Preplant Soil Fumigation and Alternatives for Berry Production

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS064E

Introduction

Establishment of commercial berry crops (predominantly raspberries, strawberries, and blueberries) in Washington requires extensive labor and expense, in addition to the continual costs of maintenance and harvest each season. Soilborne diseases, plant-parasitic nematodes, and weeds can be devastating to a berry planting, and preplant soil fumigation is commonly relied upon to mitigate the risk of crop loss. However, soil fumigation is expensive and fumigant products can be highly toxic if improperly handled or applied. This guide is intended to help growers understand the reasons for soil fumigation, techniques for preparing a field for fumigation, new regulations on soil fumigant use in Washington state, and alternatives to traditional broadcast fumigation with synthetic chemicals.

Reasons for fumigation

In berry production systems, fumigation is commonly used to control soilborne diseases, plant-parasitic nematodes, and weeds. Soilborne diseases and plant-parasitic nematodes are common in raspberry, strawberry, and blueberry. For raspberry in Washington, the most important soilborne disease is Phytophthora root rot caused by *Phytophthora rubi* (Figure 1). This disease causes infected plants to wilt and die, and can spread rapidly through a field (Wilcox, 1991). On average, 9% of annual costs for growers is directed towards pesticide applications to prevent Phytophthora root rot (MacConnell and Kangiser, 2007). The most important plant-parasitic nematodes include *Pratylenchus penetrans* (root lesion nematode) (Figure 2) and *Xiphenima spp.* (dagger nematode). Nematode-infested raspberries decline in productivity over 3–4 years (McElroy, 1991), and must be replaced at tremendous expense. Growers with extensive root rot or nematode pressure in their fields typically remove the planting after harvest, fumigate in the fall, and replant with new nursery stock the following spring. However, subsequent plantings frequently lack the vigor and productivity of the initial planting, leading many to suspect that there is a raspberry replant disorder similar to those described for apple, grape, almond, and other perennial systems (Merwin et al., 2001).

Strawberries are susceptible to black root rot, typically caused by a complex that can include *Rhizoctonia spp.*, *Pythium spp.*, the root lesion nematode, and other organisms. Strawberries are also susceptible to other diseases of

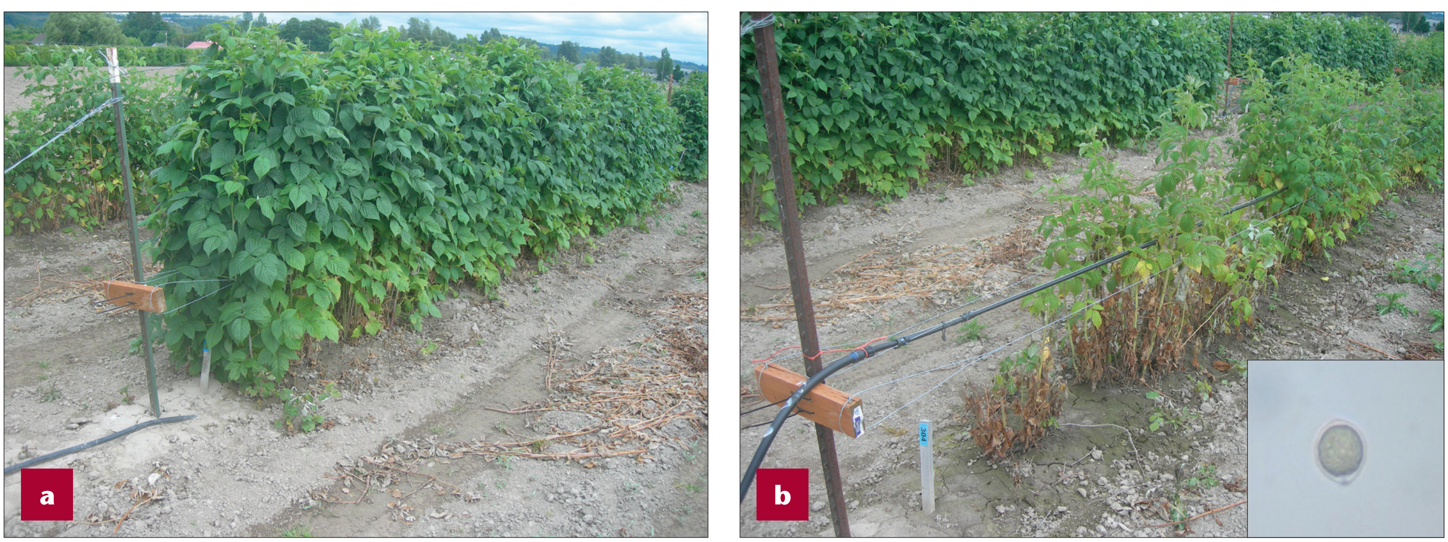

Figure 1. A) Healthy raspberry plot and B) plot infected with Phytophthora rubi *(oospore in inset at lower right).*

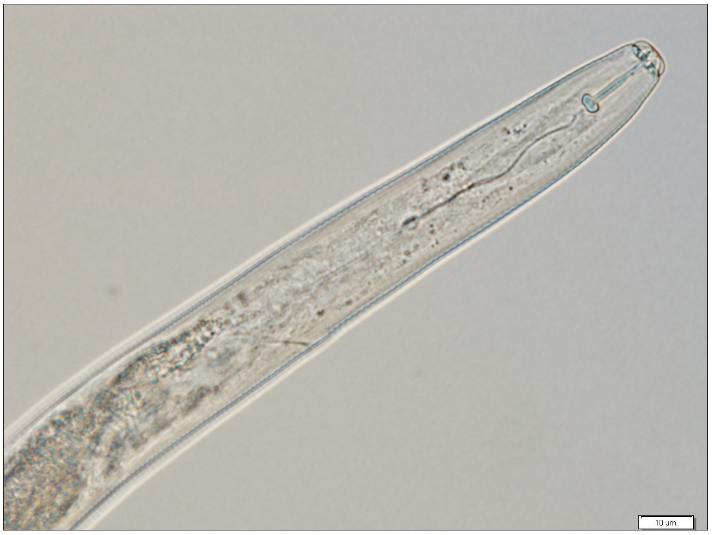

Figure 2. Head of an adult root lesion nematode, **Pratylenchus penetrans.**

the root and crown, including red stele disease caused by *Phytophthora fragariae* and Verticillium wilt caused by *Verticillium dahliae*.

Blueberry root diseases are less commonplace, but blueberries can be severely damaged by Phytophthora root rot caused by *P. cinnamomi*. Plant-parasitic nematodes are not typically a problem on blueberries in Washington, but the crop is susceptible to tomato ringspot nepovirus, vectored by the dagger nematode *X. americanum*. Even small numbers of *X. americanum* are sufficient to spread tomato ringspot virus, so the tolerance for this nematode is very low.

Crop rotation is an important practice for controlling soilborne diseases and nematodes. However, since berry crops have specific soil needs and farmland suitable for berry production is limited, many growers will commonly plant back to the same type of crop. The use of crop rotation for disease management is further restricted by the fact that many of these disease organisms produce resting spores or structures that allow the pathogen to persist in the soil for several years (Ellis et al., 1991; Wilcox, 1991).

Although fumigation can effectively manage many weeds, it is not usually used primarily for weed control. Weed populations vary greatly from one field to another, but perennial weeds such as quackgrass (*Elytrigia repens*) and yellow nutsedge (*Cyperus esculentus*) are typically the most difficult weeds to manage in berry systems. Certain hard-seeded weeds such as white clover (*Trifolium repens*) are sometimes exacerbated by fumigation, which can scarify their seed coats. Effective preplant and postplant weed management programs are available for most weed problems (Peachey, 2011).

Fumigant and rate selection is largely guided by field weed and disease history and soil testing for nematodes. A field with a history of raspberry root rot within the past five years should be considered likely to develop root rot again unless fumigation or other corrective measures are taken. Nematode population levels are assessed through soil testing. A database of laboratories providing nematode analysis in the Pacific Northwest is available online (http://www.puyallup.wsu.edu/analyticallabs/). Fields to be planted to raspberry with > 100 *P. penetrans*/100 g soil should be fumigated, as should fields to be planted to raspberry or blueberry with *X. americanum* (McElroy, 1991). Depending upon the pathogens targeted, most fields are fumigated with 1,3-dichloropropene alone or in combination with chloropicrin (Table 1, Telone II, Telone C-17, Telone C-35). Fields can also be fumigated with metam-containing products such as Vapam, but they are less volatile than the 1,3-D: chloropicrin mixtures and it is difficult to distribute them sufficiently throughout the soil profile.

Fumigation techniques

Late August through September, while soil temperatures remain above 50°F, is an optimal time to fumigate. This allows berry growers to harvest the crop, remove existing plants and trellising, and prepare the soil for fumigation. It is best to wait one full year between crop removal and fumigation to allow crop residues to degrade, but unfortunately this is not always practicable.

Washington berry growers usually hire a custom applicator to fumigate due to the specialized application equipment, the toxic nature of the fumigants, and the extensive regulation of fumigant applications. Even when hiring a custom applicator, however, it is the grower's responsibility to properly prepare the field for fumigation.

Field preparation for fumigation is similar to preparing a seedbed. The ground should be subsoiled in more than one direction to break up any hard pan present, and it should be worked to a seedbed-like texture, free from large clods and with a minimum of crop debris. Pathogens can survive fumigation within large pieces of debris, and debris can also provide channels through which fumigant gases can prematurely escape from the soil. Soil moisture should be conducive to an easily-worked soil, typically 50–70% of field capacity. Soil temperature at the depth to be fumigated (typically measured at 8") should be greater than 50°F for best efficacy.

After broadcast fumigation, the soil surface is often compacted with a roller/packer to contain the fumigant in the soil for as long as possible. Alternatively, covering the soil surface with a polyethylene tarp immediately after fumigation further improves efficacy and reduces fumigant emissions into the atmosphere, but adds over $500 per acre to the cost of broadcast fumigation. Workers are not permitted to re-enter the field for a period indicated on the fumigant label, typically five days. If a tarp is used, it may be perforated after this time, and removed the following day. The field should remain fallow or be planted with a small grain cover crop until the following spring.

Regulations on fumigants

The United States Environmental Protection Agency (EPA) recently issued Reregistration Eligibility Decisions (REDs) for most of the common soil fumigants, including metam products, chloropicrin, methyl bromide, and dazomet. The REDs include several significant changes to allowable fumigation practices. New requirements include buffer zones, fumigant management plans, posting requirements, and worker protections. As these changes become implemented and integrated into fumigant labels, the following may occur:

- Fields in close proximity to houses or other occupied structures will lie within buffer zones and may not be fumigated as in previous years.
- Depending upon the fumigant, rate and sealing method, buffer zones will be large (e.g., 650 feet for a 20-acre field fumigated with 39 gal/A Telone® C-35).
- Growers will be required to provide respirators to workers who assist a custom fumigator.
- Written notification of neighbors will be required prior to fumigation.

Some of these requirements appeared on fumigant labels late in 2010; the remainder will be implemented in new labels by early 2012. Current soil fumigant REDs and EPA fact sheets can be found at http://www.epa.gov/oppsrrd1/reregistration/soil_fumigants/#soilreds.

In order to comply with the REDs, many growers will be compelled to change practices to minimize their buffer sizes (Table 1). Examples of modifications that growers may need to make to comply with REDs include:

- Fumigate large fields in smaller sections. This may prove difficult since ideal windows for soil fumigation are limited and other growers will likely request fumigation services at the same time.
- Reduce the proportion of chloropicrin in mixtures with 1,3-dichloropropene (1,3-D) (i.e. use Telone C-17 instead of Telone C-35) since there are presently no REDs for 1,3-D. However, disease management may suffer when less chloropicrin is used.
- Consider metam products, which tend to have a smaller buffer than chloropicrin. These products are less volatile than chloropicrin however, and must be very well distributed in the soil profile to be effective.
- Try alternatives to broadcast fumigation, including soil solarization or bed fumigation.

Alternatives to broadcast fumigation

Bed fumigation refers to the practice of fumigating only the planting bed, as opposed to broadcast fumigation where the entire field is treated. Bed fumigation can reduce the amount of fumigant used for a raspberry or blueberry field to approximately one third that used for broadcast fumigation (two thirds of the fumigant used for broadcast fumigation of hill culture strawberries). Furthermore, it is less expensive to apply an impermeable tarp over fumigated beds (typically $180 to $350 per acre) than over an entire field (typically over $500 per acre). Because of these factors, the total cost of tarped bed fumigation with Telone

Table 1. Estimates of costs, EPA-mandated buffer zone size, and efficacy of fumigants and alternatives.

Treatment	Cost per acre[a]	Buffer zone[b] (ft)	Control of: Disease	Control of: Nematodes	Control of: Weeds	Comments
Telone C-35, 39 gal/A, broadcast, nontarped	$1100	625	+	+	+/-	Provides control of plant pathogenic nematodes and soil-borne disease
Telone C-17, 37 gal/A, broadcast, nontarped	$864	145	+/-	+	+/-	Control of nematodes, and some measure of disease control
Telone II, 35 gal/A, broadcast, nontarped	$650	0	-	+	+/-	Nematode control only
Telone C-35, 35 gal/A, bed fume, VIF tarp	$950	25	+	+	+	Excellent control in planting bed, but only there; no control in alleyways
Vapam or other metam-containing product, 37.5 gal/A, broadcast, nontarped	$450	50	+	+/-	+	Metam-containing products are less volatile than other fumigants, and must be carefully distributed to entire area of control
Solarization, clear plastic HDPE tarp	$485	0	+	+	+/-	Control only in upper 6-12” of soil; probably best suited to shallow-rooted crops like strawberries

[a] Fumigation costs include total cost for custom application; Solarization costs include materials only.
[b] Buffer size based upon 2009 amended EPA REDs for chloropicrin and metam-containing compounds.

C-35 at 39 gal/A (estimated at $950 per acre) is comparable to the cost of non-tarped broadcast fumigation with the same product and rate. Reduced fumigant usage and the choice of an impermeable film for bed fumigation greatly reduce EPA-mandated buffers (e.g., 25 feet for a 20-acre field bed fumigated with 39 gal/a Telone C-35 under an impermeable tarp). Bed fumigation has been widely adopted in California, where approximately half of the strawberry acreage is now bed fumigated. Bed fumigation may be applicable to many Washington berry fields as well. It would not be as useful for matted-row strawberry production, which does not generally have a well-defined bed.

Grower experience has shown that broadcast fumigation protects a new perennial planting for the first several years of its lifetime and contributes to good crop establishment. However, pests may more rapidly recolonize fumigated beds from non-fumigated areas outside the bed. Some soil organisms, like the root lesion nematode, are more mobile and may be able to move from non-fumigated areas into a fumigated bed within a growing season. While bed fumigation provides good protection to annual strawberries and vegetables, it is not clear if protection of perennial berry crops will last as long as that of broadcast fumigation. Research shows that a related practice, strip fumigation, provides long-term benefits in preventing replant disorder in almond, a crop with a 15–20 year lifespan (Browne et al., 2010). Growers should trial bed fumigation with caution, especially in fields with high densities of plant-parasitic nematodes.

Besides addressing the issue of pest recolonization of fumigated areas, a successful bed fumigation system also needs to establish beds of the correct size, in the correct place (i.e., beds must be lined up with irrigation risers), and with a suitably friable texture at planting the following spring. A typical bed fumigation apparatus is shown in Figure 3. This particular apparatus can produce beds up to 8 inches high and 40 inches wide, although some berry growers may want to make wider or taller beds.

Figure 3. Bed fumigation prior to planting raspberry. Planting beds are formed, fumigated, and covered with an impermeable tarp in a single operation.

Solarization uses the sun's energy to warm the soil, eliminating or suppressing pathogens prior to planting. Typically, soil is irrigated to field capacity and tightly covered with a clear polyethylene tarp to maximize heat gain in the soil. Solarization is most commonly used in warm, sunny regions, but trials in western Washington showed that solarization reduced *P. rubi* inoculum density and delayed the onset of raspberry root rot (Pinkerton et al., 2009; Pinkerton et al., 2002). However, the disease returned to solarized plots several years later when conditions were favorable. The relatively shallow zone of control provided by solarization in western Washington may be sufficient for shallow-rooted berry crops such as strawberry (Pinkerton et al., 2002), but it is likely that for deeper-rooted crops like raspberry, solarization will require integration with other control methods .

Potential future alternatives

Cover crops have a long history in agriculture and can be a useful component of perennial systems. Specifically, cover crops planted in berry alleyways can have multiple benefits for perennial crop systems. Primarily, the cover crops return nutrients to the soil, prevent erosion, and stimulate microbial activity (Hoagland et al., 2008). Certain types of cover crops, like mustard family varieties (e.g., *Brassica juncea, B. napus, Sinapis alba*), can also directly act on pathogens, nematodes, and weeds by releasing compounds that inhibit growth or are toxic to the organisms. Conversely, they may also serve as hosts to pathogens or nematodes, exacerbating the pest problem. Fall-planted grass cover crops are recommended for raspberry to capture late-season nitrate, to prevent nutrient leaching into groundwater, and to make residual nitrogen available to the crop the following spring. However, these types of cover crops can exacerbate *P. penetrans* problems by providing the nematode with an alternate host (Forge et al., 2000). Some varieties such as Saia oats and Wheeler rye were acceptable cover crops and did not increase P. penetrans population densities. These varieties can indirectly suppress *P. penetrans* by inhibiting growth of weeds that are good *P. penetrans* hosts (Forge et al., 2000).

Brassica seed meals are byproducts of *Brassica spp*. production for oil, condiments, or biofuels. In research plots, these seed meals killed or suppressed pathogens, nematodes, and weeds either directly by production of toxic isothiocyanates or indirectly by stimulating soil microbial communities that suppress pathogens and pests (Mazzola et al., 2007). Seed meals of *B. juncea* and *Sinapis alba* effectively suppressed *P. rubi* and *P. penetrans* in greenhouse and field research, especially in combination with solarization. However, seed meals are not labeled as pesticides, so they cannot be used as such.

New regulations will make it much more difficult for berry growers to rely on broadcast fumigation for pathogen, nematode, and weed management. However, with proper field history and nematode assessment, growers can reduce the frequency of their fumigant application, and can apply products with smaller buffer requirements. Bed fumigation can reduce buffer size and application cost. Solarization should be considered for shallow-rooted crops such as strawberry. Alleyway cover crops and *Brassica* seed meals may ultimately prove useful, pending future research and a pesticide registration for seed meals. While all of these potential treatments can have an effect on diseases, nematodes, or weeds, none will be a complete solution for every situation. Integration of these alternative control options is recommended and will be site-specific. Careful monitoring of disease symptoms and nematode and weed populations over time will allow growers to make decisions about appropriate control options for their farm and soil.

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Washington State University Extension

By **Thomas Walters**, Extension Specialist, and **Jessica Gigot**, Graduate Student, WSU Mount Vernon Research & Extension Center, and **Inga Zasada**, Nematologist, USDA-ARS Horticultural Crops and Research Laboratory, Corvallis, OR.

Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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