Journal of Nematology 24(3):457–462. 1992.

A Plant Health Care Program for Brambles in the Pacific Northwest[1]

F. D. McElroy[2]

Abstract: *Pratylenchus* and *Xiphinema* species have been associated with decline and mortality of brambles (*Rubus* species) in the Pacific Northwest of the United States. These nematodes cause direct feeding damage and (or) transmit viruses that result in poor fruit quality and plant decline. A nematode management program has been developed by the author to minimize chemical use and nematode-induced damage while optimizing fruit production. Nematode management is an integral part of a total plant health care program in which foliar and soil pests, plant stresses, and fertility are managed.
Key words: Bramble, control, nematode, nematode management, plant health care management, population dynamics, *Pratylenchus penetrans*, raspberry, sampling, *Xiphinema americanum*, *Xiphinema bakeri*.

Brambles (family Rosaceae and the genus *Rubus*) include agriculturally important species such as red raspberry, black raspberry, blackberry, boysenberry, loganberry, and dewberry. I have focused on red raspberry in this presentation because of its worldwide distribution and economic importance and because it has been studied frequently and is representative of the other bramble species. I have confined my report to a nematode management program developed for the Pacific Northwest of North America because little information is available on nematode management on brambles in other areas. After many years of attempting to diagnose and control individual disease problems, a program was developed that emphasized overall plant health rather than individual pests and diseases. This plant health care program encompasses not only pests and diseases but also fertility, environmental stresses, and management practices unique to each grower. The goal of the program is to minimize plant stress and chemical use and to maximize profit to the grower. This program reflects my experience of 10 years in research and 13 years as a private consultant in the Pacific Northwest.

The establishment of a plant health care program requires knowledge of soil and foliar pathogens, insect pests, population dynamics of pests, economic threshold levels, effect of pathogen combinations, and effect of the environment. A thorough understanding of the crop's horticultural requirements, such as propagation methods, cultivar characteristics, soil, and other environmental effects that may reduce plant health, is also necessary. Chemical, biological, and cultural pre- and postplant control options also are needed to design programs unique to each grower's requirements. Some of this information may be lacking; nevertheless, a preliminary program can be established and then continually refined with new research findings.

Red Raspberry Culture

Plants of raspberry typically have perennial roots and crowns and biennial shoots. Planting stock consists of root pieces 15–30 cm long containing several shoot nodes. These root pieces are dug during the dormant period, cold stored, and replanted in about March prior to shoot node development. After planting, shoots grow during the first growing season and then become dormant during the winter. The following spring, lateral branches develop; these flower in May and produce fruit in about July. The entire cane dies after fruiting. First-year vegetative canes (primocanes) and second-growing-year reproductive

Received for publication 24 September 1990.
[1] Symposium paper presented at the Annual Meeting of the Society of Nematologists, 13–17 August, 1989, Davis, California. Another symposium paper was published in vol. 23, pp. 334–341.
[2] Peninsu-Lab, 5795 N.E. Minder Rd., Poulsbo, WA 98340.

canes (floricanes) are both present during the growing season. At the end of the growing season, the dead floricanes are pruned out, and the most vigorous primocanes are tied to support wires. Diseased canes are also removed at this time. Most raspberry cultivars attain full production by the third year following planting. Healthy plants remain productive for 12 or more years.

Well-drained loam soils are ideal for raspberry production. Heavy, poorly drained soils reduce plant vigor and predispose plants to root rot and nematode damage. In the Pacific Northwest, raspberries are grown on a wide range of soil types, but those on other than loam soils require special management. Although many raspberry plantations in this region produce well without irrigation, increased growth and yield have been demonstrated by irrigating at the critical times just before and after fruit production (1). Both overhead and trickle methods are effective. Overirrigation, most frequently encountered with the trickle system, increases plant stress by reducing soil aeration and predisposing roots to damage by nematodes and root rot organisms.

The alleyways in most plantations are regularly tilled to reduce weeds and between-row raspberry growth. Planting slow-growing grasses in the alleyways is occasionally recommended to reduce soil erosion, compaction, and spread of nematodes and soilborne pathogens, especially on clay soils.

Fungicide applications are often needed to control cane, root, and fruit diseases, but judicious crop management significantly reduces this need. The same can be said for insecticide applications. In the Pacific Northwest, insects of concern vary with location and can damage roots, crowns, canes, foliage, and fruit. They also vector plant viruses and contaminate mechanically harvested fruit. Correct fertility balance is best managed through annual late summer sampling of the foliage and biannual or triennial sampling of the soil.

NEMATODE-CAUSED DAMAGE

Several species of nematodes attack brambles and cause direct or indirect damage (2,3). In the Pacific Northwest, *Pratylenchus penetrans, Xiphinema bakeri,* and *Xiphinema americanum* are the primary nematode pathogens of red raspberry (4,7). Nematodes at or just below detectable levels at time of planting increase to damaging levels by the sixth to eighth year (6). Damage increases with the concomitant increase in nematode populations until root damage limits food supply, after which populations decline through mortality or migration. Thus, a population density of, for example, 500 *P. penetrans*/500 cm^3 of soil could occur with plants in early decline with no above-ground symptoms or with plants in late decline with extensive above-ground damage. Lack of an understanding of this relationship has resulted in considerable confusion and controversy regarding threshold densities and nematode importance.

Pratylenchus penetrans has a wide host range and is the most important nematode pest. Feeding on the roots, this nematode reduces uptake of water and nutrients and eventually kills all feeder roots. Infected plants have decreased vigor and increased susceptibility to winter injury, resulting in dead buds (3,7). Population densities exceeding 500 *P. penetrans* per 500 cm^3 soil affect stand establishment, first-year vegetative growth, and yield (7). In established plantations, *P. penetrans* densities of 1,000–4,000/500 cm^3 soil decrease plant growth and require nematicide treatment (6).

Xiphinema bakeri feeding causes swelling of the root tips and results in stunting of the root system and poor cane growth. As few as 100 nematodes per 500 cm^3 soil can reduce root and top growth of young plants by 40–50% (4). Plant decline similar to that caused by *P. penetrans* can be caused by this species. *Xiphinema bakeri* thrives in loam soils in limited areas throughout the Pacific Northwest and is never found in soils with high (>35%) clay content.

Xiphinema americanum causes no direct damage to raspberry, but it is a vector of Tomato Ring Spot Virus (TomRSV), which results in a gradual decline over several years. The most important consequences of virus infection are crumbly fruit and reduced yield. Because the nematode is a virus vector, the presence of a single nematode in a field is of concern and requires attention. *Xiphinema americanum* occurs in heavier, poorly drained soils throughout the Pacific Northwest and frequently is found with *Phytophthora* spp.

Preplant Program for Red Raspberry

Soil sampling: Fields for which there is no information on nematodes and other pathogens are sampled to determine fumigation needs. The nematode sampling program for the grower is shown in Figure 1. Soil is sampled in the fall when populations are highest, by collecting 40 2.5-cm cores (0–30 cm deep) per hectare while walking a "W" pattern through the field. The composite sample should represent one soil type, the same cropping history, and no more than 2 hectares. At the time of sampling, the field should have been well prepared so that little undecomposed organic matter and no intact live roots remain. A systemic herbicide can be applied to the previous crop, killing the roots and causing the nematodes to move into the soil, where they are more easily controlled by fumigation.

TomRSV: If the region is known to have both *X. americanum* and TomRSV, growers are advised to sample the field 2 years before planting. If *X. americanum* is detected, growers are advised to plant a shallow-rooted grass crop for 1–2 years. This will bring nematodes to the upper part of the profile, where they are more easily controlled. Grasses are also nonhosts for the virus and thus reduce virus inoculum. Weed control is essential because TomRSV has a wide host range on nongrass crops.

Soil fumigation: If nematode populations are high, fumigation is recommended during the fall before planting in February or March. Postplant sampling is essential to determine whether nematodes were controlled. If populations after fumigation are high enough to reduce stand establishment, then an at-plant or postplant treat-

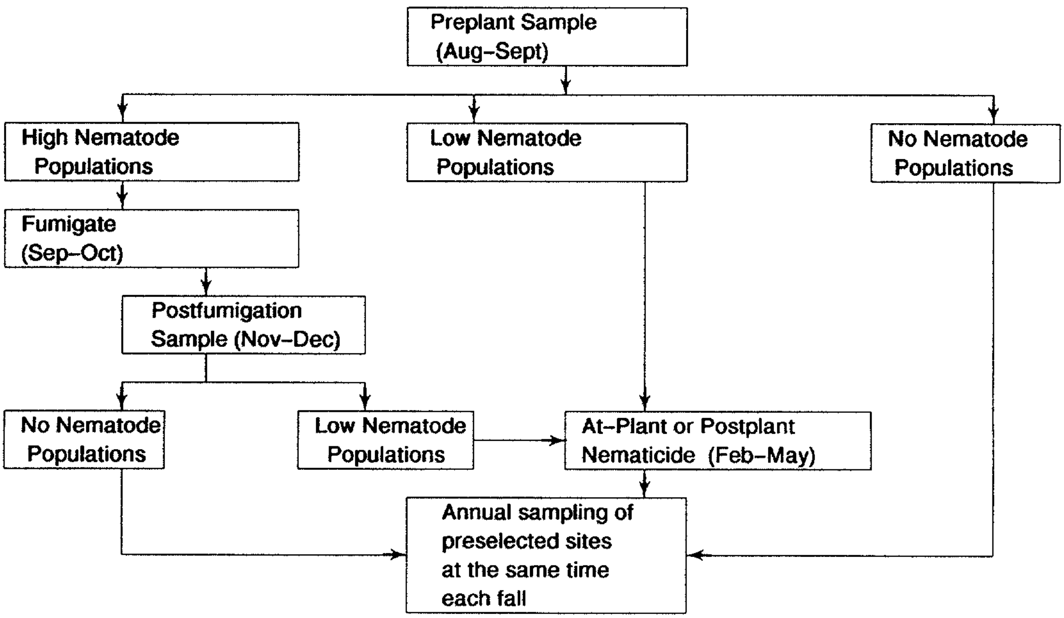

FIG. 1. Nematode management program for brambles in the Pacific Northwest of the United States.

ment with a nonfumigant nematicide is recommended. Presently, fenamiphos is the only registered postplant nematicide. Moderate populations of *P. penetrans* (200–500/500 cm^3 soil) can be effectively treated at planting or at postplant. Fields with fewer than 100 *P. penetrans*/500 cm^3 soil may be planted without any nematicide treatment but must be sampled annually to ensure that populations do not reach damaging levels. *Xiphinema* spp. require preplant fumigation because currently registered nonfumigant nematicides provide poor control of this genus. Annual sampling by the author over several years in fields treated with fenamiphos showed decline of *P. penetrans* populations, whereas *X. americanum* and *X. bakeri* populations remained unchanged or increased (unpublished data).

Planting material: Certified nursery plantations are tarp fumigated with methyl bromide-chloropicrin. Disease-free planting stock (usually from foundation stock) is used to plant these fields. Hot water treatment can be used to rid infested stock of nematodes (5). A hot water treatment at 46.6 C for 30 minutes kills nematodes without damaging most varieties, but varieties vary in sensitivity. Soil and root samples are collected at harvest and analyzed for nematodes and other pathogens to ensure clean stock. Recommendations are made to fruit production growers to plant only certified plants produced as above.

Postplant Program for Red Raspberry

Plantation evaluation: First, background information regarding the plantation is obtained from the grower. Crop history, planting date, cultivar, management practices, and fertility records are recorded. Then the site is visited during the growing season, and information on topography, soil drainage, and variations in the soil profile is collected. Roots are evaluated for depth of penetration, lateral development, symptoms of disease, and nematode or insect damage. Above-ground portions of the plant are checked for insects and diseases, overall vigor, and patterns of poor production. The soil, roots, and above-ground portions of the plant are sampled for pests. The entire field and specific problem areas are photographed; subsequent photographs are used to document changes in plant health. Preliminary findings are discussed with the grower at the conclusion of the visit.

In the laboratory, the soil and roots are analyzed for nematodes, *Phytophthora* spp., and *Pythium* spp.. The leaves are analyzed for viruses and the fungus *Phragmidium rubi-idaei* and the canes for the species of the following fungi: *Verticillium, Leptosphaeria, Didymella, Elsinoe, Botrytis,* and *Sphaerotheca.*

Based on the field evaluation and laboratory findings, the health of the plantation is evaluated in a report. Recommendations are then made to the grower. The field is revisited if the report indicated a severe problem such as high nematode numbers, severe virus infection, or Phytophthora root rot. Additional samples are collected and observations made to determine the extent of the problem and to serve as a baseline from which to evaluate progress toward optimum production.

Specific treatment programs are implemented to deal with the most severe problems. These programs range from a single nematicide application to a revamping of the entire management program. One program involves subsoiling beside the plants to improve drainage and (or) planting of grassy alleyways to prevent movement and spread of viruliferous nematodes or other soil pathogens throughout the field.

Assessing nematode damage: The cause of raspberry plant decline is not easily determined by above-ground symptoms. Root symptoms are a better indicator, but frequently more than one factor is involved. For this reason, all diagnoses and recommendations are based on laboratory analyses. For reasons discussed earlier, a single nematode sample may not give a clear representation of the causal factors.

Fields with large areas of poor growth

are best evaluated by collecting soil and root samples from neighboring areas of good and poor plant growth. Nematode densities and root pathogen evaluations of these samples provide an indicator of both primary and secondary pathogens causing the problem. When nematode populations are higher in the poor areas and no other detrimental biological or physical factors are found, nematodes are considered to be the primary cause of decline, and nematode control is recommended. However, when nematode populations in the poor area are low and are equal to or lower than those in the good area, the nematodes are not considered to be involved in the problem, and no control is recommended. *Pratylenchus penetrans* and *X. bakeri* populations below 100/500 cm^3 and 10/500 cm^3 soil, respectively, are considered low. Densities exceeding 1,000 (*P. penetrans* plus *X. bakeri*/500 cm^3 soil) are considered high. If nematode densities in the poor areas are high but are equal to or lower than those in the good areas, nematodes are considered a secondary cause of decline. In any case, nematode controls must be applied along with other corrective action to restore the plantation to full vigor. Complete evaluation and correction of all factors negatively affecting plant growth are necessary to maintain plant health.

In plantations with uniform growth, representative reference plants are selected throughout the field for annual monitoring. Reference plants are mapped and flagged to ensure that the same plant is sampled each year. Samples are always collected at the same time each fall. Samples from these plants are composited to represent a single sample for every 2-hectare block within that field. These samples must be representative of the majority of the plants in the field, the same soil type, and management regime. *Pratylenchus penetrans* and *X. bakeri* usually increase faster in loam soils than in clay soils. However, the increase in nematode numbers varies among loam fields, perhaps due to differences in management practices.

The goal is to ensure that potential nematode problems are detected early so that treatment can be made before significant damage occurs. If plants have begun to decline due to root loss, it takes 3 years before a correction of the problem is reflected in yield. The year following treatment, root growth production increases. This is followed the next year by increased cane growth, with increased fruit production on those canes the following year. These time lags make early detection of root damage, especially that caused by nematodes, very important.

If all other stresses, such as disease, insect, drought, or infertility, are kept to a minimum, the plants withstand a higher nematode threshold level, and frequency of nematicide treatment can be reduced. However, if another pest or pathogen (e.g., root weevil or *Phytophthora*) is causing significant root destruction, even low numbers of nematodes must be controlled to allow full response to treatment for those problems. In my experience, the interaction between nematodes and other organisms appears to be simply additive. However, there is little experimental evidence to explain interactive relationships or to aid in deciding what constitutes a damaging nematode density when several biological, physical, and chemical soil factors are affecting the raspberry plants negatively. Experience indicates that when several negative factors are present, even at below established threshold levels, all must be corrected to return plants to full vigor. It has been observed, for example, that controlling *Phytophthora* in a planting with low ($<$200/500 cm^3 soil) *P. penetrans* populations provides the nematodes with a better food source resulting in significant nematode population increases in the next 2 years. Therefore, the problem shifts from being Phytophthora root rot to nematode root damage, and plant health remains poor.

Conclusion

A plant health care program encourages the grower to carefully select and prepare a site before planting, thus reducing the need for less effective postplant corrective measures. Preplant site evaluation enables the selection of a cultivar appropriate to a particular site and selection of the proper soil treatment. Plants that establish fast are able to resist many root problems. All factors of plant production are considered in order to maintain a stress-free plant.

Holistic plant health care is not new. Many scientists have advocated and many growers have practiced it to some degree for years. Yields in properly managed raspberry plantations may stay high for 20 or more years. However, when site selection and management are poor, plantings are underproductive and require removal after as few as 3 years if TomRSV infection is high, or after 6 to 8 years if number of *P. penetrans* or *X. bakeri* are high. The plant health program for raspberry has been developed based on research and observations of healthy plantations. This approach has proven successful over the last 9 years for Pacific Northwest growers.

The program could be improved if additional information were available. For example, data on degree days for nematode reproduction on raspberry in different soil types would be helpful in predicting population increase. Also, a better understanding is needed of the interaction between nematodes and certain pathogens and their economic threshold densities under varying environmental conditions. Finally, more options (chemical and nonchemical) for nematode control are needed.

Literature Cited

1. Carkner, R. W., and T. W. Ley. 1987. An economic and engineering comparison of replacing overhead with trickle irrigation in red raspberries. Washington State University, Extension Bulletin 1458.

2. Jennings, D. L. 1988. Diseases caused by nematodes. Pp. 139–142 *in* Raspberries and blackberries: Their breeding, diseases, and growth. New York: Academic Press.

3. McElroy, F. D. 1972. Nematodes of tree fruits and small fruits. Pp. 335–376 *in* J. M. Webster, ed. Economic nematology. New York: Academic Press.

4. McElroy, F. D. 1972. Studies on the host range of *Xiphinema bakeri* and its pathogenicity to raspberry. Journal of Nematology 4:16–22.

5. McElroy, F. D. 1973. Control of *Pratylenchus penetrans* in raspberry root cuttings. Plant Disease Reporter 57:492–495.

6. McElroy, F. D. 1977. The nematode factor in raspberries. Canada Agriculture Fall 20–22.

7. McElroy, F. D. 1977. Effect of two nematode species on establishment, growth and yield of raspberry. Plant Disease Reporter 61:277–279.