Supplement to Journal of Nematology 23(4S):686–692. 1991.

Effects of Incorporation Method of Ethoprop and Addition of Aldicarb on Potato Tuber Infection by *Meloidogyne hapla*[1]

RUSSELL E. INGHAM,[2] MARK MORRIS,[3] AND GENE B. NEWCOMB[2]

Abstract: The efficacy of controlling *Meloidogyne hapla* on potato with water incorporation of ethoprop was compared to physical incorporation before planting. The standard practice of aldicarb application for insect control was also evaluated for *M. hapla* suppression with and without ethoprop. Physical incorporation before planting by rototilling or discing reduced ($P \leq 0.05$) tuber infection. Postplant water incorporation of ethoprop was not as effective as physical incorporation of ethoprop or postplant water incorporation of aldicarb and did not reduce ($P \leq 0.05$) tuber infection at harvest. Ethoprop did not affect yield, whereas aldicarb increased yield in one experiment.

Key words: aldicarb, chemical control, ethoprop, incorporation method, *Meloidogyne hapla*, nematicide, nematode, northern root-knot nematode, potato, *Solanum tuberosum*.

Northern root-knot nematode (*Meloidogyne hapla* Chitwood) is a serious pest of potato (4,9) and is widespread throughout the Pacific Northwest (6). Whereas *M. hapla* can generally be controlled by fumigation (10), damage may occur if initial populations are high, if numbers of degree days during the growing season are higher than normal, or if potatoes are harvested late in the season. Infection sites are best identified by brown spots that appear within the tuber after females begin egg production (8). These spots reduce tuber quality and therefore crop value. Application of nonfumigant nematicides before planting may protect roots from nematodes remaining after fumigation and thus reduce the numbers in the second generation. Postplant applications may further protect roots and developing tubers from second-stage juveniles (J2) of the second or later generations (5). Application of the nonfumigant nematicide ethoprop after fumigation has been demonstrated to further reduce tuber infection by *M. chitwoodi* Golden et al. (7,11) but has not been evaluated for *M. hapla*. Physical incorporation of ethoprop before planting is recommended, but growers in the Pacific Northwest are reluctant to do so because of the additional expense for cultivation and the risk of soil erosion in windy areas.

The objective of this study was to evaluate timing of ethoprop applications and methods of incorporating ethoprop into the soil to achieve maximum tuber protection. Several methods of water incorporation of ethoprop granules and soil injection of a liquid formulation were evaluated as alternatives to physical incorporation of granules. Previous studies have demonstrated that the downward movement of ethoprop in soils is limited (1,12–14). Treatments that included addition of gypsum to compete with sites on organic matter and soil colloids that would bind with ethoprop and treatments with a soil surfactant (ammonium laureth sulfate) were examined to determine if efficacy could be improved. Because most growers have routinely applied aldicarb for control of insects on potato, treatments with ethoprop and aldicarb combinations were included to determine if additional nematode suppression was achieved from this management practice. A field with known high populations of *M. hapla* was selected to test the efficacy of these treatments.

MATERIALS AND METHODS

This research was conducted in a field (loamy sand, 84% sand, 11% silt, 5% clay; 0.8% OM; pH 7.0) under center pivot ir-

Received for publication 12 September 1990.

[1] Based on work supported in part by Rhone-Poulenc AG Company.

[2] Assistant Professor and Research Associate, respectively, Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331-2902.

[3] Field research and development assistant, Rhone-Poulenc AG Company, 5110 Seeger Lane SE, Salem, OR 97306.

The assistance of Ron Burr, Rhone-Poulenc AG Company, and Paul Tresham, Wilbur-Ellis Company, was invaluable to the completion of this research.

rigation near Irrigon, Oregon. The field was preplant fumigated with 608 liters metham sodium/ha injected through center pivot irrigation on 15 October 1987. Populations of *M. hapla* J2 in the surface 30 cm of the field were 3,600/250 cm^3 one month before fumigation (16 September 1987), 245/250 cm^3 nearly one month after fumigation (12 November 1987), and 795/250 cm^3 before plot establishment in the spring (3 March 1988). In each of two experiments, treatments receiving ethoprop and the untreated control plots were placed in randomized complete block designs, with eight treatments and four replications. A randomly selected half of each plot was treated with aldicarb so that the final design in each experiment contained 64 plots of four rows, 9.1 m long and 3.4 m wide. Treatments and application dates for the two experiments conducted simultaneously in the same field are described (Table 1). All applications were made with commercial field equipment to mimic grower practices. In water incorporation treatments before planting, water was delivered by four impact-head sprinklers placed at the plot corners. Soil was sampled for nematodes by taking 10 (before planting, 7 April 1988) or 6 (midseason, 12 July 1988) 2.5-cm-d cores to a depth of 45 cm from the two center rows of each plot. Nematodes were extracted by wet sieving-sucrose centrifugation (2), and live and total J2 of *M. hapla* were counted. Live nematodes were defined as those already moving or moving after slight mechanical prodding.

Potato (*Solanum tuberosum* L. cv. Russet Burbank) seed pieces were planted 10 cm deep and 86 cm apart on 12 April 1988 and harvested from the center 6 m of the two middle rows in each plot on 19–23 September 1988. Plots were maintained according to standard grower practices, and foliar insecticides were applied in plots without aldicarb when needed to reduce effects of foliar-feeding insects. Tubers were graded for size and yield, and twenty-five 227–340 g tubers were selected at random from each plot for assessment of root-knot nematode infection. Tubers were stored at room temperature (20 C) for 3 weeks to ensure adequate symptom development for treatment evaluation because tuber damage from *M. hapla* infection is usually not apparent until late September or early October (8). Tubers were peeled, and the number of nematode infection sites was determined by inspection under a magnifying lamp. Infection of each tuber was ranked with an index value of 0 through 6: 0 = no infection, 1 = 1 to 3 infection sites, 2 = 4 to 5 sites, 3 = 6 to 9 sites, 4 = 10 to 49 sites, 5 = 50 to 99 sites, and 6 = 100+ sites. The percentage of culls due to nematodes was determined as the proportion of total tubers in the sample with an index of 3 or higher (7).

Nematode densities were transformed to log (x + 1), whereas percentage of tuber infection and percentage of culled tubers were transformed to arcsin (square root [x]) before analysis. Treatments in the group of plots receiving ethoprop and those receiving ethoprop plus aldicarb were analyzed by analysis of variance (ANOVA), and significant treatment differences were determined with a protected LSD. Student's *t*-test was used to compare treatments receiving ethoprop alone with like treatments receiving ethoprop plus aldicarb. Infection index data were analyzed by a Kruskal-Wallis test, and pairs of ethoprop and ethoprop plus aldicarb treatments were compared with a Wilcoxon matched-pairs test. Correlation analysis was performed between tuber infection data and J2 densities before planting or at midseason to determine if tuber damage was related to J2 density. All differences reported were significant at $P \leq 0.05$, unless otherwise stated.

Results

Soil nematode populations: Before planting (7 April) J2 populations in the soil were not significantly different for any treatment in either experiment (Tables 2, 3). Total densities of *M. hapla* J2 averaged 338 (22 live)/250 cm^3 soil in Experiment 1 and 500 (60 live)/250 cm^3 soil in Experiment 2.

TABLE 1. Descriptions of treatments used in two field experiments for management of *Meloidogyne hapla* on potato.

Treatment abbreviation†	Description
	Experiment 1
No ethoprop	No ethoprop added: = untreated control in plots without aldicarb application; = aldicarb alone in plots with aldicarb application.
Treatments initiated before planting:	
ROTO	13.2 kg a.i./ha granular ethoprop broadcast applied and rototilled (ROTO) in to a depth of 12.5 cm on 7 April 1988.
I15S + WPP	6.6 kg a.i./ha liquid ethoprop injected 30 cm deep at a 15-cm spacing (I15S) on 8 April 1988 plus postplant water incorporation (WPP) of 6.6 kg a.i./ha granular ethoprop broadcast applied on 26 April 1988.
I30S + WPP	6.6 kg a.i./ha liquid ethoprop injected 30 cm deep at a 30-cm spacing (I30S) on 8 April 1988 plus postplant water incorporation (WPP) of 6.6 kg a.i./ha granular ethoprop broadcast applied on 26 April 1988.
Treatments initiated after planting:	
WPP	13.2 kg a.i./ha granular ethoprop broadcast applied and postplant incorporated with 1 cm water in 11 minutes on 26 April 1988.
WPP + S	13.2 kg a.i./ha granular ethoprop broadcast applied and postplant incorporated with 1 cm water in 11 minutes on 26 April 1988 after ground had been moistened with the soil surfactant (S) ammonium laureth sulfate (140.3 ml a.i./ha).
WPP + GBP	13.2 kg a.i./ha granular ethoprop broadcast applied and postplant incorporated with 1 cm water in 11 minutes on 26 April 1988; 1,100 kg/ha gypsum was broadcast applied before planting (GBP) on 8 April 1988.
WPP + GPP	13.2 kg a.i./ha granular ethoprop and 1,100 kg/ha gypsum broadcast applied and postplant incorporated (GPP) with 1 cm water in 11 minutes on 26 April 1988.
	Experiment 2
No ethoprop	No ethoprop added: = untreated control in plots without aldicarb application; = aldicarb alone in plots with aldicarb application.
Treatments initiated before planting:	
ROTO (13.2)	13.2 kg a.i./ha granular ethoprop broadcast applied and rototilled in to a depth of 12.5 cm on 7 April 1988.
ROTO (6.6)	6.6 kg a.i./ha granular ethoprop broadcast applied and rototilled in to a depth of 12.5 cm on 7 April 1988.
DISC	13.2 kg a.i./ha granular ethoprop broadcast applied and disced (DISC) in to a depth of 17.5 cm on 7 April 1988.
WBP	13.2 kg a.i./ha granular ethoprop broadcast applied and incorporated before planting with 1 cm water (WBP) in 11 minutes on 7 April 1988.
Treatments initiated after planting:	
WPP	13.3 kg a.i./ha granular ethoprop broadcast applied and postplant incorporated with 1 cm water in 11 minutes on 26 April 1988.
WPP − PE	13.3 kg a.i./ha granular ethoprop broadcast applied and postplant water incorporated at preemergence (PE; 11 May 1988).
WPP − PE − LC	6.6 kg a.i./ha granular ethoprop broadcast applied and postplant water incorporated (26 April 1988) plus 3.3 kg a.i./ha water incorporated at preemergence (PE; 11 May 1988) plus 3.3 kg a.i./ha water incorporated at last cultivation (LC) before row closure (9 June 1988).

† Half of each plot was treated on 5 May 1988 with 3.3 kg a.i./ha aldicarb by banding over the row and covering. Abbreviations for these treatments in the text are as above with a + A suffix. All plots received 608 liters/ha metham sodium preplant fumigation on 15 October 1987.

Two treatments applied before planting in Experiment 1, I15S + WPP and ROTO (see Table 1 for definition of abbreviations), reduced ($P \leq 0.05$) total soil J2 at midseason (12 July) from those in the untreated control. Live nematodes were also significantly less in the I15S + WPP treatment. Rototill-incorporated ethoprop plus

TABLE 2. Effect of different methods of incorporating ethoprop on *Meloidogyne hapla* J2 densities, tuber infection, and yield in Experiment 1.

Treatment†	*M. hapla* J2/250 cm³ soil				Tuber infection (%)	Infection index	Culled tubers (%)	Yield (t/ha)
	Before planting		Midseason					
	Total	Live	Total	Live				
	No aldicarb added							
ROTO	308 a	18 a	19 a	3 ab	0 a	0.0 a	0 a	66 a
I15S + WPP	358 a	15 a	20 a	0 a	17 ab	0.3 ab	4 ab	63 a
I30S + WPP	277 a	6 a	137 ab	32 ab	29 ab	0.6 ab	9 abc	68 a
WPP	317 a	36 a	107 b	8 ab	52 b	1.1 b	20 bc	66 a
WPP + S	150 a	1 a	39 ab	8 ab	56 b	1.5 b	36 bc	59 a
WPP + GBP	633 a	50 a	194 ab	7 ab	57 b	1.2 b	23 bc	58 a
WPP + GPP	344 a	18 a	64 ab	11 ab	62 b	1.5 b	31 c	60 a
No ethoprop	318 a	28 a	189 b	19 b	62 b	1.5 b	32 c	70 a
	3.3 kg a.i./ha aldicarb added							
ROTO + A	308 a	18 a	9 a	0 a	8 a	0.1 a	0 a	62 a
I15S + WPP + A	358 a	15 a	26 ab	3 ab	8 a	0.1 a	0 a	69 a
I30S + WPP + A	277 a	6 a	22 a	4 ab	11 a	0.1 a	0 a*	70 a
WPP + A	317 a	36 a	203 c	30 c	11 a*	0.2 a	4 a*	67 a
WPP + S + A	150 a	1 a	30 ab	1 ab	8 a	0.2 a	3 a	73 a
WPP + GBP + A	633 a	50 a	48 a*	0 a	5 a	0.1 a	1 a	69 a
WPP + GPP + A	344 a	18 a	55 ab	3 ab	10 a	0.1 a	0 a	73 a*
No ethoprop + A	318 a	28 a	105 bc	11 bc	16 a	0.4 a	7 a	70 a

Data are means of four replications. Within the group receiving no aldicarb or the group receiving aldicarb, means in the same column that are followed by the same letter were not significantly different ($P \leq 0.05$) when their transformed values were analyzed.

† Treatments described in Table 1. ROTO, I15S + WPP, I30S + WPP, and ROTO + A, I15S + WPP + A, and I30S + WPP + A were initiated before planting; others were initiated after planting.

* Significantly different from the like treatment without aldicarb.

aldicarb (ROTO + A) significantly reduced midseason total and live J2, relative to aldicarb alone. Mean densities in the I30S + WPP treatment were skewed by high densities in one replicate. Average total densities without this one replicate were 50 (0 live)/250 cm³ soil, similar to densities in other preplant treatments. In addition, this treatment plus aldicarb (I30S + WPP + A) had fewer ($P \leq 0.05$) total J2 than did aldicarb alone. Thus, this method of applying ethoprop may also be effective in reducing the soil population. The only significant ($P \leq 0.05$) effect noted in the preplant treatments of Experiment 2 was fewer live J2 in the WBP treatment than in the no-ethoprop control. None of the postplant applications of ethoprop without aldicarb in either experiment significantly reduced midseason total or live numbers of J2, and only one postplant ethoprop plus aldicarb treatment (WPP + GBP + A, Experiment 1) had lower J2 densities than in the treatment with aldicarb alone.

Midseason J2 densities in treatments with aldicarb tended to be lower than in treatments without aldicarb. In Experiment 1, the WPP + GBP + A treatment had significantly ($P \leq 0.01$) fewer total J2 than did the WPP + GBP treatment. Averaged across all treatments in Experiment 2, the reduction in J2 densities from treatments with aldicarb was highly significant ($P \leq 0.003$) for live J2 (2/250 cm³ with aldicarb and 10/250 cm³ without aldicarb), and densities of total J2 (58/250 cm³ with aldicarb and 158/250 cm³ without aldicarb) were nearly significantly different ($P \leq 0.07$).

Tuber infection: Percentages of tuber infection and culled tubers and the infection index were decreased substantially by the preplant treatments in both experiments (Tables 2, 3). However, most values for

TABLE 3. Effect of different methods of incorporating ethoprop on *Meloidogyne hapla* soil (J2) populations, tuber infection, and yield in Experiment 2.

Treatment†	*M. hapla* J2/250 cm³ soil: Before planting Total	Before planting Live	Midseason Total	Midseason Live	Tuber infection (%)	Infection index	Culled tubers (%)	Yield (t/ha)
			No aldicarb added					
ROTO (13.2)	381 a	11 a	23 a	1 ab	4 a	<0.1 a	0 a	66 a
ROTO (6.6)	398 a	46 a	32 a	0 ab	9 a	0.2 a	2 ab	57 a
DISC	499 a	91 a	128 a	4 abc	8 a	0.2 a	2 ab	68 a
WBP	581 a	74 a	24 a	0 a	16 ab	0.2 ab	0 ab	61 a
WPP	406 a	17 a	52 a	4 abc	48 bc	1.4 bc	28 abc	65 a
WPP − PE	958 a	172 a	242 a	38 c	32 abc	0.9 bc	20 abc	61 a
WPP − PE − LC	538 a	34 a	210 a	28 bc	48 bc	1.3 bc	24 bc	56 a
No ethoprop	239 a	36 a	117 a	9 bc	76 c	2.6 c	59 c	50 a
			3.3 kg a.i./ha aldicarb added					
ROTO + A (13.2)	381 a	11 a	20 ab	0 a	0 a	0.0 a	0 a	65 a
ROTO + A (6.6)	398 a	46 a	6 a	0 a	17 bc	0.3 bc	2 a	68 a
DISC + A	499 a	91 a	12 abc	0 a	0 a	0.0 a	0 a	58 a
WBP + A	581 a	74 a	8 abc	0 a	23 bc	0.5 bc	9 a	65 a
WPP + A	406 a	17 a	118 bc	6 a	28 c	0.5 c	6 a	61 a
WPP − PE + A	958 a	172 a	51 abc	4 a	3 ab*	<0.1 ab	1 a	69 a
WPP − PE − LC + A	538 a	34 a	180 c	0 a	16 bc*	0.2 bc	3 a	65 a
No ethoprop + A	239 a	36 a	70 abc	7 a	5 abc	0.1 b	1 a*	68 a

Data are means of four replications. Within the group receiving no aldicarb or the group receiving aldicarb, means in the same column that are followed by the same letter were not significantly different ($P \leq 0.05$) when their transformed values were analyzed.

† Treatments described in Table 1. ROTO, I15S + WPP, I30S + WPP, and ROTO + A, I15S + WPP + A, and I30S + WPP + A were initiated before planting; others were initiated after planting.

* Significantly different from the like treatment without aldicarb.

injected liquid ethoprop treatments (Experiment 1) were not different ($P \leq 0.05$) from those in untreated controls. In contrast, none of the postplant treatments of ethoprop appeared to have any effect on tuber infection in either experiment.

Aldicarb reduced the percentage of infected or culled tubers in several treatments without ethoprop or where the ethoprop application was ineffective (Tables 2, 3). The percentage of tuber infection was significantly less in treatments with aldicarb than in the like treatments without aldicarb for the WPP + A treatment ($P \leq 0.05$) in Experiment 1 and the WPP − PE + A and WPP − PE − LC + A treatments ($P \leq 0.01$) in Experiment 2. Percentages of culled tubers were less ($P \leq 0.05$) with ethoprop and aldicarb in the WPP + A and I30S + WPP + A treatments of Experiment 1 than in those treatments without aldicarb. Addition of aldicarb alone in Experiment 2 significantly reduced the percentage of culled tubers, relative to the untreated control. In addition, the main effect of aldicarb application averaged over all treatments was significant for all infection parameters in both experiments.

Yield: None of the ethoprop treatments influenced yield in either experiment (Tables 2, 3). Addition of aldicarb increased ($P \leq 0.003$) yield in one treatment (WPP + GPP + A), and the main effect of aldicarb addition was significant ($P \leq 0.01$) in Experiment 1. Aldicarb had no effect on yield in Experiment 2.

DISCUSSION

Applications of ethoprop before planting reduced ($P \leq 0.05$) the percentage of tubers culled by *M. hapla* in six of seven treatments over both experiments. Suppression of tuber infection by physical incorporation of granules with rototilling or discing was excellent. When rototill-incorporated, a lower application rate (6.6 kg

a.i./ha, Experiment 2) was as effective as the 13.2 kg a.i./ha rate in reducing tuber infection. This would agree with Smelt et al. (12), who determined that rototilling was the most suitable method for physical incorporation, attaining deep and homogeneous distribution of granules in one pass. Injecting a liquid formulation through shanks spaced 15 cm apart was only slightly better than with a shank spacing of 30 cm. Although these treatments also included postplant granular applications, most of the effect probably was due to the preplant injection, because postplant applications alone at a higher rate were relatively ineffective. These treatments may have been more effective if all 13.2 kg a.i./ha had been injected before planting.

All postplant applications of ethoprop were ineffective, and none significantly reduced the percentage of tubers infected, the infection index, or the percentage of culled tubers. Santo et al. (11) also found postplant water incorporation of ethoprop less effective for suppression of *M. chitwoodi* than was preplant physical incorporation. The failure of postplant ethoprop applications to control tuber infection may be related to application method, because all postplant treatments were surface-applied and water-incorporated. Downward movement of ethoprop applied to loam and sandy soils is restricted to a few centimeters, even after 35.3 cm rainfall (13), and there is little chemical movement below the depth of physical incorporation (12). Similarly, Brodie (1) observed that complete control of *Meloidogyne* spp. extended only 5 cm below depth of incorporation in pots watered daily for 6 weeks. Maximum rate of ethoprop diffusion occurs at saturation (14). Surface drying lowered water content several centimeters deep and reversed the direction of diffusion. These drying patterns exist in many potato production areas and may further restrict the downward movement of ethoprop. This property of ethoprop is attractive because it decreases the probability that the compound will be leached into groundwater, but it emphasizes the need for physical incorporation to obtain effective nematode suppression. Addition of a surfactant (WPP + S) or application of gypsum (WPP + GBP, WPP + GPP) had no apparent effect on the efficacy of water incorporation of postplant application of ethoprop. Later application (WPP − PE) or splitting the application over the early part of the growing season (WPP − PE − LC) also did not improve performance. Although the WBP treatment was also a water-incorporated surface application, it was the only such method where all the ethoprop was applied before planting. This treatment may have performed better than other water-incorporated treatments because some physical incorporation would also have occurred during planting.

No significant correlation ($P \leq 0.05$) was obtained between any tuber infection parameter and preplant J2 densities for untreated plots. Increasing the sample size by including plots from all ineffective treatments with the untreated controls also did not produce a significant relationship. In contrast, midseason J2 densities were significantly correlated ($P \leq 0.001$) with percentage of tuber infection, with infection index, and with percentage of culled tubers. Because total and live J2 densities were highly correlated ($P \leq 0.001$) with each other at both sample dates, and because total and live densities each correlated highly with the different infection parameters, the additional effort of differentiating between live and dead nematodes may be unnecessary in assessing nematicide treatments. Additional study is warranted, however.

These data suggest that midseason J2 densities may be more predictive of subsequent tuber infection than are preplant estimates of J2. Further description of J2 population dynamics may determine the optimum time for midseason sampling and help growers to make management decisions, such as harvesting earlier or arranging to have tubers processed immediately after harvest rather than stored (8,10).

Griffin (3) found that properly timed postplant applications of aldicarb were ef-

fective in reducing tuber infection by *M. chitwoodi* in growing seasons with 1,684 or fewer degree days (base temperature of 5 C). In our study, aldicarb alone reduced culled tubers from 32% to 7% in Experiment 1 and from 52% to 1% in Experiment 2. However, most treatments that physically incorporated ethoprop before planting were effective, and addition of aldicarb provided no further benefit for tuber protection. This suggests that, at the nematode densities in this study, either preplant physical incorporation of ethoprop or postplant application of aldicarb would be effective in suppressing *M. hapla.*

Literature Cited

1. Brodie, B. B. 1971. Differential vertical movement of nonvolatile nematicides in soil. Journal of Nematology 3:292–295.

2. Caveness, F. E., and H. J. Jensen. 1955. Modifications of the centrifugal-flotation technique for the isolation of nematodes and their eggs from soil and plant tissue. Proceedings of the Helminthological Society of Washington 22:87–89.

3. Griffin, G. D. 1989. Comparison of fumigant and nonfumigant nematicides for control of *Meloidogyne chitwoodi* on potato. Supplement to the Journal of Nematology 21:640–644.

4. Griffin, G. D., and E. C. Jorgenson. 1969. Pathogenicity of the northern root-knot nematode (*Meloidogyne hapla*) to potato. Proceedings of the Helminthological Society of Washington 36:88–92.

5. Mojtahedi, H., G. S. Santo, J. N. Pinkerton, and J. H. Wilson. 1988. Effect of ethoprop on *Meloidogyne chitwoodi* and *M. hapla.* Journal of Nematology 20:649 (Abstr.).

6. Nyczepir, A. P., J. H. O'Bannon, G. S. Santo, and A. M. Finley. 1982. Incidence and distinguishing characteristics of *Meloidogyne chitwoodi* and *M. hapla* in potato from the Northwestern United States. Journal of Nematology 14:347–353.

7. Pinkerton, J. N., G. S. Santo, R. P. Ponti, and J. H. Wilson. 1986. Control of *Meloidogyne chitwoodi* in commercially grown Russet Burbank potatoes. Plant Disease 70:860–863.

8. Santo, G. S. 1984. Managing root-knot nematode problems in the Pacific Northwest. Pp. 9–10 *in* Proceedings of the 4th Annual North American Seed Potato Seminar.

9. Santo, G. S., and J. H. O'Bannon. 1981. Effect of soil temperature on the pathogenicity and reproduction of *Meloidogyne chitwoodi* and *M. hapla* on Russet Burbank potato. Journal of Nematology 13:483–486.

10. Santo, G. S., and M. Qualls. 1984. Control of *Meloidogyne* spp. on Russet Burbank potato by applying metham sodium through center pivot irrigation systems. Journal of Nematology 16:159–161.

11. Santo, G. S., H. Mojtahedi, and J. H. Wilson. 1988. Biology and control of root-knot nematodes on potatoes, 1987. Pp. 67–70 *in* Proceedings of the 27th Annual Washington State Potato Conference. Washington Potato Commission, Moses Lake, WA.

12. Smelt, J. H., S. Voerman, and M. Leistra. 1976. Mechanical incorporation in soil of surface-applied pesticide granules. Netherlands Journal of Plant Pathology 82:89–94.

13. Smelt, J. H., M. Leistra, and S. Voerman. 1977. Movement and rate of decomposition of ethoprophos in soil columns under field conditions. Pesticide Science 8:147–151.

14. Udy, P. B. 1975. The mass diffusion of three organophosphate insecticides into a range of New Zealand soils. Pp. 115–118 *in* Proceedings of the 28th New Zealand Weed and Pest Control Conference. The New Zealand Weed and Pest Control Society, Hamilton.