Recommendations for late blight control in Michigan for 2000.

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Potato late blight has now been confirmed in three separate locations in Montcalm County. The primary source of the infection appears to be from infected seed. A section 18 registration for Tattoo 6.25 SC has been submitted to EPA in view of the probable scarcity of effective systemic fungicides given the occurrence of late blight in Wisconsin and other areas of North America.

Potato late blight remains the most important potato disease in Michigan. The disease causes crop losses by killing foliage and producing spores which fall to the soil and infect tubers. The geographical characteristics of Michigan are ideally suited for the creation of the meteorological conditions conducive for potato late blight epidemics. Typically, the growing season coincides with periods of high rainfalls and cool temperatures, both pre-requisites for disease development. Many growers adopt a preventative approach to late blight control but in periods of high rainfall it is often not possible to maintain these insurance programs. These conditions have resulted in recommendations for disease control which are may vary or are adaptable depending on the different disease situations. In this article, the reasons for current recommendations will be presented and explained.

Studies at Michigan State University have shown that untreated vines can reach levels of 100% infection within 20 days if left untreated and that tubers decay completely after only 5 - 7 days after infection in the soil. Infected tubers that are introduced into storages decay slowly under cool conditions, typical for seed and table stock storage, but break down quickly in processing storages and may result in complete loss of storages within four weeks after storage.

The Michigan Potato Industry Commission 1995-99 pest surveys (available from the Commission Office (517) 669-8377, $25/copy) showed that growers in Michigan relied primarily on protection programs that used contact residual fungicides such as chlorothalonil-based products (Bravo ZN) and EBDC-based products (Dithane, Manzate, Manex, Penncozeb and Polyram). Applications were typically started early in the season when plants were about 6" tall and continued in many cases until the vines were completely dead. Some growers made as many as 18 fungicide application throughout the season but the average number of applications im 1998 was between 10 and 12 for the season. Effective control of the disease was achieved by growers using both aerial and ground applications. The frequency of application by aerial applicators was normally on a 5-day schedule using 5 gal water/acre. Ground rig applied fungicides were normally being applied on a 7 - 9 day schedule. The average applications were made at 25 gal water/acre at 80 - 100 psi. The potato late blight laboratory received many samples for testing through the season. Late blight was first detected in a seed lot and was confirmed as the US8/A2 biotype. The disease was confirmed in only one field in West Michigan late in July (US8/A2 biotype). Measures were taken to prevent the disease from spreading in all areas and a major epidemic was prevented by the vigilance of the growers, consultants and the extension agency. Systemic and translaminar fungicides were used sparingly in Michigan in 1998/99. The most frequently reported use during mid-season was of Curzate M8 (DuPont). Acrobat MZ 69WP was successfully used to prevent spread of infection in the one confirmed case of late blight in Michigan in 1998. Many growers used Supertin 80WP (Griffin) from canopy closure to the end of the season to prevent tuber blight. These strategies appear to have been successful. There were no reports of late blight in storages last season.

The late blight epidemic in Michigan in 1999 was potentially severe due in part to 1) environmental conditions experienced early in the growing season in Michigan; 2) the transmission of late blight from seed imported onto commercial farms; 3) the presence of sites of secondary generation of discarded tubers either as over-winter surviving volunteers in cull piles and fields. The late blight epidemic could have been more severe if not for the diligence of the potato industry in partnership with Michigan Department of Agriculture and Michigan State University, the availability and effective applications of fungicides at appropriate timings as advised under emergency announcements and procedures issued to the potato growing industry during 1996 - 99 and the effective combination of cultural practices and appropriate fungicide applications.

The prevalent strain of late blight in Michigan is the A2 mating type, US8 genotype (determined by cellulose acetate electrophoretic techniques at MSU). All samples in Michigan analyzed indicated that the population was distributed throughout the state. None of the samples received from 1997 - 1998 confirmed the presence of US1/A1 or other genotypes. No genotypes currently unclassified under the present system were confirmed. Genotype analysis is set to continue in 2000 and seed tuber lots analyzed in 1999 - 2000 have all tested negative for late blight. In 1996, two seed tuber lots were tested and the presence of US8/A2 genotype was confirmed. In 1997, of ten seed lots sampled, only one was confirmed to have late blight present.

Late blight depends on an integrated approach for effective control. The recommendations for cultural practices are largely based on varietal choice and selection of seed in combination with a preventative fungicide protection program. Studies at MSU have shown that the varieties currently grown commercially are highly susceptible to late blight. Snowden and Pike have are moderately susceptible and require an intensive fungicide application program. Trials at MSU have shown that it is possible to achieve excellent disease control with programs that combine the use of resistant varieties (not commercially available) with managed fungicide application programs. These programs have given excellent disease control under high disease pressure with applications of currently available fungicides at as low as 0.33 rate on a 10 or 15 day schedule. These studies are continuing at MSU. Other cultural practices include the use of extensive scouting programs offered by crop consultancy companies such as ABC Crop Consultants (Mark Otto, Lansing, MI). Michigan State University Integrated Crop Management Program (Dr. C. Edson) can be contacted for further measures recommended that make use of integrated techniques.

Computer programs are available that calculate disease severity values for both late blight and early blight based on weather data obtained within the crop. Michigan State University Late Blight project maintains a web site (http://potato.msu.edu) on which weather data and severity values are reported through the season from potato growing areas in Michigan. Also, for 2000 a 48 hour predictive service for some areas is offered. A full description of the weather station project for potato crops in Michigan will be published in shortly, including locations of weather stations for 2000. Disease alerts and instructions for sending in samples for diagnosis are also published on this site.

Proper disposal of potato culls remains an issue in Michigan and was the subject of an earlier article. In summary, late blight overwinters in potato tubers that are intended for seed for replanting but often the infection is harbored in waste or cull potato tubers. The crop infection in the succeeding year is always started by a late blight infected potato tuber that survived the winter. It is difficult to estimate the probability that infected potato stems or foliage will emerge from an infected tuber. Several factors can influence the fate of the infected tuber. If the infection is severe, then the tuber may rot prior to the end of sprout dormancy, or may kill the sprout prior to emergence from the soil. The tuber infection however may be localized and it is possible that a secondary sprout could become infected prior to emergence and successfully emerge from the soil infected. The infection in the tuber may be optimal in terms of the location in relation to the emerging sprout. The severity of the infection may also be optimal in that the sprout becomes infected but not to the extent that the sprout is killed. These circumstances may result in an infected sprout and infected stem or foliage. In optimal environmental conditions the disease can then spread within individual plants, between plants and neighboring crops. Volunteer potatoes that are generated from unharvested crops, tubers that are missed at harvest or re-generated from existing volunteer plants are all potential carriers of late blight or can act as "stepping stones" during an epidemic. Every effort should be taken at harvest to minimize the return of tubers to the field.

Fungicides remain the major tool for the control of late blight. At MSU the late blight project tests about twenty different fungicides in programs at various rates of application and in combination with other products. The activity of the fungicides at various stages of the late blight disease are screened in the lab and in the field. From these studies the agrochemical industry can develop strategies for the use of their fungicides. Over 120 combinations were tested at MSU in 1999. The program is set to continue in 2000. The late blight open day will be held at the Muck farm on Aug 24 from 3 pm followed by a hog roast (sponsored by Griffin).

The following tables summarize the work achieved at MSU. Two approaches to late blight control are practiced in Michigan and North America. The first is application of fungicides in a protectant program. The second is the use of a containment program. In practice, most growers use a compromise leaning more towards the protectant program. In some years, it is not possible to adhere rigidly to a fully protective program and environmental or meteorological conditions may prevent the planned implementation of the program. If a crop becomes infected, it may not be possible to effectively control the disease if it passes through a stage into another where one of the chemicals is no longer effective. It is for this reason that we require the tools to control the disease in its different stages and also to develop an educational program whereby growers, specialists and consultants may recognize which chemical to apply and when. The use of translaminar or locally systemic fungicides have been evaluated within protection programs as well as in emergency control situations.

The first table shows the comparative action or residual and systemic fungicides on the late blight disease cycle (Table 1). The active ingredients contained in the existing and development products act on several distinct developmental stages and also are active against some similar stages as well. Propamocarb (Tattoo C, Agrevo) is thought to be the most systemic of the three active ingredients and has excellent disease containment properties. Cymoxanil (Curzate 60DF, DuPont) and dimethomorph (Acrobat MZ, American Cyanamid) are also partially systemic and given current application capabilities of most growers are as effective as propamocarb in terms of plant uptake. Propamocarb does not however, have any activity against zoospore release which is a significant events in the secondary stages of epidemic development. In addition to effectiveness against, internal fungal growth, lesion formation, sporulation and tuber blight, dimethomorph also has useful activity against sporangiophore formation, zoospore release and oospore formation. The latter stage may prove to be vital if indeed there is a population shift and the two mating types are able to combine to form these potentially devastating resting spores. Cymoxanil is also unique in that it inhibits unique stages in the fungal life cycle which the other two actives have no known activity against i.e., zoospore germination, appressorium formation, and initial penetration. The range of biological activity of the three actives gives the grower the opportunity to control the development of the late blight epidemic. During canopy development, after the main stem leaves have appeared and are fully expanded, late maturing indeterminate potato varieties produce axillary branches bearing leaves often until vine desiccation. The semi-systemic chemicals, cymoxanil and dimethomorph are ideal fungicides for protectant use at this stage in crop development as they do not need to penetrate the dense canopy which under the implementation of an insurance spray program is already protected.

In the trials at MSU late blight developed rapidly during August and untreated controls reached 85 - 95% foliar infection by 25 Aug. All fungicide programs with seven-day application intervals applied as protectants reduced the level of late blight foliar infection significantly compared to the untreated control. Under the conditions experienced at the research farm in 1996 - 98, it was clear that the initial applications of protectant fungicides were vital for effective control of potato late blight. Protectant products must be applied in order to build up a residual base to prevent initial infections of potato late blight. In one trial fungicides were applied at different initiation points in the late blight disease cycle, 72 hours before inoculation, 72 hours after inoculation, and at 1% and 5% foliar infection; comparisons of fungicide programs based on containment products were made (Table 2). At both 72 hours before inoculation (HBI) and HAI spray triggers all of the fungicide programs had significantly lower RAUDPC than the untreated control. For both triggers, the only treatments with significantly higher RAUDPC values than the Manzate + Supertin treatments were the Quadris, Curzate + Bravo and Acrobat + Supertin treatments (**note:** this was not the Acrobat MZ formulation but the active ingredient dimethomorph applied alone in tank mix with Bravo WS). At the 1% FI trigger all of the fungicide programs had significantly lower RAUDPC than the untreated control. Both Manzate + Supertin treatments had a significantly lower RAUDPC than all other treatments. The Manzate + Supertin double-label rate Supertin was significantly better than the Manzate + Supertin applied at full rate. At the 10% FI trigger all fungicide treatments had significantly lower RAUDPC values than the untreated control, but did not differ from each other. All treatments gave significantly better control in comparison with untreated check plots at the final disease assessment and season-long average disease (RAUDPC). Note that the double-rate Supertin program is not registered in the US and is included to represent the rate of application used in Europe.

These (and other) trials form the basis of the recommendations for late blight control programs for 2000. In situations where disease is present recommendations for the control of disease in combination with crop destruction practices are shown in Table 3. MSU extension recommends that disease loci in crops are destroyed with Diquat and treated with fungicide (Supertin 80WP) until the loci are completely dead. Management of tubers form diseased areas in fields requires special attention. Tubers from these areas should not be introduced into storage. These areas should also be harvested last to allow infected tubers time to rot which prevents them from being picked up by the harvester. Growers should be cautious about storing tubers from fields known to have been infected even if active lesions are not observed late in the season. Samples can be tested at the MSU late blight lab.

Of special note is the use of Curzate 60DF. Curzate 60DF is not formulated with a mixture partner. The product contains only cymoxanil (the systemic ingredient of Curzate M8 72WP). Curzate 60WP should only be applied with a residual protectant mixing partner. Quadris 2SC should also be mixed with a residual protectant fungicide.

Recommendations
All the programs tested can be recommended for control of potato late blight although under high disease pressure situations the programs incorporating Acrobat 69WP, Curzate 60DF or Tattoo C 6.25SC (section 18 pending) should be used. Consult your local advisor for appropriate rates and additional combinations.

In seasons when the severity of weather conditions would not favor severe late blight development, programs based on chlorothalonil [e.g. Bravo WS 6SC, Echo 6SC, Equus 6SC (registered July 2000) or other formulations), EBDC (e.g. Dithane 75DF, Manzate 75DF, Manex 4FL, Penncozeb 75DF, Polyram 80WP] will reduce the risk of the establishment of the disease. The addition of Supertin 80WP to any of the protectant programs would enhance disease control particularly towards the end of the growing season. (Supertin 80WP has a seven day pre-harvest interval).

Fixed copper-based products (such as Champ and Kocide) can also be used in protectant programs. These products are best used early in programs or immediate post-harvest for killing spores perhaps from adjacent crops and should always be applied at the full recommended rate of application.

The observations of individuals responsible for implementing programs should determine when best to change from one product to another.

The appropriate placement of translaminar and other systemic products within programs is determined by the mode of action of the product in relation to host and disease development. For example, Tattoo C should be applied to protect new growth early in development, Curzate should be applied while the canopy is expanding but before senescence and Acrobat MZ is most effective as a post-senescence product and can be applied up to late crop senescence.

Recommended programs for late blight control are again not straightforward. The product of choice may well depend on how and from where the disease has developed. Some possible scenarios are shown in Table 3 where a range of containment procedures are described for different variety types and different levels of disease in the field.

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Table 1. Comparative action of residual and systemic fungicide sprays on the late blight disease cycle

Fungal/disease stage	Coppers	Tins	Chl	EBDC's	Fl'nam	az'st'bin	M'xyl*	P'carb	D'morph	Cym'nil
Sporangiophore formation	-	+	?	-	+++++	?	-	+++++	+++++	-
Zoospore formation	?	?	?	?	+++++	?	?	+++++	-	-
Zoospore release(primary)	+++	++++	+++++	++++	+++++	?	-	-	++	++++
Zoospore germination	+++	++++	+++++	++++	+++++	?	-	-	-	++++
Appressorium formation	++	++	-	?	+++++	?	-	-	-	++++
Initial penetration	-	+	-	++	+++++	?	-	-	-	+++++
Hyphal growth (leaf surface)	++	?	++	++++	+++++	+++++	-	-	-	-
Growth inside leaf	-	-	-	+	-	+++++	+++++	+++++	++++	+++++
Lesion formation	-	-	-	-	-	+++++	+++++	+++++	++++	++++
Sporulation (secondary)	-	+++++	-	-	+	+++++	+++++	+++++	+++++	-
Tuber blight	+	+++++	+++++	-	+	++++	+++++	+++++	+++++	-
Oospore formation	?	?	-	-	?	?	?	?	++++	?

+++++ 90 - 100% effective

++++ 80 - 90% effective

+++ 70 - 80% effective

++ 60 - 70% effective

+ 50 - 60% effective

? not known

- 0 - 50% effective

* metalaxyl sensitive strains only

efficacy is opinion of author based on trial data and literature

Tins	triphenyltin OH	e.g. Super Tin 80WP
Chl	Chlorothalonil	Bravo WS
EBDCs	Mancozeb, metiram	Manex, Dithane, Polyram
Fl'nam	Fluazinam	No product
az'st'bin	Azoxystrobin	Quadris
M'xyl	metalaxyl	Ridomil
P'carb	propamocarb	Tattoo C
D'morph	Dimethomorph	Acrobat MZ
Cym'nl	Cymoxanil	Curzate 60WP

information from Schwinn and Margot
Manufacturers R&D departments
Trials from MSU 1995 (Kirk, Lacy and Cortright); 1996 (Kirk, Kitchen, Stein, Kirk and Nobis); 1997 (Kirk, Stein, Niemira, Kitchen and Kirk).

Table 2. Late Blight Development Measured as RAUDPC Values from Containment Treatments Initiated at Different Stages in Late Blight Development for 1999.

Rates are in metric active ingredient/ha and represent full application rates. Also note final treatment is double rate Supertin 80WP which is not registered for use in USA but is here to represent European rate of application.

Treatment, formulation[1] and rate of application (kg ha^{-1})	RAUDPC[2] Spray initiation trigger			
	72 HBI[3]	72 HAI	1% FI[4]	5% FI
Untreated	0.389 a[5]	0.252 a	0.488 a	0.488 a
Quadris SC (0.28)	0.181 b	0.140 b	0.338 b	0.309 b
Bravo WS SC (1.27) + Acrobat WP (0.22)	0.116 bc	0.082 cd	0.316 bc	0.306 b
Bravo WS SC (1.27)	0.134 bc	0.088 cd	0.349 b	0.302 b
Bravo WS SC (1.27) + Curzate DF (0.15)	0.187 b	0.108 b	0.339 b	0.289 b
Tattoo C 6SC SC (2.02)	0.133 bc	0.092 cd	0.276 c	0.274 b
Acrobat WP (0.34) + Supertin WP (0.22)	0.163 b	0.099 c	0.274 c	0.295 b
Acrobat WP (0.22) + Supertin WP (0.22)	0.168 b	0.096 c	0.279 c	0.297 b
Manzate DF (1.68) + Supertin WP (0.22)	0.119 c	0.088 cd	0.224 d	0.274 b
Manzate DF (1.68) + Supertin WP (0.39)	0.067 c	0.054 d	0.144 e	0.279 b

Products containing multiple active ingredients are listed with one formulation only

1. Relative area under the disease progress curve (maximum = 1.0)
2. Hours before (HBI) or after (HAI) inoculation
3. The percentage of foliage infected with *Phytophthora infestans*
4. Values followed by the same letter are NSD (Tukey = 0.05)

Table 3. Suggestions for appropriate fungicides including section 18 fungicides under different late blight conditions in early maturing potato varieties and late maturing potato varieties.

Disease category	Early maturing varieties		Late maturing especially storage varieties	
	No senescence - early senescence	Mid - late senescence	No senescence - early senescence	Mid - late senescence
a) none	Curzate+ EBDC or chlorothalonil Chlorothalonil** Quadris + EBDC or chlorothalonil (various + ZN) Copper (various)	Supertin*+ EBDC or chlorothalonil Chlorothalonil (various + ZN) Curzate+EBDC	Curzate+ EBDC or chlorothalonil Chlorothalonil (various + ZN) Quadris + EBDC or chlorothalonil	Supertin+ EBDC or chlorothalonil Chlorothalonil (various + ZN) Acrobat MZ
b) few random lesions even distribution throughout field (0 - 1% foliar infection)	Curzate+ EBDC Acrobat MZ Chlorothalonil (various + ZN) fb EBDC+Supertin or Chlorothalonil + Supertin 5day*** fb Chlorothalonil (various + ZN) Tattoo C	Curzate+ EBDC Acrobat MZ EBDC+Supertin Chlorothalonil (various + ZN) + Supertin fb EBDC+Supertin or Chlorothalonil + Supertin 5day fb Chlorothalonil (various + ZN) Tattoo C	Curzate+ EBDC Acrobat MZ fb EBDC+Supertin or Chlorothalonil + Supertin 5day fb Chlorothalonil (various + ZN) Tattoo C	Acrobat MZ fb EBDC+Supertin or Chlorothalonil + Supertin 5day fb Chlorothalonil (various + ZN) Tattoo C
c) one or more (up to 5) loci spreading from the edge of the field or from several centers within the field (1% overall field infection but locally heavily infected plants 5 - 10%)	Tattoo C Curzate+ EBDC or chlorothalonil Acrobat MZ fb EBDC+Supertin or Chlorothalonil+ Supertin 5day fb Chlorothalonil (various + ZN) every 5 days until vines dead	EBDC+Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 days until vines dead	Tattoo C Curzate+ EBDC or chlorothalonil Acrobat MZ kill inf'd area with Diquat**** fb EBDC+Supertin or Chlorothalonil + Supertin every 5 days until vines dead	EBDC+Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 days until vines dead
d) partial crop infection large areas infected with up to 20% loss of GLA evenly distributed throughout the field or large areas of the field	EBDC+Supertin Chlorothalonil (various + ZN) +Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5days until vines dead	EBDC+Supertin Chlorothalonil (various + ZN) +Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5days until vines dead	EBDC+Supertin Chlorothalonil (various + ZN)+Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5days until vines dead	EBDC+Supertin Chlorothalonil (various + ZN) +Supertin kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5days until vines dead
e) 20-100% crop infection with large loss of GLA***	kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 day until vines dead	kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 day until vines dead	kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 day until vines dead	kill inf'd area with Diquat fb EBDC+Supertin or Chlorothalonil + Supertin every 5 day until vines dead

fb followed by
GLA Green Leaf Area
* Supertin has 7day post harvest interval (max 11.75 oz/Acre/season)
** Chlorothalonil has 7 day post harvest interval
*** Protectant applications of an EBDC or chlorothalonil-based fungicide should be maintained on a 5 day schedule until the vines are completely dead.
**** Infected areas should be treated last and a fungicide should be applied during the exit from the field