Special Edition | September 2017

The Northwest Berry Foundation's

SMALL FRUIT UPDATE

Research Update for Commercial Raspberry Growers:
Soilborne Disease & Nematode Management in a Changing Fumigation Landscape

Over the past 10 years, the research group considered many aspects of the raspberry production system.
The result: improved or alternative management of these organisms is achievable. Many opportunities exist both pre- and post-plant to deploy practices that will reduce pathogen and nematode populations and potentially improve plant productivity.

RESEARCH GROUP

INGA ZASADA
USDA-ARS, Corvallis, OR.
Inga.zasada@ars.usda.gov

LISA DEVETTER
WSU, Mount Vernon, WA.
Lisa.devetter@wsu.edu

TOM WALTERS
Walters Ag Research, Anacortes, WA.
waltersagresearch@frontier.com

JERRY WEILAND
USDA-ARS, Corvallis, OR. Jerry.
weiland@**ars.usda.gov**

FUNDING

- USDA-NIFA RAMP Project 2010-511001-21649
- Washington Red Raspberry Commission
- Washington Pesticide Commission
- Washington Specialty Crops Research Initiative Block Grant
- USDA-ARS CARE Project 2014-09501
- USDA-ARS CRIS Project5358-22000-003-00D

OVERVIEW

CONTENTS

- Overview
- Target organisms
- Economic Damage
- Decision chart
  1. Decide to replant
  2. Sampling
  3. Pre-plant management
  4. Planting material selection
  5. Plant establishment
  6. Post-plant management
- Fumigant Options (pre-plant)
- Non-fumigant Options (pre-plant)
- Conclusions
- Resources

- Soilborne diseases and plant parasitic nematodes are primary economic pests in the northwest commercial raspberry industry
- These pests have traditionally been managed through the use of pre-plant fumigants.
- The implementation of much more stringent regulations on the use of pre-plant fumigants along with increasing material costs and decreasing availability have led to the need for alternative management strategies.
- There's been a large investment of public funds researching altenative management strategies and tools.
- This Update is intended as a synopsis of this research as well as an overview of the present state of management options
- It is also meant to be a practical decision making guide for growers and their advisors.

THIS SPECIAL EDITION SMALL FRUIT UPDATE IS MADE POSSIBLE BY OUR SPONSORS:

WASHINGTON Blueberries

BRITISH COLUMBIA Strawberry GROWERS ASSOCIATION

british columbia raspberries

OREGON STRAWBERRIES

BC Blueberries Nature's Candy

Blueberries NORTH AMERICAN BLUEBERRY COUNCIL

WASHINGTON Red Raspberries

OREGON RASPBERRIES & BLACKBERRIES

Oregon Blueberry COMMISSION

TARGET ORGANISMS

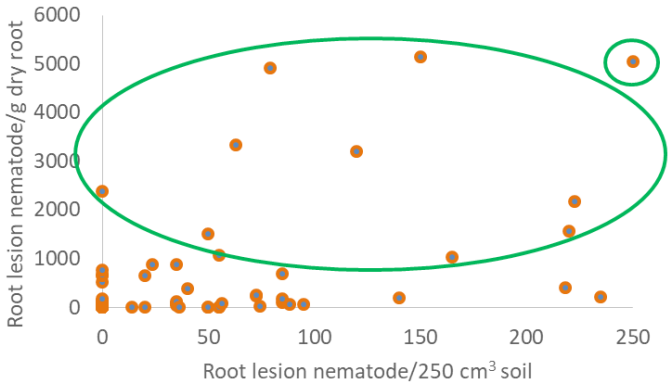
PRATYLENCHUS PENETRANS (ROOT LESION NEMATODE)

Migratory endoparasitic nematode feed inside roots, tunneling inside and moving back into soil and to new roots at will.

- This nematode has a host range that includes over 400 plant species, making this a very difficult nematode to control.

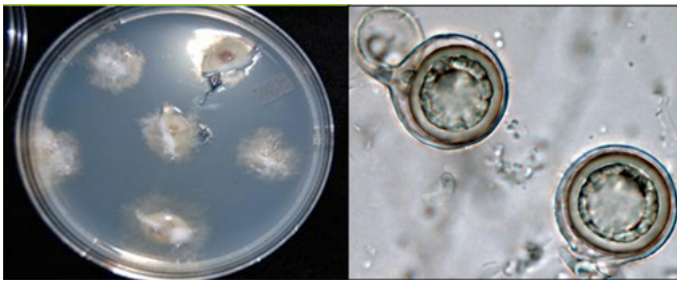
Pratylenchus penetrans, the root lesion nematode, is a migratory endoparasite that moves between roots and soil. Photo by Nema Pix.

Root lesion nematode populations in soil below the proposed threshold of 250 nematodes/250 cm3 soil (McElroy 1992) may underestimate a nematode problem. For example, in this figure soil population densities of 79 and 150 nematodes/250 cm3 soil were not reflective of very high (~5,000 nematodes/g root) populations in roots. Figure by I. Zasada



PHYTOPHTHORA RUBI

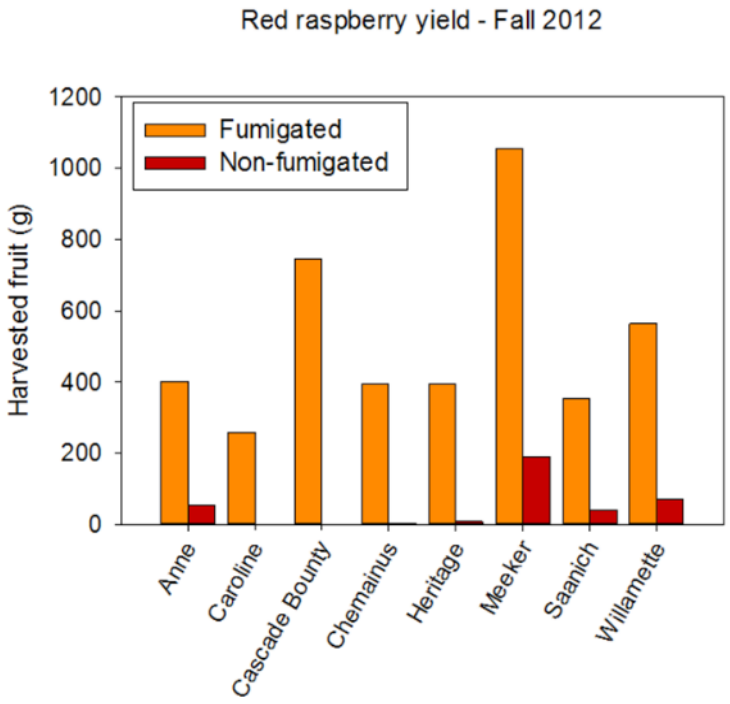
An oomycete (fungus) pathogen that produces both motile zoospores and resistant oospores that make management difficult.



Phytopthora rubi, causes root rot in raspberry. Mycelium (left) and oospores (right) of P. rubi. Photo by Jane Stewart.

Other soilborne pathogens and nematodes known to be present in raspberry include the fungal pathogen *Verticillium dahliae* and the plant-parasitic nematodes *Xiphinema bakeri* and the virus-vectoring *X. americanum*. Our experience in evaluating soil and root samples over the past years indicate that these nematodes are not widespread in northwestern raspberry fields. *Verticillium dahliae* is widespread in many northwestern raspberry fields, but is usually not associated with severe disease symptoms.

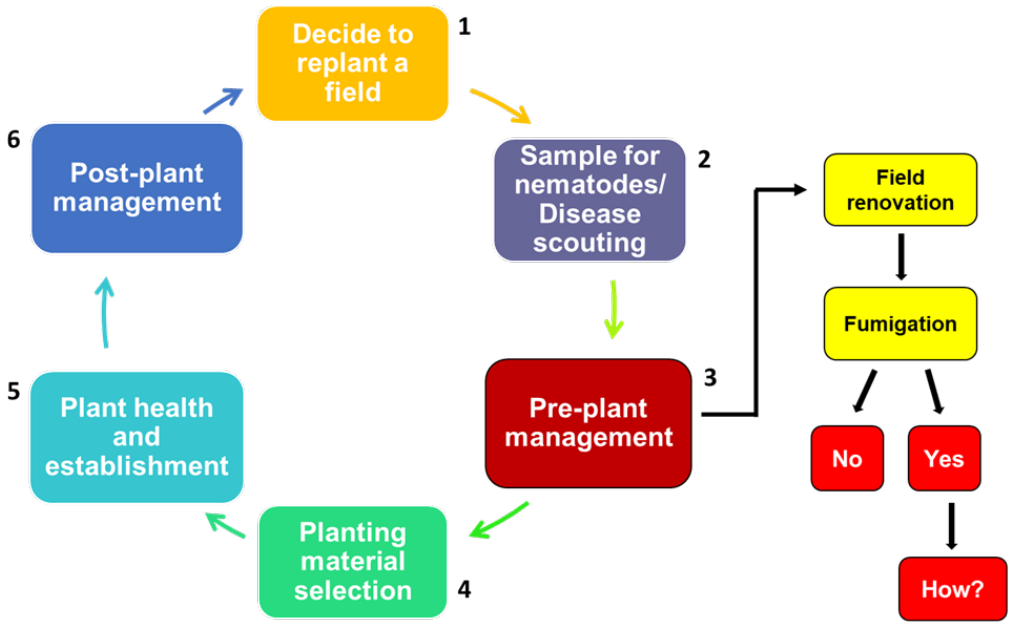
ECONOMIC DAMAGE



SOILBORNE PATHOGENS AND NEMATODES LIMIT YIELD IN RASPBERRIES.

First year yield of several raspberry cultivars when grown in fumigated soil with few root lesion nematodes and nonfumigated soil with large population densities of root lesion nematode. There was a significant reduction in yield of plants grown in nonfumigated soil compared to fumigated soil. Figure by I. Zasada

DECISION MAKING PROCESS



1. DECIDE TO REPLANT A FIELD

Reasons to replant a field:

- It no longer makes commercially viable yields
- Fruit quality has decreased
- A cultivar change is required

This is the most important time to consider ways to reduce population densities of soilborne pathogens and nematodes.

2. DISEASE SCOUTING AND SAMPLING FOR NEMATODES

Disease scouting: Phytophthora rubi

Root rot symptoms begin early in the growing season and are the most severe on floricanes in June as fruit begins to ripen and on primocanes in late summer. Symptoms include:

- Low vigor, stunted growth, low yield and sparse plant stand.
- Canes and leaves on mature plants suddenly wilt and yellow or bronze, and scorch and die in early spring.
- Fruit stems are shortened and berries, if formed, are small and wither before ripening.
- Reddish-brown root lesions may extend up into the canes. These lesions are visible throughout the growing season on canes that are beginning to die
- Plants frequently occur in patches, which may spread along rows.

Phytophthora rubi is the most aggressive soilborne pathogen in raspberry causing severe damage and plant death, particularly in poorly drained soils.

Symptoms of wilt caused by Verticillium dahliae or Phytopthora rubi on a primocane of red raspberry. Photo by J. Weiland

Redish-black lesion caused by Phytopthora rubi underneath the epidermis of raspberry 'Meeker' cane. Photo by J. Weiland

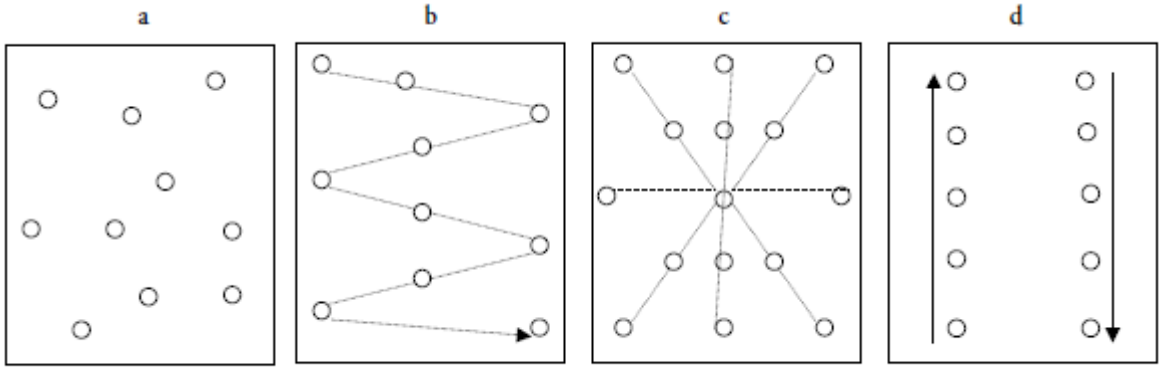
2. DISEASE SCOUTING AND SAMPLING FOR NEMATODES, CONTINUED

Sampling for nematodes:

The symptoms caused by plant-parasitic nematode feeding are non-descript and include:

- smaller plants
- reduced yield
- generally unthrifty plants
- Plants may wilt in the heat of summer.

Whether collecting soil or root samples, collect samples near the crown of the plant and down to a depth of 12 inches. Collect root samples prior to crop removal or in established crops to diagnose a problem.



Sampling patterns for nematodes. (a) Random sampling; (b–d) systematic sampling.

• It is difficult to establish action thresholds for nematodes on perennial crops because plants can compensate for nematode parasitism from year-to-year with root reserves; environmental conditions may also lessen or exacerbate a nematode problem. However, McElroy (1992; http://journals.fcla.edu/jon/article/view/66424/64092) proposed the following thresholds in his "Health Care Program for Brambles in the Pacific Northwest". These thresholds are only for soil samples.

• Preplant - >250 root lesion nematode/250 cm3 soil

• Postplant – 500 to 2,000 root lesion nematodes/250 cm3 soil

• Raspberry growers are accustomed to collecting soil to determine nematode population densities and diagnose a problem.

• However, our research shows that root samples are better than soil samples because this is the location where root lesion nematodes feed. The collection of only soil samples may underestimate the extent of the problems noted in the figure on page 3.

DECISION MAKING PROCESS

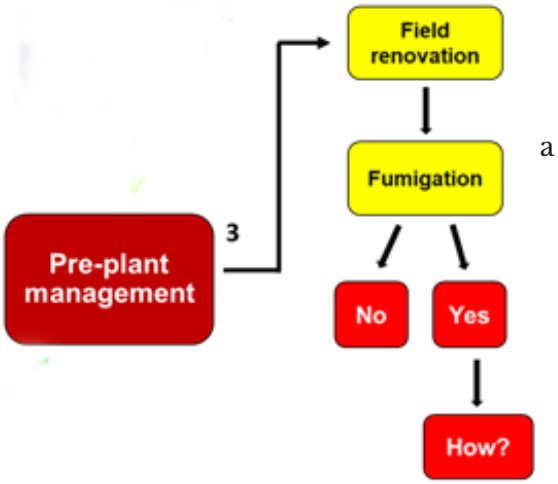
3. PRE-PLANT MANAGEMENT

"Yes or no" with regards to pre-plant management.

- If "no" is the answer, then be aware that there are few ways to mitigate soilborne pathogen or nematode problems once plants are established.
- If the answer is "yes", then there are several things to consider.

Field renovation

- Treating plants with systemic herbicides prior to mowing will decrease the longevity of root lesion nematodes in roots.
- Once the roots die, the nematodes will leave the roots and enter the soil where they will either die or are more easily managed.
- Normal field renovation activities should break up hard pans and prep the soil for fumigation. (Discuss with your fumigation applicator how soil should be prepared for effective fumigation.)



The research team evaluated whether the removal of raspberry root material prior to fumigation improves root lesion nematode control. The short answer is no. The effect of root removal on soilborne pathogens could not be evaluated, however, because the overall fumigation treatment was also ineffective at controlling soilborne pathogens

- See page 14 for non-fumigant preplant management options.
- See pages 11-13 for pre-plant fumigant options

Rotation

- Crop rotation will not reduce population densities of *Phytophtora rubi* or root lesion nematode in the raspberry production system. For *Phytophtora rubi*, the pathogen produces long-lived survival structures that would require a long-term rotation to reduce populations to non-damaging levels.
- The wide host range of the root lesion nematode makes it very difficult to rotate to a crop that is not a host or to maintain a weed-free fallow period for long enough to reduce population densities.

Summer cover crops

- In the Pacific Northwest, the use of brassica cover crops has received a lot of attention in apple and potato production systems for the management of plant-parasitic nematodes.
- No research has specifically been conducted on the use of brassica cover crops prior to establishing a raspberry planting for the management of root lesion nematode.
- However, it is known that *Brassica juncea* is more effective than *Sinapis alba* or *Brassica napus* for nematode control because of the type of chemical compound produced by this plant upon incorporation into soil. It is also known that all of these species are hosts for root lesion nematode.
- If considering use of a brassica cover crop, contact your local agricultural specialist to ensure production will not interfere with commercial brassica seed production that may be occurring in your area.
- Also, ensure seed is clean to limit spread of brassica diseases, such as black leg (*Phoma lingam* (= *Leptosphaeria maculans* and *Leptosphaeria biglobosa*).

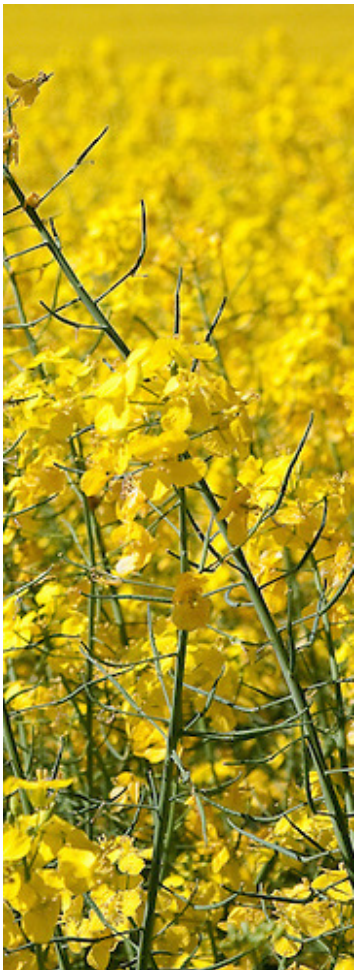


Photo by R. Rudolph

3. PRE-PLANT MANAGEMENT, CONTINUED

Amendments

- Application of dairy manure solids and composted dairy manure solids had no effect on root lesion nematode populations in raspberry (Forge and Walters 2014)
- Mustard seed meal applied preplant was ineffective in reducing densities of root lesion nematode in raspberry. This treatment requires high rates (1.5 t/ha) and is expensive (~$1,800/ton). Higher rates may be effective, but the cost of mustard seed meal limits commercial use of this material.

Bed fumigation with various fumigant products will become more common in raspberry. The research team demonstrated that bed fumigation is as effective as broadcast fumigation to control root lesion nematode and root rot, and resulted in similar yields. Photo by T. Walters

Soil fumigation

There are alternatives to broadcast fumigation with Telone C-35, the industry standard.

- Every effort should be made to minimize fumigant emissions from soil, to minimize applicator and bystander exposure and to maintain toxic concentrations of fumigants in soil to improve their efficacy against soilborne pathogens and nematodes. This includes water seals, rolling, and tarps.
- Leaving alleyways untreated in bed fumigation experiments did not result in an increase in densities of root lesion nematodes in the raspberry bed. However, there may be a risk of *P. rubi* moving into beds under flooded conditions.
- Your soil type affects how well fumigants are going to work. Soils with high sand content respond better to shallow-applications of fumigants, like Vapam. This same soil type will potentially allow for off-gasing of fumigants containing 1,3-dichloropropene (Telone C-35 and Pic-Clor 60).

4. PLANTING MATERIAL SELECTION

- Raspberry cultivars with resistance/tolerance to Phytopthora root rot are available and include 'Cascade Bounty' and 'Cascade Delight'.
- There are no raspberry cultivars with resistance/tolerance to root lesion nematode. When the floricane raspberry cultivars 'Meeker', 'Cascade Bounty', 'Willamette', 'Saanich', and 'Chemainus' were grown in areas with root lesion nematode, there was a dramatic reduction in first year yield in a field with very high root lesion nematode population densities compared to plants grown in fumigated areas with few root lesion nematodes. (see the figure on page 4)

Cascade Delight has tolerance to Phytopthora root rot.

5. PLANTING HEALTH & ESTABLISHMENT

Minimize plant stress and encourage root growth to reduce the impact of soilborne pathogens and plant-parasitic nematodes.

- This is especially true during the plant establishment period (from planting to up to three years after planting) so that plants can establish robust, extensive root systems. Improved plant health may be achieved through proper and timely irrigation and fertilization, weed management, and adequate soil conditions (well-drained soils with no hard pan).
- Research has also been conducted on the use of plant growth promoters which may or may not allow the plant to compete with soilborne pathogens and nematodes.

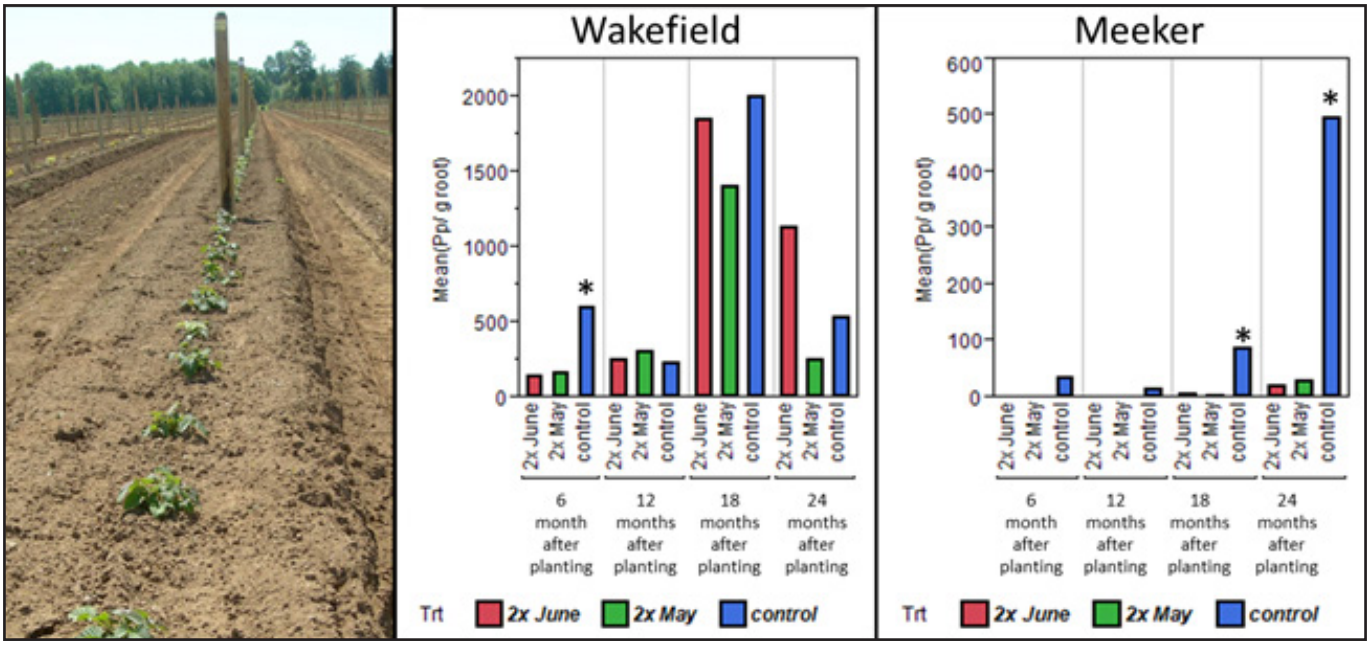
5. POST-PLANT MANAGEMENT (FUNGICIDES AND NEMATICIDES)

- The most commonly used fungicides for Phytophthora root rot control in raspberry are phosphorous acid (many trade names) and mefenoxam (Ridomil Gold) Reliance on a single fungicide chemistry, particularly mefenoxam, may lead to fungicide resistance. Therefore, it is important to rotate among fungicide chemistries to prevent the continued selection for and spread of fungicide resistant isolates. Surveys have shown that mefenoxam resistance in *Phytophthora rubi* isolated from raspberry production fields is rare.
- There are several products labeled for post-plant nematode control in raspberry – few have been evaluated in Washington on raspberry, therefore, efficacy is unknown.

REGISTERED POST-PLANT NEMATICIDES FOR USE IN RASPBERRY IN WASHINGTON: *Data from WSU Pesticide Information Center Online (PICOL) accessed July 2017 (http://cru66.cahe.wsu.edu/LabelTolerance.html). Many of these products have not been evaluated specifically in Washington on raspberry. Always consult the label prior to applying a pesticide. Table by I. Zasada.*

Name	Ingredient	Type of nematicide
Admire Pro, Alias, Nuprid	Imidacloprid	Chemical
Azaguard, Azamax, Azasol, Azatin, Azatrol, Biosafe, Debug, Ecozin, Azatrol, Mot-X, Neemix	Azadirachtin	Botanical
Melocon	*Paecilomyces lilacinus*	Biological
Debug, Neem Pro, Neemix, Plasma Neem	Neem oil	Botanical
Monterey	*Quillaja saponins*	Botanical
Vydate	Oxamyl	Chemical
Ditera	*Myrothecium verrucaria*	Biological

- In 2012, Washington raspberry growers were granted a special local needs (SLN) label for the application of Vydate (oxamyl) on nonbearing raspberry – applications must occur one year prior to fruit harvest.
- Our research demonstrates that this treatment is effective in reducing root lesion nematode populations. However, it may be more effective in fields with low nematode population densities (< 500 root lesion nematodes/g root). Consult the label for specific rates and application recommendations.



The efficacy of a nonbearing application of Vydate applied two times in either May or June was evaluated in raspberry (above). This treatment was very effective at reducing root lesion nematode populations as plant established. Long-term efficacy was observed in fields with lower (<500 nematodes/g root) densities of root lesion nematode. Photo by T. Walters and figure by I. Zasada.

FUMIGANT OPTIONS (PRE-PLANT)

PROS AND CONS OF PRE-PLANT FUMIGANT MANAGEMENT OPTIONS IN RASPBERRY.

Disclaimer: Always consult the label before applying a product. Mention of trade names or commercial products in this document is solely for the purpose of providing specific information and does not imply recommendation or endorsement by USDA and WSU.

TELONE C-35 (34.7% CHLOROPICRIN:63.4% 1,3-DICHLOROPROPENE)

	PRO	CON
Broadcast application without a tarp	• What raspberry growers are familiar with • Mixture favors nematode control over root rot (*Phytophthora rubi*) control	• Not available • In some soils with high sand content, limited efficacy at shallow soil depths • Mixture favors nematode (*Pratylenchus penetrans* and *Xiphinema* spp.) control over root rot control • Larger buffer zones
Broadcast application with a tarp	• Tarping improves efficacy at shallow soil depths • Mixture favors nematode control over root rot control • Smaller buffer zones	• Not available • Mixture favors nematode control over root rot control • Tarp is an added up-front cost
Bed application without a tarp	• Available • Mixture favors nematode control over root rot control • Leaving alleyways untreated has not been demonstrated to be an issue for nematode control • Smaller buffer zones	• Mixture favors nematode control over root rot control • Leaving alleyways untreated may be an issue for root rot control
Bed application with a tarp	• Tarping improves fumigant efficacy • Smaller buffer zones	• Not available • Tarp is an added up-front cost

PIC-CLOR 60 (59.6% CHLOROPICRIN:39% 1,3-DICHLOROPROPENE)

	PRO	CON
Broadcast application without a tarp	• Available • Mixture favors root rot control over nematode control	• Mixture favors root rot control over nematode control • In some soils, limited efficacy at shallow soil depths • Larger buffer zones
Broadcast application with a tarp	• Available • Mixture favors root rot control over nematode control • Tarping improves fumigant efficacy • Smaller buffer zones	• Mixture favors root rot control over nematode control • Not available • Tarp is an added up-front cost
Bed application without a tarp	• Available • Mixture favors root rot control over nematode control • Leaving alleyways untreated has not been demonstrated to be an issue for nematode control • Smaller buffer zones	• Mixture favors root rot control over nematode control • Leaving alleyways untreated may be an issue for root rot control
Bed application with a tarp	• Tarping improves fumigant efficacy • Smaller buffer zones	• Not available • Tarp is an added up-front cost

FUMIGANT OPTIONS (PRE-PLANT)

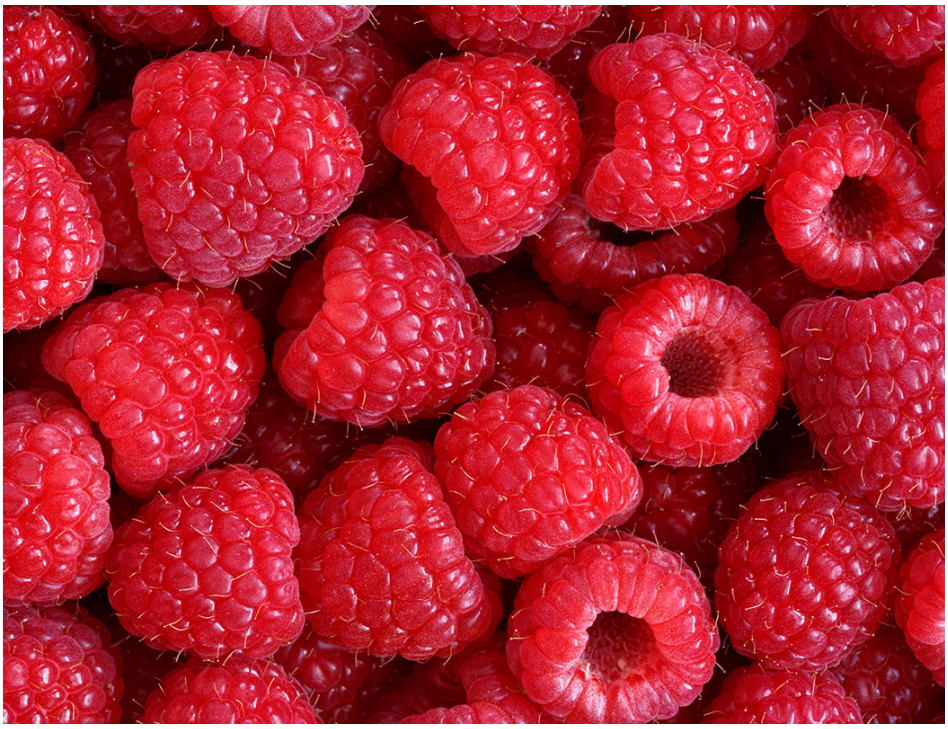
VAPAM (SODIUM METHYLDITHIOCARBAMATE) AND K-PAM (POTASSIUM N-METHYLDITHIOCARBAMATE)		
	PRO	**CON**
Broadcast application without a tarp	• Available • Affordable • Broad-spectrum fumigant (nematodes and root rot)	• May not target organisms deep in soil profile • No commercial application equipment available
Broadcast application with a tarp	• Available • Affordable • Broad-spectrum fumigant • Improved efficacy over nontarped application	• May not target organisms deep in soil profile • No commercial application available • Tarp is an added up-front cost
Bed application without a tarp	• Available • Affordable • Broad-spectrum fumigant	• May not target organisms deep in soil profile • No commercial application available
Bed application with a tarp	• Available • Affordable • Broad-spectrum fumigant • Improved efficacy over nontarped application	• May not target organisms deep in soil profile • No commercial application available • Tarp is an added up-front cost
Drip applied for crop termination	• Used effectively in other cropping systems	• Has not been tested in raspberry

BASAMID (TETRAHYDRO-3,5-DIMETHYL-2H-1,3,5-THIADIAZINE-2-THIONE)		
	PRO	**CON**
Broadcast application without a tarp	• Available • Affordable • Broad-spectrum fumigant • Experience with this product by Canadian raspberry growers	• No commercial application available • May not target organisms deep in soil profile • Irrigation required
Broadcast application with a tarp	• Available • Affordable • Broad-spectrum fumigant • Improved efficacy over nontarped application	• No commercial application available • May not target organisms deep in soil profile • Irrigation required • Tarp is an added up-front cost
Bed application without a tarp	• Available • Affordable • Broad-spectrum fumigant	• No commercial application available • May not target organisms deep in soil profile • Irrigation required • Tarp is an added up-front cost
Bed application with a tarp	• Available • Affordable • Broad-spectrum fumigant • Improved efficacy over nontarped application	• No commercial application available • May not target organisms deep in soil profile • Irrigation required • Tarp is an added up-front cost

FUMIGANT OPTIONS (PRE-PLANT)

DOMINUS (ALLYL ISOTHIOCYANTE)		
	PRO	**CON**
Broadcast application without a tarp	• Available • Broad-spectrum fumigant • Smaller buffer zones	• Expensive • May not target organisms deep in soil profile
Broadcast application with a tarp	• Available • Broad-spectrum fumigant • Smaller buffer zones • Tarping improves fumigant efficacy	• Expensive • May not target organisms deep in soil profile • Tarp is an added up-front cost
Bed application without a tarp	• Available • Broad-spectrum fumigant • Smaller buffer zones	• Expensive • Questions regarding mobility in soil
Bed application with a tarp	• Available • Broad-spectrum fumigant • Smaller buffer zones • Tarping improves fumigant efficacy •	• Not available • Expensive • Tarp is an added up-front cost
Drip applied for crop termination		• Has not been tested in raspberry • Expensive

INLINE (33.8% CHLOROPICRIN:60.8% 1,3-DICHLOROPROPENE)		
	PRO	**CON**
Drip applied for crop termination	• Used effectively in other cropping systems	• Has not been tested in raspberry



NON-FUMIGANT OPTIONS (PRE-PLANT)

	PRO	CON
SOIL SOLARIZATION	• Effective in some systems and climates • No buffer zones	• Climate in northern WA marginal for this practice • Inconsistent nematode and root rot control across years
ROTATION	• Allows the land to rest	• If weeds are allowed to grow, many are hosts for root lesion nematode; perennial weeds can also be difficult to control • Most available cover crops are a host to root lesion nematode • Unknown how long land needs to be out of raspberry production for root rot control • Increased herbicide usage • Increased tillage • Land out of raspberry production for an extended period
BRASSICA SEED MEAL	• Provides additional nitrogen to the system • Potential for improved soil health • No buffer zones	• Expensive • Not widely available • Nematode control results are inconsistent
BRASSICA COVER CROPS	• Addition of organic matter into the soil • Potential for improved soil health • No buffer zones	• Many brassica cover crops are hosts for root lesion nematode • Land out of raspberry production for an extended period • Nematode control results are inconsistent • Unknown root rot control • Need to exercise care when purchasing seeds – they need to be treated so that they are not hosts to black leg [*Phoma lingam* (sexual stage: *Leptosphaeria maculans*)] • In some areas, need to make sure they don't encroach on isolation distances for brassica seed production
ANAEROBIC SOIL DISINFESTATION	• Some promising results for soil fungal and pathogen management • No buffer zones	• Climate in northern WA likely too cool and marginal for this practice • Practice requires use of labile carbon source • Inconsistent results
POST-PLANT FUNGICIDES	• Mefenoxam and fosetyl-Al products registered for use on raspberry	• Resistance can be a concern if mefenoxam is overused
POST-PLANT NEMATICIDES	• Label for nonbearing oxamyl available • Several other nematicides registered for use in raspberry	• Efficacy of many of registered nematicides in the raspberry system is unknown

Winter Cover Crops
Using winter cover crops is a positive practice that reduces soil erosion and increase soil organic matter. However, be aware that 'Bobtail' and 'Rosalyn' winter wheat, which are commonly grown as a winter cover, are very good hosts for root lesion nematode.

CONCLUSIONS & RESOURCES

CONCLUSIONS

- There are alternatives to traditional broadcast Telone C-35 available to manage soilborne pathogens and plant-parasitic nematodes.
- An integrated approach utilizing many different management tools at different stages during the raspberry production life cycle is encouraged.
- Not all alternative management practices will work on all sites because of variability associated with soil type, nematode population densities, soilborne pathogens present, raspberry cultivar, etc.
- The research team encourages growers to experiment with some of these management practices to increase familiarity with the practices and to determine field-specific efficacy.

RESOURCES

Distribution and Longevity of the Nematode Pratylenchus penetrans in the Red Raspberry Production System: *An article in the 2016 Journal of Nematology that starts out -- "The Pacific Northwest produces a majority of the processed red raspberries (Rubus idaeus) in the United States. Within this region, Washington produces 95% of the country's total with an estimated value of over $65 million in 2015 (USDA, 2016). One of the most important factors limiting production of raspberry in this region is the presence of the plant-parasitic nematode Pratylenchus penetrans."*

Alternatives to Current Fumigation Practices in Western States Raspberry: *Over several years bed fumigation as an alternative to broadcast fumigation was evaluated in several northern Washington red raspberry fields. Bed fumigation performed as well as, and sometimes better than broadcast fumigation for the control of root lesion nematode and Phytophthora rubi and produced comparable yields.*

What Is Biofumigation and Does It Have Potential to Be Used in Pacific Northwest Red Raspberry Production Systems? *Biofumigation is an approach to soilborne pest and pathogen management that involves the use of plants primarily from the Brassicaceae family (e.g., mustards, cauliflower, and broccoli) in rotation with cash crops (Kirkegaard et al., 1993).*

Evaluating Soil Fumigation Alternatives in Washington Raspberry Fields: *A report that summarize research trials comparing broadcast applications of Dominus and Vapam to Telone C-35, as well as bed fumigation trials.*

Effect of Application Timing of Oxamyl in Nonbearing Raspberry for Pratylenchus penetrans Management: *In 2012, the Washington raspberry (Rubus idaeus) industry received a special local needs (SLN) 24(c) label to apply Vydate L (active ingredient oxamyl) to nonbearing raspberry for the management of Pratylenchus penetrans. This is a new use pattern of this nematicide for raspberry growers; therefore, research was conducted to identify the optimum spring application timing of oxamyl for the suppression of P. penetrans.*

FOR MORE INFORMATION:
http://smallfruits.wsu.edu/
http://zasadalab-usda-ars-hcru.weebly.com/