New York Berry News

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What's Inside

CURRANT EVENTS

January 20, 2010. *NE IPM Berry Webcast Series #10*: **Bramble Weed Management: cultural weed management, using herbicides effectively**. More information: Laura McDermott, lgm4@cornell.edu, 518-746-2562, http://www.fruit.cornell.edu/Berries/webinarindex.htm.

January 25-27, 2010. *Empire State Fruit and Vegetable EXPO/NYS Farmer's Direct Marketing Association Annual Conference*. OnCenter, Syracuse, NY. Mark your calendars – berry session Wednesday January 27th.

February 3, 2010. *NE IPM Berry Webcast Series #11*: **Bramble Disease Management: root and crown diseases, viruses**. More information: Laura McDermott, lgm4@cornell.edu, 518-746-2562, or go to: http://www.fruit.cornell.edu/Berries/webinarindex.htm.

February 2-4, 2010. *Mid-Atlantic Fruit and Vegetable Convention*, Hershey Lodge, Hershey, PA. For more information visit http://www.mafvc.org/html/.

February 17, 2010. *NE IPM Berry Webcast Series #12*: **Bramble Insect Management: crown/cane borers, Japanese beetles and other miscellaneous pests**. More information: Laura McDermott, lgm4@cornell.edu, 518-746-2562, http://www.fruit.cornell.edu/Berries/webinarindex.htm.

Feb 5-12, 2010. *North American Farmers Direct Market Association 25th Anniversary Convention***,** Lancaster PA. More information to follow.

February 24-26, 2010. *North American Raspberry & Blackberry Conference,* Holiday Inn, Kingston, NY. More information: Peggy 518-828-3346.

February 26, 2010. *Hudson Valley Fruit Program, Processing Berry Meeting,* Monterey, California, preceded by preconference tour. More information: http://www.raspberryblackberry.com/.

March 3, 2010. *Berry Production Short Courses,* sponsored by the Capital District Vegetable and Small Fruit Program, Voorhesville, NY. More information: news brief below or call Laura McDermott, 518-746-2562.

June 22-26, 2011. *10th International Rubus and Ribes Symposium, Zlatibor, Serbia***.** For more information contact: Prof. Dr. Mihailo Nikolic, Faculty of Agriculture, University of Belgr, Belgrade, Serbia. Phone: (381)63 801 99 23. Or contact Brankica Tanovic, Pesticide & Environment Research Inst., Belgrade, Serbia. Phone: (381) 11-31-61-773.

The Empire State Fruit & Vegetable Expo

Growing for the Health of New York

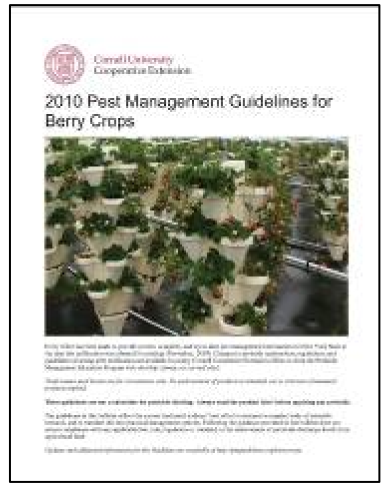
Don't miss the berry session Wednesday, January 27th, 2010. More information: http://www.fruit.cornell.edu/Berries/calendarpdf/EXPO2010berries.pdf.

NEW YORK BERRY NEWS READER SURVEY REMINDER

If you haven't yet had the opportunity to do so - please take a few moments to fill out the reader survey from last month's issue and return it to us via e-mail, fax, or US mail. Thanks!

- E-mail: mcm4@cornell.edu
- Fax: 315-787-2389 (attn. C. Heidenreich)
- US mail: M.C. Heidenreich, NYSAES Cornell University, 630 West North Street, Geneva, NY 14456

2010 BERRY PEST MANAGEMENT GUIDELINES NOW AVAILABLE ON LINE



The 2010 edition of the Pest Management Guidelines for Berry Crops is now available on line. This annual publication provides up-to-date pest management information for blueberry, bramble (raspberry and blackberry), strawberry, ribes (currant and gooseberry), cranberry, and elderberry production in New York State. Supplemental information on wildlife management and harvesting, handling, and transporting berries is also included. It has been designed as a practical guide for berry crop producers, crop consultants, Ag chemical dealers, and others who advise berry crop producers. Visit the web site at: http://ipmguidelines.org/BerryCrops/.

In addition to the annually revised pesticide and crop production information, several significant updates have been made to the 2010 edition of the *Berry Guidelines* including:

- Revised pesticide regulatory information.
- New nutrient guidelines and disease management options for cranberry and elderberry.
- Revised soil testing procedures.
- Prominently identifying pesticides acceptable for use in organic production systems.

Print copies of the 2010 *Pest Management Guidelines for Berry Crops* can be obtained through your local Cornell Cooperative Extension office or directly from the Pesticide Management Education Program (PMEP) Educational Resources Distribution Center at Cornell University. To order from PMEP, call (607) 255-7282 or send an email to patorder@cornell.edu. Cost for the *Guide* is $25, shipping included.

CAPITAL DISTRICT VEGETABLE AND SMALL FRUIT PROGRAM OFFERS BERRY PRODUCTION SHORT COURSES

On Wednesday, March 3rd the Cornell Cooperative Extension Capital District Vegetable and Small Fruit program is sponsoring two Berry Production Short Courses at the William Rice Jr. Extension Center, CCE Albany County, 24 Martin Road, Voorheesville, NY 12186.

Registration for each course will begin 30 minutes prior to the start of the course. The Strawberry Production Short Course will begin at 9:00am and end at noon. Topics covered will include site selection and early establishment; disease, weed and insect overviews with management options discussed; fertility considerations and variety review.

The Blueberry Production Short Course will begin at 1pm and end at 4pm. Topics covered will include site selection and fertility considerations; variety review; overcoming pollination challenges; management of weed and disease problems and a review of blueberry pruning techniques.

Application for DEC Pesticide recertification credits has been made. The registration cost for each short course is $20 per person. If a grower attends both short courses, the cost is $35/person. Lunch is not included, but for those interested in a cold lunch, that can be ordered the day of the class.

For more information, please contact Laura McDermott, 518-746-2562.

USDA-NRCS HIGH TUNNELS GRANTS AVAILABLE

The USDA Natural Resources Conservation Service (NRCS) has announced a new pilot project under the 'Know Your Farmer, Know Your Food' initiative for farmers to establish high tunnels to increase the availability of locally grown produce in a conservation-friendly way.

Local farmers who would like to sign-up for the high tunnel pilot should call or visit the NRCS office at a local USDA service center by January 15th. USDA service center locations are listed on-line at http://offices.usda.gov or in the phone book under Federal Government, U.S. Department of Agriculture. General program information is available on the NRCS Massachusetts website at www.ma.nrcs.usda.gov. Participating farms can receive funding for one high tunnel.

Participating states are: Alabama, Alaska, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Pacific Islands, Illinois, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Mexico, **NEW YORK**, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Washington, West Virginia, Wisconsin, and Wyoming.

NRCS will provide financial assistance for the project through the Environmental Quality Incentives Program (EQIP), the EQIP Organic Initiative and the Agricultural Management Assistance program.

UPDATE ON USDA-NRCS HIGH TUNNELS ASSISTANCE - NEW YORK GROWERS DO NOT HAVE A JANUARY 15 DEADLINE

Dianna Power, NY Program Manager – NRCS, dianna.power@ny.usda.gov

January 7, 2010. USDA-NRCS in New York State has agreed to be a pilot state for offering a new practice for financial assistance, "Seasonal Tunnel System for Crops". Seasonal Tunnels Systems are also commonly known as "Hoop Houses" or "High Tunnels".

NRCS National Headquarters has released a national press release regarding the new opportunity. The press release is available thru the national NRCS website at http://www.nrcs.usda.gov/ as well as the NY NRCS website http://www.ny.nrcs.usda.gov/. In addition, the USDA and the White House have also released a video regarding "Hoop Houses" that is available on the USDA YouTube website at http://www.youtube.com/watch?v=07vtMJgp0no.

Program decisions for announcing this Seasonal Tunnel System pilot program in New York are not yet finalized and no deadlines have been set for NY farmers to enroll. NRCS is still finalizing the technical standards and criteria that the Season Tunnel Systems must meet to be eligible for funding. The NY Seasonal Tunnel System pilot program with NY NRCS is still under development. The Massachusetts NRCS has set January 15, 2010 as the deadline for Massachusetts farmers to signup for the Seasonal Tunnel Systems. Here is a link to the Massachusetts press release announcing the Massachusetts deadline: http://www.ma.nrcs.usda.gov/news/news_high_tunnel_pilot.html. Once NY deadlines are set for the Season Tunnel Systems, NRCS NY will be sending out a press release notification.

NRCS programs are continuous sign-up programs. As a result, interested applicants can sign-up at anytime at their local USDA Service Center. Here is a link for NY producers to find their local USDA Service Center: http://offices.sc.egov.usda.gov/locator/app. Local NY NRCS field staff can explain basic USDA program eligibility to interested producers so that applicants are eligible when the pilot program in NY is announced.

Additional Background Information regarding Seasonal Tunnels Systems
A seasonal high tunnel is a greenhouse-like structure, at least 6 feet in height, which modifies the climate to create more favorable growing conditions for vegetable and other specialty crops grown in the natural soil beneath it. This pilot program will test the validity of potential conservation benefits.
Potential Resource Benefits of High Tunnels - Potential natural resource benefits from using tunnel structures include: (1) improve plant quality, (2) improve soil quality, and (3) improve water quality through methods such as reduced nutrient and pesticide transport.

Other NRCS Conservation Program Signup
NY Natural Resources Conservation Service (NRCS) has announced an application deadline for New York farmers and private forestland landowners to be considered for our "typical" Conservation Program funding for 2010. The deadline for other programs/focus areas not related to the Seasonal High Tunnel pilot program is January 22, 2010. This includes

Environmental Quality Incentives Program (EQIP), Chesapeake Bay Watershed Initiative (CBWI), Agricultural Management Assistance Program (AMA), and the Wildlife Habitat Incentives Program (WHIP).

For more information see our NY press release at: http://www.ny.nrcs.usda.gov/news/stories/signup_2010.html.

For NRCS program questions for NY please contact Dianna Power at dianna.power@ny.usda.gov

HUDSON VALLEY FRUIT PROGRAM HOSTS A PROCESSING BERRY MEETING FEBRUARY 26TH

As few as three to five years ago, berries were viewed in the Northeast as less common crops with the potential for high returns. Direct marketers such as CSAs (community supported agriculture) and vendors in green markets who produce only what they can sell directly, continue to enjoy high retail prices for the fruit, thus making a profit on a small scale. On the other hand, middle-sized to larger-sized growers selling to wholesale distributors have been disappointed by their returns recently, and have found that wholesale prices often don't even pay the costs to get fruit to market (i.e.: harvest, packaging material, transportation, commissions). This has made larger growers take a second look at their berry enterprises and consider alternatives. Mechanization, processing, and adding value to the berries provide some options to explore.

Unfortunately, as berries become plentiful on the market, the wholesalers become saturated with product. Prices drop as product arrives from the west coast and as the season peaks. As an example, flats of half pints of raspberries can open the season with prices as high as $28 on the wholesale market, and drop as low as $7.50 in a couple of weeks. Black raspberries used to command prices as high as $45 per flat of half pints, and now can drop as low as $12. Red currants start at $28, and commonly drop to $15 near season's end. At the same time, prices for some of the primary processed products have climbed. As an example, raspberry concentrate has gone from about $35 per gallon to $125 per gallon in a couple of years. Elderberry concentrate is similar with prices climbing to as high as $55 to $85 per gallon.

Mechanizing and producing for processing is an option that needs to be explored for the northeast. As the nutritional benefits of berries continue to be discovered and shared with the public, demand for both fresh and processed product will increase. Many of these crops such as currants, gooseberries, raspberries, blueberries, and Aronia are very adaptable to mechanized culture and harvest. Planting, weeding, pruning, and harvest can be done from the seat of a tractor. New equipment and infrastructure is necessary for this type of production. In addition to machinery for production, freezers, processing facilities for cleaning, juice extraction, and packaging become critical. Sufficient planting is necessary to have a level of production that can support the investment.

On February 26, 2010, Cornell Cooperative Extension will be having a meeting at the Kingston Holiday Inn in Kingston to explore these alternatives. Speakers will include specialists from Poland and the US, as well as representatives from equipment companies. A mini trade show will provide growers an opportunity to see what is available in the way of harvesters, pruners, weeding equipment, planters, and even processing equipment.

If you would be interested in attending, please call Peggy at 518-828-3346 and leave your name, address, and phone number. We will send you a registration form. The price for the day is $45.00 which includes lunch.

2010 HUDSON VALLEY BERRY PROGRAM AGENDA
February 26, 2010, Kingston, NY

8:30- 8:45 am	*Registration*
8:45- 9:00 am	*Opening Remarks, Review of 2009 Production Year* - Steven McKay, CCE
9:05- 9:25 am	*Optimizing Plant Performance* - Janet E. Hawkes, Ph.D., Managing Director, HD1, LLC
9:30- 9:45 am	*Review of Berries with Potential for Mechanization and Processing* (Also describe those with less potential for mechanization.) - Steven McKay, CCE
9:50- 10:35 am	*Mechanizing Harvest - A Panel Discussion*. Moderator: Stan Pluta, Research Institute of Pomology and Floriculture, Poland
10:35-10:45 am	Break

10:45- 11:35 am	*The European Experience with Berries: History, Economics, "Chosen Berries"* Dr. Stan Pluta, Research Institute of Pomology and Floriculture, Poland
11:40- 12:00 pm	*Economic Review of Berry Production Enterprises: Production Costs and Returns for Fresh and Processing Berries including a Historical Review of Market Prices and Industry Trends* - Steve Hadcock, CCE
12:00- 1:15 pm	*Lunch*
1:15- 1:45 pm	*Breeding Berries Adapted to Mechanization and Processing* - Dr. Stan Pluta, Research Institute of Pomology and Floriculture, Poland
1:50- 2:05 pm	*Mechanized Planting - (plugs, vs. cuttings, vs. plants; machinery available) Panel Discussion*. Moderator: Sam Erwin, Owner, Superb Horticulture Group
2:10- 2:30 pm	*Mechanizing Weed Control - Panel Discussion*. Steven McKay, Moderator
2:35- 2:50 pm	*Mechanizing Irrigation* - Fran Dellamano, Belle Terre Irrigation
2:55- 3:15 pm	*Mechanizing Pruning – Panel Discussion*. Dr. Stan Pluta, Research Institute of Pomology and Floriculture, Poland, Moderator
3:15- 3:25 pm	*Break*
3:25- 3:45 pm	*Storage of Berries: Refrigeration, Freezing, CA* (quality preservation) - Steven McKay, CCE
3:50- 4:10 pm	*Primary Processing: De-stemming, Cleaning, IQF, Non-IQF, Packaging - Panel Discussion*. Sam Erwin, Owner, Superb Horticulture Group, Moderator.
4:15- 4:40 pm	*Secondary Processing: Crushing and pressing, Concentrate and puree, Quality standardization, Dealing with seasonal variations in flavor profile and quality* - TBA
4:45- 5:00 pm	*Retail Products* - Steven McKay, CCE

SCIENTISTS SEQUENCE GENOME OF THE WOODLAND STRAWBERRY, A MODEL SYSTEM FOR ROSACEAE PLANTS

Stephanie Yao, USDA ARS Public Affairs Specialist, Room 1-2212-A, 5601 Sunnyside Ave., Beltsville, MD 20705-5129

January 11, 2010. The genome of a model plant related to peach, cherry and cultivated strawberry has been sequenced by a consortium of international researchers that includes scientists with the Agricultural Research Service (ARS).

The scientists announced the sequencing of the genome of woodland strawberry over the weekend at the Plant and Animal Genome Conference in San Diego, Ca. The project was funded by Roche Diagnostics.

Fragaria vesca, commonly known as the woodland or alpine strawberry, is a member of the Rosaceae family, which consists of more than 100 genera and 3,000 species. This large family includes many economically important and popular fruit, nut, ornamental and woody crops, such as almond, apple, peach, cherry, raspberry, strawberry and rose.

F. vesca has many traits that make it an attractive model system for functional genomics studies. Its small size and rapid life cycle enable researchers to conduct genetic analyses with great efficiency and low cost. To determine the importance of a gene of interest, *F. vesca* can be transformed in order to modulate the activity of that gene in the plant. Most importantly, *F. vesca* has a relatively small genome, yet shares most gene sequences with other members of the Rosaceae family, making it an important tool for addressing questions regarding gene function.

ARS molecular biologist Janet Slovin, with the Genetic Improvement of Fruits and Vegetables Laboratory in Beltsville, Md., created the nearly inbred line used in the *F. vesca* genome sequencing project. Named “Hawaii 4,” this line allowed

The genome of the woodland strawberry, also called the alpine strawberry, has now been sequenced. This strawberry can serve an excellent research model for other plants in the same Rosaceae family, which includes many economically important crops such as almond, apple, and peach.
(Photo courtesy of Janet Slovin, ARS.)

the researchers to more easily program a computer to piece the genome together from the relatively short lengths of sequence data generated by modern sequencing machines.

Although the *F. vesca* genome is a model genome for the Rosaceae group, critical regulatory gene functions will probably differ, hypothesizes Slovin. Scientists can use the genome sequence to identify these genes, to test their function in *F. vesca*, and to develop molecular genetic markers for more rapid breeding of crops belonging to the Rosaceae group. Slovin will use the genome to study and improve heat tolerance during fruit production in strawberry.

ARS is the principal intramural scientific research agency of the U.S. Department of Agriculture. The research supports the USDA priorities of promoting international food security and responding to climate change.

News from the NYS Berry Growers Association

Have You Contacted Your Legislators Recently?

Dale Ila Riggs, Chair, The Berry Patch, Stephentown NY

As I write, a bill that could devastate NYS Berry Growers is sitting in the NYS Senate Labor Committee. Commonly referred to as the Farm Workers Overtime bill, this bill would require that all farmers pay time and a half to their farmworkers, as well as impose other mandates to provide additional benefits for farmworkers.

It doesn't take a lot of imagination to imagine what this bill would do to the berry industry in NYS. Just imagine, it's been raining for 3 days during berry season and then the temperature hits 90 F for 2 or 3 days. Suddenly, you need to have everyone in the field for 12-14 hours a day to save your crop. Do you want to pay time and a half to your workers during this time to get your berries out of the field? Can you afford to pay time and a half to your workers during this time?

Many of you may say, "Oh, this doesn't apply to me. We only use family labor." That's how I started my farm too. We only used family labor. Now I employ 4 H2A workers to harvest my crops through the summer. And I still have a small farm – a total of about 8 acres in production, of which 2 acres are in berries. Just because the law may not apply to you now, doesn't mean it won't apply to you in the future. If you have planted a blueberry plantation, planning to have your kids harvest all the berries, what will you do when your kids no longer live with you, or grow weary of harvesting berries? Blueberries plantings can last 40 years or more. I don't know many 40 year olds that want to pick berries all day long. Some people do most of their marketing through pick your own. Pick your own may be strong in recessions like this, but it drops off dramatically in a strong economy.

No business that plans to be around in the future can plan on today's status quo working in the future.

If you want to be in the berry business in the future, contact your closest Farm Bureau advisor TODAY to find out more about the labor bill and who you should contact to oppose it. Your future in the berry industry depends on it.

NEMATODES – A MINI SERIES

Part I of this nematode mini-series aired in the December issue and covered nematode biology and their impact on small fruit production. Part II of the mini series follows below with a very well-written and informative article on strawberry black root rot, by Jim LaMondia. Also included in this part of the mini series is a research brief on "Responses of Strawberry Species and Cultivars to the Root-lesion and Northern Root-knot Nematodes", discussing results of research done by Jack Pinkerton and Chad Finn of USDA ARS Corvallis.

Part 3 will be featured in the February issue and is comprised of 3 resources provided through the nematode workshop I attended. The resources will include a factsheet on soil sampling for PPN assessment by George Abawi and Beth Gugino, and informational brochures on setting up and evaluating results of simple on farm bioassays for Root-Knot and Lesion Nematodes, also by George Abawi.

PART II: Nematodes and Strawberries

STRAWBERRY BLACK ROOT ROT

Jim LaMondia, Plant Pathologist/Nematologist and Chief Scientist, Valley Laboratory, The Connecticut Agricultural Experiment Station, P. O. Box 248, Windsor, CT 06095.

The Disease

Black root, black rot or strawberry black root rot were the descriptive names first given for a debilitating root cortical disease of uncertain cause. The disease has been a challenge for strawberry growers for at least a century, and probably longer. Early work in 1917 (Fletcher) described root rot or black root of strawberry and stated that the disease was prevalent in Massachusetts, Michigan and New York in the years 1902 to 1908. Black root rot typically causes little disease in the first year, although it has been implicated in occasional transplant failures. Generally, the loss in plant vigor and increase in plant mortality during picking, especially under conditions of environmental stress, increases in severity each year, leading to increased variability within a field and eventual loss of productivity (Maas, 1998; Strong and Strong, 1931; Zeller, 1932) (Figure 1). Infected roots develop expanding black cortical lesions leading to root girdling, cortical rot, and a resulting loss of root function and loss of root mass responsible for the decline syndrome (Figure 2).

Figure 1. Variable plant growth in a black root rot affected field.

Figure 2. Cortical root rot symptoms on a strawberry structural root.

Unraveling the cause

Heald (1920) may have been the first to assign *Rhizoctonia* as the causal pathogen responsible for 'dying out' of strawberry beds in western Washington. Since that time a fairly large number of pathogens including *Pythium* spp., *Fusarium* spp., *Cylindrocarpon* spp., *Idriella lunata*, and *Ramularia* spp. as well as environmental conditions such as drought, water-logging, compaction and winter injury have also been associated with strawberry black root rot (Maas, 1998; Martin and Bull, 2002; Miller, 1948; Nelson and Wilhelm, 1956; Nemec and Sanders, 1970; Watanabe et al., 1977, and Wing et al., 1994).

Black root rot has been generally regarded as a complex disease with multiple causes (Maas, 1998; Martin, 1988; Plakidas, 1964). However, *Rhizoctonia* fungi have been most convincingly demonstrated as the primary cause of the disease (Coons, 1924; Husain and McKeen, 1963; Martin, 1988; Molot et al., 1986; Ribeiro and Black, 1971; Wilhelm et al., 1972; and Zeller, 1932). The further identification of specific types of *Rhizoctonia* pathogenic to strawberry has been important in consistently demonstrating pathogenicity and the association of this pathogen with the disease. In 1963, isolates of binucleate *Rhizoctonia* pathogenic to strawberry were differentiated from the multinucleate *R. solani* and described as *R. fragariae* by Husain and McKeen (Figure 3). *Rhizoctonia solani* is not commonly isolated from strawberry roots and is not consistently pathogenic (Martin, 1988). Ogoshi et al. (1979) separated the binucleate *Rhizoctonia* spp. into at least 15 anastomosis groups and identified *R. fragariae* as belonging to one of three of those groups, Anastomosis groups (AG) A, G, or I.

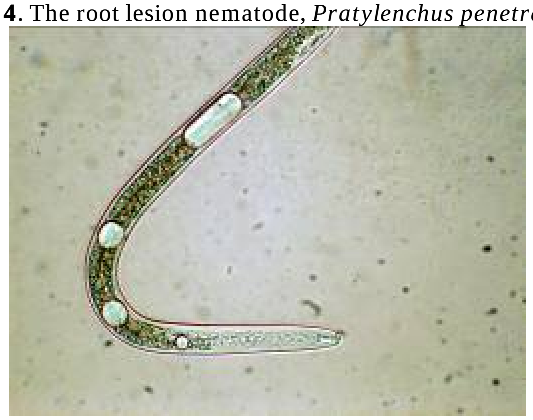
Martin (1988) isolated all three anastomosis groups (AG A, G, and I) of *R. fragariae* from commercial strawberry fields in Connecticut. He determined that isolates of different AG may differ in pathogenicity and could be recovered from roots in different frequencies in spring versus fall seasons.

Contributing factors: lesion nematodes

The lesion nematode, *Pratylenchus penetrans* (Cobb) Filip & Schur.Stek., (Figure 4) has been variously regarded as a primary cause of black root rot (Goheen and Smith, 1956; Klinkenberg, 1955), as a predisposing factor for disease (Chen and Rich, 1962; Townshend, 1962), or as a component of a disease complex involving more than one pathogen (Chen and Rich, 1962; LaMondia and Martin, 1989; Maas, 1998; Ribeiro and Black, 1971). A number of surveys have associated lesion nematodes with increased severity of black root rot under field conditions (Goheen and Bailey, 1955; Goheen and Smith, 1956; LaMondia, 1994) and controlled experiments have confirmed the role of the nematode in the disease (Chen and Rich, 1962; LaMondia, 2003; LaMondia and Martin, 1989).

Figure 3. Hyphae and monilioid cells of *Rhizoctonia fragariae*.

Figure 4. The root lesion nematode, *Pratylenchus penetrans*.



We conducted experiments in which pure cultures *of R. fragariae* AG A, G and I were inoculated to strawberry alone or in combination with monoxenically produced lesion nematodes (without contaminant microorganisms) under growth chamber conditions at 10 and 24 C (LaMondia and Martin, 1989). Our results demonstrated that the presence of *P. penetrans* increased the severity of black root rot caused by all three AG of *R. fragariae* at both 10 and 24 C. Higher inoculum levels of *P. penetrans* were more effective than low levels in this respect. Both structural and feeder root length were reduced more in the presence of both pathogens than with either one alone. In addition, temperature appears to be a factor in determining whether AG G or AG I predominates. AG I caused more root rot at cooler temperatures and may be more active in late fall to early spring. AG G was more virulent under warm conditions and may be the more important pathogen over the summer. Survey results from Connecticut have indicated that AG G is the most common AG isolated from strawberry roots in the spring and AG I was most common in the fall (Martin, 1988). The differential survival of roots infected with AG G during the summer or AG I during cool conditions may account for those results as roots infected with those AG will be killed and not recovered compared with roots infected with AGs causing less disease at those temperatures.

The timing of sampling and the type of plant sample collected may have a large influence on the ability to associate lesion nematodes with strawberry black root rot. Plant parasitic nematodes are obligate parasites and require susceptible living root tissues upon which to feed. Sampling in late stages of the disease after the complete or nearly complete loss of healthy unsuberized roots due to black root rot may effectively eliminate lesion nematode populations and mask an association of these nematodes with the early stages of the disease.

In addition to the influence of black root rot on strawberry roots and nematode populations, levels of plant-parasitic lesion nematodes infecting strawberries exhibit seasonal variation in numbers in roots and soil (DiEdwardo, 1961; Szczygiel and Hasior, 1972). These variations often make it difficult to interpret the relation between nematode density and strawberry yield loss from samples taken at different times during the year. While population change may be dramatic throughout the year, population dynamics tend to be similar and repeatable year after year within areas of similar climate on a single crop, regardless of differences in soil moisture or precipitation (Winslow, 1964). We conducted a series of experiments to investigate the relation between strawberry root type, biomass, and nematode population in roots and soil over time (LaMondia, 2002). Nematode populations are best correlated with perennial strawberry yield about one year after sampling. Perennial strawberry crowns set fruit buds in the fall, which determines yield potential for the next June crop (Maas, 1998). It may not be surprising, then, that the influence of nematode-induced stress may not be reflected in yield until the next year (LaMondia, 1999a).

Contributing factors: stress

Environmental stresses, including soil compaction, excess moisture and winter injury may also increase the severity of black root rot (Coons, 1924; Maas, 1998; Wing et al., 1994). These stresses may affect root function and the ability of the plant to respond to root infection or quickly produce new roots to replace non-functional diseased roots. The reduction in the size and function of the root system diminishes plant vigor and contributes to the decline syndrome.

Contributing factors: root type

Strawberry roots themselves may significantly add to the variation associated with disease and with sampling for nematodes. Three distinct types of roots exist on crowns at the same time and the relative abundance of each

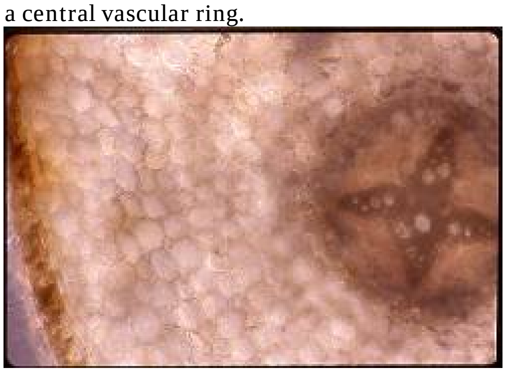
morphological type varies with time (Wilhelm and Nelson, 1970). All three of these root types have specific functions and are necessary for the growth and survival of the strawberry crown.
New structural roots (which eventually become perennial roots) are produced from crowns. Structural roots are the larger, nearly white roots produced by first year plants (Figure 5). These roots have a well-defined root cortex surrounding a central vascular ring (Figure 6).

Figure 5. Strawberry structural roots and associated feeder roots.

The terminal branches of these roots are fine lateral or feeder roots. The feeder roots do not develop secondary tissues and have a limited life span, and are replaced several times each season.

The structural roots develop secondary tissues and eventually become dark or black woody perennial roots (Figure 7). The development of secondary growth and thick-walled suberized tissues result in perennial roots that act as storage organs and conduct water with minimal mineral uptake. The corky secondary growth starts just outside the vascular tissue (Figure 8) and cuts off the cortex and epidermis, which die and become the black surface of perennial roots (Figure 9). Lesion nematode symptoms are commonly seen on young structural roots, but the relation between *P. penetrans* and root anatomy had not previously been determined. Damage from nematode infection ranges from death of individual cells (Figure 10) to elliptical lesions resulting from cell necrosis (Figure 11). Lesion nematode damage may reduce overall root growth, result in early discoloration of the endodermis (Figure 12), and stimulate suberized root production, shifting the balance between root types toward perennial roots; negatively influencing strawberry growth and vigor.

Figure 6. Cross-section of a structural root. Note the well-defined root cortex surrounding a central vascular ring.



Pratylenchus penetrans occupy niches both in soil and in morphologically distinct strawberry roots at different times of the year. The variation in nematode numbers over time reflects changes in the distribution of morphological types of strawberry roots that occur over the season. In experiments over two years, we found that *P. penetrans* populations peaked at about the end of May. The subsequent decline in numbers corresponds to changes in total strawberry root weight and root type distribution. The loss of nematode habitat results both from loss of roots of all types due to disease and also from a natural change in root type from structural root to suberized perennial root unsuitable for nematode infection.

In our studies, relatively few nematodes were extracted from soil, diseased roots, or suberized roots without associated feeder roots. Previous research in New Jersey (DiEdwardo, 1961) and in Poland (Szczygiel and Hasior, 1972) reported that *Pratylenchus* densities in soil were low and did not exhibit seasonal variation. They reported that numbers extracted from strawberry roots were higher in young roots than in older, black root rot symptomatic roots. Lesion nematode numbers peaked in June and precipitous declines were associated with aging roots (the development of perennial roots) (DiEdwardo, 1961) or a drop in the percentage of young white roots (Szczygiel and Hasior, 1972). There were no effects of root age on the ratio of female, male or juvenile nematodes (DiEdwardo, 1961). The high correlation between percent healthy white roots and lesion nematode numbers by all of these studies heavily underscores the fact that the recovery of these obligate parasites from severely diseased crowns is unlikely.

Structural strawberry roots and healthy suberized perennial roots normally produce successive crops of soft absorptive feeder roots (Wilhelm and Nelson, 1970). During the period of spring fruit production, extensive loss of all root types may occur. Strawberry roots were also reported to decline during fruiting. Lesion nematode populations mirrored the decline of root growth (DiEdwardo, 1961; Szczygiel and Hasior, 1972). Root growth recovered by fall, but nematode population density recovered more slowly than roots, probably resulting from the dilution effect of slowly increasing nematode numbers in more quickly increasing root biomass.

Figure 7. Strawberry perennial roots and associated feeder roots.

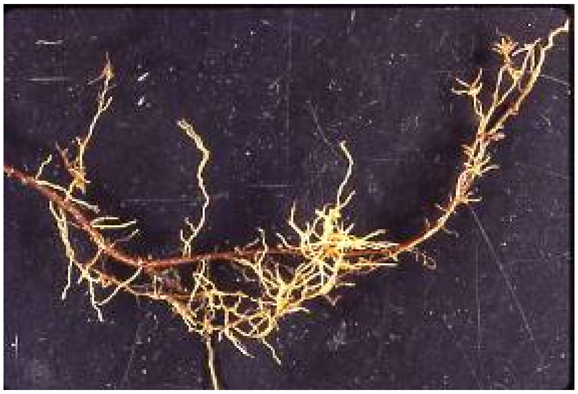


Figure 8. The initiation of secondary growth in a structural root cross-section just outside the vascular tissue.

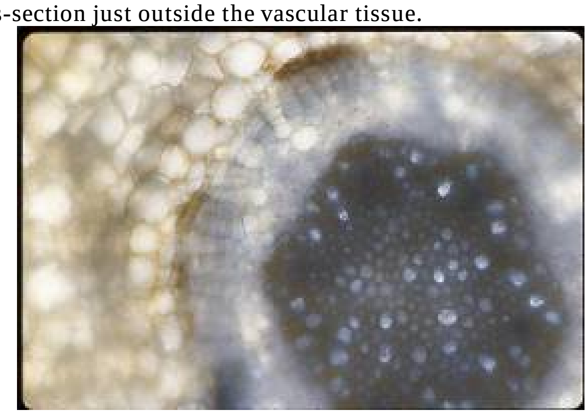


Figure 9. Cross-section of a perennial root. Note that the cut off cortex and epidermis has died and become the black surface of perennial roots.

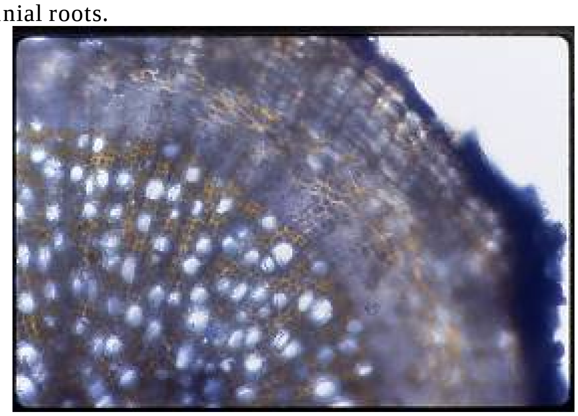


Figure 10. Damage from lesion nematode infection to an individual cortical cell.

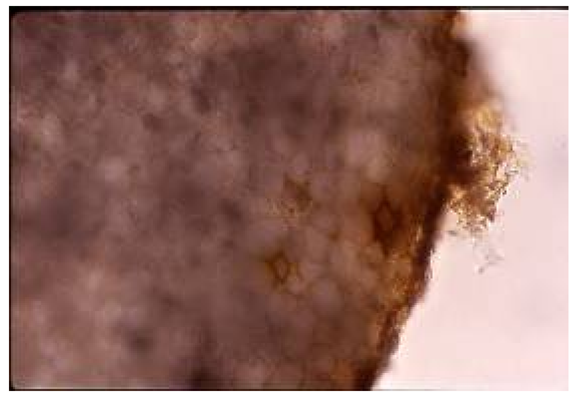
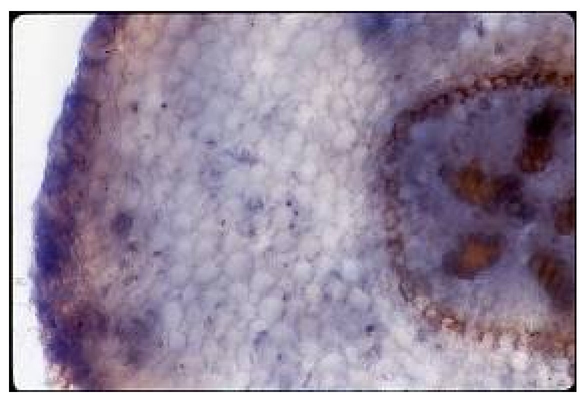


Figure 11. Elliptical cortical lesions resulting from *Pratylenchus penetrans* infection.

Figure 12. Early discoloration of endodermis tissues resulting from *Pratylenchus penetrans* infection.



The health, vigor and productivity of the crown is determined by the extent to which structural roots are produced, converted to perennial roots, and produce successive flushes of feeder roots unimpeded by root pathogens (Wilhelm and Nelson, 1970). Infection of strawberry roots by both *P. penetrans* and *R. fragariae* results in significant and severe root rot (LaMondia and Martin, 1989). Black root rot caused by *R. fragariae* reduced healthy structural root length by the development of cortical rot and also reduced feeder root length (LaMondia and Martin, 1989). Strawberry black root rot-affected plants exhibit areas of cortical necrosis, a rat-tail symptom on structural roots, and the collapse of perennial roots. The cortical root rot symptoms are transient, and the loss of root biomass, especially feeder roots, is of primary importance in the decline of the strawberry crown (LaMondia and Martin, 1989). While this disease may increase the inoculum potential of *R. fragariae* over time, populations of *P. penetrans* are already fluctuating with the cycle of root growth, and are further reduced by the destruction of remaining healthy roots and the loss of feeder root production. As a consequence, these nematodes must migrate to adjacent healthy roots to survive. These may be strawberry or weed host roots. Our results suggest that in order to optimize diagnostic sampling to best determine lesion nematode density and their involvement in black root rot disease; samples should be taken in late May or early June prior to fruiting, or later in the year after mid August. Additionally, crowns exhibiting symptoms of severe black root rot with poor or a lack of healthy roots should not be sampled. Rather, nematodes should be recovered from plants adjacent to diseased areas that still have significant amounts of healthy structural and feeder root tissue.

Interaction of lesion nematodes and *R. fragariae*:
The demonstration that *P. penetrans* increased the severity of black root rot was an important step in understanding the disease complex, but many additional questions remained. We next conducted a series of experiments to determine whether *P. penetrans* had a local or systemic influence on *R. fragariae* infection and strawberry root rot and to examine the extent of *R. fragariae* infection of morphologically different strawberry root types alone and in relation to lesion nematode infection (LaMondia, 2003). The extent of *R. fragariae* infection of morphologically different strawberry roots was determined from an established planting of 3-year-old Honeoye strawberry crowns in field plots infested with lesion nematodes and the black root rot pathogen, *R. fragariae.* Plants were sampled from March to June over two years. Root systems were washed free of soil and separated into four classes: black suberized perennial roots, new healthy structural roots, fine lateral (feeder) roots from perennial roots and fine lateral roots from structural roots. Structural roots were further subdivided into roots with or without typical lesions caused by *P. penetrans*. *Rhizoctonia fragariae* was isolated on acidified water agar from ten 0.5-cm sections of surface sterilized roots in each class. Cross sections of morphologically different strawberry roots were also examined microscopically.

First year strawberry structural roots have a well-defined cortex that becomes disrupted and detached as a result of secondary growth. Polyderm and phellogen formation isolates and ruptures the cortex, which is sloughed off with the endodermis and epidermis as secondary growth occurs. The resulting perennial roots consist in large measure of woody xylem, polyderm and phellogen (alternating layers of suberized and unsuberized cells) (Esau, 1977). The remains of the cortical and epidermal cells are retained on the exterior of the perennial roots as an amorphous black layer (Figure 9).

Rhizoctonia fragariae infection and isolation from structural roots was greater in root segments with typical *P. penetrans* cortical lesions. The isolation of *R. fragariae* from structural roots increased over time during strawberry fruit production and the initiation of secondary growth associated with the transition from structural to perennial roots. This is consistent with our previous observation that strawberry root mass declined in field soils at fruiting due to fungal infection and root rot (LaMondia, 2002). May and Pritts (1994) also noted that the strawberry root system was the only plant part that declined in biomass during fruiting. Townshend (1963) and Wilhelm and Vertrees (1964) observed that the development of polyderm due to *P. penetrans* infection was associated with the presence of fungal hyphae visible in the cortex of strawberry roots.

Pratylenchus penetrans primarily infect feeder and structural roots rather than perennial roots (LaMondia, 2002), and tend to be aggregated in the root cortex. Zunke (1990) described two types of lesion nematode feeding. Brief feeding episodes weakened cells without cell death, while extended feeding resulted in cell collapse and death. We observed the death of individual cells through which lesion nematodes had moved, along with lighter discoloration of cells adjacent to these dead cells, perhaps as a result of feeding or diffusion of substances (Figure 10). Discoloration of the endodermis was observed in proximity to nematode infection without adjacent cell damage (LaMondia, 2003). Townshend (1963) and Zunke (1990) also reported that the presence of lesion nematodes was associated with discoloration of the endodermis despite the observation that lesion nematodes did not feed on the endodermis cells. Areas of *P. penetrans* aggregation in the cortex were distinguished by a reddish brown discoloration and eventually by a distinct, usually elliptical, sunken lesion resulting from cell necrosis. Fungal hyphae that appeared to be *R. fragariae* were observed in typical *P. penetrans* lesions. Chen and Rich (1962) observed that fungi infected roots more readily at necrotic areas caused by *P. penetrans* than at healthy areas of the root.

We demonstrated that *R. fragariae* was consistently isolated from both healthy and diseased perennial roots, which is consistent with previous observations that *R. fragariae* infects the sloughed cortex (Wilhelm and Nelson, 1970; Wilhelm et al., 1972). This colonized tissue on the exterior of woody perennial roots may act as a source of infection for adjacent feeder and structural roots. In fact, we determined that feeder roots attached to perennial roots were significantly more likely to be infected with *R. fragariae* than feeder roots attached to structural roots (LaMondia, 2003).

The role of *P. penetrans* in disease complexes may differ with the interacting root pathogen, with the crop plant, or with environmental conditions. The lesion nematode systemically increased Verticillium wilt in mint, caused by the vascular wilt pathogen *Verticillium dahliae*, in a split-root system (Faulkner et al., 1970). *Pratylenchus penetrans*, but not *P. crenatus*, interacted with *V. dahliae* to increase the severity of Verticillium wilt in potato, suggesting that the mechanism of interaction with the vascular-infecting fungus may be due to more than simply root wounding due to infection and feeding. *Pratylenchus scribneri* increased wilt under high temperature stress, but not in a cool year (Riedel et al., 1985).

However, lesion nematodes had no systemic effect on Verticillium wilt in tomato in a split-root system, and a disease increase was instead attributed to an increase in local infection courts (Conroy et al., 1972).

Our experiments using individual plants with split-root systems allowed the investigation of local versus systemic pathogen interactions. *Pratylenchus penetrans* increased the severity of strawberry black root rot caused by *R. fragariae* in a local, rather than systemic manner in these experiments (LaMondia, 2003). Infection of one half of a split-root system with both pathogens exhibited greater levels of black root rot than when similar numbers of the same pathogens were infecting different halves of the same root system. As cortical root rot pathogens, *Rhizoctonia* species have not been associated with systemic disease. The northern root-knot nematode *Meloidogyne hapla* has been shown to increase root rot by *R. solani* by increasing the number of infection courts and the density of growth in infected tissues, presumably due to wounding and increased nutrition available to the fungal pathogen (Khan and Muller, 1982). Similarly, the local influence of *P. penetrans* on black root rot suggests that increased numbers of infection sites due to wounding or the predisposition of limited areas of the cortex to infection may be responsible for the increased disease in strawberry roots seen in these experiments.

It appears that *R. fragariae* commonly resides on the sloughed cortex of healthy perennial roots. In fact, our isolation of the pathogen from non-inoculated crowns in split-root experiments has demonstrated that *R. fragariae* was present at low levels on commercially produced healthy strawberry crowns. From this source, the fungus may then infect structural or feeder roots, especially when the plant is under stress or roots are damaged. Lesion nematodes aggregate in the root cortex. Nematode feeding and movement directly result in cell damage and death. The indirect effects of lesion nematode infection are discoloration of the endodermis and early polyderm formation, followed by localized areas of secondary growth and cortical cell senescence or death. Weakened or dying cells resulting from the direct or indirect effects of *P. penetrans* are more susceptible to *R. fragariae*, thereby increasing the extent of infection and cortical root rot.

Facultative pathogens such as *Rhizoctonia solani* and certain *Fusarium* spp. may infect root cortical tissues without causing damage until the plant host is placed under stress (Leach, 1947). *R. solani* is a common mycorrhizal fungus in orchid roots. The fungus assists the plant with nutrient extraction from soil. However, when environmental conditions are unfavorable for the orchid host the fungus may become an aggressive pathogen of the very same roots (Harley, 1969). In fact, previous research has reported an apparent mycorrhizal/pathogenic relationship between *R. fragariae* and strawberry roots similar to the orchid and *R. solani* relationship (Molot et al., 1986; Ribeiro and Black, 1971) and consistent with our results.

Disease Management

Management of strawberry black root rot is difficult but very important. The *R. fragariae* and *P. penetrans* pathogens are widespread and common in strawberry plantings. Martin (1988) was able to isolate *R. fragariae* from more than 70% of plants from commercial strawberry fields in cultivation for more than one year. A survey of 41 commercial strawberry fields in Connecticut (paired for healthy versus stunted in each field) demonstrated that lesion nematodes occurred in greater than 75% of sampled plants. Stunted plants had nearly twice the *Pratylenchus* populations of adjacent healthier plants and populations ranged from undetectable to 2350 per g root (LaMondia et al., 2005).

Black root rot caused by *R. fragariae* and *P. penetrans* can have severe economic consequences. An economic analysis of lesion nematode populations in *R. fragariae* -infested field soils was conducted based on the regression of yield data with *P. penetrans* populations in small plots at the Connecticut Agricultural Experiment Station Valley Laboratory in Windsor CT. A 'Strawberry Profit Spreadsheet Template' model developed by DeMarree and Riekenberg (1998) was used to analyze the effects of nematodes on profitability. Based on four years of projected fruiting from a planting, strawberry profit expressed as a percentage of gross sales was predicted to be 33%, 30%, 18% or operation at a cumulative loss over four harvest years at initial densities of 0, 12, 50, or 125 *P. penetrans* per g root, respectively. Half of the samples from surveyed growers' fields had populations in excess of 125 nematodes per g root.

Disease Management: Chemical

Management of a disease complex caused by soil borne fungal and nematode pathogens may be achieved by fumigation with a broad-spectrum biocide such as methyl bromide or chloropicrin (Wolfe et al., 1990; Yuen et al., 1991). In fact, virtually all of the strawberry acreage in California is produced on soil fumigated with methyl bromide or chloropicrin (Martin and Bull, 2002). Fumigation is not always successful for a variety of physical and biological reasons, and the application of metham-sodium did not increase root growth, health or fruit yield (Yuen et al., 1991). The only management tactic associated with nearly complete control of lesion nematodes was fumigation with methyl bromide (LaMondia et al., 2005).

The efficacy of soil fumigation may be greatly reduced if the black root rot pathogens are reintroduced on the crowns transplanted into the field. *Rhizoctonia fragariae* has been consistently isolated from healthy nursery-produced planting stock (Ribeiro and Black, 1971; LaMondia, unpublished) and lesion nematodes may also be extracted at lower frequencies

(LaMondia, unpublished). Therefore, the use of healthy planting stock is of particular importance after fumigation or rotation, and the use of fumigation and other control tactics is especially important in nursery production.

In the absence of soil fumigation, alternative control tactics may be targeted at each of the pathogens in the complex. Application of non-fumigant nematicide such as fenamiphos (Nemacur) may result in temporary nematode control and can increase strawberry vigor and yield. However, nematode populations may still increase later in the season and may eventually be higher in nematicide-treated plants than in severely diseased plants, which lack sufficient roots to support nematode populations (LaMondia, 1999a). Repeated applications of nematicides or alternate methods for suppressing nematode populations may be required to maintain plant health and productivity over time.
The use of fungicides to suppress *R. fragariae* has been attempted and is currently under investigation, but no success has yet been reported. Fungicidal control of *R. fragariae* may best be concentrated at eliminating non-symptomatic infections from planting stock.

Terbacil (Sinbar) herbicide application has been associated with increased levels of strawberry root disease based on correlation analyses of grower survey responses (Wing et al, 1995). Our research in small plots at two locations over four years at up to four times label rates indicated that terbacil did not affect the health of perennial, structural or feeder roots (Mervosh and LaMondia, in press). Correlation analyses should not be used to imply causality and the correlation between terbacil use and root disease may rather be the result of increased weed pressure in declining strawberry fields.

Disease Management: Cultural and Biological
A number of non-chemical means of control have also been investigated. Rotation was one of the first management tactics suggested for black root rot (Zeller, 1932) and current recommendations continue to suggest rotation into small grains for two years (Pritts and Wilcox, 1990; Schroeder, 1988). Small grains have been suggested to suppress *Rhizoctonia solani*, (Zeller, 1932) but some *R. solani* AG are pathogenic to small grains (Weller et al., 1986) and the effects on *R. fragariae* are unknown. Rotation away from strawberry to unspecified crops reduced *R. fragariae* isolation from plants to about one third of that seen from continuous strawberry production (Martin, 1988). A dense planting of small grains may reduce broadleaf weeds, but the lesion nematode has a wide host range, including most small grains (Mai et al., 1977) and rotation with grains has been associated with increased lesion nematode damage to potato (Florini and Loria, 1990). Growers in Connecticut have rotated to small grains and still observed poor strawberry growth and black root rot symptoms.

Nematode antagonistic rotation or cover crops such as 'Saia' oat, sorgho-sudangrass, *Rudbeckia hirta*, pearl millet '101' and 'Polynema' marigold have been reported to suppress lesion nematode populations (LaMondia, 1999b; LaMondia and Halbrendt, 2003), but many of these crops have serious drawbacks which limit their utilization, such as seed availability, difficulty in establishment or cost. Additional plant species need to be evaluated for efficacy against *P. penetrans*, the black root rot complex, seed availability, low cost and ease of establishment.

Black root rot may also be reduced through the management of mineral nutrition. Ammonium forms of nitrogen nutrition resulted in less black root rot than when plants were fertilized with nitrate nitrogen. In field plots (Elmer and LaMondia, 1995) and microplots (Elmer and LaMondia, 1999) the severity of root disease was reduced by 10% to 20% and yields were increased by about 15%. Nitrogen form may influence plant mineral composition, the pH of the rhizosphere, and the microbial ecology of the rhizosphere (Elmer and LaMondia, 1999), any of which may affect the development of disease.

Biological and physical approaches to disease management have also been attempted. Entomopathogenic nematodes have been implicated in the reduction of root-knot nematode diseases (Bird and Bird, 1986), and *Trichoderma harzianum* (RootShield) has been an effective biological control of a number of fungi, including *Rhizoctonia* spp. (Yuen et al., 1994). In small plots and field microplots, inundative application of entomopathogenic *Steinernema* carpocapsae or *S. feltiae* did not impact *P. penetrans* populations and *T. harzianum* did not affect the development of strawberry black root rot by *R. fragariae*. In the Pacific Northwest, soil solarization for two months significantly reduced strawberry root necrosis and root infection by a number of fungi including *R. fragariae* (Pinkerton et al., 2002). However, solarization did not eliminate the pathogens from the soil.

Disease Management: Summary
Black root rot management, in the absence of fumigation, may need to rely on the combination of several factors to be effective, some still under development. These management tactics may include: Rotation into new fields with low or undetectable lesion nematode populations; rotation to fields not previously planted to strawberry or rotated away from strawberry for 1 or 2 years; the identification of effective and practical nematode and *R. fragariae*-antagonistic rotation or cover crops; the possible future use of fungicides effective against *R. fragariae*, the use of pathogen-free crowns as planting stock; control of lesion nematodes, when present, at low levels with non-fumigant nematicides such as Nemacur; fertilization with ammonium forms of nitrogen rather than nitrate forms; the use of raised beds with irrigation to avoid

soil compaction and excess water or drought; mulching to avoid winter injury; and weed control to reduce plant stress as well as plants that are often hosts of lesion nematodes.

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Questions or Comments about the New York Berry News?

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