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Comparison of Fumigant and Nonfumigant Nematicides for Control of *Meloidogyne chitwoodi* on Potato[1]

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Abstract: The fumigant 1,3-dichloropropene (1,3-D) effectively controlled *Meloidogyne chitwoodi* on Russet Burbank potato, *Solanum tuberosum*. There was a maximum of 4% infected and galled tubers from the 1,3-D treatment after 2,028 degree-days with a base temperature of 5 C (DD5). This compared to 66% infected and galled tubers in aldicarb at-plant treated plots. Soil temperature, as determined by DD5, and timing of chemical applications affected the nematicidal activity on *M. chitwoodi* ($P < 0.05$). Aldicarb was most effective when applied postplant (PP) during the nematode reproductive cycle. After 1,684 DD5 of growth, there were 59, 26, 22, and 6% infected and galled tubers from untreated control plots and aldicarb treatments of 2.1 g/m row at 600 DD5, 2.1 g/m row at 1,228 DD5, and 1.3 g/m row at 600 DD5 plus 2.1 g/m row at 1,228 DD5, respectively. No aldicarb treatments were effective over a growing period of 2,028 DD5; 34% of the tubers were infected and galled following the most effective aldicarb treatment (1.3 g/m row at 504 DD5 plus 2.1 g/m row at 996 DD5).

Key words: aldicarb, chemical control, Columbia root-knot nematode, degree-day, 1,3-dichloropropene, *Meloidogyne chitwoodi*, potato, reproduction, soil temperature, *Solanum tuberosum*.

The Columbia root-knot nematode, *Meloidogyne chitwoodi* Golden, O'Bannon, Santo & Finley, is one of the most important pathogens attacking potato, *Solanum tuberosum* L. (4). It is found in most potato-producing regions of the western United States (2,5,8,13). It invades and galls potato tubers, thus suppressing both tuber quantity and quality (4,5,10,11).

Soil temperature affects *M. chitwoodi* hatching, development, and reproduction and thereby influences the severity of nematode invasion and tuber galling (5). Approximately 1,000 and 500 degree-days at a base temperature of 5 C (DD5) are required for the reproduction of the first and future nematode generation, respectively (5,11). The greater the number of nematode generations during a growing season, the greater the degree of infection and galling of potato tubers (5,6,9,11,14). Because of the large population increase of *M. chitwoodi* during the growing season, only fumigant nematicides provide acceptable chemical control (2,5,10,12).

The objective of this study was to determine 1) whether the nematicidal efficacy of aldicarb was comparable to 1,3-dichloropropene (1, 3-D) if application timing was correlated to nematode reproduction and 2) the effect of soil temperature, as determined by DD5, on aldicarb control of *M. chitwoodi*.

Materials and Methods

Three separate experiments were conducted over a 3-year period at Logan, Utah, in microplots fabricated from redwood. Microplot boxes were 3.0 m wide × 4.3 m long × 0.6 m deep and were open at the bottom. Boxes were buried 0.46 m deep, and soil was excavated from the microplots and replaced with a 1,3-D fumigated sandy loam soil (80% sand, 11% silt, 9% clay, 0.7% organic carbon; pH 7.7). *Meloidogyne chitwoodi* inoculum came originally from potato at Ft. Hall, Idaho, and was cultured in a greenhouse on wheat, *Triticum aestivum* L. cv. Nugaines. Inoculum was introduced into the microplots on Nugaines transplants and maintained on that host for 2 years.

Spring mean nematode population densities (Pi) of second-stage juveniles (J2) were determined from 10 soil samples per microplot, composited from 14 soil cores (30-cm centers × 30 cm deep) per sample, collected with a 1.9-cm-d probe. Elutriation (3) and alcohol flotation (7) were used to process 100-cm^3 aliquants of each soil sam-

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TABLE 1. Effect of time of application on chemical control of *Meloidogyne chitwoodi* on Russet Burbank potato after 1,344 DD5.

Treatment†	Rate a.i.	Time of application‡	Yield (quintal/ha)	Infected and galled tubers (%)§
1,3-D	9.4 g/m (168 kg/ha)	Preplant	328 a	0 a
1,3-D	7.6 g/m (135 kg/ha)	Preplant	336 a	2 ab
Aldicarb	2.1 g/m (5.6 kg/ha)	At plant	307 a	25 d
Aldicarb	2.1 g/m (5.6 kg/ha)	615 DD5	317 a	21 d
Aldicarb	2.1 g/m (5.6 kg/ha)	916 DD5	308 a	13 c
Aldicarb	2.1 g/m (5.6 kg/ha)	1,221 DD5	312 a	6b
Untreated			316 a	39 e

Means within a column with same letter are not different according to Duncan's new multiple-range test ($P < 0.05$).
† 1,3-D applied broadcast 16 days preplant at 11 C. Aldicarb 15G applied at plant in a 30-cm band directly over the row and rototilled into the soil 15 cm deep. Aldicarb 15G applied postplant in 15-cm band on each side of row, and raked into soil 5–8 cm deep. All treatments were followed immediately with 2.5–3.0 cm water through sprinkler irrigation system.
‡ DD5 = degree-days with a base of 5 C.
§ Tubers stored at 7 C for 64 days (128 DD5) after harvest before tuber infection and galling percentages were determined.

ple. Mean numbers of J2 were 1.8 (range: 1.6–2.1)/cm³ soil.

The nematicide treatments, rates, and time of applications for each experiment are listed in Tables 1–3. The 1,3-D was applied broadcast with a fumigant injector-gun by injecting it 30 cm deep on 15-cm intervals. The fumigant was applied 16–18 days preplant at soil temperatures of 9–11 C. At-plant (AP) aldicarb was applied with a shaker jar in a 30-cm band directly over the row and rototilled into the soil 15 cm deep immediately before planting. For postplant (PP) treatments, equal amounts of aldicarb were applied in a 15-cm band on each side of the row and hand raked into the soil 5–8 cm deep. All treatments received 2.5–3.0 cm water through a sprinkler irrigation system immediately after each aldicarb application.

Soil was fertilized immediately before planting at rates used in commercial potato production in southeastern Idaho (5). Certified Russet Burbank seed potato was planted at 15-cm spacing on 100-cm rows, three rows per microplot. No herbicide was used, and the plots were hand weeded. Soil temperatures were recorded at 15 cm deep with two thermographs located in two selected microplots.

Fifty-six soil subsamples were collected with a 1.9-cm-d probe 30 cm deep at 15-cm intervals 15 and 30 cm from each side of the center of each row immediately before harvest from each microplot. Subsamples were composited (eight subsamples per sample), thoroughly mixed, and 100-cm³ aliquants of each sample were processed to determine the numbers of *M. chitwoodi* J2. Tubers were harvested after 1,344 DD5, 1,684 DD5, and 2,028 DD5 (1) in experiments 1, 2, and 3, respectively, and fresh tuber weights were determined.

Tubers invaded by *M. chitwoodi* J2 were harvested before development of nematode-induced disease symptoms; i.e., necrotic tissue encircling embedded females preceding tuber galling. Hence, tubers were stored at 7 C for 64 days (128 DD5) to allow for symptom development. This simulated commercial operations where tubers are stored at approximately 7 C before being graded and processed. Data on tuber yields and infection and galling were subjected to analysis of variance and linear regression analysis. Treatment means were

TABLE 2. Effect of time of application on chemical control of *Meloidogyne chitwoodi* on Russet Burbank potato after 1,684 DD5.

Treatment†	Rate a.i.	Time of application	J2/cm³ soil 1,684 DD5‡	Infected and galled tubers§ (%)	Yield (quintal/ha)
1,3-D	7.6 g/m (135 kg/ha)	Preplant	0.6 a	2 a	312 a
Aldicarb	2.1 g/m (5.6 kg/ha)	At plant	8.3 g	36 e	305 a
Aldicarb	2.1 g/m (5.6 kg/ha)	600 DD5	5.8 f	26 d	313 a
Aldicarb	2.1 g/m (5.6 kg/ha)	1,228 DD5	4.2 def	22 cd	290 a
Aldicarb	1.3 + 1.3 g/m (3.4 + 3.4 kg/ha)	AP + 600 DD5	5.4 ef	24 cd	297 a
Aldicarb	1.3 + 1.3 g/m (3.4 + 3.4 kg/ha)	AP + 1,228 DD5	3.3 cd	18 c	302 a
Aldicarb	1.3 + 1.3 g/m (3.4 + 3.4 kg/ha)	600 DD5 + 1,228 DD5	3.0 cd	19 c	298 a
Aldicarb	1.3 + 2.1 g/m (3.4 + 5.6 kg/ha)	AP + 600 DD5	4.1 de	18 c	317 a
Aldicarb	1.3 + 2.1 g/m (3.4 + 5.6 kg/ha)	AP + 1,228 DD5	1.9 abc	10 b	310 a
Aldicarb	1.3 + 2.1 g/m (3.4 + 5.6 kg/ha)	600 DD5 + 1,228 DD5	1.0 ab	6 ab	322 a
Untreated			10.6 h	59 f	314 a

Means within a column with same letter are not different according to Duncan's new multiple-range test ($P < 0.05$).

† 1,3-D applied broadcast 16 days preplant at 9 C. Aldicarb 15G applied at plant (AP) in a 30-cm band directly over the row and rototilled into the soil 15 cm deep. Aldicarb 15G applied postplant in 15-cm band on each side of row, and raked into soil 5–8 cm deep. All aldicarb treatments were followed immediately with 2.5–3.0 cm water through sprinkler irrigation system.

‡ DD5 = degree-days with a base of 5 C.

§ Tubers stored at 7 C for 60 days (120 DD5) after harvest before tuber infection and galling percentages were determined.

compared by Duncan's new multiple-range test.

All experiments were similar, except for differences of accumulated DD5, and time of aldicarb applications.

RESULTS AND DISCUSSION

Experiment 1: Infection and galling of potato tubers by *M. chitwoodi* were less ($P < 0.05$) in all treated than untreated plots (Table 1). Only the aldicarb PP treatment at 1,221 DD5 was as effective as 1,3-D in controlling *M. chitwoodi.* There were no differences in tuber yields among treatments.

Experiment 2: All aldicarb treatments reduced ($P < 0.05$) the nematode population density below that of the untreated control (Table 2). The single AP treatment of aldicarb provided the poorest nematode control of the chemical treatments. The PP applications of aldicarb were consistently better than AP in controlling *M. chitwoodi.* The most effective aldicarb treatment was 1.3 g/m at 600 DD5 PP plus 2.1 g/m at 1,228 DD5 PP. This treatment was equivalent to the 1,3-D treatment. There was a positive correlation ($r = 0.94$) between the final nematode population density (Pf) and the percentage of infected and galled potato tubers.

Experiment 3: The 1,3-D was more effective than aldicarb in reducing nematode population densities and infection and galling of potato tubers (Table 3). There was a strong correlation between the percentage of infected and galled tubers and the nematode Pf ($r = 0.90$). None of the aldicarb treatments reduced *M. chitwoodi* infection and galling of tubers below that allowed by potato processors (5). The

TABLE 3. Effect of time of application on chemical control of *Meloidogyne chitwoodi* on Russet Burbank potato after 2,028 DD5.

Treatment†	Rate a.i.	Time of application	J2/cm³ soil 2,028 DD5‡	Infected and galled tubers (%)§	Yield (quintal/ha)
1,3-D	7.6 g/m (135 kg/ha)	Preplant	0.8 a	4 a	326 a
Aldicarb	2.1 g/m (5.6 kg/ha)	At plant	12.5 f	66 e	312 a
Aldicarb	2.1 g/m (5.6 kg/ha)	996 DD5	10.2 e	56 de	319 a
Aldicarb	1.3 + 1.3 g/m (3.4 + 3.4 kg/ha)	AP + 996 DD5	8.3 d	49 cd	297 a
Aldicarb	1.3 + 1.3 g/m (3.4 + 3.4 kg/ha)	504 DD5 + 996 DD5	7.8 cd	45 c	332 a
Aldicarb	1.3 + 2.1 g/m (3.4 + 5.6 kg/ha)	AP + 996 DD5	6.5 bc	39 bc	321 a
Aldicarb	1.3 + 2.1 g/m (3.4 + 5.6 kg/ha)	504 DD5 + 996 DD5	5.9 b	34 b	318 a
Untreated			14.9 g	94 f	303 a

Means within a column with same letter are not different according to Duncan's new multiple-range test ($P < 0.05$).

† 1,3-D applied broadcast 16 days preplant at 9 C. Aldicarb 15G applied at plant (AP) in a 30-cm band directly over the row and rototilled into the soil 15 cm deep. Aldicarb 15G applied postplant in 15-cm band on each side of row, raked into the soil 5–8 cm deep. All aldicarb treatments followed immediately with 2.5–3.0 cm water through sprinkler irrigation system.

‡ DD5 = degree-days with a base of 5 C.

§ Tubers stored at 7 C for 64 days (128 DD5) after harvest before tuber infection and galling percentages were determined.

greatest Pf values were in the 2.1 g/m aldicarb AP treatment.

The relationship between soil temperature and nematode reproduction was evident from this study. The greater the DD5, the greater the nematode activity, resulting in increased nematode reproduction and tuber infection and galling. There were no differences in plant growth and tuber yields among treatments. This is consistent with the results from a previous study made in eastern Idaho (5). These findings, however, differ from those reported from Washington and western Idaho (10,11). In these states, the reduction in tuber yields from *M. chitwoodi* was due to increased stress of the nematode on plant growth. Because of the greater Pi levels and DD5, there are more nematode generations and increased parasitism (5,10). It is the effect of *M. chitwoodi* on the quality, not quantity, of tuber yields that makes it such an important pathogen to potato in eastern Idaho.

Nonfumigant nematicides are easy to apply and are not generally phytotoxic. To control *M. chitwoodi* effectively, however, a nonfumigant nematicide must have a longer residual period than aldicarb or its application must be timed accurately. Continued investigations are needed for better methodology of nonfumigant nematicide applications for increased efficacy.

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