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Evaluation of potato late blight management utilizing host plant resistance and reduced rates and frequencies of fungicide applications

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Abstract

Field experiments were carried out (2001–2003) to evaluate the efficacy of combining host resistance with reduced rates and frequencies of the residual contact fungicide fluazinam to control foliar potato late blight (*Phytophthora infestans*). Potato cultivars (cvs.) and advanced breeding lines (ABL) developed in four states were used in combination with fluazinam applications at 0, 33%, 50%, 66% and 100% of the manufacturer recommended application rate (MRAR) applied at 5, 7, 10 or 14 day application intervals. Values of relative area under disease progress curve (RAUDPC) in the untreated plots demonstrated that cvs. and ABL were significantly different in susceptibility to late blight. The cv. Jacqueline Lee was used as a resistant reference and the cvs. Snowden and FL1879 as susceptible. Accordingly, the ABL MSJ317-1 and MSJ461-1 were classified as resistant and the ABL W1386, W1201, MN19515, MN15620, MN19157, MN98650-8, ND2470-27, ND5822C-7 as susceptible. The cvs./ABL Dakota Pearl, Dakota Rose, MN19350 and W1355-1 were classified as susceptible in 2001 and as moderately susceptible in 2002. Application of the full rate of fluazinam at 5 or 7 day intervals resulted in effective control in all cvs./ABL except the cv. Dakota Pearl at 7 day application interval in 2001; at 10 or 14 day intervals it provided effective control in some cv./ABL and either partial or ineffective control in others. The 50% or 66% MRAR of fluazinam applied at 5 or 7 days provided effective blight control in resistant and moderately susceptible cvs./ABL and partial control in susceptible cvs./ABL. Fluazinam applied at 33% MRAR (in 2001 trials), at any application interval, provided effective blight control in the resistant cvs. and was either partially effective or ineffective in the susceptible cvs.. The study demonstrates that potato cvs./ABL with reduced susceptibility to late blight can be managed with reduced fungicide rates and longer application intervals, thus offering a less expensive option for potato late blight control.

Keywords: Potato late blight; Disease control; Reduced fungicides application; Potato advanced breeding lines

1. Introduction

Potato late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important foliar and tuber disease of potato, both in the field and in storage (Fry and Goodwin, 1997). Late blight causes rapid defoliation of plants in the field and can infect potato tubers when spores are washed into the soil (Lacey, 1967; Lambert and Currier, 1997; Lapwood, 1977). Potato late blight management strategies have changed considerably following the migration of metalaxyl resistant isolates of *P. infestans* from Mexico to North America (Fry and Goodwin, 1997) and necessitate utilization of

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cultural control measures and modification of the previous chemical control practices. Cultural control measures can be used to reduce the pathogen populations by reducing its survival, dispersal and reproduction (Garrett and Dendy, 2001).

The cultural measures include: the use of clean seed, removal of volunteer potato plants, hilling with adequate amount of soil, management of plant nutrition and using intercropping and potato cultivar (cv.) mixtures (Garrett and Dendy, 2001). The new strategies of chemical control rely on reducing fungicide inputs, combined with using potato cvs. possessing acceptable levels of non-race specific resistance to late blight (Clayton and Shattock, 1995; Fry, 1975, 1977; Kirk et al., 2001; Lambert and Currier, 1997; Secor and Gudmestad, 1999).

Methods of reducing fungicide inputs for potato crop management include the use of protectant fungicides formulations with less active ingredient, reduced application rates, longer application intervals, and a combination of any of these strategies. Combination of cv. resistance and regular applications of protective fungicides were reported to reduce foliar late blight infection in potato (Clayton and Shattock, 1995; Kirk et al., 2001). Another approach for late blight management which is widely used in Europe is known as decision support systems (DSS) which integrate and organize all available information on the biology and life cycle of *P. infestans*, weather (historic and forecast), plant growth, cv. resistance, available fungicides, and disease pressure required for decision making to control late blight (Schepers, 2002).

There are currently no late blight resistant potato cvs. that meet commercial standards in the United States. However, controlled environment and field trials at Michigan State University have identified some potato cvs. and advanced breeding lines (ABL) that are less susceptible to late blight in the absence of fungicides than most commonly grown cvs. in the United States.

Typical fungicide application programs use a 5–7 days spray interval depending on environmental conditions and grower's preference. The frequent fungicide spray intervals and rates currently used by growers to control late blight are expensive; therefore, more economical and environmentally sound control measures are needed.

In April 2001, an alliance among potato research programs in Minnesota, North Dakota, Wisconsin and Michigan was established; this has been formally recognized as the Quad State Potato Research group (now NCR 205 [North Central Technical Group 205]). In 2001, a pilot study was carried out at MSU to determine the feasibility of this collaboration as related to late blight control. The four breeding programs submitted cvs. and ABL and late blight field trials were initiated at the Muck Soils Research Farm, Laingsburg, MI. The experiments were repeated in 2002 and 2003. The objective of this study was to determine if acceptable control of foliar late blight can be achieved by using increased fungicide spray intervals and reduced application rates of residual contact fungicides on potato germplasm with a range of susceptibility to late blight.

2. Materials and methods

2.1. Potato germplasm

Previous experiments from the collaborating breeding programs have identified potato cvs. and ABL with different responses to foliar late blight. Jacqueline Lee had consistently been one of the most late blight resistant cvs. in 5 years of testing at Michigan State University (Douches et al., 2001); whereas, the cvs. Snowden and FL1879 have consistently been the most susceptible cvs. (Douches et al., 1997). The susceptible cvs. Snowden or FL1879 and the resistant cv. Jacqueline Lee were used to assess the response of other cvs. and ABL to *P. infestans* as well as to evaluate the efficacy of increased fungicide application intervals in combination with reduced application rates of fluazinam 5SC against potato late blight. The cvs./ABL included in the 2001–2003 trials are listed in Table 1. Trials in 2002 included all cvs./ABL from 2001 trials except ABL MN19157, and, in 2002 trials two ABL (W1386 and MN19515) were added. In 2003 new cvs./ABL substituted the cvs./ABL used in 2001 or 2002. Only the cv. Jacqueline Lee and ABL W1355-1 were included in all trials from 2001 to 2003.

2.2. Residual contact fungicide rates and application intervals

Field experiments were conducted to evaluate the efficacy of various fungicide protection strategies against late blight using the protectant fungicide fluazinam 5SC (non-commercial formulation, ISK Biosciences Corporation). The manufacturer's recommended application rate (MRAR) was 0.15 kg active ingredient ai ha^{-1} and 1.5 kg ai ha^{-1} per season for fluazinam (Syngenta Corp.). Fluazinam was applied with an ATV rear-mounted spray boom (R&D Sprayers, Opelousas, LA, USA) that traveled at $1\,m\,s^{-1}$, delivering 230 l H_2O ha^{-1} (350 kPa pressure) with three XR11003VS nozzles per row, positioned 30 cm apart and 45 cm above the canopy. In 2001, the fungicide application interval and reduced dose rates trials, fluazinam 5SC was applied at 5, 7, 10 and 14-day intervals at 0, 33%, 66% and 100% MRAR. In 2002 trials, the application schedule included only 5, 10 and 14-day intervals at 0, 50% and 100% of MRAR. In 2003 trials, the application schedule was the

Table 1
Potato cultivars and advanced breeding lines (ABL) from the quad state group breeding programs included in the study

cv./ABL	State breeding program/source	Pedigree	Wild species(%)	Cross year
2001				
Jacqueline Lee	MSU-MI[a]	Tollocan × Chaleur	<5	1994
Torridon	SCRI, Scotland[b]	8372 a 17 × G58335	?	
Snowden	UW-WI[c]	Wischip × B5141-6		
Dakota Rose	NDSU-ND[d]	ND1196-2R × NorDonna	0	1987
Dakota Pearl	NDSU-ND	ND1118-1 × ND944-6	7.9	1984
MN19157	UM-MN[e]	MN169-86-2 (MN15620) × MN3002.92-3 (MN85673)	<5	1994
MN19350	UM-MN	MN623.87-1(MN16191) × MN3002.92-3 (MN85673)	<5	1995
W1355-1	UW-WI	Snowden × S440	28	1991
2002				
Jacqueline Lee	MSU-MI	Tollocan × Chaleur	<5	1994
Torridon	SCRI, Scotland	8372 a 17 × G58335		
Snowden	UW-WI	Wischip × B5141-6		
Dakota Rose	NDSU-ND	ND1196-2R × NorDonna	0	1987
Dakota Pearl	NDSU-ND	ND1118-1 × ND944-6	7.9	1984
MN19350	UM-MN	MN623.87-1(MN16191) × MN3002.92-3 (MN85673)	<5	1995
W1355-1	UW-WI	Snowden × S440	28	1991
W1386	UW-WI	W843 × S472	25	1989
MN19515	UM-MN	AC92187 (MN17876) × MN1012.85-16 (MN16506)	<5	1995
2003				
Jacqueline Lee	MSU-MI	Tollocan × Chaleur	<5	1994
FL1879	Frito-Lay, Inc.			
W1355-1	UW-WI	Snowden × S440	28	1991
W1201	WI	Wischip × FYF 85	?	1985
MSJ461-1	MSU-MI	Tollocam × Chaleur	<5	1997
MSJ317-1	MSU-MI	B0718-3 × Prestile	<5	1997
ND2470-27	NDSU-ND	Yankee Chipper × Norchip	1.6	1984
ND5822-7	NDSU-ND	ND4103-2 × Dakota Pearl	23.3	1994
MN15620	MSU-MI	MN1006.81-4 × MN8.80-12	<5	1991
COMN98650-8	CSU-CO[f]/UM-MN	MN16191 × MN85952	<5	1998

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same as in 2001 (5, 7, 10 and 14 days) at 0, 50% and 100% of the MRAR of fluazinam. The first fungicide application was at 27–30 days after planting (DAP) when potato plants were approximately 15 cm tall. Fluazinam was applied until the non-treated plots of the susceptible controls reached about 100% diseased foliar area. The 5, 7, 10 and 14 day interval treatments received 16, 12, 8 and 6 applications, respectively, in each season.

2.3. Experimental design and agronomic practices

All experiments were conducted at the Michigan State University Muck Soils Research Station, Laingsburg, MI (90% organic muck soil). Soils were prepared for planting with a mechanical cultivator in early May and fertilizers were applied during final bed preparation on the day of planting (May 15– 20). Cultivars and ABL were planted in two-row by 8 m plots (0.9 m row spacing) separated by a 1.2 m gap. Fertilizers were applied in accordance with results from soil testing carried out in the spring of each year; about 250 kg of N per hectare (total N) was applied in two equal doses at planting and hilling in each year. Additional micronutrients were applied according to petiole sampling recommendations in all years. Approximately 0.2, 0.3 and 0.2 $kg\,ha^{-1}$ boron, manganese and magnesium, respectively, were applied as chelated formulations. Seed pieces (75–150 g) of cvs. and ABL were cut 5 days prior to planting in all experiments. The experimental design for the fungicide application interval and reduced dose rate trials was a four replicate, randomized split-plot block design with cv. as the main effect.

When relative humidity (RH) was recorded below 80% (measured with relative humidity sensors mounted within the canopy, CR10X Measurement and Control

System, Campbell Scientific Inc.), a mist irrigation system (described below) was turned on to maintain RH at >80% within the plant canopy. Plots were irrigated as necessary to maintain canopy and soil moisture conditions conducive for development of foliar late blight (Madden and Hughes, 1995) with turbine rotary garden sprinklers (Gilmour Group, Somerset, PA, USA) at 1.05 l H_2O ha^{-1} h^{-1} and managed under standard potato agronomic practices. In each year, weeds were controlled by hilling and with metolachlor at 2.3 l ha^{-1} about 10 days after planting (DAP), bentazon salt at 2.3 l ha^{-1}, about 20 and 40 DAP and sethoxydim at 1.8 l ha^{-1}, about 60 DAP. Insects were controlled with imidacloprid at 1.4 kg ha^{-1} at planting; carbaryl at 1.4 kg ha^{-1}, about 30 and 55 DAP; endosulfan at 2.7 l ha^{-1}, about 65 and 85 DAP; and permethrin at 0.56 kg ha^{-1}, about 50 DAP.

2.4. Microclimate measurements

Climatic variables were measured with a CR10X Measurement and Control System (Campbell Scientific Instruments) equipped with air temperature and humidity sensors located within the potato canopy on site. Microclimate within the potato canopy was monitored beginning when 50% of the potato plants had emerged and ending when canopies of healthy plants reached 100% senescence. The Wallin Late Blight Prediction Model (Wallin, 1953) was developed in the Eastern United States under conditions similar to those in Michigan and was adapted to local conditions. Late blight disease severity values (DSV) were estimated from the Wallin Late Blight Prediction Model (Wallin, 1953) and accumulated from inoculation to final evaluation to estimate the conduciveness of the environment for late blight development.

2.5. Inoculum preparation and inoculation

Zoospore suspensions were made from *P. infestans* isolate MI 95-7 (US8 genotype, insensitive to mefenoxam/metalaxyl, A2 mating type; Goodwin et al., 1995), the predominant genotype present in the major potato growing regions of North America (Fry and Goodwin, 1997). Isolate MI 95-7 of *P. infestans* was grown on rye B agar plates for 10–12 days in the dark at 15 °C. Sporangia were harvested from the rye B agar plates by rinsing the plates with sterile, distilled water and scraping the mycelial and sporangial mat from the agar surface with a rubber policeman. The sporangia suspension was stirred with a magnetic stirrer for 1 h then strained through four layers of cheesecloth and the concentration of sporangia was adjusted to about 1×10^3 sporangia ml^{-1} with the aid of hemacytometer. Sporangial suspensions were incubated for 2 h at 4 °C to stimulate zoospore release. All plots were inoculated simultaneously using an overhead sprinkler irrigation system. The zoospore suspension of *P. infestans* was injected into the irrigation water feed pipeline under 50 kPa of CO_2 pressure and applied at a rate of about 150 ml of inoculum solution m^{-2} of trial area. The amount and rate of inoculum applied was estimated from prior calibration of the irrigation system (described above) and was intended to expose all potato foliage to inoculum of *P. infestans*.

2.6. Disease evaluation and data analysis

As soon as late blight symptoms were detected (about 7 days after inoculation [DAI]), each plant within each plot was visually rated at 3–5 day intervals for percent leaf and stem (foliar) area with late blight lesions using the assessment key of Cruickshank et al. (1982). The mean percent blighted foliar area per treatment was calculated. Evaluations continued until untreated plots of susceptible cvs. reached 100% foliar area diseased. DAI were used as key reference points for calculation of relative area under the disease progress curve (RAUDPC; Campbell, 1990; Kirk et al., 2001; Madden and Hughes, 1995).

In the present study, any cv. /ABL with a foliar late blight severity value, measured as RAUDPC, which was not significantly different from that of Jacqueline Lee was classified as late blight resistant (*R*). Any cv./ABL with a RAUDPC value that was not significantly different from that of Snowden (2001 and 2002 trials) or FL1879 (2003 trial) was classified as late blight susceptible (*S*). Cultivars/ABL were classified as moderately susceptible (MS) if the RAUDPC value was significantly higher than that of Jacqueline Lee, but significantly lower than that of Snowden or FL1879.

Similarly, if a fungicide treatment on a cv./ABL resulted in a RAUDPC that was not significantly different from the RAUDPC of the susceptible control (Snowden, 2001 and 2002; FL1879, 2003) protected with 5 or 7 day, 100% MRAR fluazinam 5SC program then it was classified as providing effective (*E*) late blight protection. Any fungicide treatment and cv. /ABL combination in which the RAUDPC was significantly higher than, or was not significantly different from that of non-treated Snowden (2001 and 2002) or FL1879 (2003), was classified as a non-effective (NE) treatment. Furthermore, if a fungicide treatment on a cv./ABL resulted in a RAUDPC significantly higher than that of the susceptible control (Snowden, 2001 and 2002; FL1879, 2003) protected with 5 or 7 day, 100% MRAR fluazinam 5SC program but significantly less than that of non-treated Snowden or FL1879, the treatment was classified as providing partial (PE) late blight protection.

3. Results

3.1. 2001 trial

Late blight developed rapidly during August 2001; the non-treated susceptible controls reached 100% diseased foliar area 39 DAI. The accumulated disease severity values (DSV) from inoculation to 100% senescence of healthy plants was 109 which indicated that environmental conditions were conducive to late blight development (DSV > 18) (Wallin, 1953). The RAUDPC values for the cvs. and ABL are shown in Fig. 1. Cultivars and ABL were significantly different in response to late blight and were classified based on RAUDPC comparisons (Fig. 1). The mean RAUDPC for non-treated Jacqueline Lee and Torridon was less than 0.3, which were classified as resistant (Fig. 1); whereas, the cvs. and ABL MN19350, Snowden, Dakota Rose, Dakota Pearl, MN19157 and W1355-1 have a mean RAUDPC of >33 (Fig. 1) and were classified as susceptible.

Application of fluazinam at full rate of application (100% of MRAR) at a 5 or 7 day interval resulted in effective blight control in all cvs. and ABL except for the cv. Dakota Pearl which was effectively protected at the 5 day interval but partially protected at the 7 day interval

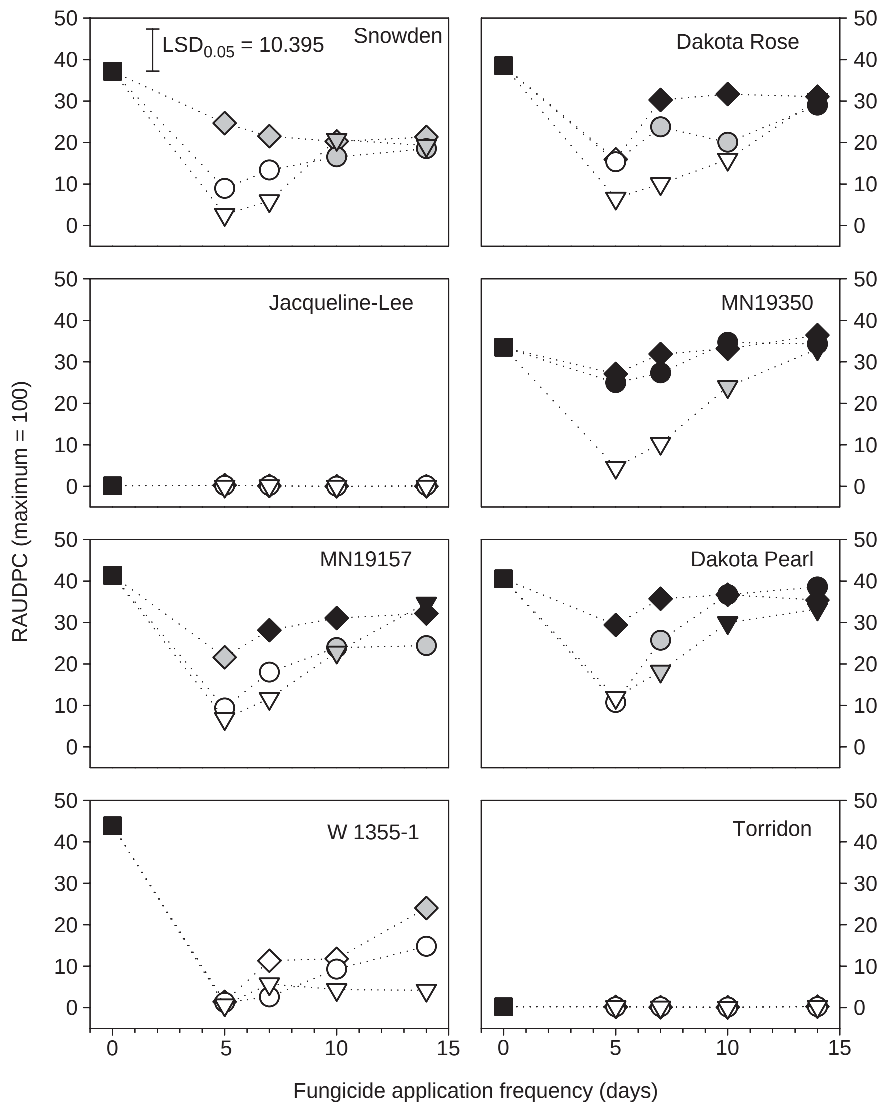

Fig. 1. Mean RAUDPC (max = 100) in potato cvs. and ABL inoculated with *Phytophthora infestans* (US8, A2) and protected with reduced rates of fluazinam applied at 0% [■ (black symbols)], 33% (♦), 66% (●) or 100% (▼) of manufacturers recommended application rate in the 2001 trial. The least significant difference was RAUDPC = 10.395, for comparisons among all cvs. at all fungicide application rates and frequencies. Effectiveness of fungicide treatments in comparison to Snowden treated with a full application rate of fluazinam at a 5 day interval or with non-treated Snowden control; white symbols = RAUDPC not significantly different from treated Snowden control (effective control); light gray symbol = significantly different from treated Snowden control and non-treated control (partially effective control); black symbols = not significantly different from Snowden non-treated control (not effective control). All comparisons were tested at $p < 0.05$.

(Fig. 1). The full rate of application at the 10 day interval resulted in effective control in the cvs. Jacqueline Lee, Torridon, Dakota Rose and ABL W1355-1; partial control in Snowden, MN19157 and MN 19350 and was not effective in the cv. Dakota Pearl. The 14 day application interval provided effective control in the cvs. Jacqueline Lee, Torridon and ABL W1355-1, partial blight control in Snowden, and was not effective in the cvs./ABL Dakota Rose, Dakota Pearl, MN19350 and MN19157.

Fluazinam applied at 66% of MRAR at a 5 day interval resulted in effective control in all cvs./ABL except for the ABL MN19350 which was not effectively protected. The ABL MN19157, W1355-1 and the cvs. Jacqueline Lee, Snowden and Torridon were effectively protected at the 7 day application interval; other cvs./ABL were either partially protected (Dakota Rose and Dakota Pearl) or were not protected effectively (MN19350; Fig. 1). At 10 day application intervals, fluazinam applied at 66% MRAR provided effective control for the cvs. Jacquline Lee and Torridon and the ABL W1355-1, partial protection for the cvs./ABL Snowden, Dakota Rose and MN19157, and was not effective for the cvs./ABL Dakota Pearl and MN19350 (Fig. 1). The 66% application rate applied at 14 day intervals provided effective control for cvs./ABL Torridon, Jacqueline Lee and W1355-1; partial protection for Snowden and MN19157 and was not effective for the cvs. Dakota Rose, Dakota Pearl and ABL MN19350.

Fluazinam applied at 33% MRAR provided effective blight control for the cvs. Jacqueline Lee and Torridon at all application intervals (5, 7, 10 and 14 days) and for the ABL W1355-1 at the 5, 7 and 10 day application intervals and partial control at the 14 day application interval (Fig. 1). This application rate provided partial blight control for the cv. Snowden at all application intervals. The cv. Dakota Rose was effectively protected at the 5 day interval only, whereas, the ABL MN19157 was partially protected at the 5 day application interval (Fig. 1). This application rate did not provide effective control for the cv. Dakota Pearl and ABL MN 19350 at any application interval (Fig. 1).

3.2. 2002 trial

In 2002 the non-treated susceptible controls reached 100% diseased foliar area 42 DAI. The accumulated DSV from inoculation to 100% senescence of healthy plants was 100, which indicated that environmental conditions were conducive to late blight. The RAUDPC values for the cvs. and ABL are shown in Fig. 2. Cultivars and ABL were significantly different in response to late blight and were classified based on RAUDPC of non-treated plots (Fig. 2). The mean RAUDPC values for non-treated Jacqueline Lee and Torridon were less than 0.30, and were classified as resistant (Fig. 2); whereas, the cvs. and ABL Dakota Pearl, W1355-1, MN19350 and Dakota Rose with RAUDPC values of 28.46, 28.49, 29.56 and 29.63 respectively were classified as moderately susceptible (Fig. 2). The susceptible cvs. and ABL included Snowden, MN19515 and W1386 with RAUDPC values of 33.19, 33.0 and 32.35, respectively.

Application of fluazinam at full rate of application to the cvs./ABL Jacqueline Lee, Torridon, W1386 and W1355-1 resulted in effective control of late blight at all application intervals (5, 10 and 15 days; Fig. 2). For all other cvs./ABL, the full rate of application of fluazinam provided effective control at 5 day intervals and only partial protection at the 10 and 15 day application schedules (Fig. 2).

Application of fluazinam at 50% of the MRAR effectively protected the cvs./ABL Jacqueline Lee, Torridon, W1386 and W1355-1 at all application intervals. All other cvs./ABL were controlled effectively at 5 day application intervals and were partially protected at 10 and 15 day application intervals; the only exception was the cv. Dakota Pearl which was partially protected at all application intervals (Fig. 2).

3.3. 2003 trial

In 2003 the non-treated susceptible controls reached 100% diseased foliar area 41DAI. The accumulated DSV from inoculation to 100% senescence of healthy plants was 126. The RAUDPC values for the cvs. and ABL are shown in Fig. 3. Cultivars and ABL were significantly different in response to late blight and were classified based on RAUDPC of non-treated plots (Fig. 3). The mean RAUDPC values for the non-treated Jacqueline Lee, MSJ461-1 and MSJ317-1 were 0.27, 0 and 0.12, respectively, which were classified as resistant (Fig. 3); whereas, the cvs. and ABL W1355-1, FL1879, ND2470-27, MN 98650-8, W1201, ND5822-7 and MN15620 were classified as susceptible with RAUDPC values of 28.35, 29.82, 32.06, 32.33, 33.79, 35.32 and 44.27, respectively.

At the full application rate of fluazinam, all cvs. and ABL were protected effectively at all application intervals except the ABL MN 15620 which was effectively protected at 5, 7 and 10 day application intervals and partially protected at the 14 day application interval. At 50% MRAR the cvs. and ABL MSJ461-1, Jacqueline Lee and MSJ317-1were protected effectively at all application intervals (5, 7, 10 and 14 days). The cvs./ABL FL1879, MN 98650-8, ND2470-27, ND5822C-7 and W1355-1 were effectively protected at 5, 7 and 10 days application intervals and were either protected partially or non-effectively at 14 day application intervals (Fig. 3). The ABL W1201 and MN15620 were protected effectively at 5 and 7 day application intervals, and were either partially protected at 10 day

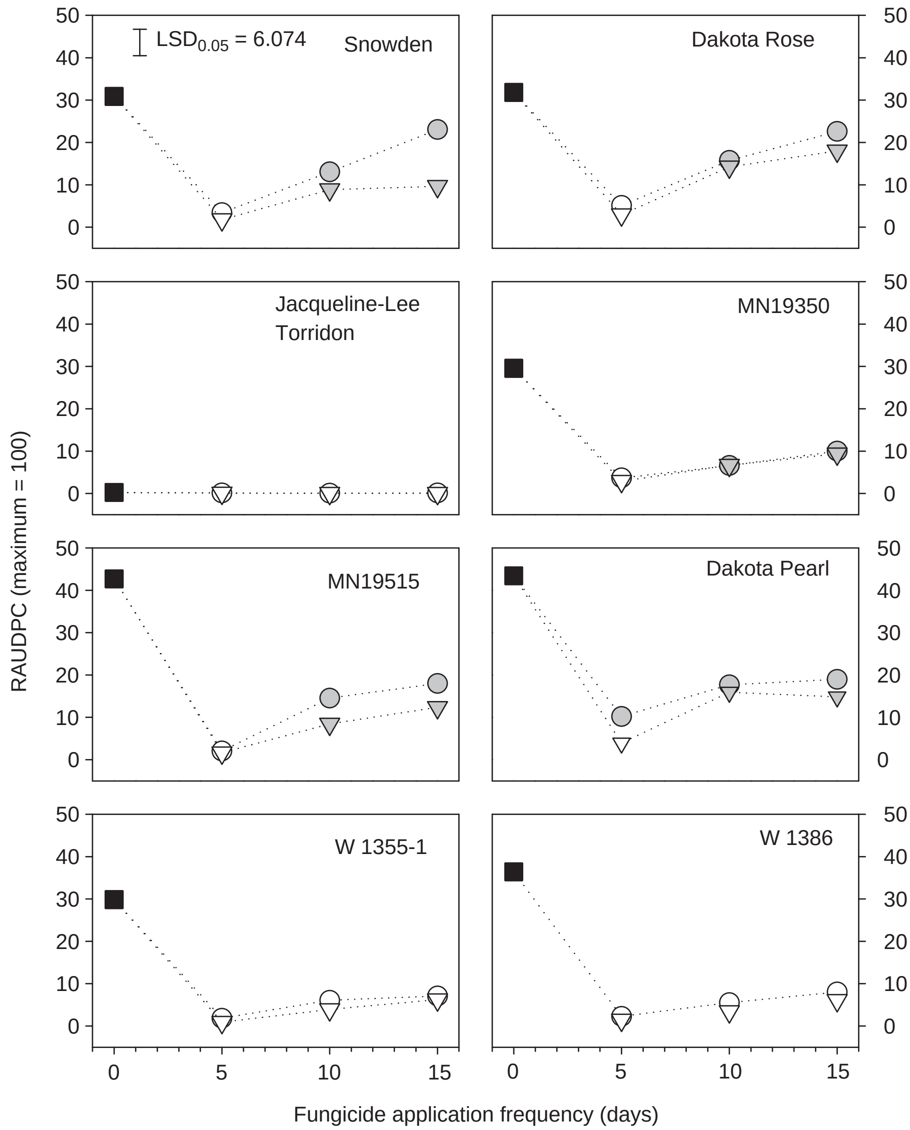

Fig. 2. Mean RAUDPC (max = 100) in potato cvs. and ABL inoculated with *Phytophthora infestans* (US8, A2) and protected with reduced rates of fluazinam applied at 0% [■ (black symbols)], 50% (●) or 100% (▼) of manufacturers recommended application rate in the 2002 trial. The least significant difference was RAUDPC = 6.074, for comparisons among all cvs. at all fungicide application rates and frequencies. Effectiveness of fungicide treatments in comparison to Snowden treated with a full application rate of fluazinam at a 5 day interval or with non-treated Snowden control; white symbols = RAUDPC not significantly different from treated Snowden control (effective control); light gray symbol = significantly different from treated Snowden control and non-treated control (partially effective control); black symbols = not significantly different from Snowden non-treated control (not effective control). All comparisons were tested at $p < 0.05$.

intervals (W1201) or were not effectively protected (MN 15620), both lines were not effectively protected at 14 day application intervals (Fig. 3).

4. Discussion

Results of this study were consistent with previous studies and indicate that a combination of cv. resistance and managed application of protective fungicides can reduce foliar late blight to acceptable levels in most situations (Clayton and Shattock, 1995; Fry, 1975, 1977; Kirk et al., 2001; Van der Plank, 1968). When conditions were moderately conducive to late blight development (as in 2001), reduced amounts of fluazinam provided effective control of late blight on most cvs. and ABL compared to the non-treated controls. However, exceptions occurred, where the 33% MRAR of fluazinam treatments provided either partial control or were not sufficient to control late blight. In some cvs./ABL, 33% of the MRAR was sufficient to achieve acceptable control, whereas other cvs./ABL required 66% MRAR

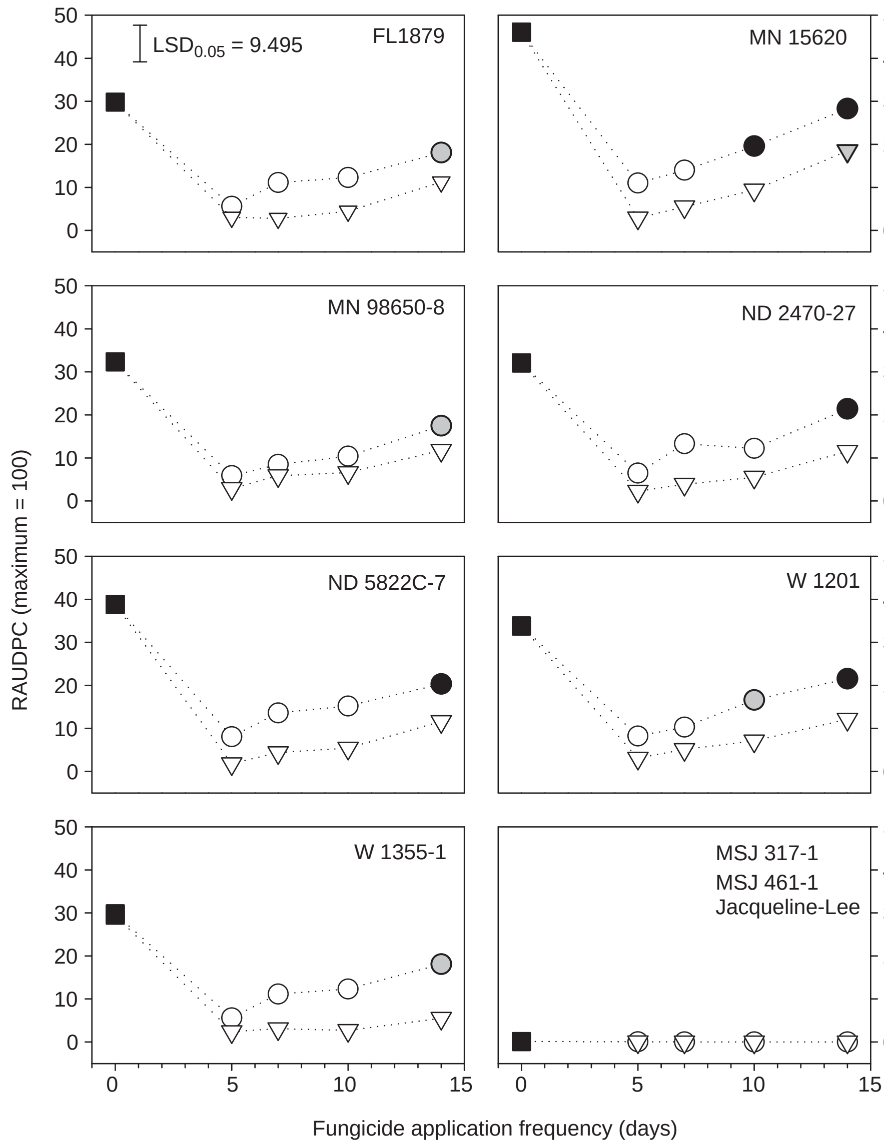

Fig. 3. Mean RAUDPC (max = 100) in potato cvs. and ABL inoculated with *Phytophthora infestans* (US8, A2) and protected with reduced rates of fluazinam applied at 0% [■ (black symbols)], 50% (●) or 100% (▼) of manufacturers recommended application rate in the 2003 trial. The least significant different was RAUDPC = 9.495, for comparisons among all cvs. at all fungicide application rates and frequencies. Effectiveness of fungicide treatments in comparison to FL1879 treated with a full application rate of fluazinam at a 5 day interval or with non-treated FL1879 control; white symbols = RAUDPC not significantly different from treated FL1879 control (effective control); light gray symbol = significantly different from treated FL1879 control and non-treated control (partially effective control); black symbols = not significantly different from FL1879 non-treated control (not effective control). All comparisons were tested at $p<0.05$.

to control late blight. On late blight susceptible cvs. and ABL, applications of fluazinam at either 10 or 14 day intervals were either partially effective or NE for controlling late blight at any application rate tested, except for the ABL W1355-1 which was effectively protected at 10 day intervals at all application rates and partially protected at the 14 day interval. However, in the resistant cvs. Torridon and Jacqueline Lee the fungicides did not reduce the RAUDPC in comparison with untreated plots of these cvs. (the mean RAUDPC at all application rates and intervals were not significantly different from the untreated plots; data not shown). Among the eight cvs. and ABL tested in this study in 2001, only the cv. Torridon demonstrated resistance that was comparable to the resistance in the standard Jacqueline Lee. All other cvs. and ABL were susceptible to late blight.

In 2002 the environmental conditions were also moderately conducive to late blight development. Reduced amounts of fluazinam were either fully or partially effective at all application rates tested on all cvs./ABL compared to the non-treated controls. In some cvs./ABL, applications of 50% of the MRAR of the fungicide fluazinam were sufficient to achieve acceptable control, whereas other cvs. /ABL required 100% of MRAR to control late blight. On late blight susceptible cvs, applications of fluazinam at either 10 or 15 day intervals were partially effective for controlling late blight at the doses tested. However, in the resistant cvs. Torridon and Jacqueline Lee the fungicides did not reduce the RAUDPC in comparison with untreated plots of these cvs. Cultivars/ABL evaluation in 2002 for potato late blight resistance demonstrated that the cv. Torridon was the only resistant cv. in addition to the standard Jacqueline Lee.

In 2003 trials, applications of fluazinam at 50% of MRAR provided effective control of late blight at the 5 and 7 day application interval in all cvs. and ABL tested. In the resistant cvs. /ABL Jacqueline Lee, MSJ317-1 and MSJ461-1 the RAUDPC values of fluazinam treatments were not significantly different from the untreated plots at any application rate or application interval (data not shown).

Over this 3-year evaluation of cvs. and ABL, some cvs. were classified as moderately susceptible in 1 year and as susceptible in another, examples include the cvs./ ABL MN 19350, Dakota Rose, Dakota Pearl and W1355-1 which were classified as susceptible in 2001 and moderately susceptible in 2002. This discrepancy is most likely due to more conducive conditions for late blight development in 2001 compared to 2002. This is obvious when comparing the RAUDPC for the cv. Snowden, the susceptible standard, in 2001 and 2002, the mean RAUDPC was lower in 2002 compared to 2001 (37.2 in 2001 and 33.19 in 2002).

The main goal of this research is to reduce fungicide input while maintaining commercially acceptable levels of late blight control. Results of this study demonstrated that reduced doses of the protective fungicide fluazinam, applied at 7–10 day intervals combined with the use of less susceptible potato cvs./ABL was in most cases sufficient in providing acceptable levels of late blight control.

As new cvs. with enhanced late blight resistance are developed and released it will be important to provide growers with recommendations for the most effective and economical chemical control of late blight in these new cvs. In the future, the type of information gathered from this study will be used to develop models, based on cv. resistance and response to fungicide application, to advise and guide growers as to which fungicide, rate and frequency of application is required to provide protection against late blight. Climatic conditions within the canopy will also impact choice of fungicide and rate and frequency of application. Therefore, new cvs. need to be carefully screened in the manner described in this study, over several seasons in order to develop accurate models for fungicide application.

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