

SITE-SPECIFIC NEMATODE MANAGEMENT FOR POTATOES IN IDAHO USING 1,3-DICHLOROPROPENE; EXPERIENCES AND ECONOMICS

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ABSTRACT

Fumigation for nematode management in irrigated potato production systems of Idaho is widely practiced. Spatially uniform fumigation with large scale soil injection equipment is the only labeled application method for 1,3-dichloropropene. Plant-parasitic nematode species exhibit spatially variable population densities that provide an opportunity to practice site-specific fumigation to reduce chemical usage and production costs. From 2002 through 2008, 62 commercial potato fields in eastern Idaho were field tested using georeferenced grid soil sampling for plant-parasitic nematode population densities. In total, 4,030 grid samples were collected representing nearly 3200 ha of commercial potato production. Collectively, 73% of the grid samples had Columbia Root Knot (CRN) (*Meloidogyne chitwoodi*) densities below the detectable limit. Site-specific fumigation is the practice of varying application rate of fumigant based on nematode population density. Over the past 3 years, 1200 ha of potato production has been site-specific fumigated for CRN nematode control in eastern Idaho. On average this practice has resulted in a 30% reduction in chemical usage and production cost savings of \$180 ha⁻¹ when 1,3-dichloropropene is used as the sole-source of nematode suppression. Further reductions in usage of 1,3-dichloropropene can exceed 50% if used in combination with another nonfumigant nematicide such as oxamyl. This combination approach can have production cost savings that exceed \$200 ha⁻¹. Based on farm-gate receipts and USDA inspections provided by potato producers, potato tuber yield and quality have not been adversely affected using site-specific fumigation technology.

Keywords: Site-specific management, nematode, fumigation, nematicide

INTRODUCTION

Based on crop production statistics for 2006 (USDA, 2007), Idaho produces 32% by weight and 28% by value (\$760 million) of all fall potatoes grown in the United States. Columbia root-knot nematode (CRN) (*Meloidogyne chitwoodi*) is a significant threat to potato quality in Idaho and the Pacific Northwest. Columbia root-knot nematodes infect and develop in potato tubers but do not cause yield loss. CRN cause quality defects such as galling on the surface and small brown spots surrounding adult females when peeled (Ingram et al., 2007). The external and internal defects render tubers unacceptable for fresh market sales and internal defects are unacceptable for processing. For the fresh market, if 5% of the tubers in the field show defects the whole field crop can be rejected. For processed potatoes, if 5 to 15% of the tubers in a field show defects the whole field crop can be substantially devalued or rejected. Based on 2006 yields and prices (USDA, 2007) the average value of potatoes in Idaho was \$5,647 ha⁻¹. The rejection of a potato crop grown on an average 52.6 ha center pivot sprinkler irrigated field represents a loss of \$297,000. Export markets have a zero tolerance for CRN and their presence will result in rejection and return of the entire shipment. There is zero tolerance for CRN in seed potato production as well. The potential for dire financial consequences from the presence of CRN in potato tubers is taken very seriously by producers.

Columbia root-knot nematode can reproduce rapidly in warm seasons (Pinkerton et al., 1991). Because of this, it is difficult to provide accurate population thresholds for a decision on when to use fumigants on a field, or when to use a less expensive, nonfumigant nematicide. Because potential for crop rejection exists with low population levels at planting, fields with any CRN must be treated with a pre-plant fumigant, nonfumigant nematicides, or both. Several products are available to reduce potato tuber infection to acceptable levels (Ingram et al., 2000). Fumigant nematicides include 1,3-dichloropropene¹ (1,3-D) and sodium N-methyldithiocarbamate (metam sodium). Nonfumigant nematicides include ethoprop, oxamyl and aldicarb. Use of a single nematicide is often insufficient to limited potato tuber damage to acceptable levels (Ingram et al., 2007). For improved CRN suppression, use of a combination of nematicides is often practiced, for example 1,3-D with metam sodium has become a potato industry standard in the Columbia Basin of Oregon and Washington (Ingram et al., 2007).

Spatial dependence of an attribute can be evaluated using geostatistical techniques to quantify the average distance of spatial correlation by direction, and the variability of measurements separated by short distances (Rossi et al., 1992). Geostatistical analyses have been used to evaluate the spatial dependence of plant-parasitic nematodes densities within agricultural fields with the goal to estimate densities at unsampled location within field boundaries (Boag et al., 1996; Evans et al., 2002; Marshall et al., 1998; Robertson and Freckman, 1995; Wallace and Hawkins, 1994; Webster and Boag, 1992; Wyse-Pester et al., 2002). When spatial

¹ Mention of trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the authors or their institutions and does not imply approval of product to the exclusion of others that may be suitable.

dependence in nematode density was found in these studies, spatial correlations ranged over distances from 1 to 600 m depending upon nematode species.

Identification of specific areas within individual fields for nematicide application may allow producers to reduce the amount of nematicide applied for nematode control and lower production costs (Evans et al., 2002). Combination of the spatially aggregated nature of nematodes, the relatively high cost of fumigant nematicides, the fact that some growers use multiple types of nematicides on the same crop and the relatively high crop value of potatoes makes site specific fumigation appealing from an economics stand point. Evans et al. (2002) evaluated the potential of site-specific nematode management in potato production systems in the UK. The nematode of concern was the potato cyst nematode (PCN) (*Globodera pallid* and *G. rostochiensis*) which causes yield reduction but not whole field crop rejection. They found that the inverse relationship between population density before planting and rate that PCN multiply makes it difficult to devise reliable spatial nematicide application procedures, especially when pre-planting population density is just less than the detection threshold. The spatial dependence found indicated that the coarse sampling grids used commercially would likely produce misleading distribution maps. They concluded that the best recommendation for site-specific PCN nematode management was to apply more expensive fumigant nematicides to “hot-spots” of infestation and treat the whole field with less expensive nonfumigant nematicides to prevent excessive multiplication of nematodes in nonfumigated areas of the field.

The success of commercial adoption of site-specific nematode management will require the development of affordable nematode distribution maps (Wyse-Peste et al., 2002). The risk of yield loss will have to be balanced by substantial cost savings from reduced chemical application. In the case of CRN, the risk of unacceptable levels of control will have to be virtually eliminated due to the potential economic consequences of potato tuber quality defects. Adoption of site-specific nematode management for CRN in irrigated potato production systems of eastern Idaho is being promoted. This paper reports on some of the findings from that effort.

METHODS AND MATERIALS

Field sites

Plant-parasitic nematode populations (densities), namely CRN and root lesion (*Pratylenchus sp.*), were field tested using geo-referenced grid soil sampling in 62 commercial fields prepared for potato production in eastern Idaho from 2002 through 2008. Fields were located in Power, Bingham, Bonneville, Jefferson and Fremont counties and ranged in size from 16 to 125 ha. Soils textures ranged from loamy sand to silt loam. Elevation ranged from 1300 to 1530 m.

Sampling

Fields scheduled to be planted to potatoes were soil sampled using a grid soil sampling system for nematodes in August or September of the preceding year following harvest of small grain crop. A square grid soil-sampling system was established within a field using a Trimble AgGPS 132 DGPS receiver for GPS data collection and Trimble's EZ-Map software (Trimble Navigation Limited, Sunnyvale, CA) connected to a portable laptop computer, mounted to a vehicle. The vehicle with GPS equipment was driven around the field boundary and the software generated an image of the field border on the computer display. The software was used to overlay a square grid of sampling points on the field map. The spacing between grid points ranged from 90 to 95 m with each grid point representing a 0.8 to 0.9 ha. Each sample grid point was located by driving the vehicle to a specific grid location selected on the computer display.

Soil sampling at each grid-point included 8-10 soil samples where the first two were collected within 2 m of the grid point and an additional 6 to 8 soil samples were collected on a 15 m radius at random around the grid point. The soil samples were uniformly mixed and separated as one single soil sample for each grid location for nematode analysis. Soil samples were collected from a 10 to 25 cm soil profile using a shovel. A 250 cm³ subsample was analyzed for nematode identification and enumeration by Western Laboratories (Parma, ID). The mobile stages of all nematodes were extracted from the soil using a modified Oostenbrink elutriator and sieved over a set of 4 sieves. The contents of each sieve were combined and collected in a cup. The nematodes and soil from the cup were separated by means of centrifugal flotation (Jenkins 1964). Plant-parasitic nematodes, most notably CRN, root lesion (*Pratylenchus sp.*) and stubby root (*Trichodorus and Paratrachodorus spp.*), were identified and quantified using microscopic techniques.

Data Analysis

The spatial distribution of CRN in each field was evaluated by quantifying the spatial dependence between samples with variograms using GS+ version 7 (Gamma Design Software, LLC, Plainwell, MI). The best fit theoretical variogram was selected based on the highest correlation coefficient between theoretical and omni-directional sample variogram. The best fit theoretical variogram was used with SSToolbox software (SST Software, Stillwater, OK) to estimate nematode density at unsampled locations using kriging. The resulting map was modified manually to reduce risk of uncontrolled CRN population by adding a buffer area of nematicide application near "hot spots" of infestation. The resulting map was downloaded to either a Raven Viper Pro (Raven Industries, Souix Falls, SD) or John Deere Greenstar (Deere & Company, Moline, IL) variable rate control system on custom applicator equipment. The control zone size for the application map was 0.4 ha square.

Site-Specific Nematode Management Strategies

Site-specific nematode management strategies are based on the recommendation of Evans et al. (2002) to apply the more expensive fumigant nematicides to “hot-spots” of infestation and treat the whole field with less expensive nonfumigant nematicides to prevent excessive multiplication of nematode. Nematicides used in this study were 1,3-D, metam sodium and oxamyl. Both metam sodium and oxamyl can be applied with water through the sprinkler irrigation system for uniform application or on a site-specific basis with ground based application systems. 1,3-D can only be applied through shank injection using ground-based equipment. Site specific application of nematicide fumigants 1,3-D and metam sodium was applied in September or early October following nematode grid sampling in the year prior to the potato crop. The particular combination of chemicals used was determined by the producer. The producer’s experience with CRN in previous potato crops on the field site influenced chemical selection and application strategy. Fields where 30% or more of the sampling grids had CRN detected; metam sodium or oxamyl was also applied for nematode control to control risk. Site-specific nematicide application strategies were as follows.

Site-specific 1,3-D only

Spatially interpolated map locations with estimated CRN density > 0 (detected) received 1,3-D application. 1,3-D application rate was 140 L ha^{-1} for CRN density between 0 and 50 juveniles/ 250 cm^3 soil and 188 L ha^{-1} for estimated CRN density greater than 50 juveniles/ 250 cm^3 soil. The lower application rate was applied to variable rate control zones bordering sampling grids with detected CRN.

Site-specific 1,3-D with uniform application of metam sodium or oxamyl

Spatially interpolated map locations with estimated CRN density > 50 juveniles/ 250 cm^3 soil received 188 L ha^{-1} 1,3-D application. 1,3-D was applied to variable rate control zones bordering sampling grids with detected CRN > 50 juveniles/ 250 cm^3 . Metam sodium or oxamyl was applied uniformly. Metam sodium was applied through the irrigation system with an application rate of 280 to 375 L ha^{-1} in September or early October following site-specific 1,3-D application. Oxamyl was applied through the irrigation system at an application rate of 5 L ha^{-1} with initial application based on growing degree days 2 to 4 times during the season on a 14 day interval depending upon crop history.

Site-specific 1,3-D with site-specific application of metam sodium

Spatially interpolated map locations with estimated CRN density > 50 juveniles/ 250 cm^3 soil received 188 L ha^{-1} 1,3-D application. 1,3-D was also applied to variable rate control zones bordering sampling grids with detected CRN > 50 juveniles/ 250 cm^3 at the same rate. Metam sodium was applied at a rate of 280 to 375 L ha^{-1} proportional to estimated CRN density to areas not

receiving 1,3-D application. One custom applicator had the capability to select between two chemicals as well as variable rate application based on field location.

Input Costs

Chemical costs used in economic analyses were \$3.20 L⁻¹, \$1.30 L⁻¹ and \$22.00 L⁻¹ for 1,3-D, metam sodium, and oxamyl, respectively. Costs for sampling, nematode analysis and mapping were \$34.50 ha⁻¹ for 0.9 ha grid sampling size. Custom uniform nematicide fumigant application costs were \$84 ha⁻¹ for metam sodium and \$99 ha⁻¹ for 1,3-D. Custom site-specific nematicide fumigant application costs were \$84 ha⁻¹ for metam sodium, \$109 ha⁻¹ for 1,3-D and \$134 ha⁻¹ for both. Application costs for injection through the irrigation system with water were assumed to be zero since this is a standard producer practice.

RESULTS AND DISCUSSION

In total, 4,030 grid samples were collected representing nearly 3200 ha of sprinkler irrigation commercial potato production in eastern Idaho over a 6-year period. Seventy three percent of the grid samples had CRN densities below the detectable limit. Ten percent had detected CRN densities below 50 juveniles/250 cm³ of soil and 17% had greater CRN densities. Relative to conventional uniform fumigant nematicide application, site-specific fumigant nematicide application has the potential to reduce environmental chemical loading 73% if fumigant nematicide could be applied only to grids where nematodes are detected. The sampled fields are not necessarily statistically representative of CRN distribution in eastern Idaho since the fields were not randomly selected, but likely indicate the potential for wide scale chemical loading reduction in the region.

More than 35% of the fields grid sampled had more than 90% of the grid sample sites with CRN densities below the detectable limit (Fig. 1). In approximately 50% of the grid sampled fields, 70% or more of the grid sample sites had CRN densities below the detectable limit. Thus, half or more of the fields sampled could potentially reduce nematicide use by 70% or more if risk was not a factor in nematicide use. In approximately 50% of the fields sampled, 10% of the grid sample sites had CRN densities greater than 50 juveniles/250 cm³ of soil. Thus, half of the fields sampled had some “hot spots” in CRN density. Fifty-three percent of the fields grid sampled had CRN densities detected but less than 50 juveniles/250 cm³ of soil. Nearly all of the fields sampled had less than 40% of the grid sample sites had CRN densities detected but less than 50 juveniles/250 cm³ of soil. Collectively all the fields sampled revealed spatial distributions in detected CRN densities that would result in reduced fumigant nematicide use if site specific fumigation technology was used.

1,3-D nematicide loading reductions relative to conventional uniform fumigant application on fields fumigated using site-specific fumigation technology in the fall of 2007 is shown in table 1. On field sites 6 and 8 there was no reduction in fumigant applied by site-specific application because grid sampled

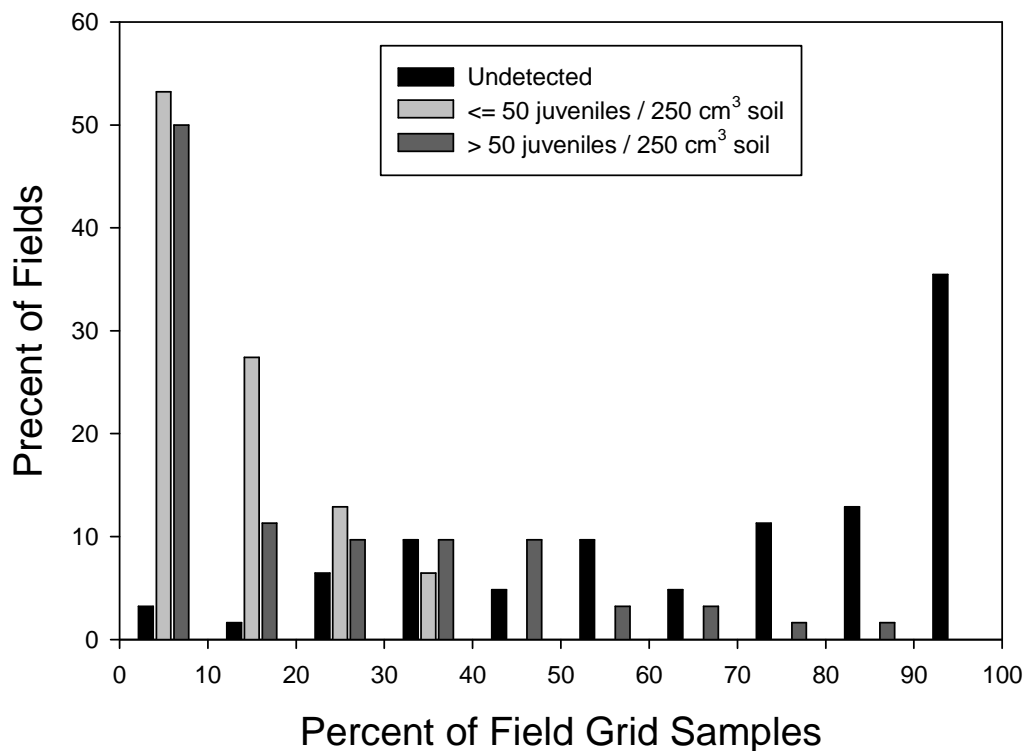


Figure 1. Histograms of the percent of sampled fields versus percentage of field grid samples having CRN densities of undetected, ≤ 50 juveniles/250 cm³ soil and > 50 juveniles/250 cm³ soil (i.e. 35% of fields sampled had undetected CRN densities in more than 90% of the grid samples).

CRN densities were relatively high and distributed throughout the field area. On field site 11, grid sampling showed that CRN densities were relatively low throughout the field area without any “hot spots” greater than 50 juveniles/250 cm³ of soil. The producer decided to use a uniform application of oxamyl during the 2008 growing season. Based on farm-gate receipts and USDA inspections provided by potato producers, potato tuber yield and quality of the 2008 crop were not adversely affected by use of site-specific fumigation technology. Total volume reduction for the 11 field sites was 38,257 L representing a fumigant cost savings of \$122,422 or \$191 ha⁻¹. However, this is not a true chemical cost savings as other nonfumigant nematicides were used to replace fumigant nematicide not applied.

Nematode control cost savings relative to uniform 1,3-D application at a rate of 188 L ha⁻¹ on a 55 ha field is shown in table 2. Depending upon the percent of area treated with 1,3-D and combination of nematicides used on other areas of the field, the cost savings associate with site-specific fumigant nematicide application can range from \$1,200 to \$22,000. The \$1,200 savings associated with 30% 1,3-D and 100% uniform metam sodium may not be worth the risk of CRN tuber damage unless both fumigants were initially going to be applied uniformly. If that is the case the cost savings would be greater than shown in table 2. The largest cost savings occur when less than 30% of the field area requires 1,3-D

Table 1. 1,3-D fumigant nematicide use on eleven fields in eastern Idaho where site-specific fumigation technology was applied in the fall of 2007.

Field site identification	Field area ha	Average application rate L ha ⁻¹	Conventional uniform rate L ha ⁻¹	Difference between application rates L ha ⁻¹	Volume reduction L
1	47	58.2	188.0	129.8	6,100
2	48	18.8	188.0	169.2	8,122
3	61	144.6	188.0	43.4	2,647
4	52	160.5	188.0	27.5	1,430
5	70	178.3	188.0	9.7	679
6	125	188.0	188.0	0	0
7	55	60.1	188.0	127.9	7,034
8	52	188.0	188.0	0	0
9	55	117.3	188.0	70.7	3,888
10	51	112.6	188.0	75.4	3,845
11	24	0.0	188.0	188	4,512
	Total = 640	Avg = 111.6		Avg = 76.5	Total = 38,257

fumigation, which allow less expensive nonfumigant nematicides to be used singly on nonfumigated areas of the field. Based on practical experience, site-specific 1,3-D fumigation alone is not recommended on fields that have CRN spatial densities requiring 1,3-D fumigation on more than 30% of the field area. The cost savings are minimal and the risk of not fumigating an undetected “hot spot” is too great. The exception may be when the area requiring fumigation is contiguous and the remainder of the field has very low or undetected CRN densities. Savings increase with lesser percentage of the field requiring 1,3-D fumigation, for example 10% of the field area in table 2. However, custom applicators are reluctant or refuse to consider fields with small percentages of fumigation because they make less money per site setup.

SUMMARY AND CONCLUSIONS

Plant-parasitic nematode populations (densities), namely CRN and root lesion, were field tested using geo-referenced grid soil sampling in 62 commercial fields prepared for potato production in eastern Idaho from 2002 through 2008. In total, 4,030 grid samples were collected representing nearly 3200 ha of sprinkler irrigation commercial potato production over a 6-year period. Collectively, 73% of the grid samples had CRN densities below the detectable limit. Thus, use of site-specific fumigant nematicide application has the potential to reduce environmental chemical loading 73% relative to uniform application. Guidelines for site-specific fumigation in combination with uniform nonfumigant nematicide application for CRN suppression has been developed and used over the past 3 years on 1200 ha of potato. On average site-specific fumigation has resulted in a

Table 2. Cost savings from site-specific fumigant nematicide application scenarios relative to uniform 1,3-D application for 55 ha field.

Field area treated		Total chemical cost	Total sampling cost	Site-specific application cost	Total cost	Unit cost	Savings relative to conventional uniform application
1,3-D	additional nematicide						
		\$	\$	\$	\$	\$ ha ⁻¹	\$
100%	0%	33,110	\$35	5,346	38,491	700	----
50%	100% oxamyl 2 times	28,655	1,900	2,997	33,552	610	4,938
30%	70% site-specific metam sodium	26,449	1,900	7,370	35,719	649	2,771
30%	100% oxamyl 2 times	22,033	1,900	1,798	25,731	468	12,759
30%	100% uniform metam sodium	33,528	1,900	1,798	37,226	677	1,265
30%	0%	9,933	1,900	1,798	13,631	248	24,859
15%	85% site-specific metam sodium	25,022	1,900	7,370	34,292	623	4,199
10%	100% oxamyl 2 times	15,411	1,900	\$600	16,200	295	22,290

30% reduction in chemical usage and production cost savings of \$180 ha⁻¹ when 1,3-dichloropropene is used as the sole-source of nematode suppression. Further reductions in usage of 1,3-dichloropropene can exceed 50% if used in combination with another nematicide such as oxamyl. This combination approach can have production cost savings approaching \$200 ha⁻¹. Based on farm-gate receipts and USDA inspections provided by potato producers, potato tuber yield and quality have not been adversely affected using site-specific fumigation technology.

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