PROJECT SUMMARY

PRIORITIZING COVER CROPS FOR IMPROVING ROOT-HEALTH AND YIELD OF VEGETABLES IN THE NORTHEAST

Project Type: Joint Research-Extension

Summary Statement: This is a multi-state joint research-extension proposal. We are requesting $108,891for research from P.L.89-106 and $45262 for extension from Smith Lever. The effectiveness of eight cover crops in managing root rot diseases of vegetables in replicated field trials under experimental and commercial production conditions in New York, Pennsylvania and Connecticut. One of the experimental sites in New York has been managed according to organic production guidelines for 15 years. The impact of the cover crops on soil health indicators will be assessed using the Cornell Soil Health Test. We will assess the efficacy of selected cover crops to reduce the severity of root diseases under varying disease pressure regimes as well as their impact on soil health parameters. The effects of the various cover crops will be determined using beans as the main indicator crop, thus enabling us to replicate conditions encountered on farms in the Northeast. For educational training, demonstration trials will be established in commercial fields during the third year using the most promising cover crops. At the end of the project we will publish a ranking of cover crops based on their ability to manage root diseases and improve specific soil health constraints. Results will be made available to stakeholders throughout the Northeast through incorporation in vegetable production guidelines, websites, fact sheets, presentations at local and regional meetings. Project leaders will collect impact data on farmer adoption of the developed cover crop recommendations for several growing cycles following the end of the proposed work.

PROJECT NARRATIVE

PRIORITIZING COVER CROPS FOR IMPROVING ROOT-HEALTH AND YIELD OF VEGETABLES IN THE NORTHEAST

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(i) PROBLEM, BACKGROUND AND JUSTIFICATION:

Problem: In recent years cover crops have been increasingly used by vegetable farmers in the Northeast to improve soil quality, prevent erosion, increase organic matter, and to suppress nematodes, root diseases and other pests. In addition, many studies have documented the various benefits of cover crops including preventing erosion, increasing organic matter, recycling of nutrients and improving soil quality in general (Clark, 2007; Magdoff and van Es, 2000). However , few studies have focused on the effect of specific cover crops on the common soilborne root pathogens of vegetables grown in the Northeast (*Rhizoctonia, Pythium, Fusarium, Thielaviopsis*, *Pratylenchus* and *Meloidogyne)* (Abawi and Widmer, 2000; Abawi et al., 2007). USDA-NASS (2007) reported that in 2006 farmers in the Northeastern states grew 1,687,080 tons of fresh market and processing vegetables on 264,490 acres that were worth $701,377,000. Many of these vegetables and their acres were subjected to disease pressure from root rot pathogens including snap and dry bean, pea, beet, crucifer, carrot, onion, cucurbit, lettuce, greens, pepper, and sweet corn crops – representing a high percentage of vegetables in the region. Although USDA Crop Profiles (2007) indicate that farmers treat only a few acres with pesticides for root diseases because of the expense, mefanoxam, PCNB (Field Use EIQ as high as 525), azoxystrobin, oxamyl and metam sodium are among the pesticides labeled for use and recommended in New York (Reiners & Petzoldt, 2008). Most frequently growers use seed treatments (not certified for organic growers), cultural practices such as cover crops, and rotation to manage soilborne root pathogens. It is estimated that 100% of the snap bean, carrot, beet, pea, onion, potato, cabbage and sweet corn acreage in New York is at risk from these organisms (USDA Crop Profiles, 2007). Similar estimates would be expected throughout the Northeast US. Even though in any given year severe root diseases only develop in 10-15% of fields, growers must carefully plan cover crop selections, crop rotations and other practices to manage these diseases economically on an annual basis. In a 2006 soil health survey mailed to vegetable growers in New York State by the Cornell Soil Health Program Work Team, 64% of respondents (n=170) indicated that soilborne pathogens and diseases affect both yield and profitability on their farm (B. Gugino, personal communication). The results of the proposed work will be useful to vegetable farmers throughout the Northeast in planning for cover crop management and in planning the location and rotation of vegetable fields for upcoming seasons. Since cover crops are an important part of the root disease management equation, detailed knowledge of the expected benefit against root disease pathogen(s) of one cover crop versus another is necessary for optimum disease management. This knowledge is particularly important for organic growers who, in most cases, are not able to use chemical seed treatments.

Background: In 2007 vegetable growers in New York placed a high priority on research that addresses “Cultural practices for yield and quality enhancement and root rot management for peas, beans, and beets [which] includes new directions in cover crops or other cultural practices.”

(http://northeastipm.org/priority/2007/nyipm_veg.cfm). The 5th priority identified by the Northeast IPM Center Vegetable Working Group was to "conduct research on how to promote plant health and suppress insect, disease and weed problems through cultural and biological production practices. These may include enhancing plant capacity to resist infection or injury, enhancing soil health, encourage conservation of beneficial organisms, using crop rotations, green manures, compost and fallow periods, to enhance whole farm health. Demonstrate efficacy of research outcomes through on-farm trials and to develop recommendations and disseminate this information in usable form for farmers." The same group also indicated that "soilborne diseases of vegetables" are also a priority research item (http://northeastipm.org/work_vegpriority2005.cfm). The PI's of this proposal are engaged with stakeholders throughout the Northeast and have experience working with root diseases of vegetables and soil health issues. This project addresses needs in biocontrol, organic, and communications and training for IPM users in the document "General IPM Priorities for the Northeast – 2006" (http://northeastipm.org/priority/2006/generalpriorities.htm). This project addresses priorities #5 (research on soil health and disease suppression) and #8 (IPM training for professionals in the "IPM Priorities for Vegetables in the Northeast – 2005" (http://northeastipm.org/work_vegpriority2005.cfm). The Pennsylvania Vegetable Growers Association and Pennsylvania Vegetable Marketing and Research Program Boards listed cover cropping, crop rotation and disease control as some of the top research priorities for 2009.

A unique site is currently available at the NYS Agricultural Experiment Station Geneva, NY to examine the effects of cover crops on root diseases, soil health status, and vegetable yield. The 8-acre site at the Vegetable Crops Research Farm near Geneva has been in use since 1995 to evaluate the economic, environmental and pest control efficacy of four different management systems with funding by USDA-NESARE, USDA-RAMP and NYS IPM programs. Conventional, IPM Present, IPM Future, and Organic systems were defined and compared on the basis of yield and quality, economics, and environmental impact. Four fields, each two acres in size, were managed using the four systems for 13 years (Petzoldt et al., 2001, 2005, 2007). From 2005 through the present season work at the site has focused on several observed differences in soil health while the integrity of the systems definitions has been maintained. In 2006 snap beans were grown in strips in the fields in order to observe if the differences in soil health would translate into yield differences. After one year, results show that while not statistically significant; the management system that was determined to have the healthiest soil also had the highest snap bean yield.

Results have shown that the different management systems practiced over time have resulted in different levels of soil health (Petzoldt et al., 2007). From the time of establishment of the systems evaluation site in 1995, annual soil nutrient tests and select soil health parameters were assessed on the four fields. Results at that time were similar among the four systems. With the establishment of the Cornell Soil Health Program Work Team (SHPWT) and the elucidation of specific tests as indicators of soil health, more extensive testing and comparison of fields at the site was conducted (Gugino et al., 2007). Using a bean bioassay, we have observed the least infection of bean plants by root disease organisms in the IPM Future field. Figure 1 shows the root rot bioassay results over time for all four fields. Root rot severity was rated on a scale of 1 (healthy roots) to 9 (>75% of stem and root tissues affected and at late stages of decay).

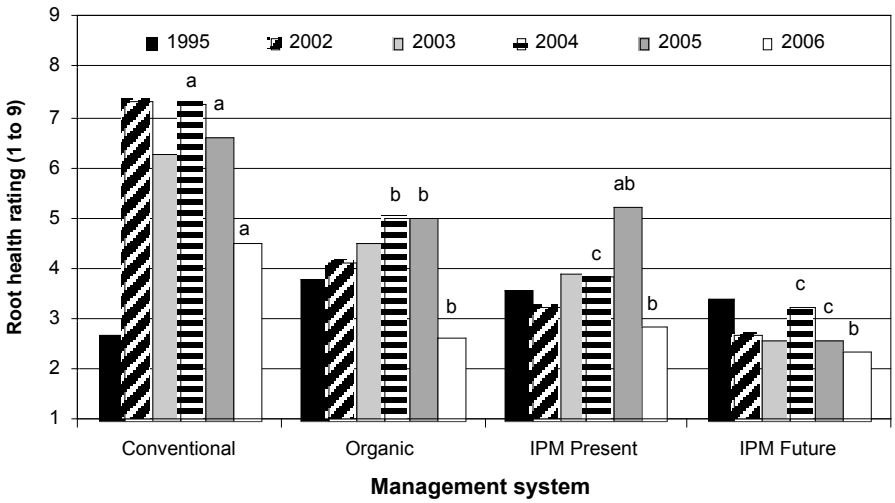


Figure 1. The average root rot severity rating of beans grown in soil collected from four different vegetable production systems at the IPM experimental research site in Geneva, NY in 1995 and from 2002 through 2006. Bars within years with different letters are significantly different at $P<0.05$ according to Fisher's LSD (SAS, Cary, NC).

We have selected to use snap bean as the major vegetable indicator for evaluating the efficacy of cover crops in suppressing root disease severity and improving soil health for the following reasons:

1. Snap beans are susceptible to the major pathogens that impact vegetable production in the Northeast including species of *Pythium*, *Rhizoctonia*, *Fusarium*, *Thielaviopsis*, *Meloidogyne*, *Pratylenchus*, and others.
2. Snap beans are a rather short season crop (55 to 60 days), thus they will allow us to establish the cover crops in late summer to produce a good biomass and also to allow the incorporation of the biofumigant-type crops while the soil still warm and the decomposing microorganisms are still active.
3. Cornell has access to a 2005 one-row Pixall BH100 bean harvester, thus making marketable yield assessment from large plots possible.
4. Snap beans are sensitive to soil health constraints and respond well and fast to pest and crop management options.
5. Snap beans are easier to plant, maintain according to commercial guidelines and to harvest and grade marketable yield, thus estimating profitability.

The selection of cover crops included in this study was based on their adaptation to Northeast conditions, commercial availability of seeds, observed or reported effectiveness in suppressing pests or improving soil conditions and a mixture of grain and legume types. The interest and increasing use of cover crops reflects the flexibility they offer as a sustainable management strategy in suppressing pest and disease problems, re-cycling of nutrients in the soil, and improving soil health parameters such as reducing surface erosion, increasing active organic matter, increasing water retention, increasing the diversity and population of the soil microbial community and others. However, only limited information is available on the impact

of cover crops on specific pathogens and the severity of their resultant root diseases as well as on individual soil health indicators; an information void which this project was designed to fill.

In 2008 we initiated the first year of the proposed work by planting the entire 8-acre site to snap beans. Yields of the 4 different systems reflected the soil health and root rot severity ratings obtained over the years: IPM Future = 3.89 T/A; IPM Present = 3.35T/A; Organic = 3.17 T/A; and Conventional = 2.43 T/A. After snap bean harvest the fields were prepared for planting 15-foot strips of cover crops across their width. Nine (eight plantings) cover crops (winter rye grain +hairy vetch, oat, sudex 'MS202 BMR', forage radish var. 'Groff', red clover 'Mammoth', 'Rangi' rapeseed, 'Mancan' buckwheat, 'Jensen' wheat) were planted in fall 2008 in a randomized design with 3 replications of each crop in each field

In Connecticut, small field plots infested with lesion and root-knot nematodes and the soilborne fungal pathogens *Pythium* and *Rhizoctonia*, and two sets of microplots, 120 infested with lesion nematodes and fungal pathogens and 96 infested with root-knot nematodes and soilborne fungal pathogens, will be used to investigate the effects of cover crops on pathogen populations and soil health parameters.

Justification: Without the results of this project, conventional growers risk spending as much as $50 - 100/A on root disease control and organic growers will suffer unnecessary 5% to 15% losses in vegetable crop yields because they have no alternatives to control root diseases. However, results obtained from this project on the beneficial effects of specific cover crops for root disease control can contribute to substantial economic returns plus positive environmental and health benefits will also be realized by Northeast vegetable producers.

Conventional and organic vegetable farmers who grow vegetables in the Northeast– particularly those vegetables susceptible to root pathogens will be the primary beneficiaries of the results of this work. Vegetable growers will be able to make more informed choices regarding the choice of cover crops to best manage root rot diseases as well as to address specific soil health constraints identified as limiting factors in vegetable production. According to USDA Crop Profiles these growers are likely to improve yields by 5-15% in the current year if they adopt cover crops that are effective in managing root rot and soil health. Additional benefits would accrue in years following the use of the cover crop if populations of root rot organisms are lowered. Additionally the environmental benefits would accrue to the Northeast by the substitution of cover crops to control root rot for several older high EIQ (Kovach et al 1992) fungicides. Organic growers would particularly benefit since they currently have very limited options for managing root disease pathogens (chemical seed treatments not allowed). The results of this project are likely to be useful to vegetable farmers throughout the Northeast region as well as in other regions.

To obtain the maximum benefit, it is critical to select the appropriate cover crop to attain the desired benefit – for example hairy vetch and clovers are excellent cover crops but they are highly susceptible to root knot and lesion nematodes as well as *Rhizoctonia* and *Pythium*. Thus they will exacerbate the problem in soils infested with these pathogens.

This project relates to the NE RIPM priorities in the following ways:

1. <u>Will reduce risks to the environment.</u>

Environmental risks will be reduced in the Northeast through the substitution of cover crops to control fungal and nematode root pathogens in place of several older, high EIQ fungicides and nematicides. PCNB (Terraclor), one of the registered fungicides for root rot

control that could be replaced by cover crop usage, has a relatively high (toxic) EIQ component for impacts on fish, bird, and beneficial organisms. Oxamyl (Vydate) a common nematicide has one of the highest EIQ's of labeled pesticides for vegetables.

2. Will reduce risks to human health.

PCNB, a fungicide that could be replaced by cover crops as a result of this project, has these cautions on its MSDS sheet: "MAY CAUSE EYE AND SKIN IRRITATION, MAY CAUSE ALLERGIC SKIN REACTION, MAY CAUSE LIVER DAMAGE". Mefenoxam, another fungicide that could be replaced by cover crops has the following cautions on its MSDS sheet: "Causes substantial but temporary eye injury, Irritating to skin, Vapors may cause drowsiness and dizziness". Oxamyl, the commonly recommended nematicide has these cautions on the MSDS sheet: Fatal if swallowed. May be fatal if inhaled. Do not breathe spray mist, Causes moderate eye irritation. Avoid contact with eyes or clothing. Contains methanol which may cause blindness". Reductions in the use of these pesticides through replacement by cover crops are likely to reduce risk for applicators, pickers and other farm workers.

3. Has stakeholder support and the priority is cited.

Stakeholders in New York and the Northeast have identified the proposed work as a priority as listed in the "Background" section above and also in their active participation in on-going IPM and soil health related projects.

4. Focuses on a pest, crop, or setting found in at least five states or cropping regions.

Root diseases are a problem potentially affecting 100% of vegetable acreage in the Northeast according to relevant crop profiles and will become more prevalent with the adoption of reduced tillage systems. Affected crops include beans, peas, carrots, lettuce, onion, tomatoes, potatoes and others. The results of the proposed work should assist vegetable farmers throughout the Northeast in managing these soilborne pathogens. We have chosen snap beans as the focus crop because of susceptibility to root disease organisms. Snap beans, our indicator crop, are grown for fresh market or processing in all states in the northeast.

5. Will fill a niche (no such tactics or approaches exist).

It is estimated that 100% of the snap bean, carrot, beet, pea, potato, onion, cabbage and sweet corn acreage in the Northeast is at risk from these organisms (USDA Crop Profiles). Even though in any given year only 10-15% of fields will actually be affected, growers must carefully plan cover crop selections and crop rotations to manage root diseases and soil health issues in a sustainable and economical manner. This project will address a disease complex where few economically viable management tools exist – including pesticides.

6. Involves three or more states in an active partnership.

This project will involve New York, Pennsylvania and Connecticut in active partnership. In addition, the results will apply to all states in the northeast region and some states in other regions that have similar soil health concerns.

7. Will advance IPM in as soon as two years.

We expect the results of this project to be available for implementation within two years of the initiation of the project. We expect a high level of implementation by vegetable farmers in the Northeast to occur in the third year of the project and continue after the completion of the project since growers are currently asking for specific cover crop recommendations for managing various soil health constraints that they have identified on their farms. Incorporation of the results into the various state and regional vegetable production guidelines will disseminate the information to a large number of growers in a short period of time.

8. Is interdisciplinary.

This project involves cooperation among two plant pathologists who focus on soilborne diseases, a plant nematologist, and an IPM Coordinator who works in implementation of disease, insect, and weed management on vegetable farms.

9. Reduces dependency on chemical pesticides.

The use of cover crops for root disease and soil health management will potentially replace fungicide and nematicide use for managing soilborne pathogens as well as reduce synthetic fertilizer need, thus reducing costs for farmers, reducing negative environmental impact from fungicide, nematicides and fertilizer applications and improving soil health.

10. Has significant economic implications.

As shown by the USDA NASS data in the "Problem" section above, vegetable farming is an important economic driver in northeastern communities contributing over $700M dollars to the Northeast economy.

11. Explains, justifies, and will serve an "underserved audience."

All vegetables in the Northeast are minor crops. Many fresh market vegetable and organic vegetable growers in the Northeast are small acreage farmers. This project directly addresses their ability to manage root disease organisms. In addition, results obtained in this project will be of special benefit to organic production.

12. Addresses an emerging pest, crop, or problem.

Although this is not an emerging new pest, there is an emerging opportunity for implementation of this project because of the increased use of cover crops by vegetable farmers in recent years as a management strategy for sustainable soil health and disease management. The knowledge gained from this project will allow vegetable farmers to better use these cover crops to address specific soil health issues.

13. Is likely to be adopted by the target audience.

Cover crop use is currently increasing in adoption throughout the Northeast – the results of this project will allow better use of cover crops to manage root diseases and soil health as well as provide in-depth science-based information for farmers to adopt cover crop practices. Farmers will make better decisions about which cover crops to use and for what specific objective that they have identified re: managing root diseases, improving aggregate stability, increasing active carbon, etc. We already receive many requests for the information that this project will develop.

14. Advances an IPM practice that is more cost-effective than the status quo.

Virginia Tech agricultural economists estimate the cost of the granular formulation of mefenoxam (Ridomil Gold PC) to be $5.61/ lb in 2007 (http://www.ext.vt.edu/pubs/agecon/446-047/Chemical07.pdf).

The recommendation for Ridomil Gold PC treatment is 12 oz/1000 linear row feet or approximately 12.9 lb/A. Thus the cost of treatment, excluding application costs, was about $72/A in 2007. In 2008, the cost of seed for the cover crops used in establishing the New York site ranged from $15 to $30 per acre, excluding planting costs. Assuming fungicide application costs and cover crop seeding costs are approximately equal, growers could realize an increased income of $42 to $57 per acre by replacing a typical recommended fungicide treatment with an effective cover crop. Similary, 1 – 4 gallons of Oxamyl at a cost of $55/gallon are used to control plant-parasitc nematodes on vegetables that can be replaced with effective antagonistic cover crop such as sudangrass, rapeseed, mustard, marigolds and others. These represent significant economic benefits for any size farm in the northeast where vegetable farm acreage typically ranges from 50 acres ($2100-$2,850 benefit annually) to 3,000 acres ($126,000-$171,000

annually). In addition most of the cover crops evaluated in this project provide an additional fertility benefit at a time when Massey at the University of Missouri (http://agebb.missouri.edu/mgt/inputs.pdf) estimates nitrogen costs for 2007 to range from 27 to 40 cents per pound and N is applied to snap beans at 40 pounds per acre. Finally, although difficult to measure in dollars, there is an economic benefit from improving general soil health through the use of cover crops.

(ii) OBJECTIVES AND ANTICIPATED IMPACTS

The overall goal of this project is to provide vegetables growers with additional information that they can use to select the appropriate cover crops when specifically trying to reduce root disease pressure or develop a cropping sequence that limits the build-up of root pathogens in addition to improving other soil health physical, biological and chemical properties. This project will address all three goals of the NE RIPM grants program by: improving the economic return to vegetable farmers, reducing the use of fungicides and nematicides for managing soilborne pathogens, and reducing the adverse environmental effects from the use of root rot fungicides.

Specific Research Objectives and Anticipated Impacts

1. Assess the impact of several types and varieties of cover crops adapted to the Northeast on the severity and damage of fungal and/or plant-parasitic nematodes in replicated field research trials in New York, Pennsylvania and Connecticut.

   Anticipated Impacts

   - Identification of cover crops that suppress specific soilborne pathogens and the damage of their resultant root diseases.

2. Evaluate the impact of the same cover crops on other non-target soil health parameters as measured using the Cornell Soil Health Test.

   Anticipated Impacts

   - Elucidation of the effect of cover crops on individual soil health parameters.
   - Increase the management options available to extension agents, consultants, and other agricultural professionals in addressing identified soil health constraints.

Specific Extension Objectives and Anticipated Impacts

1. Increase the literacy of growers, stakeholders, and other agricultural service providers in the use of cover crops for managing soilborne fungal and nematode root pathogens and their damage to vegetables.

   Anticipated Impacts

   - Vegetable farmers in the Northeast adopt cover crops as an important method for managing soilborne root diseases and resultant crop damage in their fields, thus replacing the need for soil fungicide and nematicides applications and longer crop rotations.
   - Facilitate more informed selection and use of cover crops for specific needs in improving soil biological health, in general.
   - Extension agents, consultants, and other agricultural professionals gain knowledge resource in order to better design effective cultural management

programs for clients to manage root diseases using cover crops/cropping sequences.
- Promote more sustainable long-term soil management practices.

(iii) APPROACH AND PROCEDURES:

Research Objectives 1 and 2:

Field trial design in New York: To evaluate the impact of several types and varieties of cover crops under varying levels of root pathogen populations and root disease pressures, a replicated trial will be established on four two-acre blocks (approx. 400ft x 200ft) that have each been continuously managed using one of four different vegetable production systems for the past 15 years. In summer 2008, all plots were planted with snap bean cv 'Caprice'. The plots were prepared, fitted and planted using a two-row Monosem planter. After harvesting the bean crop, the residue was disked and after two weeks the various cover crop treatments were each planted in three 15ft by 200ft strips in each of the four 2-acre blocks in a randomized complete block design using a grain drill.

In spring 2009, cover crop biomass will be measured prior to killing the cover crops not already winter killed. Composite soil samples will be collected in from each plot and assessed for root health using the root health bean bioassay. The cover crops will be disked and the blocks prepared, fitted and planted with an early [mid]-season sweet corn variety. The sweet corn will be managed using commercial production practices and following the Cornell Vegetable Production Guidelines (Reiners and Petzoldt, 2008). At harvest, sweet corn will be hand-harvested from 100ft in each of the two center rows. Total ear weight and number of ears will be recorded. The corn residue will be flail mowed and then incorporated.

In later summer 2009, the selected cover crops will be re-established in the same plots and managed as described previously. In late spring 2010, all the plots will be sampled and bio-assayed with beans to assess the root disease severity. All plots will be then planted back to snap bean cv. 'Caprice', managed and harvested as was done previously in 2008.

Greenhouse root health bioassay: Additional composite soil samples collected for the root health bioassay will be thoroughly mixed and the soil divided into two or three replicate pots (4-inch-diam.) per treatment per replicate and planted with five snap bean seeds cv. 'Hystyle', maintained in a greenhouse at 25ºC and watered and fertilized as needed. After four weeks, the plants will be removed; the roots will be washed free of soil, then examined and rated for root health on a scale based on severity of symptoms on the hypocotyl and roots using a score of 1 (healthy) to 9 (>75% of the hypocotyl and roots are showing severe symptoms and signs of decay). Roots with average root severity ratings between 1 and 3 are considered good (healthy to lightly diseased), > 3 to 6 are moderately diseased, and > 6 to 9 severely diseased/unhealthy (Gugino et al 2006 and 2007). Soil samples will be collected for the root health bioassay in the spring of each year and also following the harvest of the 2009 corn crop.

Field Trial Design in Pennsylvania: A similar field trial will be established on a grower farm in a field with a history of root diseases in snap beans. Snap beans collected from one potential field this past summer indicated the presence of both *Rhizoctonia* and *Fusarium* sp., two fungal

pathogens that commonly cause root diseases on vegetables in the Northeast. The cropping sequence and data collection will be conducted similar to the methods described for the trial in New York. The plot will be 1 to 2 acres in size and in the fall of 2009 and 2010 each of the eight selected cover crops will be replicated three times in a randomized complete block design. The planting and maintenance of the main cash snap bean and sweet corn crops and establishment of the cover crops will be made in conjunction with the collaborating grower. Yield data will be collected by hand.

Field Trial Design in Connecticut: Research will be conducted in small field plots and microplots on the CAES Valley Laboratory Research Farm. Field plots are infested with lesion and root-knot nematodes and the soilborne fungal pathogens *Pythium* and *Rhizoctonia*, and two sets of microplots, 120 infested with lesion nematodes and fungal pathogens and 96 infested with root-knot nematodes and soilborne fungal pathogens, will be used to investigate the effects of cover crops on pathogen populations and soil health parameters. The microplots and small plots have uniform, established populations of nematodes and fungal pathogens. The large number of replicates available and reduced variability will allow collection and analysis of meaningful data over the short (3-year) time frame of this proposal. Soil samples collected before initiating and after completion of the experiment will samples will submitted to Cornell for assessment using the protocols established in the Cornell Soil Health Assessment Training Manual (Gugino et al., 2007). The selected cover crop treatments plus a fallow (control) are as follows: winter rye grain, hairy vetch overseed with oat, sudangrass 'Trudan 8', forage radish (diakon), clover 'A.C. Christie', rapeseed 'Rangi', buckwheat 'Manor', pearl millet 'Tifgrain 102' and wheat 'Caledonia'. Each cover crop will be planted in a randomized complete block design.

Soil health sampling: Soil samples were collected from the New York site and processed for soil health assessment in spring 2008, thus they will be considered as base-line data. Composite soil samples will be collected for soil health analysis from the trial sites in New York, Pennsylvania and Connecticut prior to planting the 2009 crop and will be collected again in spring 2010. The soil samples will be submitted for assessment using the protocols established in the Cornell Soil Health Assessment Training Manual (Gugino et al., 2007). The Cornell Soil Health Test will evaluate the collected soil samples for aggregate stability, available water capacity, surface and subsurface hardness, percent organic matter, potentially mineralizable nitrogen, active carbon, root health assessment, and the standard array of macro and micronutrients provided by the Cornell Nutrient Analysis Laboratory (CNAL).

Statistical analysis: Root health rating data, both from the field evaluation of the snap bean crop and the from the greenhouse bioassay, will be analyzed within each year using non-parametric ordinal data analysis with an analysis of variance (ANOVA) -type statistic (SAS 9.1, SAS Institute, Cary, NC; Shah and Madden, 2004). The relative treatment effects and their corresponding confidence intervals will be calculated using the LD_CI macro (Brunner et al., 2002). Comparisons between biofumigant treatments (incorporated fallow vs incorporated oat) within each year will be analyzed using a *t*-test. Comparisons across two or more years will be analyzed using an ordinal non-parametric repeated measures analysis using an ANOVA-type statistic (Shah and Madden, 2004). Data between the four blocks with varying levels of root pathogen pressure will be compared to determine if the effect of the individual cover crop treatments varies under differing levels of pathogen pressure (the cover crop ranking changes) or

if there is only a compression effect (the ranking remains the same however, the magnitude of the effect increases or decreases under different pathogen pressure levels).

Snap bean and rotational crop yield data within years will be analyzed using an ANOVA and means separated using Fisher's least significant difference test (LSD) ($P \leq 0.05$) (SAS 9.1, SAS Institute, Cary, NC). Comparisons in snap bean yield between 2008 and 2010 will be compared within treatments using t-tests.

Non-target soil health parameters measured using the Cornell Soil Health Test will be compared within years using an ANOVA statistic and means separated with Fisher's LSD ($P \leq 0.05$). A repeated measures analysis will be used to compare changes in individual soil health parameters over time from the baseline assessment in 2008 to the final assessment in 2010. When and where possible data collected from the New York and Pennsylvania trials will be pooled for statistical analysis.

Development of specific cover crop recommendations: Once the collected results obtained under research objectives 1 & 2 have been analyzed, the project leaders will meet in person and develop a list of specific cover crops recommendations for vegetable growers based on the information gained in the multi-year trials as well as those available in the literature and research done in our programs in New York, Pennsylvania and Connecticut. The cover crops will be ranked on their ability to reduce the severity of root diseases as well as on their impact on other non-target soil health parameters as measured using the Cornell Soil Health Test.

Extension Objective 1:

On-farm demonstration of select cover crops: The promising cover crops identified after the bean harvest in 2010, will be established the same year in fields of collaborating growers. Snap bean will be planted by the growers and according to their stand practices. Rood disease severity and yield will be determined. These same demonstration sites will be used for educational purposes by holding field days.

Northeast vegetable guidelines: The developed tables and recommendations will be integrated into both the hardcopy and on-line versions of the Cornell Integrated Crop and Pest Management Guidelines for Vegetable Crops, the Pennsylvania Commercial Vegetable Production Recommendations (which is also distributed in NJ, DE, MD, and VA), the New England Vegetable Management Guide and the NY Organic Vegetable Production Guidelines being developed by Abby Seaman, NYS IPM. This will facilitate the distribution of the information to a wide variety of growers who may not be reached through more time specific activities such as field days and twilight meetings.

Extension fact sheet: The developed recommendations for root disease management using selected cover crops will be integrated with more basic information regarding the use of cover crops and laid out as a fact sheet using Adobe InDesign (Adobe Systems Incorporated, San Jose, CA). This resource will be made available at grower meetings throughout the Northeast as well as made accessible on the internet via the Cornell Soil Health, NYS IPM, and Penn State Plant Pathology websites. The fact sheet will complement other important cover crop resources such as the Managing Cover Crops Profitably.

Field days, twilight and regional meetings: Opportunities to present the information at large grower meetings will be sought including the New York State Fruit and Vegetable Expo, the New England Vegetable Conference, and the Mid-Atlantic Fruit and Vegetable Conference and others. During the first two years of the project, PI's will provide project updates at various field days and twilight meetings. In the final year, field days will be held at the research sites and all growers, extension educators and other agricultural service providers will be invited to attend. Project leaders will also participate in each other's field days.

Timetable:

	Obj.	Phase	Tasks	Complete by
Year 1 - 2009	R1 & 2	NY	Collect soil samples from all plots and conduct greenhouse root health bioassay/Soil Health test.	April - May
	R1	NY	Kill cover crops, disk and plant sweet corn	May - June
	R1	NY	Harvest sweet corn and prep plots for planting cover crops	August - September
	R1 & 2	PA	Collect soil samples from each treatment, conduct greenhouse root health bioassay/ soil health test	April - May
	R1	PA	Plant entire plot to snap bean. At flowering, sample bean roots and evaluate for symptoms and damage by soilborne root pathogens	June - July
	R1	PA	Harvest snap beans and prep plot for planting cover crops	August- September
	R1	CT	Collect soil samples from each treatment, conduct greenhouse root health bioassay/ soil health test	April - May
	R1	CT	Plant entire plot to snap bean. At flowering, sample bean roots and evaluate for symptoms and damage by soilborne root pathogens	June - July
	R1	CT	Harvest snap beans, prepare plots and plant cover crops	August- September
	E1	NY, PA, CT	Participate in various field days, twilight meeting to share about the project	August - October
Year 2 - 2010	R1	NY	Kill cover crops, disk and plant all plots with snap bean cv. 'Caprice'	May - June
	R1	NY	At flowering, sample bean roots and evaluate for symptoms and damage by soilborne root pathogens (final assessment)	July
	R1&2	NY	Harvest a sub-section of each plot using single-row fresh market bean harvester.	August - September
	R1	PA, CT	Kill cover crops, disk and plant entire plot to sweet corn	May - June

	R1	PA, CT	Harvest sweet corn; prep and plant plot with cover crops	August - September
	R1&2	NY	Collect soil samples from all plots and conduct greenhouse root health bioassay/Soil Health test.	September
	E1	NY, PA,CT	Participate in or conduct field days and twilight meetings to share about project progress	August - October
Year 3 - 2011	R1	PA, CT	Kill cover crops, disk and plant entire plot with snap bean	May - June
	R1	PA, CT	At flowering, sample bean roots and evaluate symptoms and damage by soilborne root pathogens (final assessment)	July
	R1	PA, CT	Harvest snap beans from each treatment	August - September
	R1&2	PA	Collect soil samples from each treatment and conduct greenhouse root health bioassay/ soil health test	September
	E1	NY,PA,CT	Conduct field days at NY,PA, and CT sites	August - September
	E1&2	NY,PA,CT	Analyze data and summarize results into specific recommendations for vegetable farmers.	October
	E1	NY,PA,CT	Prepare fact sheets and other informational bulletins and disseminate results via grower newsletters and the IPM website.	October - November
	E1	NY, PA, CT	Development of recommendations for inclusion in vegetable guidelines	October - November

Management Coordination:
Project leaders will meet twice annually to discuss project work plans in spring (prior to land preparation) and in late summer (after harvest and before cover crop establishment). In addition, they will be in contact through telephone conferences held monthly or as often as needed. In addition, they will be participating in each other field days and other appropriate outreach efforts. Finally, they will be collaborating on preparing reports, fact sheets, articles published in diverse media or posted on an appropriate website.

(iv) EVALUATION PLANS:

On-site data collection: Baseline data on root disease severity and/or nematode damage, bean yield and non-target soil health parameters using the Cornell Soil Health Test will be collected at the start of this project. Changes in root health will be monitored before and after changes in the cropping sequence using the greenhouse root health bioassay. Data collected on bean yield after the second snap bean crop and non-target soil health parameters before the second snap bean crop will be compared to the baseline data collected in year 1.

Statistical analysis: In addition, the proposed statistical analyses will enable the ranking of cover crops under different disease pressure levels and other soil health parameters. The data comparisons between years will enable us to determine if the effect of the individual cover crop treatments varies under differing levels of pathogen pressure (the cover crop ranking changes) or if there is only a compression effect (the ranking remains the same however, the magnitude of the effect increases or decreases under differing pathogen pressure levels). These rankings will be used to develop the specific cover crop recommendations for the growers.

Adoption of the use of cover crops on a large scale in Northeast vegetable production: Currently, cover crops are increasingly used in Northeast vegetable production. However, information is not readily available for growers to make use of them for the management of root diseases. There is strong evidence that certain cover crops are of value in reducing root disease organisms. This project will identify which of eight commonly used cover crops provide the most benefit to farmers in reducing root rot diseases. Once identified, extension educators, consultants and others will have access to the information, allowing them to more accurately advise farmers.

Initial and continuing impact evaluation: Previously, the Cornell SHPWT has conducted a survey of 1000 farms to determine their soil management practices. Cover crop questions asked in this survey will provide us with baseline information regarding their use by farmers for managing root disease. Using information gained in the proposed project we will design a set of questions that can be distributed at extension meetings throughout the Northeast to determine if the recommendations resulting from this work are implemented.

During the course of this project and after it is finished we will have several opportunities to collect data on Northeast vegetable farmers' use of cover crops for root disease management:

- In cooperation with future SHPWT surveys, questions will be included to determine the extent to which farmers in the NE are knowledge about cover crop use for root disease management.
- Survey questionnaires regarding cover crop use will be distributed, filled out, and collected at cooperative extension meetings at which this project will be discussed, including but not limited to, the New York Fruit and Vegetable Expo, the New England Vegetable Conference and the Pennsylvania Fruit and Vegetable Conference.
- The SHPWT will continue to survey for grower use of cover crops for root disease control throughout the Northeast even after the proposed work has ended. The NYS IPM Program will access the SHPWT survey database to assess adoption of the recommendations resulting from this work in the three collaborating states and throughout the Northeast.

(v) Key Personnel:

Project Directors:

George S. Abawi: Professor of Plant Pathology at Cornell University's NYS Agricultural Experiment Station since 1972. His research and extension responsibilities deal with the biology and management of root diseases of vegetables caused by plant-pathogenic fungi and pathogenic nematodes. He will be involved with the management of the project, assessing the effects of cover crops on root diseases and in the outreach efforts of the results.

Beth K. Gugino: Assistant Professor in Plant Pathology at Pennsylvania State University. She received her Ph.D. from Penn State in May 2004 and her experience and background is in soil microbiology, root diseases and disease management. She will be involved with co-managing the project, plot establishment, data collection and statistical analysis as well as recommendation development and outreach activities.

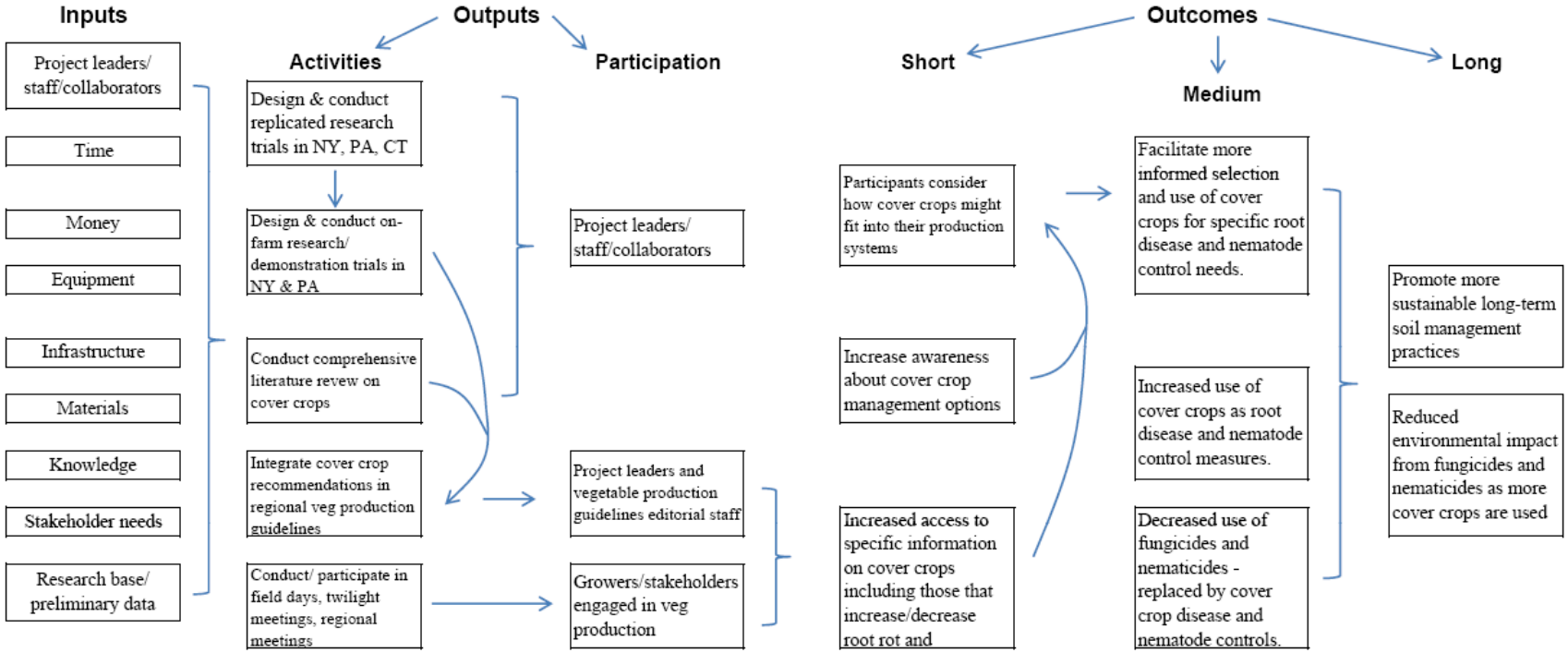
Curt H. Petzoldt: Assistant Director and Vegetable IPM Coordinator at New York State IPM Program since 1985. Project leader at the vegetable systems evaluation site since 1995 and a member of the Cornell Soil Health Program Work team since it's founding. He will be involved with co-managing the project, data collection and analysis, and impact evaluation and documentation.

James A. LaMondia: Chief Scientist of the Connecticut Agricultural Experiment Station Valley Laboratory and plant pathologist/nematologist. He has researched nematode and soilborne fungal diseases for two decades. He will be involved with conducting research, data collection and statistical analysis as well as recommendation development and outreach activities.

SITUATION: In recent years cover crops have been used increasingly by vegetable farmers in the Northeast to improve soil quality, prevent erosion, increase organic matter, and to suppress nematodes and root diseases. Many studies have been conducted to show the benefits of cover crops for preventing erosion, increasing organic matter and improving soil quality. Few studies have focused on the effect of specific cover crops on the prevelant root pathogens of vegetable crops in the Northeast.

PRIORITIES: Resources, expertise, experience, history, what we know about the situation, stakeholder needs

PROGRAM ACTION- LOGIC MODEL



Assumptions:

1 Information regarding effect on soilborne pathogens will be taken into consideration when selecting cover crops.

2 Growers are aware whether or not they have problems with soilborne pathogens.

3 Non-target effects of cover crops on other soil health parameters are known/positive.

External Factors:

1 Availability of cover crop seed - especially those varieties that suppress nematodes and diseases.

2 Cost of seeds and other inputs for establishing the selected cover crops.

3 Ease of establishing and growth vigor of the promoted cover crops are acceptable/good.

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RELEVANCE STATEMENT

Project Directors: George S. Abawi, Dept of Plant Pathology, NYSAES Geneva, Cornell University; **Beth K. Gugino**, Dept of Plant Pathology, Pennsylvania State University; **Curtis H. Petzoldt**, NYS IPM Program, NYSAES Geneva, Cornell University; **James A. LaMondia,** The Connecticut Agricultural Experiment Station, Valley Laboratory

Project Title: Prioritizing Cover Crops for Improving Root-Health and Yield of Vegetables in the Northeast

Project Type: Joint Research-Extension

Project Summary: This is a multi-state joint research-extension proposal. We are requesting $108891 for research from P.L.89-106 and $45262 for extension from Smith Lever. The effectiveness of eight cover crops in managing root rot diseases of vegetables in replicated field trials under experimental and commercial production conditions in New York, Pennsylvania and Connecticut. One of the experimental sites in New York has been managed according to organic production guidelines for 15 years. The impact of the cover crops on soil health indicators will be assessed using the Cornell Soil Health Test. We will assess the efficacy of selected cover crops to reduce the severity of root diseases under varying disease pressure regimes as well as their impact on soil health parameters. The effects of the various cover crops will be determined using beans as the main indicator crop, thus enabling us to replicate conditions encountered on farms in the Northeast. For educational training, demonstration trials will be established in commercial fields during the third year using the most promising cover crops. At the end of the project we will publish a ranking of cover crops based on their ability to manage root diseases and improve specific soil health constraints. Results will be made available to stakeholders throughout the Northeast through incorporation in vegetable production guidelines, websites, fact sheets, presentations at local and regional meetings. Project leaders will collect impact data on farmer adoption of the developed cover crop recommendations for several growing cycles following the end of the proposed work.

Problem, Background & Justification:

In recent years cover crops have been used increasingly by vegetable farmers in the Northeast to improve soil quality, prevent erosion, increase organic matter, and to suppress nematodes and root diseases. Many studies have been conducted to show the benefits of cover crops for preventing erosion, increasing organic matter and improving soil quality (Clark, 2007; Magdoff and van Es, 2000). Few studies have focused on the effect of specific cover crops on the common vegetable root rot pathogens in the Northeast (*Rhizoctonia, Pythium, Fusarium, Thielaviopsis*, *Pratylenchus* and *Meloidogyne)* (Abawi and Widmer, 2000; Abawi et al., 2007).

This project relates to the NE RIPM priorities in the following ways:

1. Will reduce risks to the environment.

Environmental risks will be reduced in the Northeast through the substitution of cover crops to control root rot and nematodes for several older, high EIQ fungicides and nematicides.

2. Will reduce risks to human health.

PCNB and oxamyl, two commonly used soil pesticides for root diseases and nematodes that could be replaced by cover crops have serious human toxicity listed on MSDS sheets.

3. Has stakeholder support and the priority is cited.

In 2007 New York growers placed a high priority on research for "Cultural Practices for Yield and Quality Enhancement and Root Rot Management for peas, beans, and beets includes new directions in cover crops…" (http://northeastipm.org/priority/2007/nyipm_veg.cfm). The 5th

priority identified by the Northeast IPM Center Vegetable Working Group was to "conduct research on how to promote plant health and suppress insect, disease and weed problems through cultural and biological production practices… include…using crop rotations, green manures, …Demonstrate efficacy of research outcomes through on-farm trials and to develop recommendations and disseminate this information in usable form for farmers." "soilborne diseases of vegetables" are a priority item (http://northeastipm.org/work_vegpriority2005.cfm). The PI's of this proposal are engaged with stakeholders throughout the Northeast. This project addresses needs in "General IPM Priorities for the Northeast – 2006" (http://northeastipm.org/priority/2006/generalpriorities.htm) addressing priorities #5 (research on soil health and disease suppression) and #8 (IPM training for professionals in the "IPM Priorities for Vegetables in the Northeast – 2005" (http://northeastipm.org/work_vegpriority2005.cfm).

4. Focuses on a pest, crop, or setting found in at least five states or cropping regions.

Root diseases are a problem potentially affecting 100% of vegetable acreage in the Northeast according to relevant crop profiles and will become more prevalent with reduced tillage systems. Affected crops include beans, peas, carrots, lettuce, onion, tomatoes, potatoes and others. Snap beans, our indicator crop, are grown in all states in the northeast.

5. Will fill a niche (no such tactics or approaches exist).

It is estimated that 100% of the snap bean, carrot, beet, pea, and sweet corn acreage in the northeast is at risk from these organisms (USDA Crop Profiles). Even though in any given year only 10-15% of fields are affected, growers must plan cover crop selections to manage root diseases and soil health issues in a sustainable and economical manner. This project will address a disease complex where few economically viable management tools exist – including pesticides.

6. Involves three or more states in an active partnership.

This project will involve New York, Pennsylvania and Connecticut in active partnership. In addition, the results will apply to all states in the northeast region.

7. Will advance IPM in as soon as two years.

Results of project will be available for implementation within two years.

8. Is interdisciplinary.

Project involves 2 plant pathologists, a plant nematologist, and an IPM Coordinator.

9. Reduces dependency on chemical pesticides.

The use of cover crops for root disease and soil health management will potentially replace fungicide use for managing soilborne pathogens as well as increase soil health.

10. Has significant economic implications.

Vegetable farming is an important economic driver in northeastern communities contributing over $700M dollars to the Northeast economy.

11. Explains, justifies, and will serve an "underserved audience."

All vegetables in the Northeast are minor crops. Many fresh market vegetable and organic vegetable growers in the Northeast are small acreage farmers.

12. Addresses an emerging pest, crop, or problem.

Although this is not an emerging new pest, there is an emerging opportunity for implementation of this project because of the increased use of cover crops by vegetable farmers in recent years as a management strategy for sustainable soil health and disease management.

13. Is likely to be adopted by the target audience.

Cover crop use is currently increasing in adoption throughout the Northeast – the results of this project will allow better use of cover crops to manage root diseases and soil health as well as provide in-depth science-based information for farmers to adopt cover crop practices.

14. Advances an IPM practice that is more cost-effective than the status quo.

Virginia Tech agricultural economists estimate the cost of the granular formulation of mefenoxam (Ridomil Gold PC) to be $5.61/ lb in 2007 (http://www.ext.vt.edu/pubs/agecon/446-047/Chemical07.pdf). The recommendation for Ridomil Gold PC treatment is 12 oz/1000 linear row feet = 12.9 lb/A. Thus the cost of treatment, excluding application costs, was about $72/A in 2007. In 2008, the cost of seed for the cover crops used in establishing the New York site ranged from $15 to $30 per acre, excluding planting costs. Assuming fungicide application costs and cover crop seeding costs are approximately equal, growers could realize an increased income of $42 to $57 per acre by replacing a typical recommended fungicide treatment with a cover crop. A 50 acre farm would see a $2,100-$2,850 benefit annually while a 3,000 acre farm would see a $126,000-$171,000 benefit. In addition most of the cover crops evaluated in this project provide an additional fertility and soil health benefit at a time when nitrogen costs are increasing.

Objectives and Anticipated Impacts:

The overall goal of this project is to provide vegetables growers with additional information that they can use to select the appropriate cover crops when specifically trying to reduce root disease pressure. This project addresses three goals of the NE RIPM grants program by: improving the economic return to farmers, reducing the use of fungicides and nematicides, and reducing the adverse environmental effects from the use of root rot fungicides and nematicides.

Specific Research Objectives and Anticipated Impacts:

1. Assess the impact of several types and varieties of cover crops adapted to the Northeast on the severity and damage of fungal and/or plant-parasitic nematodes in replicated field research trials in New York, Pennsylvania and Connecticut.

Anticipated Impacts

-Identification of cover crops that suppress specific soilborne pathogens and the damage of their resultant root diseases.

2. Evaluate the impact of the same cover crops on other non-target soil health parameters as measured using the Cornell Soil Health Test.

Anticipated Impacts

-Elucidation of the effect of cover crops on individual soil health parameters.

-Increase the management options available to extension agents, consultants, and other agricultural professionals in addressing identified soil health constraints.

Specific Extension Objectives and Anticipated Impacts

1. Increase the literacy of growers, stakeholders, and other agricultural service providers in the use of cover crops for managing soilborne fungal and nematode root pathogens and their damage to vegetables.

Anticipated Impacts

-Vegetable farmers in the Northeast adopt cover crops as an important method for managing soilborne root diseases and resultant crop damage in their fields, thus replacing the need for soil fungicide and nematicides applications and longer crop rotations.

-Facilitate more informed selection and use of cover crops for specific needs in improving soil biological health, in general.

-Extension agents, consultants, and other agricultural professionals gain knowledge resource in order to better design effective cultural management programs for clients to manage root diseases using cover crops/cropping sequences.

-Promote more sustainable long-term soil management practices.