

Host Plant Resistance and Reduced Rates and Frequencies of Fungicide Application to Control Potato Late Blight (Co-operative trial Quad State Group 2002).

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INTRODUCTION

Late blight of potato caused by *Phytophthora infestans* (Mont de Bary), is a major threat to the production of high quality potatoes (12). Unchecked, *P. infestans* can rapidly defoliate plants in the field and can infect potato tubers when spores are washed into the soil (15). Potato late blight control strategies changed following the migration of mefenoxam/metalaxyl-resistant populations of *P. infestans* from Mexico to North America (12) and necessitate cultural control methods and crop protection strategies that rely primarily on protectant foliar fungicide applications (12, 18). There are several potential methods for reducing fungicide inputs in potato crop management. These include the use of fungicides with less active ingredient, reduced application rates, longer application intervals and a combination of any of these strategies. In addition, Fry (10, 11) observed that a combination of cultivar resistance and regular applications of protective fungicides reduced foliar late blight infection in potato. There are currently no late blight resistant potato cultivars that meet commercial standards in the United States. However, controlled environment and field trials at Michigan State University have identified certain foreign cultivars and advanced breeding lines (ABL) that are less susceptible to foliar late blight in the absence of fungicides than important cultivars grown and developed in the United States (e.g. Snowden, Atlantic, Russet Burbank) (4, 5, 6, 7). Typical fungicide application programs use a 5-7 day spray interval depending on environmental conditions and grower preference. The frequent fungicide spray intervals and rates currently used by growers to control late blight are expensive and more economical control measures are needed.

In April 2001, it was agreed to form an alliance in potato research areas between North Dakota, Minnesota, Wisconsin and Michigan, this has been formally recognized as the Quad State group (now an NCT 190). In 2001, a pilot study was carried out at MSU by Kirk to determine the feasibility of the co-operation. The four breeding programs submitted varieties and a late blight field trial was implemented at the Muck Soils Research Farm, Laingsburg, MI. The results of this co-operation were very positive and have highlighted some of the constraints that growers have on accepting new varieties into their programs. It was agreed to repeat the experiment in 2002.

Therefore, the objective of this research 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 developed at each of the four potato breeding programs in Michigan, Minnesota, North Dakota and Wisconsin.

MATERIALS AND METHODS

Potato Germplasm

Previous experiments from the co-operating breeding programs have identified potato cultivars and advanced breeding lines (ABL) with different responses to foliar late blight. Jacqueline Lee has consistently been one of the most late blight resistant ABL in five years of testing at Michigan State University and was released in 2001 whereas; Snowden has consistently been one of the most susceptible (5,6,7,8). In the present study, any cultivar/ABL with foliar late blight severity measured as the Relative Area Under the Disease Progress Curve [RAUDPC (1)] value that was not significantly higher than that of Jacqueline Lee was classified as late blight resistant (R). Any cultivar/ABL with a RAUDPC value significantly higher than that of Snowden or with

a RAUDPC value that was not statistically different from that of Snowden was classified as late blight susceptible (S). Cultivars/ABL were classified as moderately resistant (M) if the RAUDPC value was significantly higher than that of Jacqueline Lee but significantly lower than that of Snowden. The potato cultivars/ABL used to assess the efficacy of reduced fungicide application rate varied among years but always included late blight susceptible controls (e.g. Snowden and Atlantic) and cultivars/ABL classified as moderately resistant or resistant to late blight (5,6,7,8). The susceptible cultivar Snowden and the resistant cultivar Jacqueline Lee was used to assess the efficacy of increased fungicide application intervals in combination with reduced application rates of chlorothalonil against potato late blight. The cultivars/ABL included in the trials from 2002 are listed in Table 1.

Residual Contact Fungicides

Field experiments to evaluate the efficacy of various fungicide protection strategies against late blight were conducted during 2001. Fluazinam 5SC (non-commercial formulation, ISK Biosciences Corporation, 5966 Heisley Road, PO Box 8000, Mentor, OH 44061-8000) was used. The manufacturer's recommended application rate (MRAR) was 0.15 ai/ha/application and 1.5 kg ai/ha/season for fluazinam (23). Fungicides were applied with an ATV rear-mounted spray boom (R&D Sprayers, Opelousas, LA, U.S.A.) that traveled at 1 m/s, delivered 230 l H₂O/ha (3.5 kg/cm² pressure) with three XR11003VS nozzles per row positioned 30 cm apart and 45 cm above the canopy. In the fungicide application interval and reduced dose rates trial, fluazinam 5SC was applied at 5, 10 and 15 day intervals at 0, 50 and 100% MRAR (16) to the ABL and cultivars described in Table 1. The first fungicide application occurred at 27 days after planting (DAP) (June 27 2002) when potato plants were approximately 15 cm tall. Fungicides were applied until non-treated plots of susceptible controls reached about 100% diseased foliar area. The 5, 10 and 15-day interval treatments received twelve, eight and six applications in 2002, respectively.

Experimental Design and Agronomic Practices

All experiments were conducted at the Michigan State University Muck Soils Research Station, Bath, MI (90% organic muck soil). Soils were plowed to 20 cm depth during October following harvest of preceding crops. Soils were prepared for planting with a mechanical cultivator in early May and fertilizer applied during final bed preparation on the day of planting. Cultivars/ABL were planted on June 9, 2002 in two-row by 8 m plots (0.9 m row spacing). Fertilizers were applied in accordance with results from soil testing carried out in the spring of each year and about 250 kg N/ha (total N) was applied in two equal doses at planting and hilling. Additional micronutrients were applied according to petiole sampling recommendations and in all years. Approximately 0.2, 0.3 and 0.2 kg/ha boron, manganese and magnesium, respectively were applied as chelated formulations. Cut and whole seed pieces (75-150g) of selected cultivars and ABL were used in all experiments.

The experimental design for the fungicide application interval and reduced dose rate trials was a randomized complete block design with four replications. If a fungicide treatment on a cultivar/ABL resulted in an RAUDPC that was not significantly higher than non-treated Jacqueline Lee, then it was classified as effective late blight control (E). Any fungicide treatment and cultivar/ABL combination in which the RAUDPC was significantly higher than, or was not significantly different from that of non-treated Snowden was classified as a non-effective (NE) treatment. Furthermore, if a fungicide treatment on a cultivar/ABL resulted in an RAUDPC significantly higher than that of non-treated Jacqueline Lee but significantly less than that of non-treated Snowden, the treatment was classified as providing intermediate late blight control (I).

When relative humidity (RH) dipped below 80% (measured with RH sensors mounted within the canopy, described below), a mist irrigation system (described below) was turned on to maintain RH at >95% within the plant canopy. Plots were irrigated as necessary to maintain

canopy and soil moisture conditions conducive for development of foliar late blight (16) with turbine rotary garden sprinklers (Gilmour Group, Somerset, PA, U.S.A.) at 1055 l H₂O ha/hr and managed under standard potato agronomic practices. Weeds were controlled by hilling and with metolachlor at 2.3 l/ha 10 days after planting (DAP), bentazon salt at 2.3 l/ha, 20 and 40 DAP and sethoxydim at 1.8 l/ha, 60 DAP. Insects were controlled with imidacloprid at 1.4 kg/ha at planting, carbaryl at 1.4 kg/ha, 31 and 55 DAP, endosulfan at 2.7 l/ha, 65 and 87 DAP and permethrin at 0.56 kg/ha, 48 DAP.

Pathogen Preparation and Inoculation.

Zoospore suspensions were made from *P. infestans* cultures of a single isolate, [MI 95-7, US8 genotype, insensitive to mefenoxam/metalaxyl, A2 mating type (13)], the predominant biotype present in the major potato growing regions of North America (12), grown on rye agar plates (3) for 14 days in the dark at 15°C. Sporangia were harvested from the rye agar plates by rinsing the mycelial/sporangial mat in cold (4°C) sterile, distilled water and scraping the mycelial/sporangial mat from the agar surface with a rubber policeman. The mycelial/sporangial suspension was stirred with a magnetic stirrer for 1 hour. The suspension was strained through four layers of cheesecloth and the concentration of sporangia was adjusted to about 1×10^3 sporangia/ml using a hemacytometer. Sporangial cultures were incubated for 2-3 hours at 4 C to stimulate zoospore release. All plots were inoculated simultaneously through an overhead sprinkler irrigation system, on July 27, 2002; by injecting the zoospore suspension of *P. infestans* into the irrigation water feed pipeline under 0.5 kg/cm² CO₂ pressure and applied at a rate of about 150 ml of inoculum solution/m² 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*.

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 to 5 day intervals for percent leaf and stem (foliar) area with late blight lesions. The mean percent blighted foliar area per treatment was calculated. Evaluations continued until untreated plots of susceptible cultivars reached 100% foliar area diseased (39 DAI in 2001). Days after inoculation were used as a key reference point for calculation of Relative Area Under the Disease Progress Curve [RAUDPC (1)].

Microclimate Measurement

Climatic variables were measured with a Davis Weather Station equipped with air temperature and humidity sensors located within the potato canopy on site (Spectrum Groweather ET Station, Spectrum Technologies, Inc., 23839 W. Andrew Road, Plainfield, IL 60544). 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 (22) was developed in the Eastern United States under conditions similar to those in Michigan and was adapted to local conditions (1). Late blight disease severity values (DSV) were estimated from the Wallin Late Blight Prediction Model and accumulated from inoculation to final evaluation to estimate the conduciveness of the environment for late blight development.

RESULTS

Microclimate conditions

Late blight developed rapidly during August; non-treated susceptible controls reached about 100% diseased foliar area 39 DAI. Accumulated DSV from inoculation to 100% senescence of healthy plants was 121. This indicated that environmental conditions were conducive to late blight development (DSV > 18) (22).

2002

Varieties were included from the Quad State potato breeding programs. The RAUDPC values are shown in Table 1. The cultivars and ABL are ranked in order of increasing RAUDPC in untreated plots. Application of fluazinam at full rate of application at a 5-day interval resulted in effective control in all varieties. The mean RAUDPC for non-treated Jacqueline Lee and Torridon was about 0.03, which were classified as resistant. Fungicide treatments did not significantly effect late blight development in either Jacqueline Lee or Torridon

The thresholds used to determine the efficacy of the fungicide and variety combination programs were RAUDPC = 1.79 and 33.1. Therefore, fungicide treatment and variety combinations with an RAUDPC ≤ 5.52 (NSD from Snowden, 100% MRAR, 5-day application interval, RAUDPC_{SF5}) were defined as effective (E); combinations NSD from the non-treated Snowden control (RAUDPC ≥ 29.6) were defined as non-effective (NE); and combinations with RAUDPC values significantly different from both standards were defined as partially effective (PE); (Table 1).

ABL W1355-1 and WI 1386 were effectively protected by application of the fungicide at 100% MRAR on 5 and 10-day intervals and control was PE on a 15-day interval. At the 50% MRAR, treatments were effective on a 5-day interval and PE at a 10 and 15-day intervals. These ABL was the most responsive of the susceptible cultivars/ABL to fungicide applications.

Snowden, MN19515 and MN19350 were effectively protected by the fungicide at 50 and 100% of the fungicide applied at 5-day intervals and PE at 50 and 100% MRAR at 10 and 15-day intervals.

Dakota Pearl and Dakota Rose were effectively protected by the fungicide at 100% MRAR at a 5-day interval. At all other rates and application intervals the fungicide was partially effective (PE).

DISCUSSION

The results of this study were consistent with previous studies and indicate that a combination of cultivar/ABL resistance and managed application of protective fungicides will reduce foliar late blight to acceptable levels in most situations (10,11,21). When conditions were moderately conducive to late blight development (as in 2002), reduced amounts of fluazinam were either fully or partially effective at all application rates tested on all cultivars/ABL compared to the non-treated controls. In some cultivars/ABL, 50% of the MRAR of either fungicide was sufficient to achieve acceptable control, whereas other cultivars/ABL required 100% MRAR to control late blight. On late blight susceptible cultivars, applications of fluazinam at either 10 or 15-day intervals were usually partially effective for controlling late blight at the doses tested. However, in the resistant cultivars Torridon and Jacqueline Lee the fungicides did not reduce the RAUDPC in comparison with untreated plots of these cultivars.

The opportunity to manage late blight by applying reduced rates of fungicides at increased spray intervals to cultivars less susceptible to late blight was demonstrated in this study. In addition, the efficacy of reduced rates and increased application intervals of fungicides against other potato pathogens such as early blight has not been established and may prove to be a major constraint in the adoption of managed fungicide applications. As new cultivars 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 cultivars. In the future, the type of information gathered in this study will be used to develop models, based on cultivar 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 (1). Therefore, new cultivars will need to be carefully screened in the manner described in this study, over several seasons in order to develop accurate models for fungicide application.

ACKNOWLEDGMENTS

This research was funded in part by the Michigan Agricultural Experiment Station GREEN (Generating Research and Extension to meet Economic and Environmental Needs) Project GR 99/111, Michigan Potato Industry Commission and supported in principal by the Quad State group. Special thanks to Rob Schafer for technical expertise. Mention of a brand or trade name does not constitute an endorsement.

Table 1. Efficacy of fluazinam applied at reduced rates and frequencies on potato cultivars and Advanced breeding lines from North Central US potato breeding programs, MSU 2002.

Cultivar/ABL	Rate of fluazinam ¹	Application frequency (days)				RAUDPC ²							
		0	5	10	15	0		5		10		15	
Torridon	0	0.0	w ³	R ⁴									
	50				0.0	E ⁵	w	0.0	E	w	0.0	E	w
	100				0.0	E	w	0.0	E	w	0.0	E	w
Jacqueline Lee	0	0.27	vw	R									
	50				0.06	E	vw	0.13	E	vw	0.13	E	vw
	100				0.13	E	vw	0.06	E	w	0.06	E	
Dakota Pearl	0	28.46	b	I									
	50				10.18	PE	ij	17.68	PE	d	18.97	PE	d
	100				3.94	E	pqrst	15.92	PE	f	14.81	PE	g
W1355-1	0	28.49	b	I									
	50				1.83	E	tuvw	6.08	PE	nopq	7.08	PE	klmno
	100			I	0.94	E	vw	3.92	E	qrst	6.25	PE	mnop
MN19350	0	29.56	b										
	50				3.69	E	rstu	6.60	PE	lmno	10.00	PE	j
	100				2.92	E	stuv	6.71	PE	lmno	9.38	PE	jk
Dakota Rose	0	29.63	b	I									
	50				5.15	PE	opqrs	15.77	PE	e	22.63	PE	c
	100				2.98	E	stuv	14.25	PE	f	18.02	PE	de
WI 1386	0	32.35	a	S									
	50				2.27	E	tuvw	5.52	PE	opqr	8.02	PE	jklmn
	100				1.44	E	uvw	3.44	E	rstu	6.08	PE	nopq
MN19515	0	33.00	a	S									
	50				2.04	E	tuvw	14.54	PE	h	17.98	PE	d
	100				1.65	E	tuvw	8.42	PE	jklm	12.38	PE	hi
Snowden	0	33.19	a	S									
	50				3.44	E	rstu	13.04	PE	g	23.04	PE	j
	100				1.79	E	tuvw	8.88	PE	jkl	9.67	PE	c

¹ Application rate of fluazinam as percent of manufacturer's recommended rate (full rate = 0.6 pt/A)

² Relative area under the disease progress curve from inoculation to 100% late blight in susceptible control (Snowden); max = 100.

³ Means followed by the same letter were not significantly different at p = 0.05; comparison between all combinations of fungicide application rate and frequency of application in all cultivars/ABL.

⁴ Susceptibility of nontreated control to late blight; R = Resistant, not significantly different from Jacqueline Lee (nontreated); S = Susceptible, not significantly different from Snowden (nontreated); I = Intermediate, significantly different from both Jacqueline Lee and Snowden (nontreated).

⁵ Effectiveness of fungicide treatment in comparison to Snowden treated with a full application rate of fluazinam at a 5-day interval or with nontreated Snowden control; E = RAUDPC NSD from treated Snowden control; PE significantly different from treated Snowden control and nontreated control; NE = NSD from Snowden nontreated control at p = 0.05.

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