Evaluation of Early Blight (*Alternaria solani)* Prediction Techniques for Southern Alberta

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EXECUTIVE SUMMARY

The infection risk from early blight (*Alternaria solani*) in potato fields is widespread throughout Alberta during the growing season. Control with an appropriate fungicide is necessary and research has indicated that applications prior to the appearance of airborne spores do not contribute to disease suppression. Protectant fungicides applied after the appearance of the disease also result in diminished disease control. Therefore, timing of fungicide applications is crucial. Various predictive models are available to assist with the timing of fungicide applications for early blight. Many predictive models are based on an initial application of fungicide after an accumulated 300 P-Days (physiological days) (e.g. WISDOM, TOMCAST, SureHarvest for Potatoes). Subsequent applications are based on factors such as hours of leaf wetness, temperature, and continuous relative humidity above a certain threshold. Other models are referred to as biological models (PLANT-Plus) and include plant factors (new growth, wear-off of chemical), factors about the nature of the disease (infection of unprotected leaves, spore formation and dispersal), as well as meteorological factors.

This research project was conducted initially to evaluate the performance of three models in prediction of early blight in potato fields. Two models used the 300 P-Day factor (WISDOM and TOMCAST) and one biological model considered plant, disease, and meteorological factors (PLANT-Plus) to initiate fungicide applications. The study was conducted in the Grassy Lake/Fincastle/Bow Island area of southern Alberta. In 2005, a field was divided into thirds and a different model was used to time fungicide applications on each third of the field. In 2006 and 2007, two cooperator's fields were divided in half and the WISDOM and PLANT-Plus models were used for early blight prediction. Two additional fields in the area in each year were monitored and evaluated for early blight infection, but the timing of fungicide and the product used was left to the discretion of the producer. The research team evaluated all fields for the presence of early blight and degree of infection on four occasions throughout the growing season in 2005 and 2006 and twice in 2007.

The source for meteorological data was also assessed and six meteorological stations were included in the evaluation for timing of fungicide application. The six meteorological stations included: Bow Island SubStation, Bow Island Provincial Building, Barnwell, Fincastle, a stand-alone meteorological station adjacent to the monitored field, and a stand-alone meteorological station within the field.

The cost of control for early blight varied with the product used, rate applied, and the frequency of application. In 2005, the highest cost (\$263.37 ha^{-1}) for early blight control was on Field 3, which had six fungicide applications. The lowest cost (\$72.12 ha^{-1}) for control was the PLANT-Plus system, which recommended two sprays. In 2006 and 2007, again the highest cost of early blight fungicide control was on fields where no prediction model was used (\$221.40 ha^{-1} and \$313.93 ha^{-1}, respectively). The fewest sprays and the lowest cost for early blight control occurred using the PLANT-Plus system.

A general trend was that disease development was lower on fields with the highest frequency of fungicide application; however, the highest number of fungicide applications for early blight control did not necessarily translate into statistically significant reduction in incidence and severity of early blight infection.

The TOMCAST model is not suitable for early blight prediction in southern Alberta without more rigorous calibration and validation to identify the temperature intervals most appropriate for semi-arid and irrigated conditions.

The WISDOM model is insensitive to seasonal weather patterns. Recommendations for spray intervals and fungicide rates (low, medium, high) were similar regardless of the source of the meteorological data. Recommendations appeared to be biased towards the accumulated P-Day calculation, even in the absence of threshold late blight disease severity values (DSV's) being attained. Using the WISDOM model for timing of fungicide applications would follow a program of prevention, independent of disease risk, and there would be no opportunity to reduce fungicide applications.

PLANT-Plus is the one prediction technique evaluated that scheduled fungicide applications based on disease risk. Thus, the opportunity for lowering the frequency and cost of sprays for early blight in years when the weather is not conducive for early blight development, may be realized.

There were no significant differences in the yield and quality of tubers in any year on the fields that used the predictive models.

The TOMCAST model requires within-field meteorological data, whereas the WISDOM and PLANT-Plus system require accurate and timely data obtained from the nearest meteorological station.

INTRODUCTION

Rising international standards for food safety and a growing demand among consumers and corporate clients to reduce the use of pesticides in food production necessitates investigation of pesticide use protocols in various food production systems.

Potato (*Solanum tuberosum* L.) is currently one of the more economically important crops grown in the irrigated areas of southern Alberta contributing more than $150 million to farm cash receipts in 2006 and approximately $300 million to the provincial economy due to value added processing. Production costs are high for potatoes (averaging $6200 ha^{-1} in 2006). The cost of pesticides to control the various insect, fungal and bacteria diseases that are common in potato production contribute to these high costs of production. Reduction in any one of the pesticide inputs to potato production would lead to both a savings for the producer and an improvement in food safety for the consumer.

The appearance of early blight (*Alternaria solani*) in potato fields in southern Alberta is a yearly occurrence. The severity of infection in any one year is variable depending on, among other things, weather conditions throughout the growing season.

Several fungicides are available to effectively control early blight, but the timing of application is crucial. Fungicide applications, prior to flowering, or before the appearance of airborne spores, are ineffective in controlling early blight (Franc et al., 1988; Gent and Schwartz, 2003). Protectant fungicides applied after appearance of early blight lesions results in diminished disease suppression and may result in yield loss (Gent and Schwartz, 2003). Thus, the timing of fungicide applications is crucial for the effective control and reduction of early blight infections.

Numerous methods have been developed to assist producers in timing fungicide applications. Methods available to predict the initiation of early blight include some measure of either Physiological Day (P-Day) (Pscheidt and Stevenson, 1988) and/or Growing-Degree Days (GDD) (Franc et al., 1988). Most predictive models (e.g. WISDOM, TOMCAST) use 300 P-Days as the threshold to start fungicide applications. Timing of subsequent applications is based either on a fixed spray schedule or on a combination of certain meteorological parameters. The PLANT-Plus technique provided by Dacom Plant Service, Emmen, the Netherlands, uses a combination of potato plant growth stages, local weather conditions, and weather forecasts to predict susceptibility of potato plants to early blight infection (Raatjes et al., 2003).

Stevenson and James (2004) compared the predictions from the WISDOM model to those of PLANT-Plus in a replicated potato trial at Hancock, WI. They concluded that the use of a disease prediction technique or decision support system (DSS) resulted in a reduction in the number of fungicide applications while attaining similar disease control compared to a regular weekly fungicide application schedule. Similar results were reported by Dowley and Burke (2005) comparing disease prediction models to a regular weekly fungicide application schedule to control late blight in potatoes in Ireland. They concluded that all DSS resulted in a decrease in fungicide use and no loss of blight control. Use of a DSS resulted in fungicide application reductions by as much as 58% compared to the weekly application schedule.

One of the impediments of widespread adoption of disease prediction techniques was identified by Gent and Schwartz (2003) as the requirement for an in-field meteorological station to provide the necessary temperature, relative humidity and/or leaf wetness parameters as input to the various models. Disease predictions obtained from regional meteorological stations would be more convenient, cover a wider geographic area and be included with general crop information via the web or some other communication medium. They concluded that early blight forecasts were just as accurate when the source of the meteorological data for the P-Day or GDD calculation was a nearby meteorological station than if the data were obtained from an in-field meteorological station.

The objectives of this research project were:

1) To evaluate three methods for prediction of the presence and prevalence of early blight in potatoes, including:

  a) PLANT-Plus
  b) WISDOM
  b) TOMCAST

2) To assess the effect of the source of the meteorological data (either in-field or off-field) on model predictions.

METHODS

Background

In 2005, three early blight prediction techniques (WISDOM, TOMCAST and PLANT-Plus) were chosen for evaluation on one potato field in southern Alberta.

The field was divided into thirds and each third of the field used one of the prediction models to predict timing of fungicide application (Fig. 1).

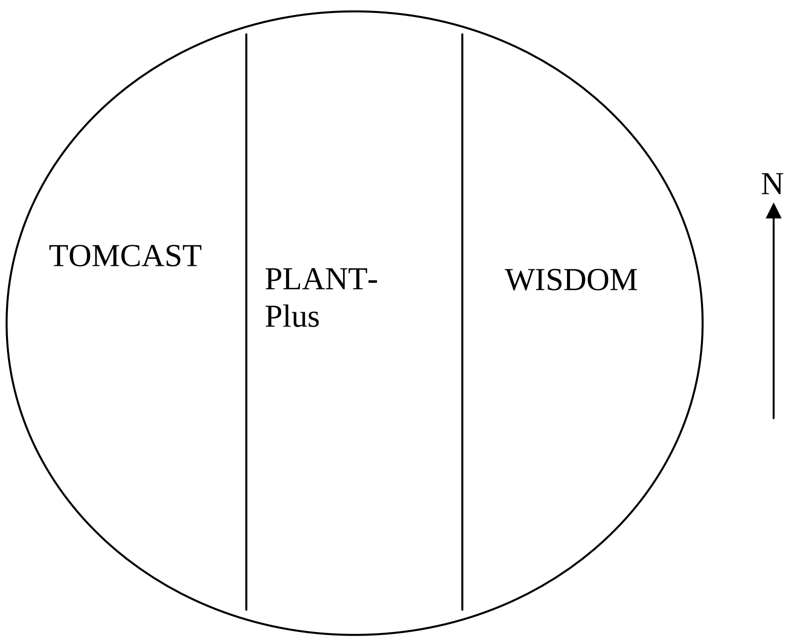

Fig. 1. Location of early blight prediction models in field.

Two additional potato fields were chosen in southern Alberta whereby the grower applied fungicide control on their own schedule without influence from any prediction technique.

Two fields were selected in 2006 and 2007 to test the early blight prediction models, WISDOM and PLANT-Plus. Based on the results of 2005, the TOMCAST model was dropped from the evaluation in 2006 and 2007. In 2006 and 2007, the fields were divided in half and spraying for early blight was based on the individual model predictions (WISDOM and PLANT-Plus).

Similar to 2005, two additional potato fields were chosen in each year whereby the grower applied fungicide control on their own schedule without influence from any prediction technique.

All fields included in the evaluation grew the Russet Burbank variety of potato. Field operations, other than timing of fungicide, were left to the discretion or "normal practice" of the cooperators. That included the type of fungicide to use for early blight control.

Crop observations and pictures for all fields were taken weekly by the technologist from Bow Island and the information was entered into the PLANT-Plus system.

Meteorological data from six different stations were used and compared. Meteorological stations used included: stations owned, maintained and operated by the Alberta Agriculture and Food (Fincastle, Barnwell and Bow Island North), a station owned and maintained by Atmospheric Environment Service (Bow Island South), and two stations owned and maintained by TruElements (in-field and off-field).

Field scouting for infection was done four times during the growing season in 2005 and 2006 and twice in 2007, with leaf samples taken to evaluate disease frequency and severity.

Tuber samples were harvested from four random locations within each treatment. At each location, a 7 m section was delineated and the tubers were collected with a two-row mechanical potato digger. Quantity and quality determinations were done for each sample.

Mean comparisons ($p < 0.05$) for yield, quality and disease were done using Tukeys means test provided the data passed the normality and equal variance test. Mean comparisons for disease were done using Kruskal-Wallis rank test when equal variance test failed (SPSS Inc, 1997).

Background on Models

Physiological Day (P-Day). The P-Day procedure was proposed by Sands et al. (1979) to predict potato yield and modified by Pscheidt and Stevenson (1986) for application to potato development and early blight appearance. The P-Day calculation requires only daily maximum and minimum temperatures as input. The algorithm is:

P-Days ={1/24[5P(Tmin) + 8P(2Tmin/3 + Tmax/3) + 8P(2Tmax/3 + Tmin/3) + 3P(Tmax)]}

Where:
$P(T) = 0$ if $T < 7°C$
$P(T) = 10[1 – (T – 21)^2/(21 – 7)^2]$ if $7°C < T < 21°C$
$P(T) = 10[1 – (T – 21)^2/(30 – 21)^2]$ if $21°C < T < 30°C$ starting at emergence.
$P(T) = 0$ if $T > 30^oC$

Tmin – minimum daily temperature (^oC)
Tmax – maximum daily temperature (^oC)

The model assumes 7°C minimum, 21°C optimum and 30°C maximum growth temperatures for potato plant development, as well as diurnal fluctuations.

Growing Degree Day. The Growing Degree Day (GDD) method was modified by Franc et al. (1988) for initiation of fungicide applications to control early blight in Colorado. The proposed base temperature of 7.2^{o}C resulted in the subsequent equation:

$$GDD = \left[\frac{(T\max + T\min)}{2}\right] + 7.2$$

They reported that primary lesions could be expected to appear at cumulative 361 GDD in the San Luis Valley area of Colorado, whereas primary lesions would only be expected to appear after 625 GDD in northeastern Colorado.

TOMCAST. The TOMCAST model was derived from the FAST model (Madden et al.,1978) developed at the University of Pennsylvania. Although it was developed to predict early blight, septoria leaf spot, and anthracnose development on tomatoes, the model has been used successfully to predict early blight development on potatoes (Pscheidt and Stevenson, 1988; Christ and Maczuga, 1989).

The first fungicide application for early blight occurs once cumulative P-Days after emergence reach 300. For subsequent sprays, the model generates disease severity values (DSVs) as units of disease development for pathogens. The DSVs are a numerical representation of the rate at which disease pressure is accumulating on the potato plant leaf tissue. The DSV is determined by two factors: leaf wetness and temperature during the leaf-wet hours. As the number of leaf wet hours and temperature increases, DSVs accumulate at a faster rate, i.e., increased disease pressure. Conversely, when there are fewer leaf-wet hours and the temperature is lower, DSV accumulate slowly if at all, i.e., decreased disease pressure (Table 1).

Table 1. Disease severity value chart.

Average Temperature (°C) During Leaf Wet Hours	Leaf Wetness per Day (h)				
13-17	0-6	7-15	16-20	21 +	
18-20	0-3	4-8	9-15	16-22	23+
21-25	0-2	3-5	6-12	13-20	21+
26-29	0-3	4-8	9-15	16-22	23+
Daily DSV =	**0**	**1**	**2**	**3**	**4**

When the total number of accumulated DSV exceeds a pre-determined limit, the spray threshold, a fungicide spray is recommended to protect the foliage from disease development. The spray threshold can range between 15-20 DSV and for this study we used 17.

WISDOM. The WISDOM model was developed by the University of Wisconsin Extension in Madison, Wisconsin, as a four module Integrated Pest Management and Irrigation Scheduling decision support tool (Stevenson, 1993). Advice on timing and application rate (low, medium, and high) of fungicides for both early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) disease development on potatoes is contained in the disease management module. Insect management, weed management, and irrigation scheduling are the other modules contained within the WISDOM model (Fig. 2).

Fig. 2. User interface for the WISDOM model.

Like TOMCAST, the first fungicide application for early blight, within the WISDOM model, occurs once cumulative P-Days after emergence reach 300. Subsequent sprays for early blight are on a fixed-spray schedule (depending on time of season and how fast P-Days are accumulating). The spray schedule varies from 14 days immediately after the first fungicide application to 7 days later in the season.

PLANT-Plus. Plant-Plus is a decision support system (DSS) provided by Dacom Plant Service, Emmen, the Netherlands. The system aids in the timing of fungicide applications by predicting infection events using fungal life-cycle models and weather prediction models. PLANT-Plus integrates the rate of crop development with infection pressure, local weather data, and weather forecasts to provide fungicide application advice (Raatjes et al., 2003).

The model can be divided into three submodels:

1) Unprotected part of the crop
   a. Growth of new leaves
   b. Degradation and wear off of chemicals

2) Infection events of the disease
   a. Formation of spores on each infected leaf
   b. Ejection and dispersal of spores into the air
   c. Germination of spores and penetration into unprotected leaves

3) A combination of unprotected leaf area and infection events into treatment recommendations.

Integrating local meteorological data of temperature, wind speed, rainfall, and humidity; five-day meteorological forecasts and input from the grower on crop conditions, PLANT-Plus calculates when an infection event is likely to occur and advises on when to apply a spray and what type of chemical to use. The PLANT-Plus system depends on ratings to assess how much of the crop is unprotected from previous fungicide applications. The spray thresholds are portrayed as a graph that indicates the disease pressure (Fig. 3).

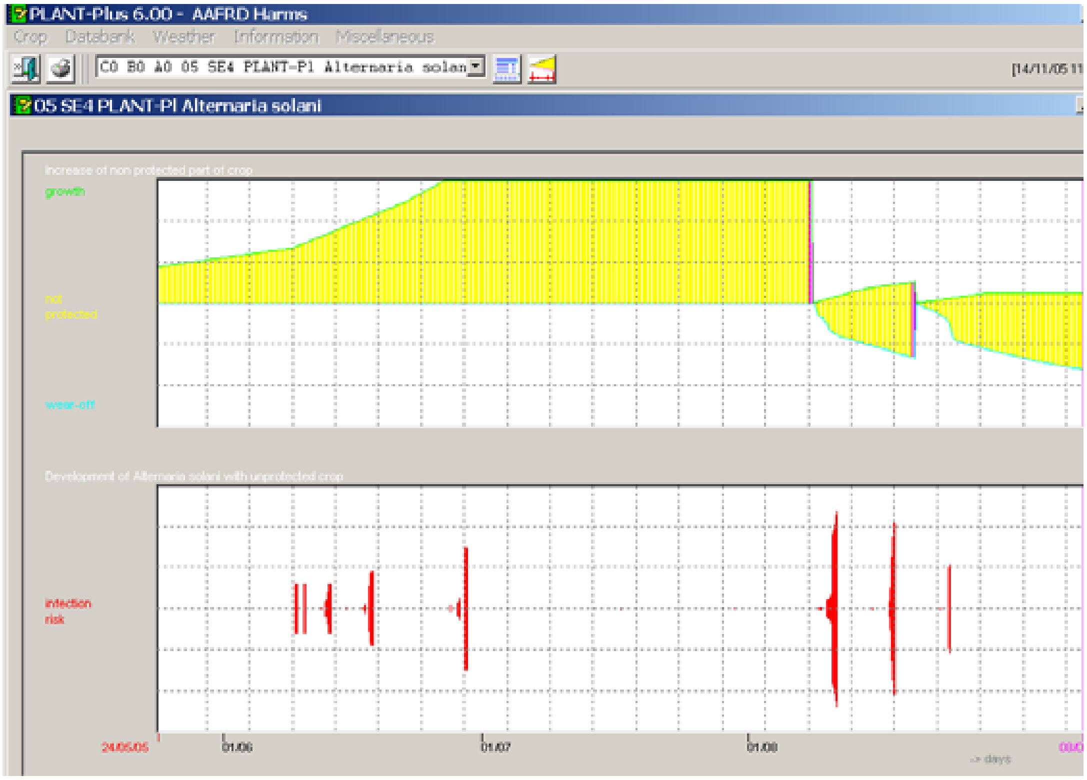

Fig. 3. Display from PLANT-Plus system indicating disease infection risk.

RESULTS

Meteorology

Growing season weather conditions for 2005 to 2007 were quite variable, but the critical months for early blight development, typically July and August in southern Alberta, had well below the long normal precipitation (LTN) in July in all years, and in August in 2006 and 2007 (Table 2).

Table 2. Monthly precipitation amounts for Fincastle and Bow Island for 2005-2007.

	May 31	June 30	July 31	August 31
Bow Island				
2005	3.0	149.8	1.6	49.2
2006	39.6	156.1	13.7	16.1
2007	74.1	53.3	3.6	24.8
LTN	26.8	61.4	55.3	46.9
Fincastle				
2005	11.6	173.0	2.0	53.0
2006	27.8	151.1	9.5	26.7
2007	73.5	23.5	0.8	33.9
LTN	47	62.7	34.1	42.8

Cumulative P-Days were more consistent at month-ending in all years (Table 3) compared to cumulative growing degree days (Table 4). The lowest cumulative P-Days and growing-degree days were calculated in 2005, a reflection of lower average seasonal temperatures.

Table 3. Cumulative P-Days from May 20 emergence to month ending.

	May 31	June 30	July 31	August 31
Bow Island				
2005	61	263	504	707
2006	72	310	569	799
2007	47	270	513	744
LTN	87	331	592	829
Fincastle				
2005	66	280	512	723
2006	72	310	569	799
2007	47	270	513	744
LTN	71	293	554	799

Table 4. Cumulative growing degree days from May 1 to month ending.

	May 31	June 30	July 31	August 31
Bow Island				
2005	199	490	922	1260
2006	259	623	1114	1527
2007	215	559	1094	1499
LTN	330	707	1159	1552
Fincastle				
2005	214	533	942	1285
2006	255	610	1094	1500
2007	227	565	1098	1491
LTN	212	541	957	1342

Fungicide Applications

In 2005, the 300 P-Day threshold from all meteorological stations was reached between July 5 and July 9. The first sprays for the east and west third of the field using schedules predicted with the WISDOM and TOMCAST techniques occurred on July 5. Subsequent sprays occurred on July 25, August 8, and August 20. The first spray for the center third using the PLANT-Plus system for prediction occurred on August 8 (535 cumulative P-Days, 796 cumulative GDD), with a subsequent spray on August 20 (Table 5).

In 2006, the 300 P-Day threshold from all meteorological stations was reached between June 29 and July 4. The first sprays for early blight, as predicted by the WISDOM model, occurred on June 29. In 2007, similar to the previous years, 300 cumulative P-Days occurred the first week of July for all meteorological stations. The subsequent sprays and chemicals used by the individual cooperators are detailed in Table 5.

Table 5. Timing of fungicide application, chemical used, and rate.

Field No.	Model Used	Spray Date and Product Used					
				2005			
One	WISDOM	July 5 Quadris 0.49L/ha	July 25 Bravo 1.6 L/ha	August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
One	TOMCAST	July 5 Quadris 0.49 L/ha	July 25 Bravo 1.6 L/ha	August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
One	PLANT-Plus			August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
Two	None	July 14 Bravo 1.6 L/ha *Ridomil 2.47* *kg/ha*	Aug 3 Quadris 0.98 L/ha				
Three	None	June 20 Bravo 2.47 L/ha	June 29 Quadris 0.98 L/ha *Ridomil 2.2* *L/ha*	July 13 Manzate 2.22 Kg/ha	July 20 Bravo 2.47 L/ha *Curzate 0.22* *kg/ha*	Aug 6 Bravo 2.47 L/ha	Aug 20 Manzate 2.22 kg/ha
				2006			
One	WISDOM	June 29 Bravo 2.2 L/ha	July 13 Penncozeb 1.5 kg/ha	July 30 Bravo 1.7 L/ha	August 14[b]	August 28[b]	
One	PLANT-Plus		July 13[a] Penncozeb 1.5 kg/ha	July 30[a] Bravo 1.7 L/ha	August 8[b]	August 23[b]	
Two	WISDOM	July 1 Quadris 0.74 L/ha	July 15[b]	July 31 Bravo 2.2L/ha	August 10[b]	Aug 27 Bravo 2.2 L/ha	
Two	PLANT-Plus		July 31[a] Bravo 2.2L/ha		August 8[b]	Aug 27 Bravo 2.2 L/ha	
Three	None	June 21 Quadris 0.98 L/ha	July 10 Bravo 2.47 L/ha	July 25 Bravo 2.47 L/ha	Aug 8 Bravo 2.47 L/ha		
Four	None	June 12 Bravo 2.2L/ha	July 8 Bravo 2.2L/ha				
				2007			
One	WISDOM	June 29 Ridomil Gold 2.2 L/ha	July 19 Ridomil Gold 2.2 L/ha	Aug 8 Hail damage ended trial			
One	PLANT-Plus	June 29[a] Ridomil Gold 2.2 L/ha		Hail damage ended trial			
Two	WISDOM	July 4 Ridomil Gold 2.2 L/ha	July 20 Ridomil Gold 2.2 L/ha	Aug 9 Quadris 0.98 L/ha	Aug 18[b]	Aug 29[b]	
Two	PLANT-Plus	July 4[a] Ridomil Gold 2.2 L/ha	July 20[a] Ridomil Gold 2.2 L/ha	Aug 9[a] Quadris 0.98 L/ha	Aug 18[b]		
Three	None	June 22 Quadris 0.98 L/ha	July 6 Bravo 2.47 L/ha	July 20 Manzate 2.2 kg/ha	Aug 4 Quadris 0.98 L/ha	Aug 24 Manzate 2.2 kg/ha	
Four	None	June 25 Ridomil Gold 2.2 L/ha	July 3 Quadris 0.98 L/ha	July 30 Bravo 2.47 L/ha	Aug 16 Bravo 2.47 L/ha	Aug 25 Bravo 2.47 L/ha	

Note: Chemical in italics not for early blight control. Not included in calculations for spray costs.
[a] – spray applied but not dictated by prediction program. [b] – spray dictated but not applied by cooperator.

Growing-Degree Days

Cumulative GDD from planting for all stations, up until the first spray (July 5, 2005; June 29, 2006; July 4, 2007) are listed in Table 6. Cumulative GDD were less variable among stations in a given year but more variable for a given station in comparitive years.

Table 6. Cumulative growing-degree days from May 15 to 300 cumulative P-Days for individual stations.

Station	Bow Island Substation	Bow Island Provincial Bldg	Fincastle	Adcon On-Field	Adcon Off-field	Barnwell
2005	468	456	466	No data	434	Missing data
2006	Missing data	542	529	557	557	508
2007	508	528	506	No data	No data	493

TOMCAST (2005)

The within-field leaf wetness sensor failed in mid-July of 2005, and it was felt that the off-field leaf wetness sensor underestimated the parameters to initiate a spray. Therefore, the TOMCAST field received its second fungicide application on July 25 based on the timing of the WISDOM field. The off-field leaf wetness sensor failed in mid-August and recorded continuous wet conditions.

The PLANT-Plus prediction model identified two fungicide applications in both 2005 and 2006 and one application in 2007. In all three years, the PLANT-Plus system did not identify a fungicide application until early August.

Dacom personnel made the fungicide application timing decisions for PLANT-Plus based on model results and the crop observations of the field technologist. In 2005, the Bow Island North meteorological station was used as the primary, near-field meteorological station; however, access to any other station was available. There were problems expressed in obtaining timely meteorological data. Personnel both from Alberta Agriculture and Dacom worked to resolve many of the initial data acquisition problems.

Economics

The cost of control for early blight varied with the product used, rate applied, and the frequency of application. In 2005, the highest cost per acre for early blight control was on Field 3, which had six fungicide applications. The lowest cost per acre for control was the PLANT-Plus system, which recommended two sprays (Table 7). In 2006 and 2007, again the highest cost of early blight fungicide control was on fields where no prediction model was used. The fewest sprays and the lowest cost for early blight control occurred using the PLANT-Plus system.

Table 7. Cost of fungicide to control early blight.

2005	
Field One	
WISDOM	$144.86/ha
TOMCAST	$144.86/ha
PLANT-Plus	$72.12/ha
Field Two	
No prediction model used	$122.03/ha
Field Three	
No prediction model used	$263.37/ha
2006	
Field One	
WISDOM	$184.50/ha**
PLANT-Plus	$81.76/ha**
Field Two	
WISDOM	$238.10/ha**
PLANT-Plus	$81.76/ha**
Field Three	
No prediction model used	$221.40/ha
Field Four	
No prediction model used	$81.76/acre
2007	
Field One	
WISDOM	$145.38/ha*
PLANT-Plus	No application initiated*
Field Two	
WISDOM	$244.15/ha
PLANT-Plus	$40.88/ha**
Field Three	
No prediction model used	$280.38/ha
Field Four	
No prediction model used	$313.93/ha

* hail damage ended trial
** based on recommended application schedule of contact fungicide.
Note: Pricing of chemical based on suggested retail price.

Disease Incidence and Severity

In 2005, there were no significant differences among the treatments on the first and second sampling dates. By the August 16 sampling dates, significant differences (P<0.05) were seen among the PLANT-Plus, TOMCAST, and Field 2 compared to the WISDOM and Field 3 ratings. For the Sept 1 sampling date, ratings for WISDOM and

Field 3 were still significantly different from PLANT-Plus and TOMCAST, but not from Field 2 (Table 8).

It was unexpected the disease ratings for the TOMCAST and WISDOM treatments would be significantly different for the last two sampling dates since both treatments were sprayed at the same time with the same chemical throughout the season. A prevailing wind phenomenon may have exposed the west part of the field to airborne spores from adjacent fields first, thereby increasing the disease incidence on that part of the field.

In 2006, right from the first sampling date on June 29, Field 3 consistently had the highest incidence and severity of disease. There were some anomalies in the evaluations but by the end of the season, Field 3 and both prediction methods in Field 2 had higher disease severity. All samples collected at the last sampling date (August 30) showed evidence of early blight.

Table 8. Disease incidence and severity.

2005									
Sample Dates		4-Jul		26-Jul		16-Aug		1-Sep	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]	DS[2]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	100	0	0.0%	0	4.0%	0.2a	24.0%	1.3a	84.8%
Field 1 TOMCAST	100	0	0.8%	0.1	6.0%	0.8b	71.0%	1.6b	96.0%
Field 1 PLANT-Plus	100	0	0.0%	0.1	8.0%	0.5b	41.0%	2.3b	99.2%
Field 2	200	0	4.4%	0.2	14.5%	0.5b	49.5%	1.5b	93.6%
Field 3	200	0	0.0%	0.2	17.5%	0.2a	23.5%	0.9a	70.0%

2006									
Sample Dates		June 29		July 19		August 10		August 30	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]	DS[2]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	125	0.5a	49%	0.2a	15%	0.5a	43%	2.0a	99%
Field 1 PLANT-Plus	125	0.2b	23%	0.1a	6%	0.4a	34%	1.9a	99%
Field 2 WISDOM	125	0.1b	9%	0.2a	18%	0.6a	46%	2.2b	100%
Field 2 PLANT-Plus	125	0.1b	14%	0.5a	65%	0.4a	43%	2.3b	98%
Field 3	250	0.6a	49%	0.8b	70%	1.9b	98%	3.4b	99%
Field 4	250	0.2b	19%	0.3a	32%	0.6a	50%	2.2ab	100%

2007					
Sample Dates		July 11		Aug 8	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	120	0.08	8%	0.9ab	80%
Field 1 PLANT-Plus	125	0.10	10%	0.8ab	70%
Field 2 WISDOM	125	0.02	4%	1.1a	89%
Field 2 PLANT-Plus	125	0.02	5%	1.0ab	86%
Field 3	250	0.06	6%	0.8ab	70%
Field 4	250	0.02	2%	0.7b	59%

[1]Disease severity (DS) ratings scale of 0-5 based on the percent area of the compound leaf showing blight.
[2]Disease incidence (DI) is calculated by dividing the number of infected compound leaves by the total number of compound leaves collected and expressed as a percent.
Column means followed by the same letter are not significantly different at the $P< 0.05$ probability level.

Potato Yield and Quality

There were no significant differences (*P*<0.05) in yield or quality among any of the treatments in any year.

Table 6. Yield and quality assessment.

Treatment	Total yield (tons/acre)	Marketable yield (tons/acre)	Specific gravity
2005			
Field 1 WISDOM	19.8	14.3	1.099
Field 1 TOMCAST	21.3	15.6	1.101
Field 1 PLANT-Plus	22.7	17.2	1.096
2006			
Field 1 WISDOM	32.9	22.4	1.083
Field 1 PLANT-Plus	29.3	19.8	1.085
Field 2 WISDOM	30.1	21.3	1.088
Field 2 PLANT-Plus	31.7	22.9	1.084
2007			
Field 1		No yield taken due to hail	
Field 2 WISDOM	28.5	20.4	1.103
Field 2 PLANT-Plus	32.9	21.1	1.104

DISCUSSION

It was difficult in all years ensuring the cooperators followed the fungicide application regime based on the advice of the prediction models. A general comment from all cooperators was they were uncomfortable waiting for a fungicide application based on PLANT-Plus. PLANT-Plus did not call for a fungicide to be applied until sometime in August in all years. Cooperators used to putting on a first fungicide application in late June or early July did not want to risk disease development waiting for the conditions necessary to recommend a fungicide application according to the PLANT-Plus system.

The first fungicide application in late June or early July, as called for by WISDOM after 300 P-Days had accumulated, corresponded with a typical first fungicide application for early blight, cooperators were accustomed to apply. However, cooperators felt the timing of subsequent fungicide applications, as predicted by the WISDOM model, were excessive and often did not apply the fungicide according to model output.

An additional complication was with the use of Ridomil Gold. Ridomil was typically used for controlling pink rot and is applied late June or early July as the tubers start to develop. With the introduction of Ridomil Gold, an application timed to control pink rot also includes metalaxyl, the active ingredient in Bravo, which controls early blight.

TOMCAST (2005)

The TOMCAST procedure was developed in Ohio and modified for potatoes in Ontario. The minimum temperature required, with conditions of sustained leaf wetness, was 13°C in the TOMCAST model. In the semi-arid region of southern Alberta, even under irrigated conditions, the 13°C threshold with sustained leaf wetness occurred on one day in 2005 thus, it was felt the model would not identify blight risk. The four temperature thresholds were arbitrarily lowered by 3°C (e.g. 13°C minimum temperature was lowered to 10°C) to more closely coincide with output from other prediction techniques. A reduction of 3°C to the temperature ranges helped to reach 17 DSVs on a couple of occasions through the growing season in 2005, but the reduction was somewhat arbitrary by evaluating the hours of leaf wetness and temperatures observed during the growing season. A more thorough calibration and verification of the model, in an environment where temperature and leaf wetness hours could be varied, would have to be done before the model could be considered for early blight prediction for the semi-arid and irrigated conditions of southern Alberta. It was felt the calibration and validation work required for the model were outside the scope of this study.

WISDOM

The WISDOM model is somewhat insensitive to hourly temperature and relative humidity conditions for early blight prediction. Recommendations are based on cumulative P-Days and how fast they are accumulating or on the time of year. Following the initial spray after 300 cumulative P-Days, the recommendation was to spray on a 14-day schedule (regardless of the meteorological station used or weather conditions). Later in July, after the second spray, the WISDOM model reduced the spray schedule to 10 days and finally to 7 days near the middle of August. The WISDOM model also predicts late blight based on hourly temperature and hours with RH above 90%. The threshold for spraying for late blight is 15 and although the 15 DSV threshold was only reached for the in-field meteorological station in 2005, the WISDOM model would still recommend to shorten the spray schedule, and increase application rates, independent of the source of meteorological data (whether in-field, off-field or regional).

The WISDOM model recommendations of fixed spray schedules of 14 days, reduced to 7 days during the season, is a fairly easy program for producers to adopt. However, being insensitive to meteorological conditions translates into a spray program of prevention, rather than a program whereby the fungicide is applied as the risk of disease increases. The advantage of the WISDOM model is that the calculation of cumulative P-Days does not require an in-field weather station. The nearest meteorological station would provide adequate and similar data to an in-field meteorological station.

PLANT-Plus

The PLANT-Plus system seems to be the only one evaluated that bases the spray timing and rate on current meteorological conditions, future meteorological conditions and plant growth factors. Unlike the WISDOM or TOMCAST models, where no plant specific information is required, the PLANT-Plus system requires weekly input from the producer on growth and canopy density ratings. The advantage of the PLANT-Plus system is that fungicide applications are based on disease risk. Therefore, the potential to reduce fungicide applications and reduce costs is real. In-field meteorological stations are not necessary since a nearby, representative meteorological station will provide adequate data.

Early Blight Infection and Control

A general trend was that disease development was lower on fields with the highest frequency of fungicide application; however, the highest number of fungicide applications for early blight control did not necessarily translate into a statistically significant reduction in incidence and severity of early blight infection.

Early blight was detected in nearly all leaf samples at the end of season sampling in 2005 and 2006 and on the August 8 sampling date in 2007. Six fungicide applications resulted in similar early blight control as four applications in 2005, and disease development was similar in a field with three fungicide applications by August 8, 2007 compared to a field that had one application. In 2006, Field 3 had the highest disease development for all sampling dates, yet the highest number of fungicide applications at the greatest cost was for this field.

Factors such as fertility, rotations, proximity to other potato fields and reduced soil moisture can result in a potato plant being more susceptible to early blight infection (Miller and Miller, 2004). Application of fungicide should be a part of an integrated approach to reduce early blight infection.

The complication with TOMCAST and WISDOM disease ratings in 2005 made it difficult to be definitive about the difference between two sprays with the PLANT-Plus system versus four sprays with WISDOM and TOMCAST. The disease ratings were lower for the WISDOM model, but it could have easily been from other factors, none of them related to the fungicide applications.

CONCLUSIONS

Different threshold Growing-Degree Days (GDD) were accumulated in all years from May 15 to a total of 300 cumulated P-Days using the same source for the meteorological data. Timing of initial fungicide sprays based on GDD would require many more years of data to obtain a degree of consistency, or to obtain a reasonable average. Cumulative P-Days was less variable and, similar to the conclusions reached by Gent and Swartz (2002), would be a better value to use when initiating fungicide applications.

The TOMCAST model is not suitable for early blight prediction in southern Alberta without more rigorous calibration and validation to identify the temperature intervals most appropriate for semi-arid and irrigated conditions.

The WISDOM model is insensitive to seasonal weather patterns. Recommendations for spray intervals and fungicide rates (low, medium, high) were similar regardless of the source of the meteorological data. Recommendations appeared to be biased towards the accumulated P-Day calculation, even in the absence of threshold late blight DSV being attained. Using the WISDOM model for timing of fungicide applications would follow a program of prevention, independent of disease risk.

PLANT-Plus is the one prediction technique evaluated that scheduled fungicide applications based on disease risk. Thus, the opportunity for lowering the frequency and cost of sprays for early blight in years when the weather is not conducive for early blight development, may be realized.

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