Journal of Nematology 34(3):189–193. 2002.

Plant Pathogen Population Dynamics in Potato Fields[1]

G. D. Morgan,[2] W. R. Stevenson,[3] A. E. MacGuidwin,[3] K. A. Kelling,[4] L. K. Binning, and J. Zhu[5]

Abstract: Modern technologies incorporating Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing, and geostatistics provide unique opportunities to advance ecological understanding of pests across a landscape. Increased knowledge of the population dynamics of plant pathogens will promote management strategies, such as site-specific management, and cultural practices minimizing the introduction and impact of plant pathogens. The population dynamics of *Alternaria solani, Verticillium dahliae,* and *Pratylenchus penetrans* were investigated in commercial potato fields. A 0.5-ha diamond grid-sampling scheme was georeferenced, and all disease ratings and nematode samples were taken at these grid points. Percent disease severity was rated weekly, and *P. penetrans* densities were quantified 4 weeks after potato emergence. Spatial statistics and interpolation methods were used to identify the spatial distribution and population dynamics of each pathogen. Interpolated maps and aerial imagery identified *A. solani* intra-season progression across the fields as the potato crop matured. Late-season nitrogen application reduced *A. solani* severity. The spatial distributions of *V. dahliae* and *P. penetrans* were spatially correlated.

Key words: *Alternaria solani,* early blight, early dying, geostatistics, population dynamics, potato, *Pratylenchus penetrans,* root-lesion nematode, spatial distribution, *Verticillium dahliae.*

Pesticides represent a substantial portion of crop production costs, and pesticide use has given rise to food safety and environmental contamination-related issues (USDA-NAPIAP, 1998). Addressing environmental quality while maintaining crop protection is a main focus of current pest management research. However, pest management research has focused on preventative and (or) remedial management tactics by using broadcast pesticide applications. Modern technologies, including Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing, and geostatistics, provide researchers with new mechanisms to study pest biology/ecology and to evaluate site-specific pest management tactics that may ultimately reduce pesticide inputs.

Obtaining information on pest population dynamics and interactions among pests over a landscape can enhance models of pest introduction, dissemination, and population changes that occur during rotational cropping systems. This new knowledge regarding pest population dynamics should contribute to implementation of new cultural practices and alteration of current management strategies, such as site-specific management. Pest management based on spatial parameters provides opportunities to reduce pesticide quantities that are traditionally used in broadcast applications (Cousens, 1987; Morgan et al., 2002). Currently, fungicides and soil fumigants are applied on a broadcast basis for managing foliar diseases like *Alternaria solani* (Ell. and Mart.) and soilborne pathogens like *Verticillium dahliae*(Kleb.) and *Pratylenchus penetrans* (Cobb) in potato. These broadcast pesticide applications are made despite known clustered distributions of the pathogens within production fields. Once the spatial distribution of these pathogens is identified, growers can effectively use site-specific pesticide applications with associated reductions in pesticide use. To accurately estimate pest clustering across a field landscape, the level of spatial structure and temporal stability needs to be accurately quantified.

Therefore, the objectives of this research were to determine: (i) the existing spatial distribution of early blight, early dying, root-lesion nematodes, and yield differences within production potato fields; (ii) the correlation between the spatial distribution of each pest, soil parameters, and crop yields; and (iii) the temporal stability of root-lesion nematode distribution through a 3-year crop rotation.

Materials and Methods

Research was conducted on two commercial potato fields in Coloma, Wisconsin, 1998 through 2000. In 1998, a 42-ha field (Field 1) and a 53-ha field (Field 2) were planted in a Russet Burbank and Snowden variety, respectively. The soil texture ranged from a sand to a loamy sand within each field, and the soil mapping units were Plainfield sand (sandy mixed, mesic Typic Udipsamments) and Richford loamy sand (sandy, mixed, mesic Psammentic Hapudalfs) with slopes ranging from 0 to 3.5 percent. Each field was in a 3-year potato, corn, and vegetable (pea or pepper) crop rotation.

Pest management, soil fertility, and irrigation practices were typical for the region. During fall 1997, prior to the potato crop, a fumigant biocide (sodium methyldithiocarbamate) was commercially injected into one-third of Field 1 at a rate of 134 kg/ha and was immediately followed by irrigation (Fig. 1). The remaining

Received for publication 14 September 2001.

[1] Supported by the USDA-CSREES Hatch Project from the Wisconsin Agricultural Experiment Station. Paper delivered in a symposium on Application of GIS and GPS Precision Agriculture Technologies in Nematology and Plant Pathology, Society of Nematologists Annual Meeting, 24–29 August 2001, Salt Lake City, UT.

[2] Former Graduate Research Assistant in the Department of Horticulture at the University of Wisconsin-Madison, WI 53706. Present address: Department of Plant Sciences and Landscape Systems, University of Tennessee, Knoxville, TN 37996-4500.
[3] Professor, Department of Plant Pathology, University of Wisconsin-Madison.
[4] Professor, Department of Soil Science, University of Wisconsin-Madison.
[5] Assistant Professor, Department of Statistics, University of Wisconsin-Madison.
E-mail: gmorgan2@utk.edu

This paper was edited by B. C. Hyman.

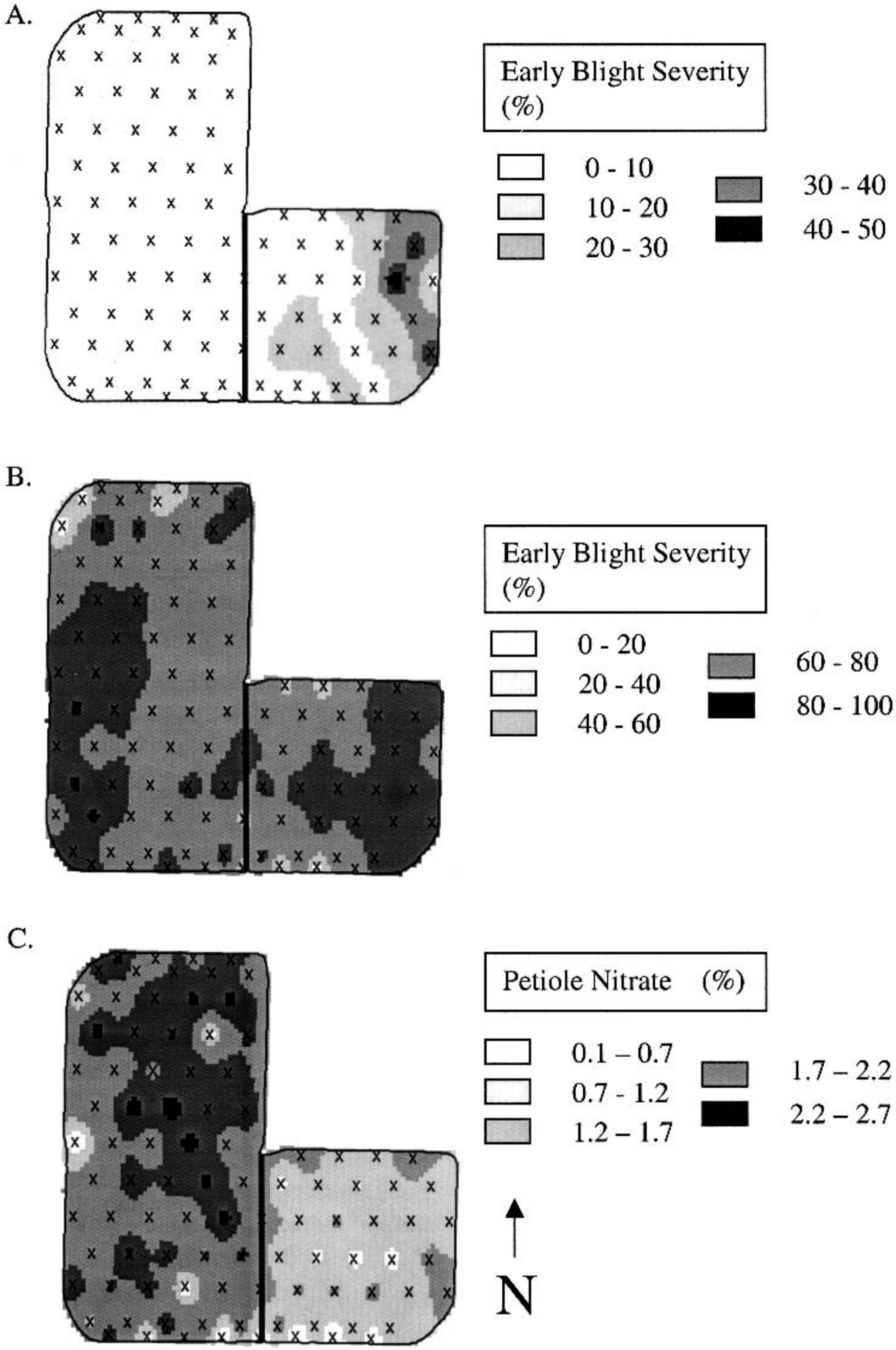

FIG. 1. Field 1 spatial distribution of early blight percent severity. A) 4 August 1998. B) 24 August 1998. C) Petiole nitrate levels on 28 June 1998. South-east field portion received an application of methyl dithiocarbamate prior to potato crop. North-west field portion received a late application of nitrogen fertilizer. Field size was 42 ha, and the 0.5-ha grid-sample locations are indicated by an X.

two-thirds of Field 1 and all of Field 2 received an application of methyldithiocarbamate 3 years prior to initiating this study. The potato seed pieces were planted in mid-April, and plant emergence occurred in early to mid-May. Pre-emergence and post-emergence herbicides were broadcast applied to each field according to the herbicide label timing and rate. Mid-season nitrogen fertilizer was applied to the non-fumigated portion of Field 1 based on the low petiole nitrate levels and cooperators' judgment of poor crop vigor. Fungicides were applied to the potato foliage with a ground applicator and application timing according to the

WISDOM (Stevenson et al., 1995). An area of Field 2 received a scheduled application of azoxystrobin fungicide (Fig. 2) while the remainder of the field received chlorothalonil on the same application schedule. Following potato harvest, potato crop residues were incorporated into the soil and a winter wheat cover crop was planted in both fields.

A 0.5-ha diamond grid (160 m × 80 m) was created in each field where grid-sample locations were flagged and georeferenced with a differential GPS (DGPS) backpack unit (Trimble, Sunnyvale, CA). Visual weekly percent disease severity ratings for early blight, late blight, and early dying symptoms were taken from a 9.3-m^2 area around each grid-sample point. Verticillium wilt assessment was based on premature senescence and loss of turgor and wilting in single stems (Hooker, 1981). Annual soil samples were taken between 17 and 29 June 1998 to quantify root-lesion

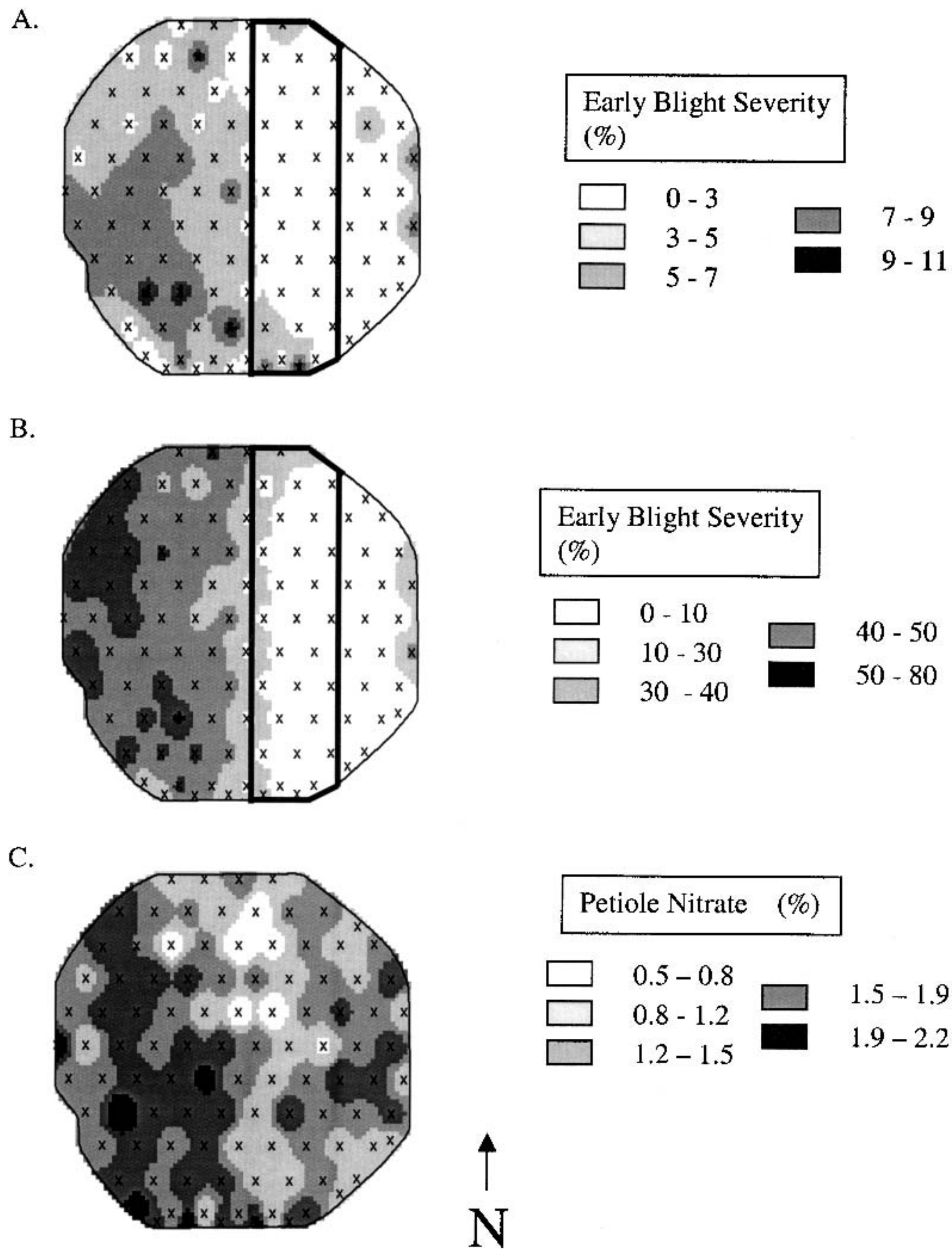

Fig. 2. Field 2 spatial distribution of early blight percent severity. A) 4 August 1998. B) 24 August 1998. C) Petiole nitrate levels on 28 June 1998. Foliar applications of azoxystrobin were applied to a fraction of the eastern side of the field. Field size is 53 ha, and the 0.5-ha grid-sample locations are indicated by an X.

nematodes (RLN; *P. penetrans*) at each georeferenced sample location throughout the 3-year crop rotation. The RLNs from roots and soil were quantified from a 100-cm^3 soil sample using the Baermann funnel technique with a 48-hour-incubation for root fragments and centrifugation-sugar flotation process for soil (Jenkins, 1964).

Soil and crop information was collected to determine relationships between plant pathogens and other biotic and abiotic parameters. To identify the need for a mid-season application of nitrogen fertilizer, potato petiole nitrate levels were quantified on 28 June 1998 from the last fully expanded potato leaf. Soil pH and soil volumetric water content were quantified following irrigation during the third season (2000) for Fields 1 and 2. The soil pH in $CaCl_2$ was measured using Thomas' (1996) procedures and a Corning model pH 30 probe. Soil volumetric water content was measured to a 20-cm depth following irrigation, using a HydroSense soil moisture probe (Campbell Scientific, Australia Pty. Ltd.). Potato yields were estimated from each grid-sample point within the field by harvesting 1.52 m from four potato rows (total of 6.8 m) adjacent to georeferenced sample points.

Inverse-distance (fourth power) interpolation maps were created for severity indices of early blight and early dying diseases and densities of the root-lesion nematode using SSToolbox, a GIS software package (SST Development Group, Stillwater, OK). Interpolation maps were used to visually compare pathogen population distributions to soil parameters, weeds, and crop parameters. Only selected interpolated maps are presented.

Differentially corrected GPS information was imported into the statistical software S-Plus version 4 (Mathsoft Inc., Seattle, WA) equipped with the spatial statistical module. Data normality was evaluated using a quantile plot for early blight, early dying, root-lesion nematodes and other field parameters. A $\log_{10}$ data transformation was required to achieve normal data distribution. All parameters were analyzed for sample independence (spatial autocorrelation) using semivariograms (Kaluzny et al., 1997). A 95% confidence interval was placed on the semivariogram points at each sample lag to aid in evaluation of sample independence and determination of spatial structure. A semivariogram model, including the range, sill, and nugget, was computed using weighted least squares algorithm as stated in the S-Plus spatial statistics manual (Kaluzny et al., 1997) for dependent (spatial autocorrelated) data. The best model was selected based on minimum mean squared error values. Independent data (not spatially autocorrelated) were analyzed using traditional statistical methods. A paired T-test was used to compare RLN population changes over time, and a two-independent-sample T-test was used to compare parameters in fumigated vs. unfumigated field portions.

Intra and inter-season temporal stability was quantified using Spearman's rank sum correlation tests ($P \leq 0.05$) (S-PLUS, 1997) based on non-transformed data. Spearman's rank correlation test was used to quantify relationships between spatial distribution of pathogen populations and the spatial distribution of other soil and crop parameters (Ludwig and Reynolds, 1988). The index of dispersion, a spatial point pattern analysis, also was used to quantify the temporal spatial aggregation of the pathogens within each field (Ludwig and Reynolds, 1988).

Results

Semivariograms indicated minimal spatial autocorrelation of disease severity in either of the fields using the 0.5-ha grid sampling system. Therefore, the level or degree of aggregation could not be determined using this sampling scheme. The index of dispersion test results coincided with the semivariogram analysis and did not indicate spatial aggregation for early blight symptoms. Soil pH and field elevation were correlated to all early blight ratings in Field 2. However, no measured parameters were correlated to early blight ratings in Field 1.

The interpolation maps indicated that early blight severity was not uniformly distributed across either of the potato fields and the severity distribution was related to both mid-season nitrogen application and efficacy of the fungicide program. A mid-season application of nitrogen fertilizer was associated with higher petiole nitrate levels and appeared to postpone onset of severe early blight symptoms (Fig. 1). Barclay et al. (1973) and MacKenzie (1981) reported similar results of apparent reduced infection and the final amount of early blight due to additional nitrogen applications in small plot experiments. In Field 2, early blight severity was significantly less in the azoxystrobin-treated area of the field vs. the chlorthalonil treatment area (Fig. 2). Interpolation maps from both fields identified early infection in the portion of the field adjacent to a field that was planted in potato the previous season. These results coincide with findings by Shtienberg and Fry (1990), who reported initial early blight lesions occurred earlier in the season when the preceding crop was potato. As the growing season progressed, weekly ratings of early blight severity indicated the progression of early blight symptoms across the field, ceasing when potato vine desiccants were applied. Early blight progression was much slower in the section of the field treated with azoxystrobin fungicide.

Geostatistical analysis of the RLN data indicated some degree of aggregation in Field 2 for the two seasons following the potato crop. However, semivariograms from the Field 1 data did not identify spatial aggregation in the potato crop or the two subsequent rotational crops (data not shown). However, inverse-distance interpolation maps provided visual indication of RLN aggregation within both fields over the entire 3-year rotation. The RLN densities were typically the largest near tillage implement entry points into the fields. These higher densities at the tillage entry locations may have resulted from pathogen introduction to the fields after the most recent soil fumigant application and (or) improper application of the soil fumigant at or near the field entry points (Morgan et al., 2002). Densities of RLN were significantly lower in the fumigated portion of Field 1 than the non-fumigated portion. The exception to an annual RLN density increase was in the non-fumigated portion of Field 1, where RLN densities were lower after the Russet Burbank potato crop. Early dying symptoms were obvious in each field relatively early in the season. Symptoms of *V. dahliae* infection were significantly correlated to the soilborne RLN populations. Soil pH, soil type, and volumetric water content were not consistently correlated to the weekly severity ratings of early dying (Morgan, 2001).

Discussion

Modern technologies provide numerous research opportunities to investigate the plant pathogen population dynamics and discover interactions among plant pathogens and other field parameters. Information and applications of these technologies also make excellent educational demonstrations for producers to visualize the effect of management and cultural practices on pest populations. This research identified the influence of management strategies, cultural practices, and field location on the introduction and progression of early blight and RLN across a production field landscape. Based on this information, management strategies may be modified to minimize pesticide application areas and maximize economic return. Likewise site-specific strategies for pest management may be useful in changing grower practices from uniformly applied pesticide treatments to timely and targeted treatments with highly effective and environmentally compatible materials.

Literature Cited

Barclay, G. M., H. J. Murphy, F. E. Manzer, and F. E. Hutchinson. 1973. Effects of differential rates of nitrogen and phosphorus on early blight in potato. American Potato Journal 50:43–47.

Cousens, R. 1987. Theory and reality of weed control thresholds. Plant Protection Quarterly 2:13–20.

Hooker, W. J. 1981. Compendium of potato diseases: Part II. p. 62. St. Paul, MN: The American Phytopathological Society.

Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for extracting nematode from soil. Plant Disease Reporter 48:692.

Kaluzny, S. P., S. C. Vega, T. P. Cardoso, and A. A. Shelly. 1997. Analyzing geostatistical data. Pp. 91–97 *in* S+ spatial stats user's manual for Windows® and UNIX®. New York: Springer.

Ludwig, J. A., and J. R. Reynolds. 1988. Species affinity. Pp. 148–155 *in* Statistical ecology: A primer on methods and computing. New York: John Wiley and Sons.

MacKenzie, D. R. 1981. Association of potato early blight, nitrogen fertilizer rate, and potato yield. Plant Disease 65:575–577.

Morgan, G. D. 2001. Weed and root-lesion nematode population dynamics over a 3-year crop rotation: Spatial distribution and temporal stability. Ph.D. dissertation. University of Wisconsin, Madison, WI.

Morgan, G. D., T. R. Connell, L. K. Binning, and W. G. Schmitt. 2000. Potential for weed management in potato fields using GIS technology. Proc. Wisconsin's Fertilizer, Aglime, and Pest Management Conference, Madison, WI. 39:182–184.

Morgan, G. D., A. E. MacGuidwin, J. Zhu, and L. K. Binning. 2002. Population dynamics and distribution of root lesion nematode (*Pratylenchus penetrans*) over a 3-year potato crop rotation. Agronomy Journal, in press.

Shtienberg, D., and W. E. Fry. 1990. Influence of host resistance and crop rotation on initial appearance of potato early blight. Plant Disease 74:849–852.

Stevenson, W. R., L. K. Binning, J. A. Wyman, and D. Curwen. 1995. Integrated Pest Management WISDOM - Professional Software For Agricultural Systems, Version 1.0. University of Wisconsin Integrated Pest Management Program. 101.

Thomas, G. W. 1996. Chemical methods. Pp. 486–489 *in* J. M. Bigham et al., ed. Methods of soil analysis: Part 3. Madison, WI: Soil Science Society of America.

USDA-NAPIAP. 1998. Use, target pests, and economic impact of pesticides applied to potatoes in the United States. Ag Communications, University of Idaho, Moscow, ID.