Columbia Root-knot Nematode Control in Potato
Using Crop Rotations and Cover Crops

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The Columbia root-knot nematode *(Meloidogyne chitwoodi)* attacks potatoes and causes injury to tubers in the Columbia Basin of Oregon and Washington as well as other areas of the Pacific Northwest. Infected potato tubers become rough and bumpy on the surface. Inside the potato, adult female nematodes produce brown spots that discolor further during frying.

The FDA does not allow nematodes in processed potato products. If 5–15 percent of the tubers in a field are culled (i.e., rejected) because of infection, the entire field may be rejected. Depending on the price for potatoes in a given year, the resulting loss can total $250,000 or more for a 120-acre (49-ha) irrigated circle.

M. chitwoodi can complete many generations during the Columbia Basin's long, warm growing season if host plants (plants in which *M. chitwoodi* can reproduce) are present. Even when sampling finds no juveniles per 250 g dry soil at planting time, there may be sufficient nematodes present to cause economic damage at harvest. Nematode density may be so low that sampling misses them, or they may be present in the soil below the sampling depth. (*M. chitwoodi* has been found as deep as 6 feet below the soil surface.)

Traditionally, *M. chitwoodi* is controlled with chemical nematicides, many of which risk suspension for use on potatoes due to health and environmental concerns. It is essential to develop and refine alternative strategies for controlling Columbia root-knot nematode now, so that productive and profitable potato acreage will not be lost if nematicide use is prohibited.

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Dependence on fumigant nematicides can be reduced or eliminated if *M. chitwoodi* populations are depressed sufficiently by rotating potatoes with nonhost crops. Nematode populations can be reduced further when cover crops with a nematicidal action are included in the rotation.

Control with nematicides

Nematicides kill nematodes directly if the nematodes are exposed to the agent long enough. However, when *M. chitwoodi* populations are high, application of nematicides may not reduce nematode levels sufficiently to prevent economic damage. 1,3-dichloropropene (Telone II), applied at rates recommended by its label, provides the best control of any single nematicide, but occasionally infections still are present after its use. In some cases, more than one nematicide is used for adequate disease and nematode suppression, e.g., 1,3-dichloropropene plus metham sodium (Vapam). Note that a separate label for the combined use of 1,3-dichloropropene and metham sodium permits lower application rates of each than are required if either is used alone.

Fumigants versus nonfumigants

Fumigants such as 1,3-dichloropropene and metham sodium are injected into the soil to a depth of 18 inches. Metham sodium also can be applied through chemigation. Both are phytotoxic (they kill plants), so they must be applied before planting.

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Nonfumigants such as ethoprop (Mocap) and oxamyl (Vydate) are broadcast over the soil surface and mixed into the soil with tillage, or are applied with irrigation water. Nonfumigants are not phytotoxic and can be applied before or after planting if permitted by the label.

All nematicides are expensive to buy and apply. Fumigants generally are more effective than nonfumigants but also cost considerably more. Nonfumigant costs are approximately $120–220 per acre, and fumigant costs vary from $250–480 per acre.

Potential suspensions

All registered nonfumigant nematicides are carbamates or organophosphates, and 1,3-dichloropropene is a B2 carcinogen. All carbamates, organophosphates, and B2 carcinogens are at the top of the suspension "hit list" developed to implement the Food Quality Protection Act.

Nematicides have experienced sudden suspensions by the EPA in the past. For example, the fumigant 1,3-dichloropropene was suspended in California with little notice in 1990. The same year, the manufacturer of the nonfumigant aldicarb (Temik) voluntarily withdrew its use nationwide following the detection of higher than expected residues in potatoes.

If effective fumigants are suspended, potato acreage will be drastically reduced unless alternative cultural control strategies are implemented. Oregon State University research has shown that nonfumigants alone do not provide adequate control in most conventional rotation systems, and even they are at risk of suspension.

Breaking the cycle

If *M. chitwoodi* population levels are high or are deep in the soil, enough nematodes to cause damage may remain even after nematicide applications. Thus, control of *M. chitwoodi* often involves a combination of methods.

It's possible to reduce *M. chitwoodi* populations over time by depriving them of a suitable environment in which to reproduce. Plant-parasitic nematodes must have plants to feed on, but not all plants are an adequate food source (host) for *M. chitwoodi.* Thus, rotating potato production with fallow periods or nonhost cash and cover crops can reduce populations. Some cover crop residues also produce nematicidal compounds as they decompose that kill *M. chitwoodi*. Some weeds are good hosts for *M. chitwoodi* and must be controlled to minimize nematode reproduction.

Research at Oregon State University and Washington State University has documented that selected crop rotations decrease *M. chitwoodi* populations to levels resulting in less than 5 percent culls (Ingham, 1994). Use of nonhost cash and cover crops in potato rotations may reduce root-knot nematode populations enough that the less expensive nonfumigant nematicides are effective.

Reproductive indices

Cash crops, cover crops, and weeds can be rated with a reproductive index (R value) that indicates the reproductive efficiency of *M. chitwoodi* on a particular plant. R values are obtained by counting nematodes in soil samples taken before planting and after harvest (or incorporation). The calculation is:

R value = final population ÷ initial population

The host status of a crop is defined as follows:

R > 1.0 =	Good host; nematode levels will stay the same or increase.
R 0.1–1.0 =	Poor host; nematode levels will decrease to 10–99 percent of initial levels.
R < 0.1 =	Nonhost; nematode levels will decrease to less than 10 percent of initial levels.

Note that R values may vary considerably among cultivars of the same crop. In other words, some cultivars of a particular crop may be nonhosts, while others are hosts. The R value also may vary with the particular race of *M. chitwoodi;* for example, alfalfa is a host of race 2 but a nonhost of race 1. Proper cultivar selection is essential when using crop rotation to suppress nematode populations. Growers should always find out the R value for the variety they plan to plant with respect to the race of *M. chitwoodi* present in their fields.

Although absolute R values usually vary from year to year and field to field, the R values of tested crops are relatively constant when compared to each other under the same conditions. For that reason, a relative R value often is reported. The relative R value makes it easier to compare the results of one test with another. It is calculated as:

$$\text{Relative R value}_{\text{crop}} = \frac{(\text{R value}_{\text{crop}})}{(\text{R value}_{\text{reference crop}})}$$

The reference crop usually is a specific field corn cultivar.

Rotation crop host status

Many crops currently favored for rotation with potato, such as wheat, field corn, cereal corn, and alfalfa, increase Columbia root-knot nematode populations greatly. (Alfalfa increases only populations of *M. chitwoodi* race 2.)

Nonhost summer crops include supersweet corn (certain cultivars), pepper, lima bean, turnip, cowpea, muskmelon, watermelon, and squash (Ingham, 1990). The diversity of choices increases each year as more varieties are tested. Table 1 lists several crop varieties and their respective R values.

Table 1.—Reproductive efficiency (R values) of *Meloidogyne chitwoodi* race 1 on selected rotation crop cultivars. Means followed by the same letter are not significantly different (p=0.05).[1]

Common name	*Cultivar name*	*R=Pf/Pi*
Potato	Russet Burbank	68.00 a
Cereal corn	Pioneer x816W	58.53 a
Cereal corn	Pioneer 3737	28.24 ab
Cereal corn	Pioneer 3283W	22.66 ab
Field corn	Pioneer 3732	12.38 abc
Sudangrass	P877F	9.53 abc
Cereal corn	Pioneer x8516	6.68 abc
Sudangrass	P855F	6.64 abc
Popcorn	Robust 30-72	4.90 abc
Popcorn	Robust 47-31	3.84 abc
Popcorn	Robust 20-60	3.58 abc
Popcorn	Robust 30-71	3.57 abc
Popcorn	Robust 10-84	3.27 abc
Popcorn	Purdue 410	2.98 abc
Sudangrass	Pipper	1.52 bcd
Sudangrass	Sordun 79	0.89 bcde
Popcorn	Robust 30-77	0.77 bcde
Sudangrass	Trudex 9	0.57 cde
Wheat	Stephens	0.48 cde
Rapeseed	Ceres	0.094 def
Rapeseed	Westar	0.069 def
Turnip	Forage Star	0.068 def
Sudangrass	Trudex 8	0.043 ef
Wheat	Hard Red 906R	0.036 ef
Rapeseed	Cascade	0.034 ef
Pepper	California Wonder	0.0081 fg
Muskmelon	Tokyo King	0.0013 gh
Squash	Butternut	0.00075 gh
Cowpea	California Blackeye	0.00024 h
Muskmelon	Superstar Hybrid	0.00006 h
Lima bean	Henderson Bush	0.00006 h

[1]Oregon Potato Commission, 1989–1990.

Cover crop host status

Cover crop host status also varies among crops and among varieties of a particular crop. Cover crops that are poor hosts include rapeseed, mustard, and the sudangrass cultivars Sordan 79 and Trudan 8. Table 1 lists several cover crops and their R values. Note that sudangrass varieties range from poor to good hosts.

Weed host status

The elimination of host weeds or volunteers is important when using a nonhost cash crop or cover crop to reduce nematode reproduction. Host weeds that are present during the rotation will allow nematode populations to grow. Although actual R values are not available, Table 2 lists selected weeds and whether or not they are hosts of *M. chitwoodi.*

Cover crops with nematicidal qualities

Rapeseed, sudangrass, and mustard are non-hosts to *M. chitwoodi* and also release nematicidal compounds when their plant tissues decompose, thus providing substantial suppression of *M. chitwoodi* (Mojtahedi et al., 1993a, 1993b). See the rapeseed and sudangrass sections in EM 8704, *Using Cover Crops in Oregon*, for management information.

Rapeseed is a large, stemmy, winter or spring annual. Industrial varieties of rapeseed are more effective at killing *M. chitwoodi* than those used for animal or human consumption because they contain higher levels of glucosinolate. Glucosinolate is not toxic to nematodes, but it breaks down in the soil into isothiocyanate, which is nematicidal.

Generally, rapeseed is planted in late summer so that it has time to reach the six- to eight-leaf stage before cold weather. In the Columbia Basin, winter rapeseed should be incorporated in mid-March to maximize the nematicidal effect. Older plants develop thick stems, which do not decompose as readily and have lower concentrations of glucosinolates.

Sudangrass and sorghum-sudangrass hybrids are frost-sensitive, warm-season, erect annual grasses. They can grow from 6–8 feet tall and produce large amounts of dry matter if planted in summer. Sudangrass should be incorporated after it has been stressed (e.g., after first frost or after withdrawal of irrigation). It is believed that stress maximizes dhurrin in residues, and that dhurrin breaks down into hydrogen cyanide, which kills *M. chitwoodi*.

Growers may be able to turn these cover crops into viable economic enterprises or treat them as an alternative to pesticides. If rapeseed is allowed to mature, growers can sell the seed crop as well as reduce nematode populations. Sudangrass can be planted early (e.g., June), cropped as hay throughout the summer, and tilled under in fall. Alternatively, it can be planted after wheat or a short-season summer crop and used solely as a green manure cover crop.

Note that government authorities regulate the production of some crops. For example, rapeseed production is regulated in Oregon and other Pacific Northwest states. The Oregon Department of Agriculture has established rapeseed production districts in the state. In order to grow rapeseed, even as a cover crop, it may be necessary to "activate" the production district in your area. Much of the Willamette Valley is a restricted production zone due to potential cross pollination between rapeseed and other brassica seed crops. However, rapeseed cover crops are most effective if incorporated into the soil before bloom.

Table 2.—Host status of selected weeds for *Meloidogyne chitwoodi* Race 1 in the Pacific Northwest. Hosts are indicated by a plus sign (+), nonhosts by a minus sign (-).

Weed	*Host Status*
Dandelion	+
Nightshade	+
Lambsquarters	-
Common milkweed	-
Meadow foxtail	-
Yellow foxtail	-
Pigweed	-
Barnyardgrass	+
Shepherdspurse	+
Russian thistle	+
Bluegrass	-

Concurrent benefits from cover crop use

Cover crops can increase or maintain soil organic matter when their residues are returned to the soil. Organic matter provides food for soil organisms, improves soil structure, increases infiltration rates, and acts as a sink for nutrients. Generally, organic matter additions improve potato plant health, which improves resistance to diseases such as verticillium wilt.

Winter cover crops in the Columbia Basin commonly are used for wind erosion control. They also aid in controlling winter weeds, provide habitat for beneficial insects, and take up inorganic nitrogen from the soil, preventing it from leaching below the root zone to the underlying aquifer.

Rotations

Planting potatoes in rotation with nonhost cash and cover crops reduces Columbia root-knot nematode populations. Longer rotations reduce nematode populations more than short rotations. Properly managed nematicidal cover crops can reduce populations further.

Rotational control may reduce populations sufficiently to eliminate nematicide applications altogether. However, it is more likely that populations can be lowered sufficiently so that nonfumigant nematicides (instead of fumigants) can be used to further suppress them to nondamaging levels.

Figure 1 shows how nematode populations changed over a 2-year period with different rotations. Note that nonhost crops and rapeseed cover crops reduce *M. chitwoodi* populations

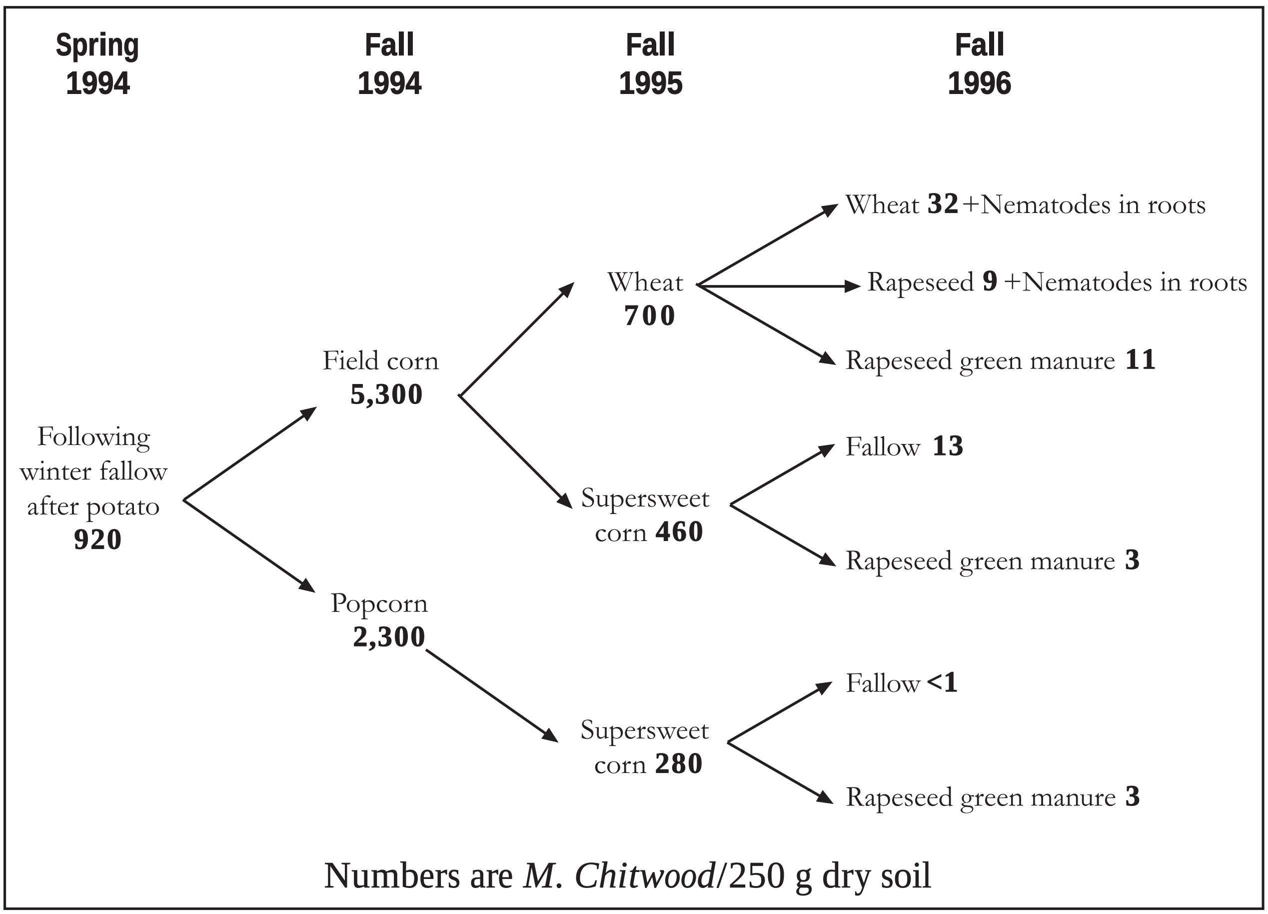

Figure 1.—Change in Meloidogyne chitwoodi *race 1 populations with various rotations. Numbers indicate* M. chitwoodi *per 250 grams of soil. Popcorn and supersweet corn, both nonhost rotation crops, reduce* M. chitwoodi *populations. Rapeseed, a nonhost with nematicidal qualities, reduces populations further. Note that it is likely many uncounted nematodes were in the wheat roots in spring 1996, while few nematodes were in rapeseed roots.*

more than host crops. The most successful control is obtained by planting nonhost cash crops several years in a row.

Ingham (1994) measured *M. chitwoodi* populations when potatoes were grown in various rotations with good host and poor or nonhost crops. The 4-year study in Hermiston, OR included supersweet corn, lima bean, popcorn, rapeseed, and sudangrass. See Table 3 for specific varieties. Some of the results, summarized in Table 3, are as follows:

- A [wheat/wheat/potato without nematicides] rotation resulted in 91 percent tuber culls. Adding sudangrass after the second year of wheat and/or applying preplant ethoprop (Mocap, a nonfumigant) resulted in 45–48 percent culls.
- [Lima bean/supersweet corn/potato without nematicides] rotations reduced culls significantly, to an average of 19 percent. Adding rapeseed after lima bean and/or sudangrass after supersweet corn did not significantly improve results.
- Rotations of [lima bean–rapeseed/supersweet corn–rapeseed/potato without nematicides] and [lima bean–rapeseed/supersweet corn–sudangrass/potato with preplant ethoprop] reduced culls to less than 2 percent, which is below FDA tolerance.

Table 3.—Cropping sequence effects on Columbia root-knot nematode infection. Differences in tuber infection among sequences with the same letter are not statistically significant.

No. of treatments	***Cropping sequence 1990***	***1991***	***1992***	***1993***	***Percent culls***	***Statistical grouping***
1	Potato	Wheat	Wheat	Potato	91	D
1	Potato	Wheat	Wheat	Ethoprop + potato	45	C
1	Potato	Wheat	Wheat–Sudangrass	Potato	48	C
1	Potato	Wheat	Wheat–Sudangrass	Ethoprop + potato	47	C
4	Potato	Lima bean + ?	Sweet corn + ?	Potato	19	B
Adding rapeseed after lima bean and/or sudangrass after sweet corn added no benefit.						
1	Potato	Lima bean–rapeseed	Sweet corn – rapeseed	Potato	<1	A
3	Potato	Lima bean–rapeseed	Sweet corn – sudangrass	Ethoprop + potato	<2	A
6	Potato	Popcorn	Lima bean + ?	? + potato	2	A

? = Several treatments are combined in one line. Cropping sequences with similar results were combined if the variations made no difference on the basic theme of the sequence.
Wheat = Spring cv ‘Penewawa’ in 1991 and winter cv ‘Stephens’ in 1992.
Sudangrass = cv ‘Trudan 8’ as a summer-planted, fall-incorporated cover crop.
Lima bean = cv ‘Maffi 15.’
Sweet corn = Supersweet corn cv ‘Crisp and Sweet 711.’
Popcorn = cv ‘Robust 85-210.’
Ethoprop = Mocap 10 G broadcast and preplant incorporated at 12 lb active ingredient/acre.
Rapeseed = Winter rapeseed cv ‘Humus’ as a summer-planted, spring-incorporated cover crop.

- Rotations of [popcorn/lima bean/potato] also reduced culls below FDA tolerance regardless of whether rapeseed or sudangrass was included after lima bean, or whether preplant ethoprop was used.

Leased land considerations

Growers who lease land for potato production should be aware of recent cropping history and how it might affect nematode populations. The market value of acreage rented for potato production may reflect past usage. For example, rental rates might be higher for parcels that have been rotated with nonhost and poor-host crops and nematicidal cover crops, when compared to parcels that have been planted to good-host crops.

Challenges

The most significant challenge to reducing *M. chitwoodi* populations through rotations with poor-host or nonhost crops and nematicidal cover crops is finding markets for these alternative crops. Present markets for poor and nonhost rotation crops could not absorb the production that would result if all infested acreage were planted to them. For example, in the Columbia Basin, 72 percent of the total irrigated acreage is planted to alfalfa, wheat, or field corn, while only 3 percent is planted to sweet corn or lima bean.

Another challenge is to accurately estimate nematode population densities. Difficulties arise because nematode densities tend to be patchy rather than uniform. Increasing the number of soil subsamples and thereby decreasing the average represented by a single soil sample improves estimates. However, nematodes may move as far as 5 to 6 feet below the soil surface, where sampling is not practical. Nematode sampling methods are described in the *Pacific Northwest Plant Disease Control Handbook*, available through the OSU Extension Service, and in Chapter 22 of *Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties* (Ingham, 1994), available from the author.

Conclusions

Columbia root-knot nematode populations can be reduced by rotating potatoes with nonhost cash and cover crops. Best results are achieved by including nematicidal cover crops in the rotation immediately preceding potato. A rotation including 2 years of nonhost summer crops and a winter rapeseed cover crop before potato reduced nematode populations to 0–1 juveniles/250 g soil. Although rotations may not control nematodes completely, they can reduce populations sufficiently that nonfumigant nematicides may be adequate, thus reducing dependence on more expensive fumigant nematicides.

For more information

OSU Extension publications

Cover Crop Weed Suppression in Annual Rotations, EM 8725 (1999). $1.50

Cover Crop Dry Matter and Nitrogen Accumulation in Western Oregon, EM 8739 (1999). $1.50

Nitrogen Scavenging: Using Cover Crops to Reduce Nitrate Leaching in Western Oregon, EM 8728 (1999). $1.50

Oregon Cover Crops: Rapeseed, EM 8700 (1997). 50¢

Oregon Cover Crops: Sudangrass and Sorghum-Sudangrass Hybrids, EM 8703 (1997). 50¢

Pacific Northwest Plant Disease Control Handbook, PLANT (revised edition available March 15 annually). $25.00

Using Cover Crops in Oregon, EM 8704 (includes publications EM 8691–8703 (published 1997, reprinted 1998). $5.50

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Other publications

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