Supplement to Journal of Nematology 22(4S):681–688. 1990.

Effects of Soil Fumigants and Aldicarb on Bacterial Wilt and Root-knot Nematodes in Potato[1]

D. P. Weingartner and J. R. Shumaker[2]

Abstract: Standard single-chisel and similated broadcast applications of ethylene dibromide (EDB), EDB + chloropicrin, and 1,3-dichloropropene (1,3-D), both singly and in combination with aldicarb, were evaluated for control of bacterial wilt and *Meloidogyne incognita* on the potato cultivars Atlantic and Sebago. Best control of bacterial wilt and *M. incognita* was by EDB + chloropicrin. EDB and 1,3-D were more effective for controlling both bacterial wilt and *M. incognita* when they were applied with three chisels rather than one chisel per row. Addition of aldicarb to single-chisel EDB and 1,3-D treatments provided nematode control equivalent to that of the same fumigants applied with three chisels per row. Atlantic was more susceptible than Sebago to bacterial wilt. Incidence of bacterial wilt in Sebago following single-chisel fumigation was equivalent to that in Atlantic following triple-chisel fumigation. Aldicarb did not enhance control of bacterial wilt. In 1983, 23.9% ($P = 0.0001$) of the variability in the number of wilted plants per plot (y) was described by the equation $y = 3.03 + 0.67x$, where x = *M. incognita* per 100 cm^3 soil at harvest.

Key words: aldicarb, bacterial wilt, brown rot, chloropicrin, 1,3-dichloropropene (1,3-D), ethylene dibromide (EDB), interaction, *Meloidogyne incognita,* potato, root-knot nematode, *Solanum tuberosum.*

Potatoes (*Solanum tuberosum* L.) have been grown commercially in northeast Florida since the early 1900s (14). Bacterial wilt caused by *Pseudomonas solanacearum* E. F. Smith was among the first serious diseases encountered by early potato farmers in this region (4). The symptoms and history of bacterial wilt and its renewed importance in Florida potato production have been reviewed (19).

Usually the first sign of bacterial wilt on infected potato plants is epinasty of terminal leaves. Tuber brown rot is usually found when individual plants are 25–50% wilted. Numerous tubers decay in the field before harvest, but many affected tubers are harvested and must be culled during grading.

Several wilt diseases caused by *P. solanacearum* are more severe in the presence of *Meloidogyne* spp. (3,7–10,13). Severity of bacterial wilt on potato was enhanced by *M. javanica* (Treub) Chitwood (15), *M. incognita* (Kofoid and White) Chitwood (2), and *M. incognita acrita* Chitwood (5). *Meloidogyne incognita* is known to occur on more than 85% of northeast Florida potato farms (20). It is often prevalent in potato fields affected by bacterial wilt.

Several wilt diseases caused by *P. solanacearum* in other crops have been controlled by soil fumigation. Among several fumigants tested, chloropicrin (Pic) was the only one that provided significant full-season control of bacterial wilt in Georgia tomatoes (1). The incidence of Granville wilt in tobacco was also reduced by Pic (8). Other fumigants, including DD-MENCS and metham-sodium, reduced wilt in field-grown tomatoes in Florida, but only when applied under plastic (6). Some reduction in the percentage of tuber brown rot in potatoes was observed in India following treatment with DD or the nonfumigant zinophos (12). Incidence of wilt, but not tuber brown rot, was reduced in northeast Florida in 1975 and 1976 following in-row applications of 1,3-dichloropropene (1,3-D) at 75 liters/ha (unpubl. data).

In this paper we report on the effects of ethylene dibromide (EDB), EDB + Pic, and 1,3-D applied with one or three chisels per row, both singly and in combination with aldicarb, on bacterial wilt, tuber brown rot, and *M. incognita* in the potato cultivars Atlantic and Sebago.

Materials and Methods

Unless noted otherwise, methods of treatment, plot design, nematode sampling

Received for publication 19 June 1989.

[1] Florida Agricultural Experiment Station Journal Series No. 9991.

[2] Associate Professors, IFAS Agricultural Research and Education Center, Hastings, FL 32145.

We thank Jill Meldrum and Louis Wallis III for technical assistance.

TABLE 1. Analysis of variance for the number of wilted plants per plot, percentage of tubers with brown rot, severity of brown rot, and densities of *Meloidogyne incognita*, 1982.

Source of variation	df	Mean squares (×10²)					
		Wilted plants per plot (no.)			Tubers with brown rot (%)	Brown rot severity	*M. incognita* density mean squares
		1 Apr	19 Apr	30 Apr			
Replications	5	14.0	35.8*	121.1	21.8	115.0	20.4
No. chisels/row (C)	1	39.3	176.7**	43.0	2.6	7.1	299.4**
Error a	5	9.4	4.7	103.7	15.2	29.2	26.9
Variety (V)	1	39.5**	209.5*	9.2	195.3*	34.8*	62.1
Error b	5	1.7	14.4	28.1	22.0	7.6	26.9
V × C	1	1.4	28.9*	98.8*	2.8	19.2	39.8
Error c	5	3.0	1.4	12.5	12.1	25.0	18.9
Fumigant (F)	2	27.8	136.5**	109.3*	5.7	10.4	343.3*
F × C	2	14.3	1.8	23.4	1.3	8.5	45.5*
F × V	2	3.3	7.0	39.3	4.5	3.9	29.0*
F × C × V	2	10.7	6.4	30.7	6.6	10.0	12.9
Error d	40	7.7	15.1	29.5	10.1	741.0	9.4
Nematicide (N)†	1	8.6	3.3	11.4	11.6	40.1	175.8**
N × C	1	4.7	3.8	4.8	2.1	0.4	105.0**
N × V	1	21.9	3.9	8.8	0.2	4.4	105.3**
N × F	2	21.3	15.3	54.3	34.6	10.4	100.2**
N × C × V	1	0.2	0.1	93.0	0.4	0.6	14.0
N × C × F	2	1.0	1.3	28.0	4.7	31.9	44.7**
N × V × F	2	0.8	10.6	49.2	41.8*	17.4	42.1**
N × C × V × F	2	6.1	3.0	19.9	5.7	4.3	0.7
Error e	60	8.9	19.0	24.2	11.1	29.5	8.1

* $P \leq 0.05$; ** $P \leq 0.01$.

Prior to analysis of variance, numbers of *M. incognita*, wilted plants per plot, and percentages of tubers with brown rot were transformed by $\sqrt{n + 1}$. Brown rot severity values (1–10 where 1 = all tubers free of rot and 10 = all tubers affected) were not transformed.

† The nonfumigant nematicide, aldicarb.

and extraction, and cultural practices for growing the crop were as described previously (17). Two experiments (1982 and 1983) were conducted; treatments were replicated six times in both experiments. A three-level split-plot (3 fumigants × 2 application methods × 2 aldicarb levels) coupled with a split-strip (two cultivars) was used as the plot design. The sub-subplots were 7.6 m long and four rows wide with 1.0 m between the rows. The cultivars were planted in adjacent pairs of rows so the center two rows (i.e., data rows) of each plot consisted of one row of each variety. Seed tubers were spaced 20 cm apart.

The fumigants were applied using the standard single-chisel method of application or as a similated broadcast treatment using three chisels per row. The fumigant rates applied through each chisel in the 1982 experiment were EDB, 16.8 liters/ha (52 ml/chisel for each 30.5 m); 54% EDB + 45% Pic, 23.9 liters/ha (74 ml/chisel for each 30.5 m); and 1,3-D, 56.1 liters/ha (174 ml/chisel for each 30.5 m). The same rates were used in 1983, except that EDB was applied at 12.6 liters/ha (39 ml/chisel for each 30.5 m). At planting, aldicarb was banded over the seed pieces at a rate of 3.4 kg a.i./ha (10.4 g/30.5 m of row).

Soil samples for nematode assay were taken just before harvest each year. Ten soil cores (2.5 × cm d × 20–25 cm deep) were taken within each data row of each plot. Soil samples from individual rows were processed in 1982, whereas soil from the two data rows were bulked and processed as composites in 1983. Nematodes were extracted from 100-cm³ aliquants using a modification of the sugar-centrifugation method (11).

TABLE 2. Analyses of variance for the number of wilted plants per plot, percentage of tubers with brown rot, and densities of *Meloidogyne incognita*, 1983.

Source of variation	Mean squares			Mean squares ($\times 10^{-2}$)†	
	df	Wilted plants per plot, 16 May	Tubers with brown rot (%)	df	*M. incognita* density
Replications	5	4.7	0.3	5	0.6
No. chisels/row (C)	1	24.5*	4.5*	1	39.2**
Error a	5	2.6	0.4	(5)	0.4
Variety (V)	1	31.8*	5.5**	—	—
Error b	5	2.0	0.3	—	—
V × C	1	5.3	1.2**	—	—
Error c	5	1.4	0.4	—	—
Fumigant (F)	2	2.7*	1.5**	2	8.8**
F × C	2	3.4**	0.5*	2	4.8**
F × V	2	< 0.1	0.6*	—	—
F × C × V	2	0.5	0.1	—	—
Error d	40	0.6	0.1	(20)	0.4
Nematicide (N)‡	1	0.1	0.2	1	7.7**
N × C	1	0.5	0.2	1	7.3**
N × V	1	0.4	< 0.1	—	—
N × F	2	0.9*	0.6*	2	1.2*
N × C × V	1	0.3	< 0.1	—	—
N × C × F	2	0.4	0.3	2	1.2*
N × V × F	2	0.1	0.3	—	—
N × C × V × F	2	0.1	0.1	—	—
Error e	60	0.2	0.1	(30)	0.3

* $P \leq 0.05$; ** $P \leq 0.01$.

Prior to analyses of variance, numbers of *M. incognita*, wilted plants per plot, and percentages of tubers with brown rot were transformed by $\sqrt{n+1}$.

† Soil samples from individual variety rows were bulked in 1983, changing the design for analysis of variance and the degrees of freedom for *M. incognita* numbers. Degree of freedom values in ( ) are, from top to bottom, error terms a, b, and c, respectively; dashes (—) indicate terms not present in analysis of *M. incognita* numbers.

‡ The nonfumigant nematicide, aldicarb.

Bacterial wilt was assessed in the field and brown rot in tubers was assessed at the time of grading. The wilted plants in each plot were counted on three different dates in 1982 and once in 1983. In 1982, after the potatoes from each plot were washed and graded, the severity of tuber brown rot was rated visually on a scale of 1–10, with 1 = all tubers free of brown rot and 10 = all tubers affected. After the tubers were graded and weighed, 20 tubers sampled randomly from each row of each plot were sliced and the presence or absence of internal brown rot recorded.

All data were subjected to analysis of variance (ANOVA). Prior to ANOVA, all data except severity of brown rot were transformed by $\sqrt{n+1}$. Unless otherwise indicated, all mean separations were calculated at $P = 0.05$.

RESULTS

Analysis of variance revealed several significant ($P \leq 0.05$) effects and interactions in 1982 (Table 1) and 1983 (Table 2).

Bacterial wilt: Bacterial wilt was more severe in 1983 than in 1982, but results of the treatment effects were similar in both years. In both years, fewer plants wilted in triple-chisel than in single-chisel plots (Tables 3, 6) and in plots with Sebago than in those with Atlantic (Tables 3–5). Incidence of wilt in 1982 was less in plots treated with EDB and EDB + Pic than in 1,3-D plots (Table 4). In 1983 most wilt occurred in EDB plots (Table 6). Similar significant chisel × cultivar effects on incidence of bacterial wilt were noted on 19 April 1982 (Table 3) and 15 May 1983 (Table 5). In both instances fewer wilted Sebago plants

TABLE 3. Mean numbers of wilted plants per plot in 1982 as affected by potato cultivar and fumigant application method.

Cultivar	Wilted plants per plot			
	19 Apr		30 Apr	
	One chisel	Three chisels	One chisel	Three chisels
Atlantic	1.7 c	0.8 b	2.7 b	1.8 a
Sebago	0.7 b	0.3 a	2.1 ab	2.3 ab
Means	1.2 n	0.5 m	2.4 m	2.0 m

Values within a treatment level (cultivar × application method [a–c], application method [m–n]) on an individual date followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test. Data are averaged across all fumigant and aldicarb treatments.

were noted after the triple-chisel fumigation treatments than after the other treatment combinations, and incidence of wilt in Atlantic following triple-chisel applications was equivalent to that in Sebago after fumigation with a single chisel. On 30 April 1982, however, this trend was reversed (Table 3).

Tuber brown rot: Incidence of brown rot was less in 1982 than in 1983. Most treatment means did not differ in 1982. In 1982, 4.5% of Atlantic and 1.0% of Sebago tubers had brown rot (Table 4), compared with 9.2% and 2.5%, respectively, in 1983 (Table 7).

In 1983 the percentages of tuber brown rot generally followed the same trends as those of bacterial wilt. Overall, increasing the number of chisels reduced the percentage of tubers with brown rot. Atlantic had more brown rot than did Sebago (Ta-

TABLE 4. Mean number of wilted plants per plot and incidence and severity of tuber brown rot during 1982 as affected by potato cultivar and soil fumigant.

	Wilted plants per plot			Tuber brown rot	
	1 Apr	19 Apr	30 Apr	Incidence (%)	Severity†
Cultivar‡					
Atlantic	0.6 b	1.2 b	2.3 a	4.5 b	1.7 b
Sebago	0.2 a	0.5 a	2.2 a	1.0 a	1.4 a
Fumigant§					
EDB	0.3 x	0.9 y	1.9 x	3.5 x	1.5 x
EDB + Pic	0.3 x	0.3 x	1.7 x	2.0 x	1.5 x
1,3-D	0.7 y	1.4 y	3.0 y	1.7 x	1.6 x

Individual variables within columns, and within cultivar or fumigation levels followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

† Rated on a scale of 1–10 with 1 = all tubers visually free of brown rot and 10 = all tubers affected.

‡ Cultivar data are averaged across all nematicide treatments.

§ Fumigation data are averaged across both chisel and aldicarb treatments and both cultivars.

TABLE 5. Mean numbers of wilted plants per plot as affected by potato cultivar and fumigant application method on 15 May 1983.

Cultivar	Wilted plants per plot		
	One chisel	Three chisels	Cultivar means
Atlantic	9.4 c	2.5 b	5.9 n
Sebago	2.1 b	0.4 a	1.3 m

Values within a treatment level (number of chisels × cultivar [a–c], cultivar [m–n]) followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

TABLE 6. Mean numbers of wilted plants per plot as affected by soil fumigant, fumigant application method, and aldicarb, 1983.

Treatment	Wilted plants per plot		
	One chisel	Three chisels	Fumigant–aldicarb means
EDB			
+ aldicarb	5.8 a	1.7 a	3.5 j
− aldicarb	10.5 a	1.4 a	6.0 k
EDB chisel means	8.2 y	1.3 x	
EDB mean	4.7 n		
EDB + chloropicrin (Pic)			
+ aldicarb	3.2 a	1.9 a	2.5 ij
− aldicarb	2.8 a	1.6 a	2.2 i
EDB + Pic chisel means	3.0 x	1.8 x	
EDB + Pic mean	2.4 m		
1,3-D			
+ aldicarb	6.1 a	1.7 a	3.9 j
− aldicarb	6.1 a	1.1 a	3.6 j
1,3-D chisel means	6.1 y	1.4 x	
1,3-D mean	3.7 mn		
Overall chisel means	5.7 q	1.5 p	

Values within a treatment level (fumigant [m–n], number of chisels [p–q], number of chisels × aldicarb [a–b], number of chisels × fumigant [x–y], fumigant × aldicarb [i–k]) followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

TABLE 7. Effects of soil fumigant, application method, and potato cultivar on incidence (%) of tuber brown rot, 1983.

Cultivar	Soil fumigants			One chisel	Three chisels	Cultivar means
	EDB	EDB + Pic	1,3-D			
Atlantic	15.2 c	4.6 ab	7.7 b	14.1 o	3.8 mn	9.2 q
Sebago	3.8 ab	1.9 a	1.7 a	4.3 n	1.1 m	2.5 p

Values within a treatment level (cultivar [p–q], fumigant × cultivar [a–c], number of chisels × cultivar [m–o]) followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

ble 7). Dosage × cultivar and fumigant × cultivar interactions were detected and these followed the same trends as for wilted plants. A fumigant × aldicarb interaction (Table 8) also occurred. This was due to a greater percentage of brown rot in tubers from EDB + aldicarb plots than from those of other treatments.

Meloidogyne incognita: Final population densities (Pf) of *M. incognita* were lower in 1982 than in 1983 (Tables 9, 10) although relative Pf among treatments during the two seasons were similar. Significant fumigant, fumigant × dosage, and aldicarb effects on Pf occurred both years (Tables 9, 10). The Pf were lower in plots treated with either EDB or EDB + Pic than those treated with 1,3-D. Using three chisels reduced Pf both years and a fumigant × dosage interaction occurred (Table 9).

Aldicarb added to soil fumigants reduced Pf from 57 to 12 in 1982 and from 388 to 103 in 1983 (Table 9), but the effect was not uniform between the chisel treatments. Aldicarb added to the triple-chisel fumigation treatments failed to further reduce Pf. Adding aldicarb to single-chisel applications resulted in Pf similar to the triple-chisel treatments without aldicarb in 1982 but not in 1983 (Table 9). A significant aldicarb × dosage × fumigant interaction effect on Pf occurred both years (Table 9). Addition of aldicarb to EDB + Pic did not further reduce the Pf because of the superior efficacy of the fumigation treatment. Although the overall difference in Pf between Atlantic and Sebago in 1982 was not significant (Table 10), the aldicarb × cultivar and aldicarb × fumigant × cultivar interactions indicated a cultivar influence with greater Pf occurring in Sebago. These interactions were due to greater Pf in the non-aldicarb 1,3-D plots of Sebago (252/100 cm^3 soil) than in those of Atlantic (51/100 cm^3 soil) (Table 10); and also to greater Pf in Sebago (95/100 cm^3 soil) than in Atlantic (19/100 cm^3 soil) when neither cultivar was treated with aldicarb (Table 10).

Regression analyses showed that the relationship of bacterial wilt incidence to Pf varied during the two seasons. The r^2 values were low and not significant ($P \leq 0.05$) in 1982; the greatest r^2 value was 0.144 in Sebago on 1 April. In 1983, the relationship between numbers of wilted plants (w) and Pf was expressed by $w = 3.03 + 0.67Pf$ ($r^2 = 0.239$, $P = 0.0001$), and that

TABLE 8. Mean percentages of potato tubers with brown rot as affected by soil fumigant, application method, and aldicarb, 1983.

Fumigant	One chisel	Three chisels	With aldicarb	Without aldicarb	Fumigant means
EDB	15.0 c	4.0 ab	6.1 y	12.9 z	9.5 q
EDB + Pic	5.4 b	1.1 a	4.2 xy	2.3 x	3.3 p
1,3-D	6.3 b	3.2 ab	4.4 xy	5.0 xy	4.7 p
Means	8.9 n	2.7 m	4.9 s	6.7 s	

Data are averaged across both potato cultivars. Values within a level (fumigant [p–q], aldicarb [s–t], number of chisels [m–n], fumigant × number of chisels [a–c], or fumigant × aldicarb [x–z]) followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

TABLE 9. Population densities of *Meloidogyne incognita* following different nematicide treatments in 1982 and 1983.

Treatment	Nematodes per 100 cm³ soil					
	1982			1983		
	One chisel	Three chisels	Fumigant–aldicarb means	One chisel	Three chisels	Fumigant–aldicarb means
EDB						
+ aldicarb	4 ab	0 a	2 i	128 b	3 a	65 i
− aldicarb	13 a–c	0 a	6 i	816 d	1 a	409 j
EDB chisel	9 xy	0 x		472 y	2 x	
EDB means	4 m			237 n		
EDB + chloropicrin (Pic)						
+ aldicarb	11 a–c	0 a	6 i	28 ab	0 a	14 i
− aldicarb	27 bc	0 a	13 ij	84 ab	1 a	43 i
EDB + Pic chisel means	19 y	0 x		56 x	< 1 x	
EDB + Pic means	10 m			28 m		
1,3-D						
+ aldicarb	37 bc	19 a–c	28 j	432 c	28 ab	230 j
− aldicarb	255 d	48 c	151 k	1,387 e	37 ab	712 k
1,3-D chisel means	146 z	33 y		909 z	32 x	
1,3-D means	90 n			471 o		
Overall chisel-aldicarb						
+ aldicarb	17 u	6 u	12 r	196 v	10 u	103 r
− aldicarb	98 v	16 u	57 s	763 w	13 u	388 s
Overall chisel means	58 q	11 p		479 q	12 p	

Values within treatment levels (fumigant [m–o], aldicarb [r–s], fumigant × number of chisels [x–z], number of chisels × aldicarb [u–w], number of chisels × fumigant × aldicarb [a–d], fumigant × aldicarb [i–k]) during an individual year followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test. Respective dosages per chisel of EDB, EDB + Pic, and 1,3-D in 1982 were 16.8, 23.9, and 56.1 liters/ha. Dosages per chisel in 1983 were the same except for EDB which was applied at 12.6 liters/ha.

between incidence of brown rot (BR) and Pf by BR = 1.41 + 0.09Pf ($r^2 = 0.157$, $P = 0.0001$).

DISCUSSION

These data further confirm that Atlantic is more susceptible than Sebago to bacterial wilt (19). The level of bacterial wilt control in Sebago following single-chisel applications of soil fumigants was equal to that of the similated broadcast treatments in Atlantic. The level of bacterial wilt tolerance in Sebago is certainly sufficient for use in a wilt management program. It should be noted, however, that *P. solanacearum* occurring in northeast Florida is race 1, tomato race (16). The tolerance observed in Sebago in the northeast Florida bacterial wilt pathosystem may not be adequate in other pathosystems having race 3, potato race.

Generally, EDB + Pic was the most effective fumigant for bacterial wilt control. The Pic component of this fumigant provided an additional level of wilt control not provided by EDB alone. Economically acceptable levels of wilt control, particularly in Sebago and the triple-chisel treatment in Atlantic, were obtained with 1,3-D. Addition of aldicarb to single-chisel fumigation treatments generally enhanced control of *M. incognita*, but it did not improve control of bacterial wilt.

The regression analyses of wilt and Pf in 1983 reveal an interaction between *M. incognita* and *P. solanacearum* on potatoes in northeast Florida. The r^2 values observed in 1983 could be considered high, since the experiment was performed under conditions of natural inoculum and the distribution of both *M. incognita* and *P. solanacearum* tend to be aggregated. Our data

TABLE 10. *Meloidogyne incognita* population densities in Atlantic and Sebago potatoes following different nematicide treatments, 1982.

Treatment	Nematodes/100 cm³ soil	
	Atlantic	Sebago
EDB		
+ aldicarb	1 a	3 ab
− aldicarb	1 a	12 ab
EDB–cultivar means	1 m	8 m
EDB + Pic		
+ aldicarb	8 ab	3 ab
− aldicarb	6 ab	21 ab
EDB + Pic–cultivar means	7 m	12 m
1,3-D		
+ aldicarb	26 bc	30 bc
− aldicarb	51 c	252 d
1,3-D–cultivar means	38 n	141 n
Overall cultivar–aldicarb means		
+ aldicarb	12 p	12 p
− aldicarb	19 p	95 q
Overall cultivar mean	15 x	53 x

Values within a treatment level (fumigant × cultivar × aldicarb [a–d], fumigant × cultivar [m–n], cultivar × aldicarb [p–q], cultivar [x–y]) followed by the same letter do not differ ($P = 0.05$) according to Duncan's multiple-range test.

support previous reports describing increased severity of bacterial wilt in potatoes following concomitant infection with *M. incognita* and *P. solanacearum* (2,5,9,10,13). More detailed studies have shown interactions between other root-knot nematodes and *P. solanacearum* on potatoes (15). Additional data are needed on the mechanism of the bacterial wilt–*M. incognita* interaction, particularly at the pathogen inoculum levels existing in commercial fields. These types of studies may have value in developing management programs for bacterial wilt in northeast Florida.

Because EDB can no longer be used in the United States, the most effective current means for controlling bacterial wilt are to plant Sebago and fumigate with 1,3-D (≥ 56 liters/ha), 1,3-D + Pic (≥ 68 liters/ha), or metham sodium (≥ 187 liters/ha) injected with at least two chisels per row (18). Use of triple-chisel applications of 1,3-D or 1,3-D + Pic is advisable when bacterial wilt is severe (18).

LITERATURE CITED

1. Enfinger, J. M., S. M. McCarter, and C. A. Jaworski. 1979. Evaluation of chemicals and application methods for control of bacterial wilt of tomato transplants. Phytopathology 69:637–640.

2. Feldmesser, J., and R. W. Goth. 1970. Association of root-knot with bacterial wilt of potato. Phytopathology 60:1014 (Abstr.).

3. Goth, R. W. 1983. Effects of root-knot nematode on bacterial wilt of tomato. Phytopathology 73: 966 (Abstr.).

4. Hume, H. 1904. Potato diseases. Bulletin 75, Florida Agricultural Experiment Station, Gainesville. Pp. 181–199.

5. Jatala, P., E. R. French, and L. Gutarra. 1976. Interrelationships of *Meloidogyne incognita acrita* and *Pseudomonas solanacearum* on potatoes. Journal of Nematology 8:325 (Abstr.).

6. Jones, J. P., A. J. Overman, and C. M. Geraldson. 1966. Effects of fumigants and plastic film on the control of several soil-borne pathogens of tomato. Phytopathology 56:929–932.

7. Johnson, A. W., and N. T. Powell. 1969. Influence of root-knot nematodes on bacterial wilt development in flue cured tobacco. Phytopathology 59: 486–491.

8. Kelman, A. 1953. The bacterial wilt caused by *Pseudomonas solanacearum.* Technical Bulletin 99, North Carolina Agricultural Experiment Station, Raleigh.

9. Lucas, G. B., J. N. Sasser, and A. Kelman. 1955. The relationship of root-knot nematodes to Granville wilt resistance in tobacco. Phytopathology 45:537–540.

10. McLaughlin, R. J., L. Sequeira, and D. P. Weingartner. 1990. Biocontrol of bacterial wilt of potato with an avirulent strain of *Pseudomonas solanacearum*: Interactions with root-knot nematodes. American Potato Journal 67:93–107.

11. Miller, P. M. 1957. A method for quick separation of nematodes from soil samples. Plant Disease Reporter 41:194.

12. Nirula, K. K., and K. D. Patharia. 1970. Role of root-knot nematodes in spread of brown rot of potatoes. Indian Phytopathology 23:158–159.

13. Reddy, P. P., D. B. Singh, and R. Kishman. 1979. Effect of root-knot nematode on the susceptibility of pusa purple cluster brinjal to bacterial wilt. Current Science 48:915–916.

14. Rose, G. N. 1976. Irish potato production—a historic data series. Economics Report 8, Food and Resource Economics Department, Agricultural Experiment Station, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

15. Ruchijat, E. 1985. Interaction between *Meloidogyne javanica* and *P. solanacearum* on bacterial wilt susceptible and resistant potato genotypes. Ph.D. thesis, University of Georgia, Athens.

16. Velupillai, M., and R. E. Stall. 1984. Variation among strains of *Pseudomonas solanacearum* from Florida. Proceedings of the Florida State Horticultural Society 97:209–218.

17. Weingartner, D. P., and J. R. Shumaker. 1990.

Effects of soil fumigants and aldicarb on corky ringspot disease and trichodorid nematodes in potato. Supplement to the Journal of Nematology (Annals of Applied Nematology) 22:665–671.

18. Weingartner, D. P., and J. R. Shumaker. 1988. In-row injection of metham-sodium and other soil fumigants for control of nematodes and soil-borne diseases in Florida. American Potato Journal 65:504 (Abstr.).

19. Weingartner, D. P., and J. R. Shumaker. 1984. Bacterial wilt and tuber brown rot as a potential threat to potato production in northeast Florida. Proceedings of the Florida State Horticultural Society 97: 198–200.

20. Weingartner, D. P., J. R. Shumaker, and G. C. Smart, Jr. 1983. Why soil fumigation fails to control potato corky ringspot disease in Florida. Plant Disease 67:130–135.

21. Weingartner, D. P., and J. R. Shumaker. 1983. Nematicide options for northeast Florida potato growers. Proceedings of the Florida State Horticultural Society 96:122–127.