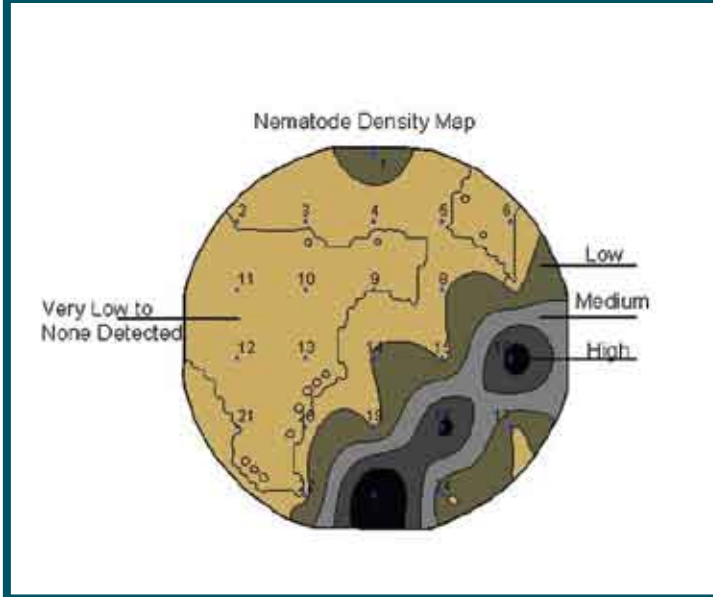
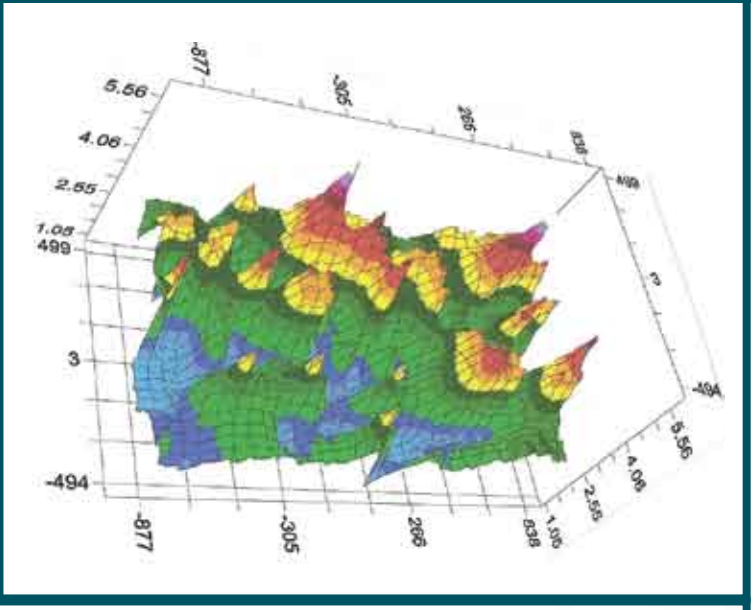
GPS-Guided and Site-Specific Application of Telone II for Nematode Management





by John Taberna, Jr
Western Ag Research

Project participants included the following farms, USDA staff, and businesses located in Idaho.

Farm Operations

Cedar Farms AF, Tom Ternus, American Falls
Cedar Farms, Todd Jensen, Fort Hall
Egbert Farms, Kirk Egbert, Terreton
Mickelsen Farms, Mark Mickelsen and Todd Suitter, Rigby
Morgans Pasture, Mike Murdoch, Blackfoot
Neville Brothers, Stan Neville, Hamer
RRRanches, Rene Jensen, Blackfoot
Wada Farms Pingree, Troy Watt, Pingree
Walters Produce, Gene Bair, Newdale
Wilcox Farms, Larry Neiderer and Terry Wilcox, Rexburg

Businesses

Holley Brothers Custom Farming, Jon Holley, Shelley
NuVision Ag, Randy Thomas, Blackfoot
Straight-Line Custom Farming, Josh Hansen, Rexburg
Western Ag Research, John Taberna, Jr., Blackfoot
Western Laboratories, Harry Kreeft, Parma
Western Laboratories, John P Taberna, Parma

USDA

Brad King, USDA NWIRSL, Kimberly

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John Taberna, Jr., Research Agronomist with Western Ag Research LLC, was the principal investigator on this project and author of this publication. The results and suggestions are based upon the growing conditions found in eastern Idaho at an elevation of 4,000 to 5,300 feet. Taberna received both his B.S. and M.S. degrees in Agronomy from the University of Idaho. He is a Certified Professional Agronomist (CPA_g) with the American Society of Agronomy.

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect the view of the U.S. Department of Agriculture or the participating farmers.

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Background

The use of Global Positioning Systems (GPS) in agriculture began in the late 1980s and has become increasingly popular since 2002. Growers in Idaho first sampled soil on a grid basis for developing GPS-guided variable rate fertilizer applications. Most of those maps were designed for variable rate applications of phosphorus, potassium, and elemental sulfur. In regions of the United States where soil pH is low, GPS has been used for variable rate lime application based on the sampling results for soil pH. GPS use has also become common in tractor guidance, grain yield monitoring, wheat and corn planting, and in making rows for potatoes and other crops. In addition, GPS is used in ground and aerial sprayers.

Western Ag Research's experience thus far has shown that potato yields and quality from fields treated with site-specific fumigation have been similar to fields treated with uniform fumigation.

Prior to 1997, grid sampling for nematodes and the site-specific treatment for them was virtually non-existent. Around that time, the first scientific publications appeared on the subject of site-specific treatment with a nematicide for nematode suppression.

More recently, GPS technology has been utilized for nematode management because nematodes are not always uniformly distributed in a field. Growers have begun grid sampling for nematodes to direct the site-specific application of fumigants, rather than treating the entire field.

GPS-guided, site-specific technology, whether for the

application of fertilizers or fumigants, begins with soil sampling a field in grids using GPS. The soil is analyzed for the pest or nutrient and the data are entered into a Geographical Information Systems (GIS) database. The GIS software is then used to estimate values of the pest or nutrient for specific sites located between the actual sampled points and create a nematode population map. These data, both the sampled values and estimated values, are used to develop the recommended treatment maps. Western Ag Research adds an additional step in the site-specific treatment of nematodes. We investigate the spatial correlation of each nematode population map through what is called geostatistics or variogram analysis and then modify the recommended treatment maps accordingly.

In 1997, Western Laboratories in Parma, Idaho conducted its first grid sampling for nematodes on a 145-acre potato field in Washington. The results showed that the nematode population was not uniform, but was highly variable with localized areas of both very low and high populations even though that field had a long history of uniform fumigant application. Other fields that were grid sampled for nematodes showed similar results. Because of these results, we became interested in the potential benefits of treating only those areas of the field where nematodes were a problem.

From 2001 through 2006, few farmers used GPS-guided site-specific technology for the treatment of nematodes. Most farmers were reluctant to try this technology for fear of missing areas of high

The site-specific application of Telone uses information gained from intensive nematode sampling and Global Positioning Systems (GPS) to apply Telone to only specific locations in a field. This technology is often used to apply Telone to 15-30% of the total field acreage, leaving areas of the field where no Telone is applied. In some situations, the areas not treated with Telone are treated with a combination nematicide, such as Vydate CL-V.

nematode populations and the resulting yield loss. Western Ag Research in Blackfoot adds a step to the process, variogram analysis, to address growers' concerns that pockets of high nematode populations might be missed. Depending on the results of variogram analysis, we may modify the recommended treatment maps to apply Telone to a larger area in order to capture any undetected pockets of nematodes.

By 2007, potato farmers expressed greater interest in the technology, as they faced increasing production costs. Farmers were also more willing to utilize GPS technology due to its greater usage in other areas of agriculture.

Western Ag Research's experience thus far has shown that potato yields and quality from fields treated with site-specific fumigation have been similar to fields treated with uniform fumigation. Our cooperating farmers often save at least $8,500 per field by using GPS-guided, site-specific application of Telone.

The key to successful site-specific Telone fumigation is an accurate nematode population map, careful interpretation of the map, and appropriate recommendations for Telone treatment.

Our cooperating farmers often save at least $8,500 per field by using GPS-guided, site-specific application of Telone.

The site-specific application of Telone for nematode management can be approached in four different ways.

1) Telone applied throughout the field at variable rates, based on pest populations.

Rates vary from 10 to 20 gallons per acre. This method usually reduces Telone use by 3 to 6 gallons per acre.

2) Telone applied to only some areas of the field, with the remainder of the field left untreated.

This method usually reduces Telone use by 8 to 10 gallons per acre.

3) Telone is applied in combination with another fumigant.

This method is often used when metam sodium is the preferred product, but there are a few areas in the field with high root-knot nematode populations. Telone is applied site-specifically only to these few areas and the rest of the field is treated with another fumigant.

4) Telone is applied in combination with a non-fumigant nematicide.

In this approach, Telone is applied only to the areas of the field with the highest nematode populations and the rest of the field is treated with a lower cost nematicide, such as Vydate CL-V. This approach is effective, since non-fumigant nematicides usually work well on low to medium nematode populations. The fumigant is needed to treat the areas with high population levels. This combination approach is cost-effective for the grower, since fumigants usually cost $120 to $150 more than most nematicides. (The theory and practicalities of this approach are clearly addressed in the *Journal of Nematology* in articles such as "Site-Specific Management of Nematodes –Pitfalls and Practicalities" and others included in the reference section.)

Economics of the Site-Specific Treatment of Nematodes with Telone

Fumigants, such as Telone, are one of the largest input costs in potato production. The uniform application of Telone, at 20 gallons per acre, to a 136-acre field can cost $31,000 or more, depending upon applicator fees and the cost per gallon.

By treating only a portion of the field where nematode populations are problematic, growers can achieve significant cost savings while still producing a high yielding, quality potato crop (Table 1).

Growers can also choose to treat the field or portions of the field with less expensive nematicides. For instance, a grower may have a few hot spots of root-knot nematodes and so may choose to treat those areas site specifically with Telone and the rest of the field with nematicides, such as Vydate CL-V. This combination approach is cost effective for the grower, since fumigants usually cost $120 to $150 more than most nematicides. It also has the environmental benefit of reducing active-ingredient use.

By treating only a portion of the field where nematode populations are problematic, growers can achieve significant cost savings

Table 1: The economics of uniform and site-specific Telone application on a 136-acre field. All Telone applications were made at 20 gallons per acre.

AREA OF FIELD TREATED WITH NEMATICIDES (%)		PRODUCT COST* ($)	SAMPLING COST ($)	APPLI-CATOR FEES** ($)	TOTAL COST ($)	COST PER ACRE ($/AC)	SAVINGS OVER UNIFORM TELONE APPLICATION ($/FIELD)
Telone	**Other nematicides**						
100%	—	$ 32,912	$35 for 1 soil sample	$ 3,400	$ 36,347	$ 267	—
50%	100% Vydate (2 qts)	$ 22,984	$1,900 for 2-acre grid	$ 3,000	$ 27,884	$ 205	+ **$ 8,463**
30%	70% Metam Sodium***	$ 24,440	$1,900 for 2-acre grid	$ 6,000	$ 32,300	$ 238	+ **$ 4,047**
30%	100% Vydate (2 qts)	$ 16,402	$1,900 for 2-acre grid	$ 2,500	$ 20,802	$ 153	+ **$ 15,545**
30%	—	$ 9,874	$1,900 for 2-acre grid	$ 2,500	$ 14,274	$ 105	+ **$ 22,073**
15%	85% Metam Sodium	$ 22,624	$1,900 for 2-acre grid	$ 6,000	$ 30,524	$ 224	+ **$ 5,823**
10%	100% Vydate (2 qts)	$ 9,819	$1,900 for 2-acre grid	$ 2,000	$ 13,719	$ 101	+ **$ 22,628**

* Based upon a projected cost for Telone at $12.10 per gallon, Metam Sodium at $5.10 per gallon, Vydate CL-V at $10.48 per pint ($83.84/gallon).

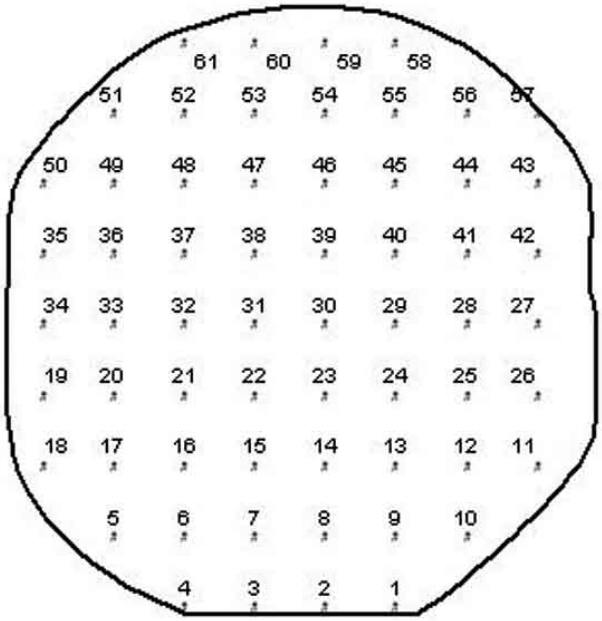
** Applicator fees are based on the percentage of area treated and whether it is uniform application or site-specific application. Site-specific application is more expensive per acre.

*** Metam Sodium is injected into soil at 30 gallons per acre.

Seven Steps to GPS-Guided, Site-Specific Application of Telone

The typical nematode sampling procedure often involves collecting several cores of soil from a 120- to 160-acre field and then combining the cores into one soil sample for a single nematode analysis. Growers then decide to treat the entire field based upon results of this single composite sample.

In grid-based sampling for nematodes, soil samples are collected individually on a grid that often varies from 1.85 to 3.00 acres. Each site of soil collection is mapped via GPS. A 136-acre pivot on a two-acre grid contains 60 to 70 individual soil sampling sites, depending upon field layout.



Step 1: Geo-referenced grid points established on 136-acre field.

STEP 1: Fixing field boundary and soil sampling points by GPS

To lock in the field boundary, we drive a four-wheeler or truck around the edge of the field with a mounted GPS receiver. The field area is calculated by special GPS software. This method provides the most accurate acreage and identification of grid points within the field, with an error rate of only 1 to 3 meters. Other methods, such as aerial photos, often produce errors up to 10 meters.

Once the field boundary is designated, most GPS data-collection software packages will request the desired grid size for a soil sampling plan and then automatically fix the geo-referenced positions for the soil sampling sites within the designated field boundary.

The grid size is fixed to 1.85-2.00 acres, if stubby-root and root-knot nematodes are of concern. A smaller grid size is used because the distribution of root-knot and stubby-root nematode populations is often patchy. If only root-lesion is of concern, then grid sizes of 2.25-3.00 acres are adequate. Root-lesion nematodes are more widely distributed and found in nearly every soil sample.

STEP 2: Collecting and analyzing individual soil samples

Next, we collect soil samples at each individual geo-referenced grid point that was fixed in step 1. Each of these soil samples is actually a composite of several sampling cores collected within 45 feet of the geo-referenced grid point. For nematodes, especially root-knot and stubby-root, we suggest at least 8 to 10 sampling cores at each grid point due to the patchy and sporadic nature of their distribution. Soil sampling for root-lesion nematodes only requires 5 to 7 sampling cores at each grid point, because of their wider distribution. Each composite sample is analyzed individually for nematode populations per 250 cc soil.

Step 2: Soil samples collected for laboratory analysis of nematodes.

In grid-based sampling for nematodes, soil samples are collected individually on a grid that often varies from 1.85 to 3.00 acres.

Shape	Sampleid	Longitude	Latitude	CRN	RL
Point	1	-112.39082755	43.79072765	0	780
Point	2	-112.39201645	43.79072765	0	3320
Point	3	-112.39320518	43.79072765	0	800
Point	4	-112.39439390	43.79072765	0	80
Point	5	-112.39558280	43.79158588	260	400
Point	6	-112.39439390	43.79158588	0	2600
Point	7	-112.39320500	43.79158588	0	1100
Point	8	-112.39201627	43.79158588	400	530
Point	9	-112.39082755	43.79158588	460	650
Point	10	-112.38963864	43.79158588	1560	400
Point	11	-112.38844974	43.79244410	0	400
Point	12	-112.38963864	43.79244410	0	280
Point	13	-112.39082719	43.79244410	0	200
Point	14	-112.39201609	43.79244410	200	250
Point	15	-112.39320500	43.79244410	0	50
Point	16	-112.39439390	43.79244410	50	60
Point	17	-112.39558262	43.79244410	200	330
Point	18	-112.39677135	43.79244410	510	260
Point	19	-112.39677135	43.79330218	10	330
Point	20	-112.39558244	43.79330218	100	910
Point	21	-112.39439390	43.79330218	50	1560
Point	22	-112.39320500	43.79330218	130	780
Point	23	-112.39201609	43.79330218	0	780
Point	24	-112.39082719	43.79330218	0	460
Point	25	-112.38963828	43.79330218	390	3000
Point	26	-112.38844956	43.79330218	520	5590
Point	27	-112.38844938	43.79416024	20	280
Point	28	-112.38963828	43.79416024	0	140
Point	29	-112.39082719	43.79416024	0	60

Step 3: Nematode counts and sampling sites are entered into GIS software.

STEP 3: Entering nematode counts and location in GIS software

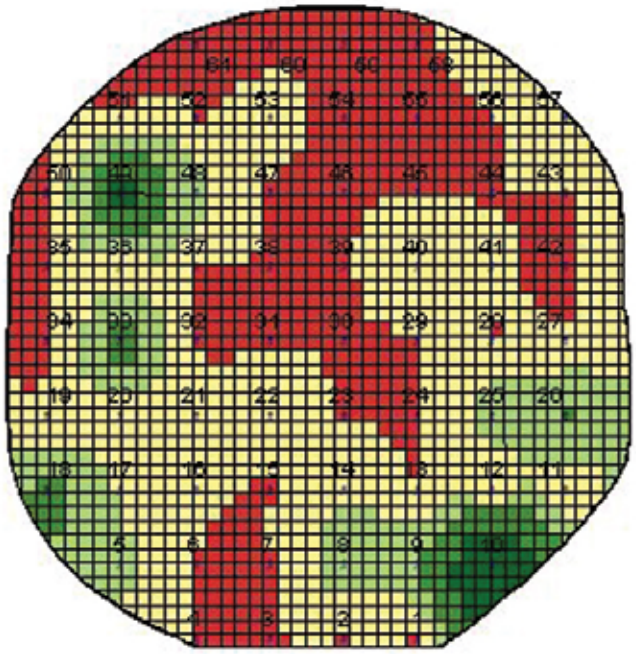
The nematode counts and corresponding GPS location of each soil sample are entered into a GIS software package. All nematode data are geo-referenced to the known GPS locations within the field. The nematode counts and corresponding GPS coordinates are used to generate the spacial map of nematode populations.

STEP 4: Generating spatial map of nematode populations

The next step is to create a map of the nematode populations across the field using a GIS software program and the nematode data entered in step 3. These maps are developed using interpolation models based upon the nematode population at each sampling point. Interpolation is a mathematical evaluation of areas that were soil sampled and then autocorrelated to the areas that were not soil sampled. One popular interpolation model in site-specific agriculture is kriging.

Kriging estimates nematode population levels between known nearby sampling points to generate values for the non-sampling points. These data, both the sampled values and estimated values, are used to make a color-coded map that clearly shows the nematode populations in a field.

In the example map, the red areas indicate elevated nematode populations and yellow areas show lower population levels. The green areas represent very low nematode population.



Step 4: Spatial map of nematode population is generated.

STEP 5: Variogram Analysis of Nematode Data

Western Ag Research looks at the variation of the nematode data for all of our fields that we grid sample for nematodes. This process is called variogram analysis. It is important to have a high degree of correlation in the nematode data. The higher the correlation, the more confidence we have in applying Telone site specifically according to the generated nematode map. If the correlation is not strong, we increase the borders on the areas to be treated. If there is no correlation in the nematode data sampled, then it is better to treat the entire field with a uniform application of Telone.

Correlations are most often reported as r^2. An r^2 value is a comparison of the data to an assumed model. An r^2 value of 0 indicates no correlation. An r^2 value of 1.00 is a perfect match and shows a strong correlation. The closer the r^2 values are to 1.00, the higher the correlation. For nematode data that are sampled in grids, we consider any r^2

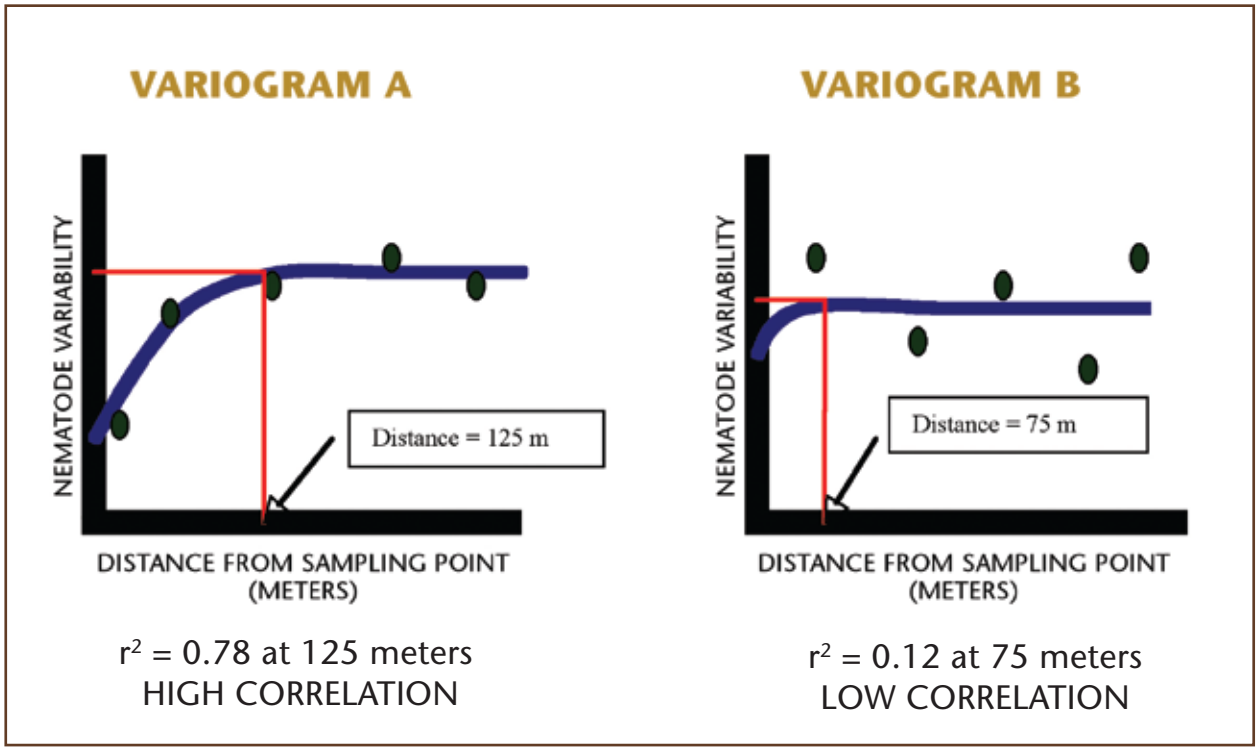
value of 0.60 or higher to be a strong correlation of the nematode dataset. An r^2 value of 0.40 to 0.59 shows a moderately good correlation to the nematode dataset. An r^2 value below 0.40 shows poor correlation. The Telone treatment maps are then modified, depending upon the r^2 value.

We also modify the Telone application maps based upon the distance over which the data are correlated, which is also generated by the variogram analysis. If the variogram distance surpasses our sampling point distance, then we have greater confidence in the nematode population map and the recommended treatment map. If the variogram distance is relatively small, then we have less confidence and will modify the treatment map to include a larger portion of the field. A large distance correlation is typically 130 meters. A small distance is typically less than 95 meters.

To illustrate variogram analysis, two simplified variograms are shown below. The nematode data used to make the color nematode population map shown in step 4 could produce either variogram A or B. Variogram A has a much stronger correlation than Variogram B. In Variogram A, the nematode dataset has a correlation of $r^2 = 0.78$ and a distance of 125 meters. This means there is a strong correlation of nematode data to 125 meters from the sampling points. This is good because the grid size for 2 acres is around 95 meters between sampling points. Therefore, Variogram A has a strong correlation that surpasses the grid-sampling distance of 95 meters.

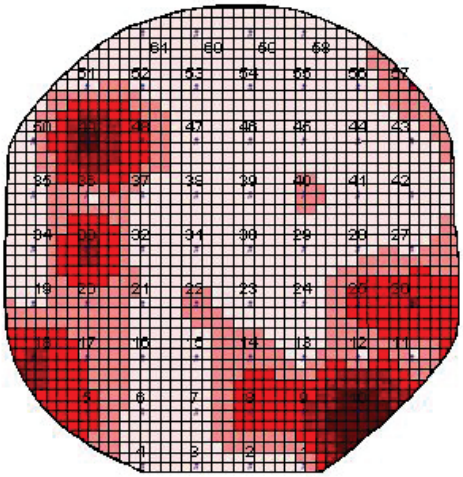
Variogram B has a poor correlation of $r^2 = 0.12$ and a distance of only 75 meters. This means the nematode data are poorly correlated within the sampling distance of 95 meters. If the analysis of the data yielded Variogram B, confidence in the site-specific application of Telone in that field would be greatly reduced.

After we conduct the variogram analysis, we carefully review the nematode population map and the variogram analysis with the farmer. This information is then used to make the Telone application map.

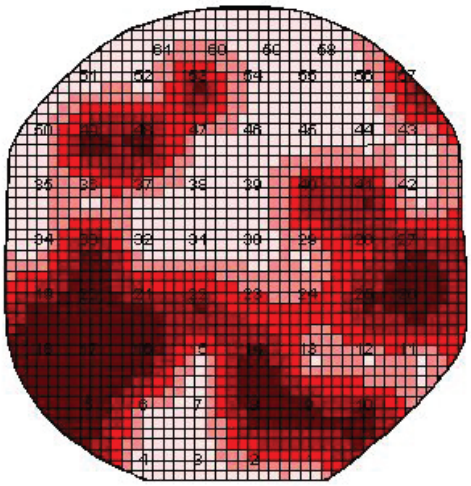


STEP 6: Making a Telone Application Map

After variogram analysis of the nematode data, we begin making a site-specific Telone application map for that field. With the farmer's participation, the Telone application map is built based on the nematode population, variogram analysis, field history, and the farmer's comfort level. The final Telone application map is converted to a readable map of the custom applicator's software. The Telone application map tells the applicator's software and controllers where and how much Telone to apply on a site-specific basis.



Columbia Root-knot Population Map



Corresponding Telone Application Map

Below is an example of an actual nematode population map converted to a Telone application map. The 136-acre field was located in Hamer, Idaho. It was grid sampled on a 2.23-acre grid, with a total of 61 sampling sites. Of the 61 sampling grid sites, 27 grid sites contained Columbia root-knot at an average of 128 nematodes per 250 cc soil. The kriging interpolation determined that the area covered by the root-knot nematode populations was around 98 acres.

The variogram analysis for this map showed a low correlation of $r^2 = 0.31$ over a distance of 174 meters, thus we lacked some confidence in the map provided by kriging of our root-knot nematode data. We made a Telone application map that covered the entire field at an average rate of 14.3 gallons per acre, or a total 1,944 gallons for the 136-acre field. A normal rate for root-knot suppression would have had 2,720 gallons to the field at the current cost of $10.35 per gallon (2008). The cost for a full 20-gallon rate on this field would have been $28,152. Using site-specific application, the cost for 1,944 gallons on this field was $20,120, for a savings of $8,032.

Maps: The 27 grids containing root-knot nematode were entered into GIS software and the results were interpolated using the kriging method. The 27 grids indicated that roughly 60 acres (27 grids x 2.23 acres) contained root-knot nematodes. The kriging interpolation of the 27 grids in the GIS software showed that approximately 98 acres contained root-knot nematodes in the sampled and non-sampled areas. The data showed a low degree of correlation, based upon variogram analysis, so we made a Telone application map that expanded the borders of the nematode population map made through kriging. The darkest red areas in the Telone application map were treated with 20 gallons per acre. The medium red areas were treated with an average of 15 gallons per acre. The lighter red and white areas were treated with 8 to 10 gallons per acre.

STEP 7: Sending the Map to a GPS-Guided Custom Applicator

Once the Telone application map is made, it can be sent to a custom applicator. The Telone application map must be converted to a file that is readable by the custom applicator. Custom applicators are able to apply Telone to some areas of the field and not to other areas, based upon the Telone application maps provided by an agronomist who followed steps 1 through 6.

The picture above is from Holley Brothers Custom Farming's computer screen located inside their tractor cab. It shows the screen in "real-time" during an application of Telone on one of the fields mapped by Western Ag Research. From left to right in the display, the yellow and red show the areas that will be treated with 20 gallons per acre of Telone. The blue designates the area that has been treated. The green shows the areas that will not be treated with Telone.

The picture of the display screen to the right shows that the current application is 18 gallons per acre. The average and current application rates are updated continuously as the tractor and soil injection equipment travel through the field.

From the Telone application map we made, 1,590 gallons of Telone would be used to treat this field. At the time the screen was photographed, 705.9 gallons had already been applied.

The final treatment map and the amount of Telone applied per acre is recorded on the screen and then saved by the applicator. The saved file is often referred to as the "as applied" file. This file can be kept for records and viewed by the agronomist and farmer.

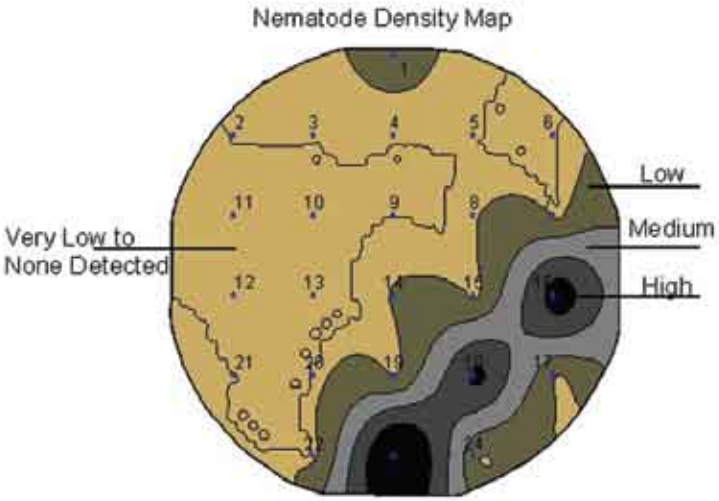
Subsequent Field Management after Site-Specific Telone Application

The nematode maps provided by Western Ag Research can be used more than once in a potato cropping system cycle, if the fields are managed properly. Western Ag Research has worked on numerous fields where the initial nematode map from grid sampling has been successfully used for the following two or three potato crops.

Below is an example of how a field was subsequently managed after the site-specific application of Telone.

FALL 2002: GRID SAMPLING AND SITE-SPECIFIC TREATMENT WITH TELONE

The field shown below was in a typical potato-wheat rotation, common in the sandy fields of eastern Idaho. The field was grid sampled in fall 2002 prior to planting of the spring potato crop. The farmer fumigated with Telone in the areas with low, medium, and high nematode densities. The remaining areas of the field, shown in tan, were not treated.



FALL 2004: SPOT ANALYSIS OF NEMATODE POPULATIONS; NO TELONE APPLICATION

In fall 2004, we soil sampled the field in zones of known root-knot populations based on the grid-sampling results from 2002. We collected three different soil samples in the tan areas and three in the grey areas. We did not detect root-knot nematodes in any of the samples. The farmer decided to use only Vydate CL-V at the lower labeled rate, prior to planting his 2005 potato crop. He used Vydate because of its lower cost at $45 per acre (1/2 gallon) versus Telone at $220 per acre (18-20 gallons).

FALL 2006: SPOT ANALYSIS OF NEMATODE POPULATIONS; NO TELONE APPLICATION

In 2006, we repeated the same sampling regime as in 2004. Three separate soil samples were collected from the tan areas and three separate soil samples from the grey areas. Again, no root-knot nematodes were detected, so the farmer only treated with Vydate CL-V. The grower was pleased with the yields and quality of the potatoes harvested, which he said were as good as his uniformly fumigated fields.

FALL 2008: GRID SAMPLED THE FIELD WITH THE SAME GRID POINTS AS ESTABLISHED IN 2002

After relying on the information from the first grid sampling for two successive potato crops, the farmer decided to grid sample the field again using the same soil sampling sites that were created in 2002. The farmer reduced his use of Telone by 1,000 gallons, equal to $10,350, in 2002 when he used grid sampling and site-specific application. He decided it was worth the cost of collecting grid samples again in 2008 because he would likely recover his investment if he reduced his use of Telone by just 200 gallons.

(Other farmers have decided to use a uniform application at this stage and then sample the grid points for future site-specific management of nematodes.)

Evidence that Site-Specific Telone Application Works

The effectiveness of site-specific Telone application has been monitored by assessing yields and comparing nematode levels before treatment and after harvest.

Many of the farmers we have worked with have found that their yields were equivalent, whether they used a uniform or site-specific application of Telone.

We have sampled soil from hundreds of the same grid points after harvest to compare nematode levels. In some cases, samples were collected from the same grids across the entire field and in other cases samples were collected from only selected areas because of economic limitations. All post-harvest soil nematode data were compared to the pre-application of Telone for those same grid sites. In general, the areas with low nematode populations that were not treated with Telone did not show a large increase in nematode levels as compared to areas high in nematodes that were treated with Telone.

Below are three examples of pre-application and post-harvest soil sampling results for nematodes.

The results in Table 2 are from a 345-acre field in Osgood, Idaho. This field had a history of root-knot damage in the tubers. The grid sampling results showed that the root-knot nematodes were isolated to mostly the eastern area of the field. No root-knot nematodes were detected in soil samples collected from the western portion of the field. Of the 170 grid points, root-knot nematodes were detected in 64 sampling sites. Variogram analysis of the nematode population map yielded a low correlation of r^2 =0.384 and a distance of 136 meters. Because of this low correlation, we expanded the area to be treated and applied 20 gallons of Telone per acre to

an area covered by 96 grids, or approximately 192 acres of the 345-acre field.

For the areas that were treated with Telone, nematodes were detected in only 17 of the sampling grid points after harvest as compared to 63 before treatment. For the most part, Telone treatment reduced the level of detectable root-knot nematodes. Residual root-knot nematodes are often found after potato harvest in areas treated with Telone at 20 gallons per acre, because root-knot nematodes are protected from treatment when located inside tubers or roots as larvae or eggs.

The remaining 153 acres covered by 74 of the 170 grids were not treated with Telone. The post harvest analysis showed that only three of these 74 grids contained root-knot nematodes, which was an increase of only two of the grid sampling points showing detectable nematodes from the previous sampling. The single grid sampling point that showed detectable root-knot nematodes, but was not treated with Telone, had 10 root-knot nematodes per 250 cc soil. The three grid soil samples in the area not treated with Telone averaged 67 root-knot nematodes per 250 cc soil at post-harvest.

	TELONE (20 GALLONS/ACRE)		NEMATICIDE TREATED (NO TELONE APPLIED)	
	Total Grid #	Grids with root-knot	Total Grid #	Grids with root-knot
Before Telone	96	63	74	1
After Telone	96	17	74	3

Table 2: Nematode levels in soil samples collected before Telone application and after harvest in a 345-acre field with 170 sampling grid points.

	TELONE (0 GAL/ACRE)		TELONE (12 GAL/ACRE)		TELONE (15 GAL/ACRE)		TELONE (20-22 GAL/ACRE)	
	Total Grid #	Grids with root-knot	Total Grid #	Grids with root-knot	Total Grid #	Grids with root-knot	Total Grid #	Grids with root-knot
Before	20	0	10	8	15	15	21	21
After	20	2	10	3	15	0	21	1

Table 3: Nematode levels in soil samples collected before Telone application and after harvest in a field that was treated with different rates of Telone, from 0 to 22 gallons.

Table 3 shows another example of nematode levels in soil samples collected before Telone treatment and after harvest in a field which included a total of 66 grid sampling points. Of the 66 grid sampling points, 20 were not treated with Telone because no detectable root-knot nematodes were present. After harvest, only two of these grid sampling points showed detectable root-knot nematodes. Of the 36 grid sampling points that initially contained root-knot nematodes and were treated with 15 or more gallons per acre of Telone, only one still showed detectable root-knot nematode levels after harvest.

The results shown in tables 2 and 3 were generated by collecting soil from the same initial sampling grid points on the entire field both before Telone treatment and after harvest. These data are extremely useful and reliable, but expensive to collect.

Table 4 shows another method Western Ag Research uses to provide evidence of the value of site-specific Telone application. Only a representative collection of sampling grid points are sampled at post-harvest in this more economical method of verification.

The areas treated with Telone in this field were based solely on the nematode population map

generated by kriging. There were several samples collected after harvest that showed high levels of root-knot nematode. Because of these undesired results, we decided to add the additional step of variogram analysis before making our final Telone application maps. If we would have used the results from a variogram analysis of the nematode population map for this field, we likely would have treated a larger area and would have reduced the number of after harvest grid sampling points with high levels of root-knot nematodes.

Potatoes infected with root-knot *(M. chitwoodi)* nematode, three with severe infections.

TELONE (0 GAL/ACRE)			TELONE (12 GAL/ACRE)			TELONE (15 GAL/ACRE)			TELONE (20 GAL/ACRE)		
Grid-site	Before	After	Grid-site	Before	After	Grid-site	Before	After	Grid-site	Before	After
17	0	6360	3	20	180	16	60	0	5	700	0
29	0	0	5	20	0	19	80	0	6	780	0
46	0	0	28	40	0	23	60	0	8	160	30
53	10	0	39	20	0	25	180	0	14	420	0
62	0	0	55	0	0	52	240	0	21	300	240
67	0	1800							22	160	0
									27	520	0
									41	900	0
									51	960	0
									60	780	0
									61	5100	0

Table 4: Levels of root-knot *(M. chitwoodi)* nematode per 250 cc soil in soil samples collected before Telone application and after harvest in a field with high population levels. Post-harvest samples were collected from only a representative collection of grid sampling points.

CONCLUSIONS

- The site-specific application of Telone can be successful, when based upon careful mapping and interpretation. The use of 2-acre grids and variogram analysis are key components in ensuring that success.
- Telone use can be reduced through the use of site-specific application based upon nematode populations.
- There is always a certain amount of sampling error and some nematodes are missed, no matter the soil sampling or grid method used. Careful interpretation of the maps and the variogram analysis reduces that error to an acceptable level.

Appendix A

Telone II (1,3-Dichloropropene)

- Preplant soil fumigant for control of all major species of nematodes, including root-knot, root lesion, stubby root, and cyst nematodes. Suppressive properties on Verticillium in potatoes (www.dowagro.com).

- Labeled for use in almost all vegetable crops, sugar beets, cotton, and mint.

- Proven track record for pest suppression, when used correctly.

- Ranks among the top 10 most commonly used pesticides in the U.S., based upon the pounds of active ingredient applied.

- Applied at a rate of 9 to 55 gallons per acre for most vegetable crops. Usually 20 gallons are used on potato fields, if the fields have root-knot nematodes, stubby-root nematodes, cyst nematodes, or wireworms. If only root-lesion nematode is present, 15 to 20 gallons are used.

- A typical field of 136 acres (an 8-tower pivot with an end gun) treated with 20 gallons per acre receives 26,802 pounds of 1,3 dichloropropene. At this rate, 1 million pounds of active ingredient are applied on only 38 typical-sized fields.

- For 2009 and beyond, the availability of Telone is very uncertain and will likely be less than in 2008. The projected cost is also unknown and could vary from the price during this project ($12.10 per gallon).

- In situations where Telone is in short supply, such as in 2008, 2009, and as projected through 2011, it is in the author's opinion that the best way to "ration" Telone is through the utilization of site-specific technology.

This project does not endorse or reject any product mentioned in the report.

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JOHN TABERNA, JR
WESTERN AG RESEARCH, LLC
BLACKFOOT, IDAHO

208-681-5081
taberna@cableone.net

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