1997 NORTH AMERICAN LATE BLIGHT FUNGICIDE TRIAL

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For many years, university personnel have independently evaluated both registered and experimental fungicides for control of late blight (*Phytophthora infestans*) on potato. The purpose of these trials has often been to establish efficacy and appropriate use rates. Trials at different locations are often dissimilar because different products and rates are tested. Moreover, comparisons of season-long fungicide programs consisting of multiple products (similar to the spray programs growers actually use) have not been reported.

In 1996 we coordinated the evaluation of seven fungicide programs against late blight under a wide range of environments, disease pressure, and host susceptibility. This study, called *The 1996 National Late Blight Fungicide Trial*, was designed to evaluate the newly available Section 18 fungicides with registered fungicides. The seven protectant fungicide programs which were tested performed similarly across locations, although as disease pressure increased, fungicide program effectiveness decreased.

A similar trial, *The 1997 North American Late Blight Fungicide Trial*, was done this year. Its purpose was to compare performance of Section 18 fungicides and registered fungicides within protectant spray programs for the control of both foliar and tuber symptoms of late blight.

Methods

The 17 collaborators in Canada, Mexico and the United States (Appendix I) followed the experimental protocol outlined below.

1. Planting of *Snowden* (because of tuber blight susceptibility) if possible, otherwise a susceptible cultivar typical of location.
2. Experimental units of two, three or four-row plots (a minimum 5 ft alley or 2-3 spreader rows between plots to minimize interplot interference).
3. Spreader rows positioned uniformly among treatments to insure uniform inoculation.
4. Reliance on natural infections by *P. infestans* or inoculation of plots or spreader rows with *P. infestans* within 24-48 hr following initial fungicide applications.
5. Experimental design a randomized complete block; 4 treatment replications.
6. Fungicide applications in 35-50 gpa at 35-100 psi; flat fan or hollow cone nozzles.
7. Products used as provided by chemical manufacturers. No additional additives.
8. Fungicide applications beginning when plants 10 in. tall, or earlier if necessary.

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9. Fungicide applications every 7 days.
10. Fungicide programs maintained until vines completely dead with adherence to preharvest intervals and maximum allowable amounts of product/acre/season.
11. Vines killed by rolling and Diquat @ 1 pt. product/acre. A second application of Diquat 7 days later if needed. A 2 wk interval between vine kill and harvest.
12. Foliar disease readings (as percent blighted foliage/plot) a minimum of every 7 days.
13. Tuber blight readings at harvest and 3 mo. post-storage.

Foliar fungicide programs were designed with input from both cooperating chemical companies and collaborators. These programs featured Acrobat MZ, Curzate DF + Manzate 200 and Tattoo C as the Section 18 fungicide products in various combinations with Bravo WS, or consisted of Bravo WS, Dithane DF, Kocide 2000 + Manex, and Polyram 80 DF + SuperTin 80 WP as the registered fungicide products. Application rates, maximum allowable amounts per acre per season and pre-harvest intervals for each product met label requirements. The spray schedule used for each treatment programs:

Program Name	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8
Acrobat MZ	B	B	A	A	A	B	B	A
Curzate 60 DF + Manzate 200	B	C/Mz	C/Mz	C/Mz	C/Mz	C/Mz	B	B
Tattoo C	B	T	B	T	B	T	B	B
Bravo WS	B	B	B	B	B	B	B	B
Dithane DF	D	D	D	D	D	D	D	D
Polyram 80 DF + Super Tin 80 WP	P only	P/ST	P/ST	P/ST	P/ST	P/ST	P/ST	P/ST
Kocide 2000 + Manex	K/Mx	K/Mx	K/Mx	K/Mx	K/Mx	K/Mx	K/Mx	K only

Data on percent foliar symptoms over time, total tuber yield, percent tuber blight, seasonal rainfall/irrigation and max./min. temperature were collected. Relative area under the disease progress curve (RAUDPC) was used for comparison of fungicide programs. RAUDPC in this study is the area under the disease progress curve (AUDPC) divided by the time of the epidemic expressed as degree days (base temperature = 12.5 C). Based on RAUDPC of the nontreated control, sites were characterized as having mild (RAUDPC < 49), moderate (RAUDPC = 50-69), or severe (RAUDPC > 70) disease pressure.

The effect of fungicide spray programs on associated tuber yield was standardized by calculating percent increase in yield compared to the nontreated control. Based on date of disease onset in the nontreated control, sites were classified as having early season (<350 DDAP), midseason (350-600 DDAP), or late season (>600 DDAP) epidemics. DDAP is the number of degree days after planting.

Results

Across locations, six different potato cultivars were grown. Although, these cultivars vary somewhat in their relative susceptibility to the foliar and tuber phases of late blight, all are susceptible. The predominant *P. infestans* genotype was US8 (metalaxyl-insensitive, A2 mating type). Disease developed at 13 of the 17 sites; three, six and four of the 13 sites, respectively, had mild, moderate or severe disease pressure. Disease onset was early, mid or late at four, six and three of the sites, respectively (Table 1).

Percent reduction in RAUDPC relative to the nontreated control across all locations averaged 77% (Table 2). Percent reduction in RAUDPC averaged 90, 77, and 66% for locations classified as having mild, moderate and severe disease pressure, respectively. At the mild disease pressure sites, the average percent reduction in disease for programs with and without Section 18 compounds was 93 and 89%, respectively. Fungicide programs were 13% less effective under moderate compared to a mild disease pressure. Within the moderate disease pressure sites, fungicide programs with Section 18 compounds reduced disease severity by 85% compared to 71% for registered products. Fungicide programs were similar in their efficacy under severe disease pressure, i.e., 68 versus 65% reduction in RAUDPC for programs featuring either Section 18 or registered fungicides, respectively.

The greatest increase in tuber yield occurred at the Mexico site (Table 3). At this location, disease was apparent at emergence; percent increase in yield was quite similar regardless of fungicide program, ~1400%. Excluding Mexico, at the other locations where disease developed early in the growing season (the development stage when rate of foliage growth is the highest), yield increase averaged 90%. Yield increase in programs with Section 18 fungicides versus registered products averaged 103 and 80%, respectively. However as the season progressed, value of the fungicide programs decreased; e.g. average increase in yield for midseason epidemics was 48%. When disease started during the middle of the season (the time period when the canopy was fully developed), increase in yield was 55 and 41% for Section 18 fungicide programs and programs with registered fungicides, respectively. Finally, when disease onset occurred late in the season (the time when the foliage had begun senescence), yield increases associated with control of foliar symptoms were small (6%). Percent yield increase between programs featuring Section 18 or registered compounds was 4 and 8%, respectively.

Tuber blight (adequate for making comparisons) developed at 3 of the 13 locations (Table 4). Incidence of tuber blight was significantly higher in some, but not all, fungicide treatments compared to the nontreated control. The higher incidence of tuber blight in some of the fungicide-treated plots is probably a function of both fungicide efficacy and the longer time period over which disease developed in the fungicide treatments compared to nontreated control.

Interestingly, control of foliar symptoms with a foliar fungicide program did not necessarily translate into control of tuber blight. Other factors such as hill size and weather conditions preceding harvest may have contributed to the development of tuber blight at these locations.

Fungicide programs were ranked on their efficacy in controlling foliar symptoms of late blight and on the associated yield increase (Table 5 and 6). The program featuring Tattoo C had the lowest overall ranking (the lower the ranking, the more effective the fungicide program); the program featuring Kocide + Manex had the highest overall ranking (Table 7). Section 18 programs ranked lower than programs with registered fungicides. Of the programs with Section 18 fungicides, Tattoo C was more effective than Curzate 60 DF and Acrobat MZ.

Overall rankings of percent yield increase were only slightly higher (the higher the ranking the better the program) for Section 18 programs compared to programs with registered fungicides. Tattoo C had the highest overall ranking and Kocide 2000 tank-mixed with Manex had the lowest overall ranking of the fungicide programs compared.

Conclusions

Regardless of location, all fungicide programs significantly suppressed foliar symptoms of late blight compared to the nontreated control. Under mild disease pressure, both Section 18 and registered fungicide programs were similar in their effectiveness. Under moderate or severe disease pressure, programs with Section 18 fungicides, as a group, were slightly more effective than programs with only registered fungicides.

Fungicide programs proved most valuable in increasing tuber yield when onset of disease occurred early in the growing season. Section 18 products slightly outperformed those programs with only registered products. When disease onset occurred midseason, Section 18 and registered fungicide programs performed similarly. Fungicides had little impact on tuber yield in environments where disease onset occurred late in the growing season.

Highlights

Foliar blight

- With an increase in disease pressure, effectiveness of fungicide programs decreased.
- Under moderate or severe disease pressure, programs with Section 18 fungicides, as a group, were more effective than programs with registered fungicides.
- Under mild disease pressure, both Section 18 and registered fungicide programs were similar in their effectiveness.
- Kocide 2000 tank-mixed with Manex was the least effective fungicide program.

Tuber yield

- When disease onset occurred early or the middle of the growing season, programs with Section 18 products outperformed programs with only registered products.
- When disease onset occurred late in the season, fungicides had little effect on tuber yield.
- Kocide 2000 tank-mixed with Manex was the least effective program when disease occurred early or midseason.

Tuber blight

- Control of foliar symptoms did not necessarily result in control of tuber symptoms.

Appendix I

1997 NALBFT Contributors

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Table 1. Site variables of 1997 North American Late Blight Fungicide Trial.

Location	Cultivar[1]	Genotype of *P. infestans*	Disease pressure[2]	Days to disease onset[3]
Florida	Atlantic	US8	moderate	317
Idaho	Shepody	US8	severe	594
Mexico	Alpha	not determined	moderate	145
Michigan	Snowden	US8	mild	512
New York	Superior	US8	moderate	382
North Dakota	Snowden	US8	moderate	490
Oregon-I (Corvallis)	Snowden	US8	severe	463
Oregon-II (Woodburn)	Russet Burbank	US8	severe	536
Pennsylvania	Snowden	US8	moderate	598
Prince Edward Island	Russet Burbank	US8	moderate	294
Washington	Russet Burbank	US8, US11, US14	mild	134
Wisconsin	Snowden	US8	severe	631
Wyoming	Snowden	US1; others yet not reported	mild	624

[1] Snowden planted at several sites because tubers are very susceptible.
[2] Disease pressure class based on relative area under the disease progress curve in the nontreated control; total time of epidemic in nontreated control calculated in degree days (base 12.5 C).
[3] Estimated days to disease onset based on degree days (base 12.5 C) after planting in the nontreated control.

Table 2. Effect of foliar fungicide programs on percent reduction in relative area under the disease progress curve (RAUDPC) relative to the nontreated control.

Fungicide program	Disease Pressure[1]													Average
	Mild			Moderate						Severe				
	MI	WA	WY	FL	MX	ND	NY	PA	PEI	ID	OR-I	OR-II	WI	
Acrobat	94	94	87	73	95	62	88	93	90	60	78	83	42	79.9
Curzate	96	97	90	73	93	75	83	92	83	58	91	92	28	80.8
Tattoo	95	96	87	74	93	75	97	94	93	56	91	92	41	83.4
Bravo	90	86	90	54	85	54	89	89	69	53	85	86	39	74.5
Dithane	91	82	89	60	93	68	74	94	68	51	73	95	54	76.3
Super Tin + Polyram	89	95	89	55	87	63	85	86	72	62	79	91	59	77.8
Kocide + Manex	85	91	88	54	82	70	59	57	48	48	62	70	38	65.5

[1] Locations were classified as mild, moderate, or severe disease pressure sites based on RAUDPC of the nontreated control.

Table 3. Effect of foliar fungicide programs on percent increase in tuber yield of potato relative to the nontreated control.

Fungicide program	Disease Onset[1]												Average
	Early				Mid[2]						Late		
	WA	MX	PEI	FL	NY	MI	OR-I	OR-II	ND	PA	WY	WI	
Acrobat	90	1490	51	161	58	90	25	35	13	56	6	7	174
Curzate	100	1480	44	187	69	70	44	5	28	77	9	-2	176
Tattoo	84	1500	49	166	93	106	70	31	25	87	1	2	184
Bravo	94	1280	40	141	87	46	45	2	23	61	6	10	153
Dithane	75	1190	29	147	32	77	26	-23	27	78	13	10	140
Super Tin + Polyram	93	1250	36	117	22	90	49	14	22	65	-2	10	147
Kocide + Manex	71	1300	30	91	45	40	28	-9	32	43	10	5	140

[1] Locations were classified as having early, mid, or late season onset (degree days after planting) of disease in the nontreated control.
[2] Idaho data not included.

Table 4. Incidence of tuber blight at harvest and post-storage.

Fungicide Program	% infected tubers at harvest			% infected tubers post-storage[1]	
	NY	OR-I	PA	NY	OR-I
Acrobat	7 a	31 bc	7 bc	9 abc	78 bc
Curzate	16 b	37 c	5 ab	18 cd	92 bc
Tattoo	5 a	19 ab	4 ab	3 a	75 bc
Bravo	11 ab	43 c	8 bc	13 bc	84 bc
Dithane	18 b	43 c	12 c	15 c	94 c
SuperTin + Polyram	9 ab	42 c	6 ab	25 d	67 bc
Kocide + Manex	5 a	41 c	5 ab	4 ab	58 b
Control	5 a	10 a	0 a	2 a	21 a
LSD[2] ($P = 0.05$)	8.14	13.56	5.753	8.97	34.29

[1] 3 mo post-storage in NY; 1 mo post-storage in OR due to extremely wet conditions at harvest and bacterial soft rot breakdown in storage.

[2] Means followed by the same letter within a column are not significantly different according to least significant difference (LSD) means test.

Table 5. Rankings[1] of foliar fungicide programs within location for control of foliar symptoms of late blight.

Fungicide programs	Locations[2]												
	Mild			Moderate						Severe			
	MI	WA	WY	FL	MX	ND	NY	PA	PEI	ID	OR-I	OR-II	WI
Acrobat	9 ab	13 a	15	8 a	8 a	16 abc	10 b	10 a	7 a	9 ab	16 bc	19 d	14 ab
Curzate	19 c	11 a	10	8 a	10 ab	8 a	14 b	13 ab	10 a	13 abc	6 a	11 abc	20 bc
Tattoo	5 a	12 a	20	7 a	10 ab	9 ab	3 a	8 a	5 a	15 a-d	4 a	9 ab	16 ab
Bravo	14 abc	25 b	13	22 b	22 cd	23 cd	10 b	18 b	18 b	19 bcd	12 b	16 cd	16 ab
Dithane	15 bc	26 b	14	17 b	11 ab	15 abc	20 c	8 a	18 b	22 cd	21 cd	6 a	11 ab
Super Tin + Polyram	18 bc	17 ab	13	19 b	19 bc	18 bc	14 b	18 b	16 b	8 a	18 c	14 bcd	8 a
Kocide + Manex	21 cd	20 ab	17	21 b	22 cd	13 ab	24 cd	26 c	26 c	22 cd	26 de	26 e	17 ab
Control	30 d	38 c	30	30 c	30 d	30 d	28 d	30 c	30 c	24 d	30 d	30 e	30 c
LSD[3] (P=0.05)	9.8	9.6	NSD	7.2	9.5	9.4	6.0	7.9	5.9	10.6	5.2	6.2	11.3

[1] Rankings were based on RAUDPC; the lower the rank number, the more effective the fungicide program.

[2] Locations were classified as having mild, moderate, or severe disease pressure based on RAUDPC of the nontreated control.

[3] Means followed by the same letter within a column are not significantly different according to least significant difference (LSD) means test.

Table 6. Rankings[1] of foliar fungicide programs within location for tuber yield.

Fungicide programs	Disease onset at locations[2]												
	Early				Mid						Late[3]		
	WA	MX	PEI	FL	NY	MI	OR-I	OR-II	ND	PA	WY	WI	ID
Acrobat	24 a	24 ab	24 a	21 a	16 ab	22 ab	12 bc	24	13.0	16 ab	18	18	18
Curzate	29 a	23 abc	21 ab	26 a	17 ab	17 ab	20 ab	16	19	19 ab	19	10	20
Tattoo	21 a	25 a	22 ab	23 a	24 a	25 a	26 a	25	17	25 a	13	15	18
Bravo	26 a	15 d	19 ab	19 ab	20 ab	13 bc	19 ab	14	17	19 ab	19	21	19
Dithane	17 a	11 d	14 b	20 ab	11 bc	18 ab	13 bc	7	19	21 ab	23	20	14
Super Tin + Polyram	28 a	16 cd	15 ab	12 bc	14 b	21 ab	21 ab	19	15	17 ab	10	21	16
Kocide + Manex	17 a	16 bcd	14 b	8 cd	11 bc	12 bc	15 b	12	21	10 bc	19	16	10
Control	3 b	2 e	3 c	2 d	3 c	4 c	5 c	15	5	4 c	9	10	16
LSD[4] (P=0.05)	12.0	8.2	9.0	8.6	10.2	10.7	10.1	NSD	NSD	11.6	NSD	NSD	NSD

[1] Rankings were based on total tuber yield; the higher the rank number, the more effective the fungicide program.
[2] Locations were classified as having early, midseason, or late onset (degree days after planting) of disease in the nontreated control.
[3] Idaho data not included.
[4] Means followed by the same letter within a column are not significantly different according to least significant difference (LSD) means test.

Table 7. Overall rankings[1] of foliar fungicide programs across locations for percent reduction in relative area under the disease progress curve (RAUDPC) and percent increase in tuber yield.

Fungicide Program	% Reduction RAUDPC[2]	% Yield Increase[3]
Acrobat	188 b	171 ab
Curzate	190 b	173 ab
Tattoo	217 a	187 a
Bravo	149 c	167 b
Dithane	163 c	161 bc
Super Tin + Polyram	161 c	165 b
Kocide + Manex	110 d	145 c
Control	---	---
LSD[4] (P=0.05)	15	17

[1] Overall rankings assigned by PROC Rank in SAS; the higher the ranking, the better the program.
[2] Wyoming foliar disease data not included.
[3] Idaho yield data not included.
[4] Means followed by the same letter within a column are not significantly different ($P = 0.0001$) according to least significant difference (LSD) means test.