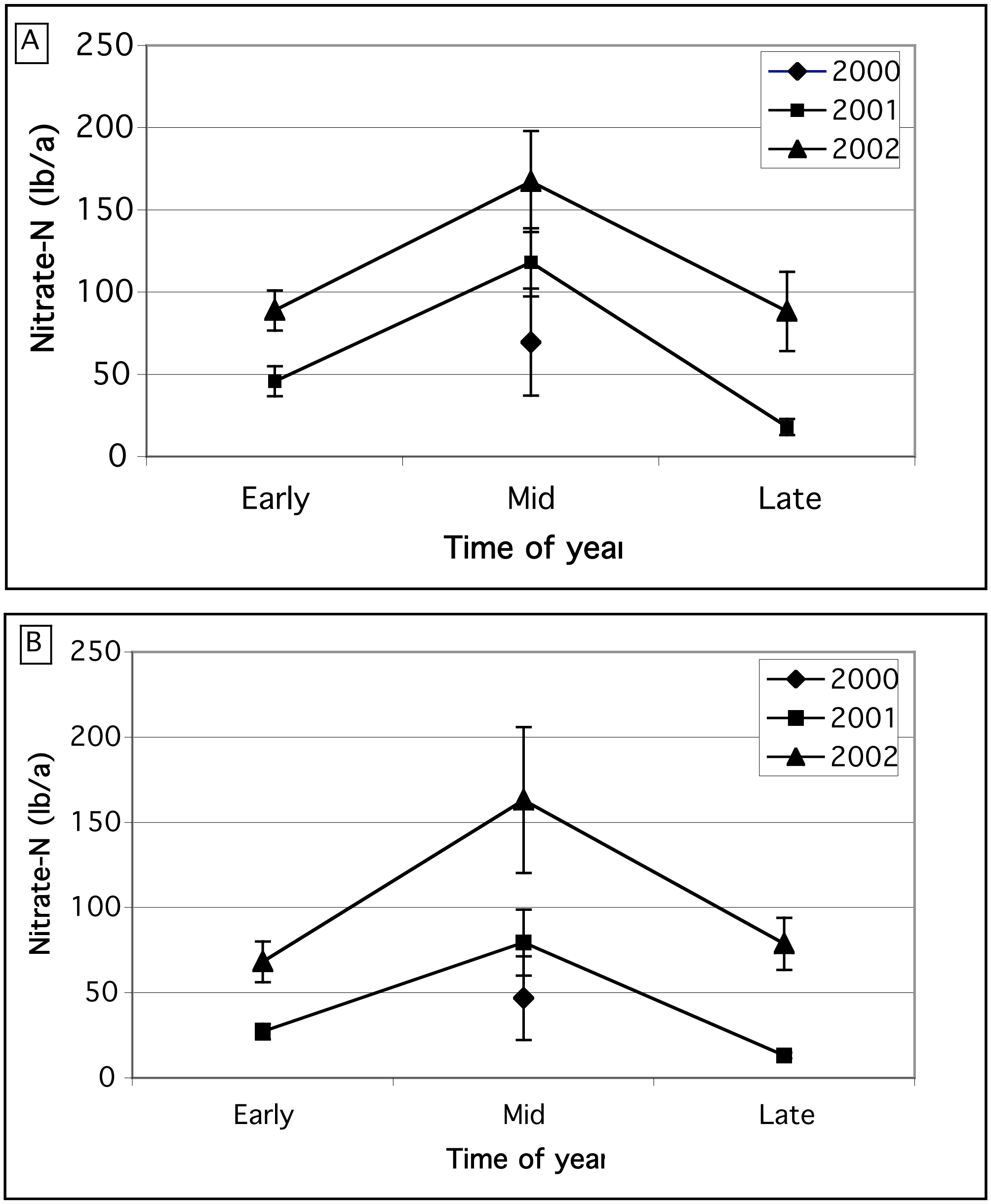


Figure 2. Nitrate nitrogen concentration (lb/a) sampled at three times during t season, early (two weeks after planting), midseason (rapid growth phase) and l harvest), averaged over conventionally managed (A) and organically managed (farms. Results presented for 3 years. In 2000, Nitrate-N was measured only on midseason.

The 2002 season could be characterized as warmer and drier than the previous two years. In this season, NO3N levels were much higher at all sampling times, and may have resulted in greater leaching losses of NO3N in the late season. However, no differences were measured among the two systems. Soil electrical conductivity, a measure of soil ion concentration, was also similar among the two systems and the two crops and varied only by year (Table 3).

Stepwise regression was used to identify some of the most important factors affecting soil NO3N on the study farms. For a midseason soil NO3N measurement, all three POM fractions had a significant positive effect on nitate-N, and total POM and total soil carbon had negative correlations with soil NO3N. Neither the total N added to the soil nor the N added as compost or cover crops, the amount of rainfall or irrigation, or the soil microbial activity had a significant correlation with this soil nitrate-N measure. This was observed for both organic and conventionally managed farms.

Relationships between soil quality measures and pest populations

Three soil parameters measured in this study can be considered estimates of biological activity: soil microbial activity, nitrogen mineralization, and the POM fraction between 250 and 2000 μm, which has been correlated with disease suppression in some studies. Each was regressed against season-long estimates of pest pressure (usually the modified AUDPC) for major pests of both crops. The ratio of calcium to magnesium in the soil (Ca:Mg), which is cited by some farmers as a soil attribute that contributes to pest resistance in plants, was also regressed against pest pressure as was the deviation of the Ca:Mg ratio from the ideal of 15:1 (by weight).

Regressions between pest and soil quality variables for potato and squash are summarized in Appendices 5 and 6. In general, few relationships were found between soil quality indicators and pest pressure, and those found do not always indicate pest suppression. In addition, some of the significant relationships we found are suspect for reasons explained in the narrative below. Because pest pressure was maintained at low levels on most conventional farms by the use of pesticides, regressions within the data from the organic farms are where we would expect to find relationships between soil factors and pests if they exist.

In potatoes, a significant negative relationship was seen between early blight and the percent (of total POM) 250-2000 μm POM fraction (POM250) for the combined organic and conventional and conventional only data sets. No significant relationship was seen between these variables for the organic data set, but the data was flawed because of the hopperburn problem discussed above. A significant positive relationship between early blight and percent 53-250μm POM fraction (POM53) was seen in the combined and conventional data sets, but again, not in the organic data. A significant positive relationship was seen between early blight and microbial activity in the organic data set, but that is based on the flawed estimates of early blight as discussed above and should be discounted. Significant regressions between aphid populations and percent and total POM 250 and POM 53 fractions in the combined and conventional data sets and between aphid populations and microbial activity in the conventional data set were highly influenced by two observations with very high values for aphid pressure and probably do not reflect real relationships. No relationships were found between the (Ca:Mg) or its deviation from the 15:1 ideal and any pest populations, however none of the fields in the study had (Ca:Mg) ratios in the ideal range.

In squash, positive relationships between aphid populations and microbial activity and POM fractions were highly influenced by one or two individual observations and probably do not reflect real relationships. Relationships between different soil quality indicators and striped cucumber beetle (SCB) populations are diverse and contradictory. We found a significant positive relationship between SCB and percent POM 250 for the combined and conventional, but not for the organic data. We also found a significant positive relationship between SCB and total POM 250 for the combined data. We found a significant negative relationship between SCB and the percent POM53 fractions for the combined and conventional data sets, but not for the organic data. In the organic data set, a significant negative relationship was found between the total POM 53 fraction and striped cucumber beetle populations. No significant relationships were found between soil microbial activity or Ca:Mg ratio and any of the squash pests.

Regressions between variables that are common to both crops are summarized in Appendix 7. Regressions were performed on the combined data set (48 observations including both crops and both management systems), data separated by crop (including both management systems), and data separated by management system (including both crops).

We found a significant negative relationship between the root rot rating from the disease severity bioassay and soil microbial activity for the combined, squash, and organic data. In squash, significant negative relationships were seen between bean root rot rating and POM250, POM53, and nitrogen mineralization. Significant relationships between soil biological activity measures and root rot rating are conspicuously absent in the potato data. A significant negative relationship between root rot rating and seasonal total water received (rainfall plus irrigation) for the potato data set is very subtle, and not what would be expected given that root rot pathogens are often promoted by wet soils.

Relationships between beneficial and pest insects

In potatoes, beneficial numbers (aggregate of all beneficial species) showed a significant positive relationship with aphid populations in the combined, conventional, and organic data sets suggesting that beneficials respond to aphid outbreaks through either colonization or reproduction. Similar relationships were not found between the aggregate beneficial population and either Colorado potato beetle or potato leafhopper.

In squash, a similar positive relationship was seen between beneficials and aphids for the organic farms only, but was highly influenced by one observation. Significant relationships were not seen between beneficials and striped cucumber beetle or squash bug.

Relationships between in-field and border beneficials

Our data reveal strong positive relationships between both the number and diversity of beneficial insects caught in border and in-field pitfall traps, indicating that there is an exchange of ground-dwelling beneficials between field borders and fields. We did not find the same relationships for beneficials above the ground surface. The number and diversity of beneficials caught in in-field pitfall traps do not appear to be influenced by the seasonal average weed population in the field. We did not see relationships between beneficials found on plants during scouting and beneficials found in the borders in sweep net samples.

Relationship between pesticide EIQ and in-field beneficials

The calculated EIQs for insecticides and fungicides individually were not related to the number or diversity of natural enemies found on plants. When EIQs for insecticides and fungicides were summed, we saw a significant negative relationship between EIQ and beneficial diversity for potatoes but not for squash.

Relationships between in-field beneficials, and field shape and border composition

Neither the ratio of crop area to total border nor the ratio of crop area to non-crop border was related to the number or diversity of beneficials found on plants while scouting. We did see a significant positive correlation between the crop area to non-crop border ratio and the number of beneficials caught on yellow sticky cards for the combined and organic data sets.

Relationships between beneficials in borders and border vegetation composition

We found a positive correlation between the percent forb cover in the field borders and the number of beneficials found in the borders in sweep samples in the combined, conventional, and potato data sets. The diversity of forbs in the border was positively correlated with beneficial numbers only for the conventional data set. We found a negative correlation between the percent ground cover in the border and beneficials for the conventional data set. Three observations are largely responsible for this relationship.

Relationships between sampling methods for beneficials

We did not see a significant correlation between the number of beneficials caught on yellow sticky cards and the number found on plants. We did see a significant positive relationship between the diversity of beneficials caught on yellow sticky cards and the diversity found on plants for the combined and conventional data sets.

Relationships between organic matter additions and particulate organic matter

Estimated dry matter added to the soil from both compost and cover crops was positively correlated with the percent particulate organic matter (POM) in the soil. Estimated dry matter from compost was positively correlated with the POM2000 and POM 53 fractions. Estimated dry matter from cover crops was positively correlated with the POM250 fraction.

Relationships between soil quality indicators

Saprophytic nematodes, microbial activity, and nitrogen mineralization are all positively correlated with soil percent organic matter, percent POM, and the POM2000, POM250 and POM53 fractions. For saprophytic nematodes, the correlation with the POM250 fraction had the highest level of significance. Relationships between microbial activity and all the organic matter fractions are highly significant. Nitrogen mineralization rate was most significantly correlated with the percent total POM.

Economic analysis

The farmers cooperating in this project were marketing through a combination of retail and wholesale avenues, thus the incomes reported here represent a snapshot of these nine farms, not organic and conventional potato and winter squash production in general. The cost of production for organic squash (Table 4) and organic potatoes (Table 5) was significantly higher than that for their conventional counterpart. Labor and equipment stand out as major factors determining the higher cost on organic farms. This difference may be exaggerated because of the very small field size on some organic farms, and the difficulty of estimating the cost of use of different types of equipment. Actual costs for equipment use may be overestimated, especially on the organic farms. However, because of the price premium organic growers receive, the return over variable costs for both squash and potatoes is higher on the organic farms.

Table 4

	Conventional Squash		Organic Squash	
	Per Acre	**Per Ton**	**Per Acre**	**Per Ton**
Income	**$4168.59**	**$500.00**	**$7029.21**	**$1200.00**
Expense				
Labor	$718.30	$148.30	$1650.42	$353.07
Equipment	$920.64	$195.79	$1575.90	$398.80
Seed	$10.09	$1.73	$38.52	$6.56
Fertilizer	$61.18	$13.29	$159.18	$36.12
Herbicide	$9.68	$2.87	$0.00	$0.00
Insecticide	$21.15	$3.49	$0.00	$0.00
Fungicide	$59.96	$10.71	$0.54	$0.08
Supplies	$77.88	$11.88	$150.37	$37.49
Cover Crop	$8.33	$1.23	$16.75	$3.35
Interest	$50.33	$10.38	$95.78	$22.81
Total Expense	**$1937.53**	**$399.68**	**$3687.46**	**$341.72**
Return Over Variable Cost	**2231.07**	**$100.32**	**$3341.75**	**$341.72**

Table 5

	Conventional Potatoes		**Organic Potatoes**	
	Per Acre	**Per Cwt**	**Per Acre**	**Per Cwt**
Income	**$2997.87**	**$10.75**	**$8004.11**	**$53.00**
Expense				
Labor	$562.37	$3.17	$1148.29	$9.70
Equipment	$596.45	$3.52	$810.17	$7.93
Seed	$237.95	$1.30	$221.29	$3.39
Fertilizer	$72.20	$0.34	$160.70	$1.91
Herbicide	$22.13	$0.09	$0.00	$0.00
Insecticide	$46.68	$0.14	$0.00	$0.00
Fungicide	$90.82	$0.47	$0.00	$0.00
Supplies	$36.14	$0.14	$0.00	$0.00
Cover Crop	$12.50	$0.05	$16.67	$0.24
Interest	$44.73	$0.25	$62.86	$0.62
Total Expense	$1721.97	$9.46	$2419.96	$23.79
Return Over Variable Cost	$1275.90	$1.29	$5584.15	$29.21

B. Efficacy trials of OMRI approved materials on vegetable crops

Potato leafhopper

Two rates of the commercial formulation of Surround and two experimental formulations were included a 2001 potato leafhopper trial conducted on a university research farm. The trial was planted with the variety Superior. It was a good year for a leafhopper trial; leafhopper numbers were relatively high and there were good differences between treatments. Treatments were applied five times at approximately weekly intervals starting June 26th. Hopperburn was rated on a 1-4 scale as follows:

1) Little or no leaf curling
2) Moderate leaf curling plus some leaflet necrosis
3) Severe leaf curling accompanied by leaf necrosis
4) Most lower leaves necrotic and/or dead

Table 6

Treatment	Mean PLH Nymphs/5 lvs*	Mean Hopperburn Rating	Yield (cwt/A)
Surround WP (13.5 lb./A)	11.8	3.2	142.0
Engelhard KV-36 (13.5 lb./A)	12.2	3.5	173.8
Engelhard KV-3 (13.5 lb./A)	12.8	3.5	184.0
Surround WP (20.5 lb./A)	13.8	3.3	155.2
Untreated control (water)	16.5	3.6	140.2

* Seasonal mean

Because the results for the organically-approved materials were extracted from a larger data set, I can't assign letters indicating significantly different means to this table without breaking statistical rules because the validity of the test that was used to see if the means are statistically different depends on all of the treatments (there were 28). In the context of the larger trial, all the kaolin formulations reduced the mean number of leafhopper nymphs compared with the untreated control (Table 6). The two Surround treatments reduced the mean hopperburn rating compared with the control, but the rating reductions did not translate into significant increases in yield compared with the control. The reductions in leafhopper numbers and hopperburn ratings were not enough to prevent significant yield reduction. The yields of the most effective treatments in this trial ranged from 277-305 cwt/A.

Crucifer flea beetle

Two separate trials were conducted. Broccoli transplants were grown in four inch pots until they reached the 5-leaf stage, treated, and placed in caged in which field collected flea beetles were released and allowed to feed for four days. A spreader-sticker was added to all treatments. Damage was evaluated using a rating system which ranged from 0 (no damage) to 4 (severely injured).

Table 7

Treatment	Rate/A	Mean damage rating 8/29	9/7
Surround WP	15 lb.	2.3 a	2.5 b
Hot Pepper Wax	8.0 oz	2.4 ab	2.0 a
Rotenone 5%	3 lb.	2.5 ab	2.3 ab
Surround/Safer soap	15 lb.	3.6 cd	3.0 b
Ecozin	8.0 oz	4.0 d	4.0 c
Neemix	16.0 oz	4.0 d	4.0 c
Control		4.0 d	4.0 c

Values followed by the same letter are not significantly different

In these trials both Surround and Hot Pepper Wax provided control equivalent to rotenone (Table 7). While the level of control is not what you would want for greens, it may be enough to get seedlings and small transplants established. They may need frequent re-application; that aspect was not tested in these trials.

Cabbage aphid

Broccoli transplants were grown in six inch pots until they reached the 6-leaf stage and were then placed in cages into which field collected cabbage leaf aphids were released, and allowed to colonize and acclimate. The plants were removed from the cages to be treated, returned to the cage, and evaluated after seven days by counting the number of live aphids. After evaluation, an additional application was applied to treatments that still had living aphids, and again evaluated after 7 days.

Table 8

Treatment	Rate/A	Mean # aphids/leaf 10/2	10/9
Surround WP	15 lb.	21.9 a	8.0 a
Rotenone 5%	3 lb.	24.3 ab	12.3 a
Ecozin	8.0 oz.	29.9 ab	14.3 ab
Naturalis L	16 oz.	33.9 b	21.0 b
Control		75.9 c	86.4 c

Values followed by the same letter are not significantly different

All of the treatments significantly reduced the aphid populations compared with the controls (Table 8), but this level of reduction may not be enough to make the crop marketable . The two treatments with the best control are the least attractive in terms of potential residue. The Surround product leaves a significant visible residue on the plants, which may render them unmarketable, and cool fall conditions may delay the breakdown of the Rotenone residue.

Onion thrips on onion

The thrips trials were conducted in the greenhouse on 5-6 leaf onion plants (variety Stuttgart) grown from sets. Plants were treated, and field-collected immature thrips were caged on individual plants for five days, after which time surviving thrips were counted.

Table 9

Treatment	Rate/A	Adjusted* % Mortality
Mycotrol	0.3 qt.	69 a
Engelhard F-01-KV-3	15 lb.	61 ab
Engelhard F-01-KV-6	15 lb.	58 ab
Surround WP	15 lb.	64 ab
Neemix 4.5	1 pt.	48 ab
Ecozin	8 oz.	46 ab
Rotenone 5%	48 oz.	39 b
Control		0 c

* Adjusted to account for the background population of thrips in the greenhouse
Values followed by the same letter are not significantly different

All of the treatments reduced thrips numbers compared with the control. Rotenone caused the lowest mortality, and Mycotrol (a commercial product containing the entomopathogenic fungus Beauveria bassiana) the highest. The three kaolin formulations (Surround WP and the two numbered formulations) and the two neem products (Neemix and Ecozin) produced intermediate mortality levels.

Tomato early blight

A total of five materials approved for organic production were tested for foliar disease control on tomatoes on a certified organic farm in western New York. Trials were conducted during the 2001 and 2002 growing seasons. Tomatoes of the variety Daybreak were transplanted into black plastic with trickle irrigation on June 8 in 2001 and June 10 in 2002. The field rotation for the previous two years had been barley underseeded with clover followed by a year of clover hay. Composted chicken manure was broadcast over the field at a rate of 1T/A, and an additional 1.5T/A was rototilled into the beds before the plastic was laid. Between-row spacing was 6 ft. and in-row spacing was 18 inches. The plants were not staked. Plots consisted of 15 ft of a single row of plants. Treatments were replicated four times and randomized in a complete block design. Treatments are outlined in Table 10.

Table 10

Treatment	2001	2002	Rate
Plantshield drench at transplanting	÷	÷	10 oz./100 gallons
Plantshield foliar applications	÷	÷	2 lb./A
Mycostop drench at transplanting		÷	.01% suspension
Plantshield drench plus foliar	÷	÷	10 oz./100 gallons drench, 2 lb./A foliar
Trilogy	÷	÷	1% solution
Serenade		÷	4 lb./A
Serenade		÷	8 lb./A
Oxidate		÷	128 oz/100 gallons
Untreated control	÷	÷	

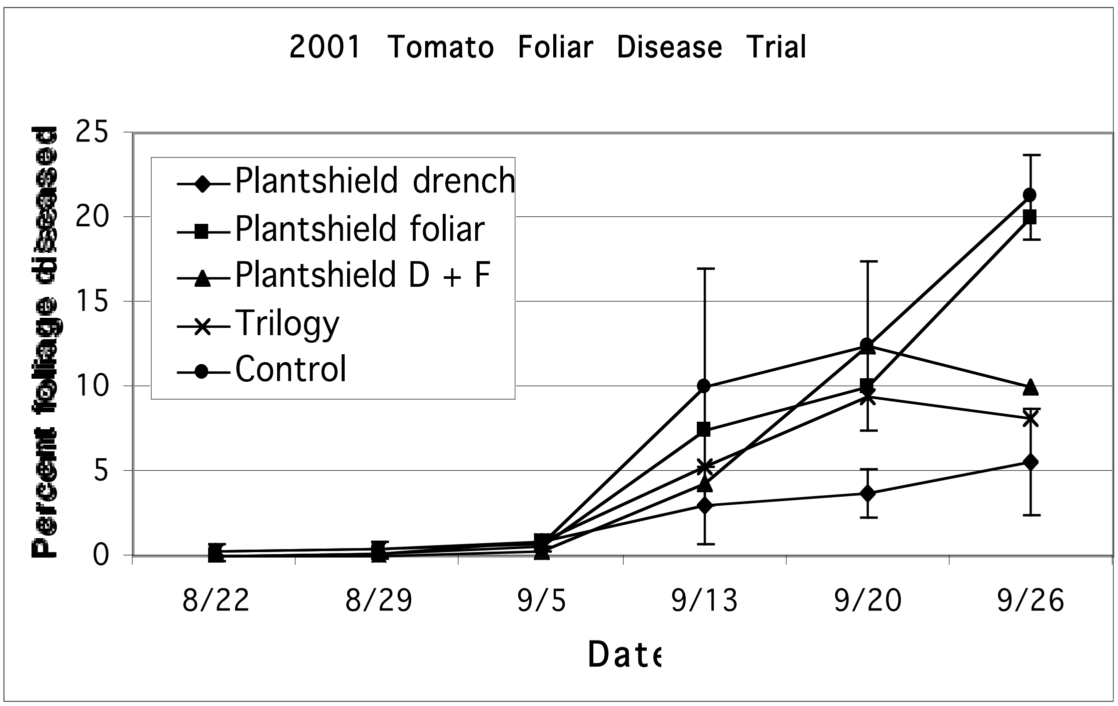
Plantshield is a formulation of the beneficial fungus *Trichoderma harzianum* labeled for foliar and soil drench applications. Mycostop is a formulation of the beneficial actinomycete *Streptomyces griseoviridis* labeled for seed treatment, potting soil amendment, and drench applications. Trilogy is a neem oil extract labeled for foliar application on a variety of fruit and vegetable crops. Serenade is a formulation of the beneficial bacterium *Bacillus subtilis* labeled for foliar application on a number of fruit and vegetable crops. Oxidate is a hydrogen peroxide product that is labeled for pre-pant dip treatment, soil drench, and foliar applications on a variety of crops. Plants in plots receiving the drench treatments were drenched the day after transplanting in 2001 and nine days after transplanting in 2002 with 4 oz. of solution, enough to saturate the root ball. Foliar treatments were applied with a CO2 backpack sprayer in the equivalent of 60 gpa of water. A soy oil-based spreader-sticker (Natur'l Oil, 0.2%) was used with the Plantshield and Serenade foliar applications. Each foliar treatment was applied three times, at approximately two-week intervals, starting on July 27 and ending on August 22 in 2001, and starting on July 31 and ending on August 28 in 2002. Percent foliage diseased was recorded for each plot at weekly intervals, starting

August 22 in 2001 and September 12 in 2002.   Plants in the middle 5 ft. of each plot were rated.

Both growing seasons were very dry at this location, with a total 7.5 inches of rain falling during the months on June through September of 2001 and a total of 7.7 inches falling during the months of June through September in 2002. Leaf wetness periods were short during the entire period of both trials, and disease pressure was very light. The trickle irrigation kept the plants growing well, and the fruit load was heavy. When the last foliar treatments were applied, disease had not yet started to appear on the plants and harvest had not begun. Early blight (caused by *Alternaria solani*) was the only foliar disease observed in both trials.

Figure 3 shows the disease progression for the 2001 season. The error bars indicate the standard deviation for the Plantshield drench treatment and untreated control.

Figure 3



An analysis of variance performed on the data from the final disease rating revealed significant differences between treatments (p=.001). Least significant differences were calculated to separate means. Lowest levels of disease were observed in the Plantshield drench and Trilogy treatments (Table 1), which were both significantly different from the control. The Plantshield foliar and foliar plus drench treatments were not significantly different from the untreated control.

Table 11

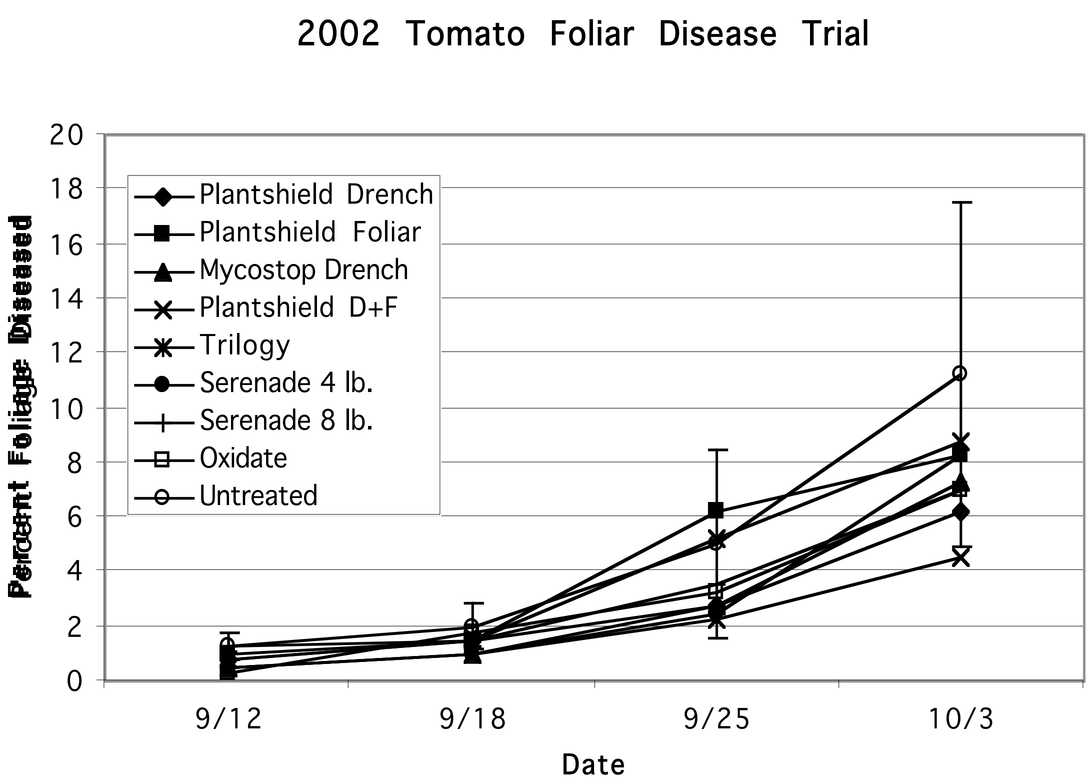
For 9/26 rating

Treatment	Mean	St. Dev
Plantshield drench	5.6a	3.1
Plantshield foliar	20b	7.1
Plantshield D + F	10ab	7.1
Trilogy	8.1a	3.7
Control	21.3b	2.5

LSD = 11.85

Figure 4 shows the disease progression for the 2002 growing season. The error bar indicates the standard deviation for the untreated control.

Figure 4.



An analysis of variance performed on the data from the final disease rating showed significant differences between treatments (p=.032). Least significant differences were calculated to separate means. Lowest levels of disease were observed in the Plantshield drench plus foliar treatment, which was significantly different from all other treatments. The Plantshield drench, Mycostop drench, Serenade 8 lb., and Oxidate treatments were significantly different from the untreated control. The Plantshield foliar, Trilogy, and Serenade 4 lb. treatments were not significantly different from the untreated control (Table 12).

Table 12.

Treatment	Percent Foliage Diseased
Plantshield Drench	6.25 bc
Plantshield Foliar	8.25 ab
Mycostop Drench	7.25 bc
Plantshield Drench + Foliar	4.50 c
Trilogy	8.75 ab
Serenade 4 lb.	8.25 ab
Serenade 8 lb.	7.00 bc
Oxidate	7.00 bc
Untreated Control	11.25 a

LSD = 3.4

Because both these trials were conducted in such dry seasons with low levels of disease in the untreated controls, it's difficult to demonstrate significant differences and also not possible to say with confidence that any of the products would provide adequate disease control during a wetter season. However, it is interesting to note that a treatment involving a drench of Plantshield resulted in the lowest disease levels in both trials, and that the foliar treatment alone was not significantly different from the control in either trail, indicating that the drench component of the treatment is providing the effect. The two soil-applied products (Plantshield and Mycostop) could be affecting the disease resistance of the foliage by inducing disease resistance or by increasing the vigor of the plants, making them less susceptible to a disease like early blight that is associated with plant stress.

Because of the dry seasons in which the trials were conducted, and the variable performance of Trilogy between the two trials, it would be useful to repeat the trial for one more season, hopefully one with better disease pressure.

Outcomes

A. This study was valuable for describing and comparing the systems organic and conventional growers are using for winter squash and potato production. Pesticide use was very infrequent on the organic farms (and consisted of only approved materials). On conventional farms, pesticide use varied in terms of materials used and application frequency. In general, pesticides provided good pest control on the conventional farms. Three pests: potato leafhopper, potato flea beetle, and striped cucumber beetle, were significantly higher on the organic than on conventional farms. All three are frequently cited by organic growers as problem pests that are not managed by the combination of soil building, cultural practices and ecosystem functions organic growers rely upon for pest management. Other pests, including squash bugs and Colorado potato beetle, were not significantly different between farm types, although they were higher on organic farms. Powdery mildew, aphids, and weeds were generally found at lower levels on organic farms, although again, differences were not significant.

Potato yields on organic farms were negatively impacted by pest pressure (potato leafhopper), but no significant relationship was found between pests and yield or quality for squash. For both crops, yields on certain organic farms were similar to those on conventional farms despite the higher levels of major pests. These farms may warrant further study to determine what factors are contributing to yields higher than the other organic farms.

Soil quality indicators, including percent organic matter, particulate organic matter, saprophytic nematodes, and microbial activity were significantly higher on organic farms. We were generally not able to identify relationships between soil quality factors and pests for these two crops. It is very possible that our extensive sampling approach was not precise enough to detect relationships if they do exist. Several important pests are present at acceptably low levels on organic farms, but we were unable to determine from this study what factors are most important for suppressing those pests.

B. New organic growers come from a variety of backgrounds, and often do not have a formal education in agriculture. The educational programs presented with this funding helped provide a solid foundation in the basic concepts and practices of organic vegetable production. One of the organic growers presenting at the workshops announced to the group that he wished that something similar had been available when they were starting out. The meeting proceedings allows growers throughout the northeast who did not attend the workshops to benefit from the information shared by the presenters.

C. A number of new OMRI-approved botanical and microbial pest management products have come onto the market in the past few years. Very few of them have been tested in University research and extension programs. We were able to generate useful information on several products through this trial. Several of the trials reported here were conducted by faculty members who regularly conduct efficacy trials in one or more crops. Since being involved in this project, one has sought outside funding to continue efficacy trials with organically approved products, recruiting other faculty and producing fact sheets on the products with funding from another grant.

Publications/Outreach

Articles summarizing the results of the organic product efficacy trials were printed in the NOFA-NY and Natural Farmer Newsletters. A proceedings from the organic vegetable production workshops was produced and is being distributed by NRAES (NRAES-165). Descriptions of the research survey were presented at one educational meeting and several grower advisory committee meetings. The bulk of the outreach for this project has yet to occur, and will include presentations at the 2003 NOFA summer conference and at the Northeast SARE Conference in October of 2004.

Areas Needing Further Study

We found that potato leafhopper is an important factor limiting potato yield on organic farms. More research is needed to find organically-acceptable management strategies for this pest.

A more controlled approach is needed to determine if there are relationships between crop pest resistance and soil quality on organic farms. Because of the high levels of variability in this study, conducted on different farms, in different geographic areas, our sampling procedures were not sensitive enough to detect such relationships if they do exist. There is an argument to be made for building understanding of a system through a series of intensive controlled experiments rather than an extensive multidisciplinary sampling effort that necessarily sacrifices sample precision for breadth of scope.

Our data set could be subjected to further analyses. Future analyses could include comparing weed species composition between farms, looking at soil quality and nutrient influences on weed species composition, and comparing the beneficial flora between farming systems

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