Michigan State University
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In Cooperation with the
Michigan Potato Industry Commission

2006 Michigan Potato Research Report

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MICHIGAN POTATOES
MICHIGAN POTATO INDUSTRY COMMISSION

Michigan Potato Industry Commission

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To All Michigan Potato Growers & Shippers:

The Michigan Potato Industry Commission, Michigan State University's Agricultural Experiment Station and Cooperative Extension Service are pleased to provide you with a copy of the results from the 2006 potato research projects.

This report includes research projects funded by the Michigan Potato Industry Commission, the USDA Special Grant and special allocations by the Commission. Additionally, the Commission expresses appreciation to suppliers of products for research purposes and special grants to the Commission and researchers.

Providing research funding and direction to principal investigators at MSU is a function of the Michigan Potato Industry Commission's Research Committee.

Best wishes for a prosperous 2007 season.

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2006 MICHIGAN POTATO RESEARCH REPORT

C. M. Long, Coordinator

INTRODUCTION AND ACKNOWLEDGMENTS

The 2006 Potato Research Report contains reports of the many potato research projects conducted by MSU potato researchers at several locations. The 2006 report is the 38th volume, which has been prepared annually since 1969. This volume includes research projects funded by the Potato Special Federal Grant, the Michigan Potato Industry Commission (MPIC), GREEEN and numerous other sources. The principal source of funding for each project has been noted at the beginning of each report.

We wish to acknowledge the excellent cooperation of the Michigan potato industry and the MPIC for their continued support of the MSU potato research program. We also want to acknowledge the significant impact that the funds from the Potato Special Federal Grant have had on the scope and magnitude of potato related research in Michigan.

Many other contributions to MSU potato research have been made in the form of fertilizers, pesticides, seed, supplies and monetary grants. We also recognize the tremendous cooperation of individual producers who participate in the numerous on-farm projects. It is this dedicated support and cooperation that makes for a productive research program for the betterment of the Michigan potato industry.

We further acknowledge the professionalism of the MPIC Research Committee. The Michigan potato industry should be proud of the dedication of this Committee and the keen interest they take in determining the needs and direction of Michigan's potato research.

Special thanks go to Dick Crawford for the management of the MSU Montcalm Research Farm (MRF) and the many details which are a part of its operation. We also want to recognize Barb Smith and Esther Haviland at MPIC and Sheila Crooks for helping with the details of this final draft.

WEATHER

The overall 6-month average temperatures during the 2006 growing season were lower than the 6-month average for the 2005 season and were equal to the 15-year average (Table 1). There were eight recorded temperature readings of 90 °F or above in 2006. Four of these days occurred in late July and early August during potato bulking. Two nights in early August the average minimum temperature remained above 70 ºF. There were two days in May that the temperature was below 32 °F. There were 12 daytime lows, below 50 °F, during harvest in mid to late October. The average maximum temperatures for June, July and August of 2006 were above the 15-year average (Table 1).

Rainfall for April through September was 20.31 inches (Table 2). Rainfall recorded during the months of May, July and September was above the 15-year average for the same months. Rainfall recorded during the month of July was the highest recorded for that month in 15 years. Irrigation at MRF was applied 12 times from June 13th to September 6th averaging 0.65 inches for each application. The total amount of irrigation water applied during this time period was 7.9 inches.

Table 1. The 15-year summary of average maximum and minimum temperatures (°F) during the growing season at the Montcalm Research Farm.

Year	April		May		June		July		August		September		6-Month Average	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1992	51	34	70	42	76	50	76	54	75	51	69	46	70	46
1993	54	33	68	45	74	55	81	61	79	60	64	46	70	50
1994	57	34	66	43	78	55	79	60	75	55	73	51	71	50
1995	51	31	66	45	81	57	82	60	82	65	70	45	72	51
1996	50	31	64	44	75	57	76	55	80	59	70	51	69	50
1997	54	31	59	39	79	56	80	57	73	55	69	50	69	48
1998	60	37	75	51	77	56	82	58	81	60	76	52	75	52
1999	59	37	71	48	77	55	84	62	76	56	73	48	73	51
2000	56	34	70	49	75	57	77	56	79	57	70	49	71	50
2001	61	37	70	49	78	57	83	58	72	70	69	48	72	53
2002	56	36	63	42	79	58	85	62	81	58	77	52	73	51
2003	56	33	64	44	77	52	81	58	82	58	72	48	72	49
2004	62	37	67	46	74	54	79	57	76	53	78	49	73	49
2005	62	36	65	41	82	60	82	58	81	58	77	51	75	51
2006	**62**	**36**	**61**	**46**	**78**	**54**	**83**	**61**	**80**	**58**	**68**	**48**	**72**	**50**
15-Year Average	57	34	67	45	77	56	81	58	78	58	72	49	72	50

Table 2. The 15-year summary of precipitation (inches per month) recorded during the growing season at the Montcalm Research Farm.

Year	April	May	June	July	August	September	Total
1992	3.07	0.47	1.18	3.51	3.20	3.90	15.33
1993	3.47	3.27	4.32	2.58	6.40	3.56	23.60
1994	3.84	2.63	6.04	5.16	8.05	1.18	26.90
1995	3.65	1.87	2.30	5.25	4.59	1.38	19.04
1996	2.46	3.99	6.28	3.39	3.69	2.96	22.77
1997	2.02	3.13	3.54	2.80	2.71	1.46	15.66
1998	2.40	2.21	1.82	0.40	2.22	3.05	12.10
1999	5.49	5.07	5.82	4.29	5.46	4.03	30.16
2000	3.18	6.46	4.50	3.79	5.28	5.25	28.46
2001	3.28	6.74	2.90	2.49	5.71	4.43	25.55
2002	2.88	4.16	3.28	3.62	7.12	1.59	22.65
2003	0.70	3.44	1.85	2.60	2.60	2.06	13.25
2004	1.79	8.18	3.13	1.72	1.99	0.32	17.13
2005	0.69	1.39	3.57	3.65	1.85	3.90	15.05
2006	**2.73**	**4.45**	**2.18**	**5.55**	**2.25**	**3.15**	**20.31**
15-Year Average	2.78	3.83	3.51	3.39	4.21	2.81	20.97

GROWING DEGREE DAYS

Tables 3 and 4 summarize the cumulative growing degree days (GDD) for 2006. Growing degree days base 50 for May through September, 2006 are in (Table 3) and growing degree days base 40 for May through October, 2006 are in (Table 4). The total GDD base 50, for 2006 were 2271 (Table 3) which is slightly lower than the 10-year average. The total GDD base 40, for 2006 were 3923 (Table 4).

Table 3. Growing Degree Days* - Base 50°F.

Cumulative Monthly Totals					
Year	May	June	July	August	September
1997	110	635	1211	1637	1956
1998	427	932	1545	2180	2616
1999	317	865	1573	2070	2401
2000	313	780	1301	1851	2256
2001	317	808	1441	2079	2379
2002	319	903	1646	2214	2613
2003	330	762	1302	1922	2256
2004	245	662	1200	1639	2060
2005	195	826	1449	2035	2458
2006	**283**	**765**	**1444**	**2016**	**2271**
10-Year Average	286	794	1411	1964	2327

Table 4. Growing Degree Days* - Base 40°F.

Cumulative Monthly Totals						
Year	May	June	July	August	September	October
2006	**532**	**1310**	**2298**	**3180**	**3707**	**3923**
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
10-Year Average	532	1310	2298	3180	3707	3923

*1997-2006 data from the weather station at MSU Montcalm Research Farm (Michigan Automated Weather Network System Entrican, MI.)

PREVIOUS CROPS, SOIL TESTS AND FERTILIZERS

The general potato research area utilized in 2006 was rented from Steve Comden, directly to the West of the Montcalm Research Farm. This acreage was planted to a soybean cover crop in the Spring of 2004 and was disked under in the fall due to poor yield. The crop for this same acreage in the 2005 growing season was field corn. In the spring of 2006, the recommended rate of potash was applied and disked into the remaining corn stubble. The ground was moldboard plowed for direct potato planting. The area was not fumigated prior to potato planting. Potato early die was not an issue in 2006.

The soil test analysis for the general crop area was as follows:

	lbs/A			
pH	P_2O_5	K_2O	Ca	Mg
5.7	348 (174 ppm)	194 (97 ppm)	1000 (500 ppm)	172 (86 ppm)

The fertilizers used in the general plot area are as follows. (Variances in fertilizers used for specific research projects are included in the individual project reports.)

Application	Analysis	Rate	Nutrients ($N-P_20_5-K_20$)
Broadcast at plow down	0-0-60	250 lbs/A	0-0-150
At planting	19-17-0	19 gpa	40-36-0
At emergence	46-0-0	175 lbs/A	81-0-0
1^{st} Early side dress	46-0-0	175 lbs/A	81-0-0
2^{nd} Late side dress (late varieties)	46-0-0	100 lbs/A	46-0-0

HERBICIDES AND PEST CONTROL

Hilling was done in late May, followed by a pre-emergence application of Sencor at 2/3 lb/A and Cinch at 1.33 pints/A. A post-emergence application of Sencor at ¼ lb/A and Matrix at 1 oz/A was made in mid June.

Platinum was applied at planting at a rate of 8 Fl oz/A. Asanna XL was applied once in late July at 9.6 Fl oz/A. Fungicides used were Bravo, Echo and Manzate over 11 applications. Potato vines were desiccated with Reglone in mid August at a rate of 1 pint/A.

2006 POTATO BREEDING AND GENETICS RESEARCH REPORT

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INTRODUCTION

At Michigan State University we are breeding potatoes for the chip-processing and tablestock markets. The program is one of four integrated breeding program in the North Central region. At MSU, we conduct a multi-disciplinary program for potato breeding and variety development that integrates traditional and biotechnological approaches. In Michigan, it requires that we primarily develop high yielding round white potatoes with excellent chip-processing from the field and/or storage. We conduct variety trials of advanced selections and field experiments at MSU research locations (Montcalm Research Farm, Lake City Experiment Station, Muck Soils Research Farm and MSU Soils Farm), we ship seed to other states and Canadian provinces for variety trials, and we cooperate with Chris Long on 23 grower trials throughout Michigan. Through conventional crosses in the greenhouse, we develop new genetic combinations in the breeding program, and also screen and identify exotic germplasm that will enhance the varietal breeding efforts. With each cycle of crossing and selection we are seeing directed improvement towards improved varieties (e.g. combining chip-processing, scab resistance and late blight resistance). In addition, our program has been utilizing genetic engineering as a tool to introduce new genes to improve varieties and advanced germplasm for traits such as solids, insect resistance, disease resistance and nutritional enhancement. We feel that these in-house capacities (both conventional and biotechnological) put us in a unique position to respond to and focus on the most promising directions for variety development and effectively integrate the breeding of improved chip-processing and tablestock potatoes.

The breeding goals at MSU are based upon current and future needs of the Michigan potato industry. Traits of importance include yield potential, disease resistance (scab, late blight, early die and PVY), insect (Colorado potato beetle) resistance, chipping (out-of-the-field, storage, and extended cold storage) and cooking quality, bruise resistance, storability, along with shape, internal quality and appearance. We are also developing potato tuber moth resistant lines as a component of our international research project. If these goals can be met, we will be able to reduce the grower's reliance on chemical inputs such as insecticides, fungicides and sprout inhibitors, and improve overall agronomic performance with new potato varieties.

Over the years, key infrastructure changes have been established for the breeding program to make sound assessments of the breeding selections moving through the program. These include the establishment and expansion of the scab nursery, the development of the Muck Soils Research Farm for late blight testing, the incorporation of no-choice caged studies for Colorado potato beetle assessment, the Michigan Potato Industry Commission (MPIC)-funded construction of the B.F. (Burt) Cargill Demonstration Storage adjacent to the Montcalm Research Farm, new land at the Lake City Experiment Station along with a well for irrigation and expanded land at the Montcalm Research Farm.

PROCEDURE

I. Varietal Development

Each year, during the winter months, 500-1000 crosses are made using about 150 of the most promising cultivars and advanced breeding lines. The parents are chosen on the basis of yield potential, tuber shape and appearance, chip quality, specific gravity, disease resistance, adaptation, lack of internal and external defects, etc. These seeds are then used as the breeding base for the program. We also obtain seedling tubers or crosses from other breeding programs in the US. The seedlings are grown annually for visual evaluation (size, shape, set, internal defects) at the Montcalm and Lake City Research Farms as part of the first year selection process of this germplasm each fall. Each selection is then evaluated post harvest for specific gravity and chip processing. These selections each represent a potential variety. This system of generating new seedlings is the initial step in an 8-12 year process to develop new varieties. This step is followed by evaluation and selection at the 8-hill, 20-hill and 30-hill stages. The best selections out of the four-year process are then advanced for testing in replicated trials (Preliminary, Adaptation, Dates-of-Harvest, Grower-cooperator trials, North Central Regional Trials, Snack Food Association Trials, and other out-of-state trials) over time and locations. The agronomic evaluation of the advanced breeding lines in the replicated trials is reported in the annual Potato Variety Evaluation Report.

II. Evaluation of Advanced Selections for Extended Storage

With the Demonstration Storage facility adjacent to the Montcalm Research Farm we are positioned to evaluate advanced selections from the breeding program for chip-processing over the whole extended storage season (October-June). Tuber samples of our elite chip-processing selections are placed in the demonstration storage facility in October and are sampled monthly to determine their ability to chip-process from colder (42-48°F) and/or 50˚F storage. In addition, Chris Long evaluates the more advanced selections in the 10 cwt box bins and manages the 500 cwt. storage bins which may have MSU-bred lines. In 2006-7 we are incorporating a preliminary sugar profiling evaluation of advanced selections from the breeding program.

III. Germplasm Enhancement

To supplement the genetic base of the varietal breeding program, we have a "diploid" (2x = 24 chromosomes) breeding program in an effort to simplify the genetic system in potato (which normally has 4x chromosomes) and exploit more efficient selection of desirable traits. This added approach to breeding represents a large source of valuable germplasm, which can broaden the genetic base of the cultivated potato. The diploid breeding program germplasm base at MSU is a synthesis of seven species: *S. tuberosum* (adaptation, tuber appearance), *S. raphanifolium* (cold chipping), *S. phureja* (cold-chipping, specific gravity, PVY resistance, self-compatability), *S. tarijense* and *S. berthaultii* (tuber appearance, insect resistance, late blight resistance, verticillium wilt resistance), *S. microdontum* (late blight resistance) and *S. chacoense* (specific gravity, low sugars, dormancy and leptine-based insect resistance). In general, diploid breeding utilizes haploids (half the chromosomes) from potato varieties, and diploid wild and cultivated tuber-bearing relatives of the potato. Even though these potatoes have only half the chromosomes of the varieties in the U.S., we can cross these potatoes to transfer the desirable genes by conventional crossing methods via 2n pollen.

IV. Integration of Genetic Engineering with Potato Breeding

Through transgenic approaches we have the opportunity to introduce new genes into our cultivated germplasm that otherwise would not be exploited. It has been used in potato as a tool to improve commercially acceptable cultivars for specific traits. Our laboratory has 14 years experience in *Agrobacterium*-mediated transformation to introduce genes into important potato cultivars and advanced breeding lines. We are presently using genes in vector constructs that confer resistance to Colorado potato beetle and potato tuber moth (*Bt-cry3A*, *Bt-cry1Ia1* and avidin), potato tuber moth, late blight resistance via the *RB* gene, drought resistance (*CBF1*) and vitamin E. Furthermore, we are investing our efforts in developing new vector constructs that use alternative selectable markers and give us the freedom to operate from an intellectual property rights perspective. In addition, we are exploring transformation techniques that eliminate the need for a selectable marker (antibiotic resistance) from the production of transgenic plants.

RESULTS AND DISCUSSION

I. Varietal Development

Breeding

The MSU potato breeding and genetics program is actively producing new germplasm and advanced seedlings that are improved for cold chipping, and resistance to scab, late blight, and Colorado potato beetle. For the 2006 field season, progeny from over 500 crosses were planted and evaluated. Of those, the majority were crosses to select for round whites (chip-processing and tablestock), with the remainder to select for yellow flesh, long/russet types, red-skin, and novelty market classes. In addition to crosses from the MSU breeding program, crosses were planted and evaluated from collaborative germplasm exchange from other breeding programs including North Dakota State University, University of Minnesota, and the USDA/ARS program at the University of Wisconsin as part of the Quad state cooperative effort. During the 2006 harvest, over 800 selections were made from the 40,000 seedlings produced. All potential chip-processing selections will be tested in January or March 2007 directly out of 40°F and 45°F storages. Atlantic (50°F chipper) and Snowden (45°F chipper) are chip-processed as check cultivars. Selections have been identified at each stage of the selection process that have desirable agronomic characteristics and chip-processing potential. At the 8-hill and 20-hill evaluation state, over 400 and 100 selections were made, respectively. Selection in the early generation stages has been enhanced by the incorporation of the Colorado potato beetle, scab and late blight evaluations of the early generation material.

Chip-Processing

Over 80% of the single hill selections have a chip-processing parent in their pedigree. Based upon the pedigrees of the parents we have identified for breeding cold-chipping potato varieties, there is a diverse genetic base. We have at least eight cultivated sources of cold-chipping. Examination of pedigrees shows up to three different cold-chipping germplasm sources have been combined in these selections. Our promising chip-processing lines are MSJ147-1, MSJ036-A (scab resistant), MSH228-6 (moderate scab resistance), MSJ126-9Y (moderate scab resistance), MSJ316-A (moderate scab resistance), MSK061-4 (moderate scab resistance), MSK409-1 (scab resistant), MSN099-B (scab resistance), MSN238-A (scab resistance), MSL007-B (scab resistance) and MSQ070-1 (scab and late blight resistant).

Dr. Joe Sowokinos, Univ. of Minnesota, has conducted biochemical analyses of our best chipping lines and has discovered that our lines differ from older varieties in their proteins (UGPase) involved in chipping. Some of these lines are MSJ147-1, MSG227-2 and MSJ126-9Y. Moreover, MSJ147-1 and MSJ126-9Y have the desirable levels of acid invertase to chip process from colder storage. We are using this information to help us design specific crosses to find improved chip-processing varieties that will allow processing from colder storage temperatures.

Tablestock

Efforts have been made to identify lines with good appearance, low internal defects, good cooking quality, high marketable yield and resistance to scab and late blight. Our current tablestock development goals now are to continue to improve the frequency of scab resistant lines, incorporate resistance to late blight along with marketable maturity and excellent tuber quality, and select more russet and yellow-fleshed lines. From our breeding efforts we have identified mostly round white lines, but we also have a number of yellow-fleshed and red-skinned lines, as well as long, russet type and purple skin selections that carry many of the characteristics mentioned above. We are also selecting for a dual-purpose russet, round white, red-skin, and improved Yukon Gold-type yellow-fleshed potatoes. Some of the tablestock lines were tested in on-farm trials in 2006, while others were tested under replicated conditions at the Montcalm Research Farm. Promising tablestock lines include MSE221-1 as a scab resistant tablestock, and MSN084-3, a round white with a smooth round shape and bright skin. We have a number of tablestock selections with late blight resistance. These are MSL072-C and MSM171-A. MSL211-3 and MSN105-1 has late blight and scab resistance. MSE192-8RUS and MSA8254-2BRUS are two russet table selections that have scab resistance, while MSL794-BRUS has late blight resistance.. MSI005-20Y is a yellow-fleshed line with smooth round appearance and high yield potential. Some newer lines with promise include MSQ176-5, MSQ441-6R, MSN230-6RY and MSQ087-3.

Disease and Insect Resistance Breeding

Scab: Disease screening for scab has been an on-going process since 1988. Results from the 2006 MSU scab nursery indicate that 21 of 176 lines evaluated had a scab rating of 1.0

or less (little to no infection to common scab). The limitation of breeding for scab resistance is the reliance on the scab nursery. The environmental conditions can influence the infection each year, thus multiple year data provides more reliable data. A study was conducted to develop a laboratory-based screening process that would use thaxtomin in tissue culture and tuber disks to expedite selection of material with potential scab resistance. We found no correlation between thaxtomin reaction and scab rating. In addition, we found a moderate correlation between the field screening and greenhouse screening for scab. In 2004, we expanded the scab nursery with an additional acre of land nearby. This expansion has allowed us to conduct early generation selection for scab resistance among our breeding material. In 2006, 110 of 293 early generation selections showed strong scab resistance. These data were incorporated into the early generation evaluation process at Lake City. We are seeing that this expanded effort is leading to more scab resistant lines advancing through the breeding program.

Late Blight: With support from GREEEN, the Muck Soils Research Farm, Bath, Michigan has become an excellent North American site for late blight testing because of the humid microclimate and isolation from major commercial potato production. As a result, late blight infection has been consistently achieved each year making breeding efforts to select late blight resistant germplasm very efficient. In 2006 untimely flooding led to the loss of the field experiments. No data was collected.

Colorado potato beetle: With support from GREEEN, we also introduced an early generation Colorado potato beetle screen at the Montcalm Research Farm. In 2006, 480 clones from 52 families were evaluated at the Montcalm Research Farm Beetle Nursery. The beetle pressure was extremely high leading to complete defoliation in all susceptible check lines. Percent defoliation was visually estimated during the beetle infestation in June and July. The lines were then sorted into four categories: susceptible, reduced susceptibility, moderately resistant and resistant. From 15 families, 72 clones were classified as resistant. The majority of the lines that were moderately resistant or resistant can be attributed to the expression of the *Bt-cry3A* gene or glycoalkaloid/leptine based mechanisms. The most resistant material was selected for further advancement in the breeding program and also for use in the next round of crossing to develop beetle resistant cultivars. Concurrently, a field cage (no-choice) experiment was conducted to evaluate 6 lines. In 2006 beetle behavior was evaluated in lines that expressed differing levels of Bt genes. The data from this experiment has not been analyzed yet.

It is a great challenge to achieve host plant resistance in a commercially acceptable line. We have some promising advanced selections with partial resistance to Colorado potato beetle. In addition, we have *Bt-cry3A* transgenic lines that could be commercialized if the processors renewed their acceptance and regulatory environment was modified to reduce costs. I am on a national committee to help build infrastructure to so that transgenic specialty crops like potato can be deregulated in a more efficient and less costly manner.

II. Evaluation of Advanced Selections for Extended Storage: MSU Potato Breeding Chip-processing Results From the MPIC Demonstration Commercial Storage (October 2005 - June 2006)

The MSU Potato Breeding Program has been conducting chip-processing evaluations each year on potato lines from the MSU breeding program and from other states. For 7 years we have been conducting a long-term storage study to evaluate advanced breeding lines with chip-processing potential in the Dr. B. F. (Burt) Cargill Potato Demonstration Storage facility directly adjacent to the MSU Montcalm Research Farm to identify extended storage chippers. We evaluated advanced selections from the breeding program for chip-processing over the whole extended storage season (October-June). Tuber samples of our elite chip-processing selections are placed in the demonstration storage facility in October and are sampled monthly to determine their ability to chip-process from storage. In addition, Chris Long and the Storage Committee evaluate the more advanced selections in the 10 cwt box bins and manage the 500 cwt. storage bins which may include MSU lines.

In October 2005, tuber samples from 5 MSU lines, 2 Frito Lay lines, Beacon Chipper, NY132, along with the standards of Pike and Atlantic from the Montcalm Research Farm trials were placed in the bin to be cooled to 48°F. The bin temperature in December was 52°F and reached a low of 48°F in February. Tubers from 5 other MSU lines, FL1879, USDA line A91814-2, W2128-8 and Snowden were placed in the bin that was to be cooled to 46°F. The bin was at 50°F in November and down to 46°F by January. The first samples were chip-processed at MSU in November and then, each month until May 2005. Samples were evaluated for chip-processing color and quality.

Table 1 summarizes the chip-processing color of select lines over the 7-month storage season. In the 48°F temperature bin, Atlantic and Pike were the check varieties. From November to March all lines chip-processed acceptably. This is not surprising since the best chip-processing lines were selected for this study. In some cases, SED or hollow heart was observed in a few chips, but no patterns emerged. The storage test was terminated in mid-May. Based upon the data, many of these lines have potential to be further tested in storage tests. Based upon chip color and defects the most promising chip-processing lines for storage and scab resistance are Beacon Chipper, MSJ036-A, MSH228-6, NY132 and FL1922. MSJ461-1 also has strong foliar resistance to late blight.

In the bin for colder temperature storage (46°F), Snowden was used as check variety and chip-processed acceptably except in May. All other lines produced acceptable chips throughout the storage season. MSG227-2 and MSK061-4, MSM051-3 offer scab resistance along with their ability to chip-process. MSJ147-1 was one line that gave consistently low color scores through out the season. See Chris Long's storage report for those results and results from the box bins and 500cwt storage bins.

III. Germplasm Enhancement

In 2006, less than 3% of the populations evaluated as single hills were diploid. From this breeding cycle, we plan to screen the selections chip-processing from storage. In addition, selections were made from over progeny that was obtained from the USDA/ARS at the University of Wisconsin. These families represent material from South American potato species and other countries around the world that are potential sources of resistance to Colorado potato beetle, late blight, potato early die, and ability to cold-chip process. Through GREEEN funding, we were able to initiate a breeding effort to introgress leptine-based insect resistance. From previous research we determined that the leptine-based resistance is effective against Colorado potato beetle. We will continue conducting extensive field screening for resistance to Colorado potato beetle at the Montcalm Research Farm and at the Michigan State University Horticulture Farm in 2007. In 2004 we made crosses with late blight resistant diploid lines derived from *Solanum microdontum* to our tetraploid lines. This *S. microdontum*-based resistance is unique and very effective against the US-8 strains. These progeny are being grown in the greenhouse and now we have used DNA marker analysis to identify which lines have the late blight resistance. We have lab-based detached leaf bioassays planned for the winter of 2007 to evaluate these lines.

IV. Integration of Genetic Engineering with Potato Breeding

Combining engineered and natural host plant resistance to *Phytophthora infestans* in cultivated potato

General susceptibility of potato cultivars to *Phytophthora infestans* (Mont.) de Bary is a major concern for potato production. The major resistance gene *RB* was cloned from *Solanum bulbocastanum* Dun.a diploid (2n=2x=24) Mexican species that is highly resistant to all known races of *P. infestans*. The objective of this work is to combine conventionally bred sources of resistance with the *RB* gene via *Agrobacterium* transformation. Our hypothesis is that by pyramiding engineered resistance with natural plant resistance we expect to obtain stronger and more durable resistance to potato late blight. Therefore, this study was undertaken to test the effectiveness of the *RB* gene on its own by transforming late blight-susceptible clones (Spunta, and the breeding lines MSE149-5Y and MSG227-2), and to test the effectiveness of the gene in combination with natural late blight resistance by transforming resistant clones (Stirling, and the advanced breeding line MSJ461-1). In 2005 we identified 5 lines with RB-based late blight resistance (MSE149-5Y, Spunta and MSG227-2) at the Muck Soils Research Farm trials. No data collected in 2006. The Spunta and MSE149-5Y lines were used in crosses to transfer the RB-based resistance to other genetic backgrounds in the breeding program. We have conducted tissue culture regeneration studies this past year to identify the best lines we can use in our RB transformation studies. In addition, we have created new vectors that may help us achieve high transformation efficiency with the RB gene.

Insecticidal activity of avidin against Colorado potato beetle larvae, *Leptinotarsa decemlineata* (Say)

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most destructive insect pest of potato, *S. tuberosum* (L.) in eastern North America. Biotin is an essential co-enzyme required for all organisms, including insects. Avidin binds to biotin, therefore limiting its availability during insect growth and development. Without this co-enzyme, an insect's growth is severely stunted, eventually leading to death. We have expressed avidin in two potato lines: MSE149-5Y, a susceptible potato line, and ND5873-15, a high glycoalkaloid line. The expression levels of avidin in the transgenic MSE149-5Y and ND5873-15 was determined to be 108.6 ± 0.4μg /mg and 108.2± 0.9μg/mg, respectively. Detached leaf bioassays were performed on transgenic and non-transgenic lines of MSE149-5Y and ND5873-15 using Colorado potato beetle first and third stage larvae. First stage larvae survivorship was significantly less for larvae feeding transgenic MSE149-5Y and ND5873-15 lines compared to the non-transgenic lines, but third stage larvae survivorship did not significantly differ for larvae feeding on transgenic MSE149-5Y and ND5873-15 lines compared to larvae feeding on non-transgenic lines. The growth of first stage larvae was significantly stunted for larvae feeding on the transgenic MSE149-5Y and ND5873-15 lines compared to the non-transgenic lines. Subsequently, we placed neonates on non-transgenic and transgenic MSE149-5Y and ND5873-15 lines and monitored growth and development of insects. Avidin expressing potato plants appearred to delay development and resulted in significantly less emerging adults. Potatoes expressing avidin may have value in managing insect pests.

Commercialization of Potato Tuber Moth Resistant Potatoes in South Africa

The potato tuber moth (*Phthorimaea operculella* Zeller) is a primary insect problem facing potato farmers in developing countries. Currently, the only available means to control the potato tuber moth (PTM) and avoid major crop losses is the use of chemical pesticides, however, it is problematic to use this strategy to control the tuberworm in storage potatoes. Michigan State University (MSU), funded by the U.S. Agency for International Development (USAID) through its Agricultural Biotechnology Support Project (ABSP), initiated biotechnology research on the development of PTM resistant varieties in 1992. A *Bacillus thuringiensis* (Bt)-*cry1Ia1* gene, was obtained from ICI Seeds (now Syngenta) and successfully introduced into several potato varieties, including Spunta. Transgenic lines and their progeny were shown to have excellent control of the larvae. The Bt Potato will be the first public sector-developed products to reach farmers in developing countries and will serve as a model for the public-sector deployment of crops that are resistant to insects. When the farmers choose to grow the Bt potato, the benefits to the farmer and end-users will be reduced input costs (less insecticides used), increased marketable yield, improved quality, reduced post-harvest losses, reduced human exposure to pesticides, and less pesticide residues on potato tubers. The commercialization project includes six components: Product Development, Regulatory File Development, Obtaining Freedom to Operate and Establishing Licensing Relationships, Marketing and Technology Delivery, Documentation of Socio-Economic Benefits, and Public Communication. This technology would also have benefits in controlling PTM in the US and reducing the need for insectcide-based protection.

V. Variety Release

No lines are planned for release in 2007, but we are continuing to promote the seed production and testing of Beacon Chipper, a 2005 release. In addition, we are continuing to promote Michigan Purple, Jacqueline Lee, MSE192-8-RUS, A8254-2BRUS, MSI005-20Y and MSN105-1 for the tablestock markets. Lastly, commercial seed of MSH228-6, MSJ147-1, MSK061-4, MSJ126-9Y and MSJ036-A are being produced and we will continue to seek commercial testing of these lines. We have also initiated a focused ribavirin-based virus eradication system to generate virus-free lines for the industry.

2005-2006 Demonstration Storage Chip Results
Michigan State University Potato Breeding and Genetics
Montcalm Research Farm
Chip Scores: SFA Scale[†]

		Sample Dates:					
	Date:	11/8/2005	12/14/2005	1/10/2006	2/8/2006	3/8/2006	5/15/2006
Line	**Temp:**	50 °F	52 °F	48 °F	48 °F	52 °F	53 °F
ATLANTIC		**1.5**	**1.5**	**1.5**	**1.0**	**1.0**	**1.5**
Beacon Chipper		1.0	1.0	1.0	1.0	1.0	1.5
FL1833		1.0	1.0	1.0	1.0	1.0	1.0
FL1922		1.5	1.0	1.0	1.0	1.0	1.0
MSH228-6		1.0	1.0	1.0	1.0	1.0	-
MSJ036-A		1.5	1.0	1.5	1.0	1.0	2.0
MSJ316-A		1.0	1.5	1.0	1.0	1.0	1.0
MSJ461-1		1.5	1.5	1.5	1.0	1.0	1.0
MSK049-A		1.5	1.0	1.0	1.0	1.0	-
NY132		1.0	1.0	1.0	1.0	1.5	1.0
PIKE		**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
	Temp:	50 °F	46 °F	46 °F	46 °F	46 °F	53 °F
A91814-2		1.5	1.0	1.5	1.0	1.0	1.5
FL1879		1.5	1.0	1.0	1.0	1.0	1.0
MSG227-2		1.0	1.0	1.0	1.0	1.0	1.0
MSJ147-1		1.0	1.0	1.0	1.0	1.0	1.5
MSK009-B		1.0	1.0	1.0	1.0	1.0	2.0
MSK061-4		1.0	1.0	1.0	1.0	1.0	1.5
MSM051-3		1.0	1.0	1.0	1.0	1.0	1.5
SNOWDEN		**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**2.5**
W2128-8		1.5	1.0	1.5	1.0	1.0	1.5

[†]Snack Food Association Chip Score
Ratings: 1 - 5
1: Excellent
5: Poor

Chip scores were from two-slice samples from five tubers of each line collected at each sample date.

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2006 POTATO VARIETY EVALUATIONS

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INTRODUCTION

Each year we conduct a series of variety trials to assess advanced potato selections from the Michigan State University and other potato breeding programs at the Montcalm Research Farm. The evaluation also includes disease evaluation in the scab nursery and foliar and tuber late blight evaluation at the Muck Soils Research Farm. The objectives of the evaluations are to identify superior varieties for fresh market or for processing and to develop recommendations for the growing of those varieties. The varieties were compared in groups according to the tuber type and skin color and to the advancement in selection. Each season, total and marketable yields, specific gravity, tuber appearance, incidence of external and internal defects, chip color (from field, 45°F and 50°F storage), as well as susceptibilities to late blight (foliar and tuber), common scab, and blackspot bruising are determined.

PROCEDURE

Ten field experiments were conducted at the Montcalm Research Farm in Entrican, MI. They were planted as randomized complete block designs with two to four replications. The plots were 23 feet long and spacing between plants was 12 inches. Inter-row spacing was 34 inches. Supplemental irrigation was applied as needed. The field experiments were conducted on new potato ground that was in corn the previous year.

The round white tuber types were divided into chip-processors and tablestock and were harvested at two dates (Date-of-Harvest trial: Early and Late). The other field experiments were the North Central White, Russet, Red, Adaptation (tablestock and chip-processors), and Preliminary (tablestock and chip-processors) and Transgenic trials. In each of these trials, the yield was graded into four size classes, incidence of external and internal defects in > 3.25 in. diameter or 10 oz. potatoes were recorded, and samples for specific gravity, chipping, disease tests, bruising, and cooking tests were taken. Chip quality was assessed on 25-tuber samples, taking two slices from each tuber. Chips were fried at 365°F. The color was measured visually with the SFA 1-5 color chart. Tuber samples were also stored at 45°F and 50°F for chip-processing out of storage in January and March. Advanced selections are also placed in the Commercial Demonstration Storage for monthly sampling. The scab nursery at the MSU Soils Farm and the late blight trial at the Muck Soils Research Farm are used for scab and foliar late blight assessment of lines in the agronomic trials.

RESULTS

A. Date of Harvest Trial Varieties:

Chip-processors and Tablestock (Tables 1 and 2)

There were 24 entries that were compared at two harvest dates. Atlantic, Snowden, Pike and four Frito-Lay clones were used as checks. The two new Frito-Lay clones evaluated this year were FL2048 and FL2053. The plot yields were below average in the early harvest (94 days), and specific gravity values were more typical to an average year. Most lines increased at least 100 cwt/a in yield for the second harvest date (152 days). The results are summarized in **Tables 1 and 2**. Hollow heart and vascular discoloration were the most prevalent internal defects this year, and above average internal brown spots in the late harvest material. *Note that last year we changed the format of all variety trial tables so that the internal defects are presented as percentages rather than as a count.* Atlantic and FL1879 showed the highest incidence of hollow heart between the two harvest dates. In the early harvest trial, the best yielding chipping lines were FL1879, FL2053, MSJ036-A, and MSJ147-1. MSM171-A is a round-white tablestock line with scab resistance, strong foliar late resistance, and an early maturity. The highest yielder for the late harvest was MSJ036-A, followed by FL1879, Beacon Chipper and MSJ461-1. MSJ036-A has high yield potential and shows scab resistance and chip-processing potential. Beacon Chipper also has high yield potential, reduced scab susceptibility and chip-processing potential. MSJ147-1 is showing promise as a chipper out of colder and long term storage. MSJ461-1 is a promising chip-processing line with strong foliar resistance to late blight that also has tablestock quality. MSL211-3 is a bright skinned round white with both late blight and scab resistance. MSN105-1 is a round-white tablestock with good scab resistance and moderate late blight resistance. In addition, MSJ036-A, MSJ316-A, MSH228-6, MSK061-4, MSM171-A, MSN105-1, MSL007-B, MSK409-1 and FL1922 offer scab resistance.

The out-of-the-field chip scores for 2006 were darker than we have seen in past years. The chips were consistently darker for all trials from the Montcalm Research Farm, including control reference varieties. In general, chip scores seemed to be 0.5 to 1.0 degrees darker, using the Snack Food Association 1-5 rating system (i.e. chip scores for Atlantic, Snowden, Pike, and FL1879).

Variety Characteristics

<u>Beacon Chipper</u> – an unknown eastern chip processing line thought to be from USDA-Beltsville. It has high yield potential and scab tolerance along with excellent chip-processing quality. Beacon Chipper was named and released in 2005.

MSE221-1 – an MSU tablestock selection. A ‘Superior-type’ potato that has moderate scab resistance and a higher yield potential than the variety Superior. The tuber type is also more attractive than Superior.

MSH228-6 – a chip-processing line with moderate scab resistance. It has a good type and has performed well in on-farm trials.

MSJ036-A – an MSU chip-processing selection with high yield potential. It also has a high specific gravity and scab resistance. The tuber type of MSJ036-A is round and attractive.

MSJ126-9Y – an earlier season chip-processing line with excellent chip quality and long-term storage potential. This line also has moderate scab resistance and an attractive type.

MSJ147-1 – a full season storage chipper that also has some early sizing. It has excellent chip-processing quality and a large percentage of A-size tubers. It has performed well in on-farm trials and has demonstrated an excellent long-term storage chipping profile.

MSJ316-A – an MSU chip-processing selection. Has high yield potential and scab resistance and bright skin appearance. Currently in on-farm trials.

MSJ461-1 – an MSU chip-processing selection with strong foliar resistance to late blight and maturity similar to Snowden. It has excellent chip-processing quality, smooth round shape and above average yield, but an intermediate specific gravity in most years. The chips show few defects. It has good tablestock quality too.

MSK061-4 – an attractive round-white chip-processing line with good scab resistance. This line produces clean chips with good specific gravity and average yield, with low blackspot bruising.

MSK409-1 – a round-white chip-processing line with good scab resistance. This earlier maturing line has average yield and slightly lower specific gravity.

MSL007-B – an MSU chip-processing selection with strong scab resistance, uniform round type, and a unique netted skin. This newer line produces excellent chips with a good specific gravity and average yield.

MSL211-3 – an attractive round-white tablestock line with strong foliar late blight resistance, moderate scab resistance, and an early maturity.

MSM171-A – a round-white tablestock line in excellent scab resistance and strong foliar late blight resistance. This line also has an early maturity with an attractive set of tubers.

Note: In December 2004 and 2005, MPIC sponsored a booth at the Great Lakes Expo to market Liberator, Michigan Purple and Jacqueline to the farm market/roadside stand market segment. This grass roots effort may be the method to have these potatoes reach the consumers. The description of these varieties are below. The booth was not at the Great Lakes Expo in 2006 due to a scheduling conflict.

MICHIGAN PURPLE - a tablestock selection with an attractive purple skin. This selection has high yield potential and the tubers have a low incidence of internal defects. The vine maturity is mid-season to mid-early. Do not let the tubers oversize. A thin skin makes this variety a challenge market on a large scale without making adjustments in harvest, washing and grading process. We regard this as a variety that can compete in the red market. It has great potential in the roadside stand and farm markets.

JACQUELINE LEE – an MSU oval/oblong tablestock selection with a high tuber set. The tubers have the bright skinned, smooth and attractive appearance that is typical of many European cultivars. The tubers have very low incidence of internal defects and good baking quality. It is our best tasting potato! The strength of this selection is also its strong foliar resistance to the US8 genotype of late blight. Vine maturity is similar to Snowden. There is interest in California to market this variety. It has great potential in the roadside stand and farm markets.

B. North Central Regional Trial Entries (Tables 3, 4, 5)

The North Central Trial is conducted in a wide range of environments (11 regional locations) to provide adaptability data for the release of new varieties from North Dakota, Minnesota, Wisconsin, Michigan and Canada. Eighteen breeding lines and 6 varieties were tested in Michigan. The clones were incorporated in the Round White (7 entries), Russet (7 entries), or Red-Skinned (4 entries) trials according to market class, and the results are presented in **Tables 3, 4, and 5**. These lines are all designated with the superscript$^{\mathbf{NCR}}$ in the tables. The MSU lines MSJ461-1, MSI005-20Y and MSA8254-2BRUS were the Michigan representatives included in the North Central Trial. MSJ461-1 has a uniformly nice type with strong foliar late blight resistance. MSI005-20Y is a yellow-fleshed line with high yield potential and an attractive round appearance. The russet line MSA8254-2BRUS has good agronomic characteristics including high yield potential and strong scab resistance. The most promising Wisconsin selections were W2324-1 (the highest yielder in the Round White Trial) and W2133-1.

C. Round White Trial (Table 3)

The 23 lines in the Round White Trial consisted mainly of the round-white chip-processing entries from the North Central Regional Trial, as well as other breeding lines from New York, Wisconsin, and Colorado. The top yielding lines were W2324-1, ND5775-3, and MSJ461-1. The specific gravities were comparable to a typical year in Michigan (1.087 for Atlantic). Hollow heart and vascular discoloration were the predominant internal defects, as well as higher levels of internal brown spots. The greatest hollow heart was seen in Atlantic (58%) and ND5775-3 (53%). MSL268-D is round-white chip-processing line with foliar late blight resistance and a mid-early maturity.

D. Russet Varieties (Table 4)

The russet trial had 23 lines evaluated in 2006. Russet Burbank and Russet Norkotah were the reference varieties used in the trial and the results are summarized in **Table 4**. Scab resistance was prevalent among the lines tested. Hollow heart was the most prevalent internal defect. The most hollow heart was observed in A93157-6LS, AND98324-1RUS, and MSA8254-2BRUS. Specific gravity measurements were average with Russet Burbank and Russet Norkotah having 1.076 and 1.066 readings, respectively. The yield of the overall trial was below average for 2006, which has been typical for the Russet trials at the Montcalm Research Farm. Off type and cull tubers were found in nearly all lines tested. Vine maturity varied among lines but it did not correlate with yield. The highest yielding entry was MSL794-BRUS, which has foliar late blight resistance, but does not exhibit strong resistance to scab. MSA8254-2BRUS is a high yielding MSU selection with excellent scab resistance that has also performed well in on-farm trials. Stampede Russet has a very attractive type, but has a low yield. Two of the russets evaluated are being considered for release from Idaho (A93157-6LS) and Wisconsin (W2683-2RUS).

E. Red-Skinned Tablestock Trial (Table 5)

Twelve lines were tested in the red trial in 2006. The highest yielding line was Michigan Purple by 100 cwt, followed by ND5002-3R. In general, internal quality was good, with only MN99460-14R having 18% hollow heart. Tolerance to scab was generally high among the lines in the trial. MSN230-1RY has a rose skin, yellow flesh and late blight resistance. MSN215-2P is a hybrid between Norland and Michigan Purple that has a stronger purple skin than Michigan Purple and has good scab tolerance. MSL228-1 has unique splashes of color around the eyes that may make it attractive to the specialty market. The MSU line MSN109-6RR is a red-skinned and red-flesh line which may offer some specialty tablestock market niches.

F. Adaptation Trial (Tables 6 and 7)

The Adaptation Trial was divided into chip-processing and tablestock trials. The majority of the lines evaluated in the Adaptation Trial were tested in the Preliminary Trial the previous year. Three reference cultivars (Atlantic, Snowden and Pike), two recently released varieties (MegaChip and Monticello) and 19 advanced breeding lines are reported in the chip-processing trial. The trial was harvested after 141 days and the results are summarized in **Table 6**. Lines that combine scab resistance and chip-processing are MSM058-A, MSM102-A, MSN099-B, MSN238-A, and MSN073-2. Good scab resistance was also noted in MSM060-3, MSN190-2, and MSP292-7. MSL603-319Y has foliar late blight resistance and shows promise as a chip-processing line. MS246-B is a good chip-processing line that has yield potential and a specific gravity comparable to Atlantic. Two other promising chip-processing lines are MSL292-A and MSN191-2Y.

In the tablestock trial, Saginaw Gold was the check variety and 11 advanced breeding lines are summarized in the table. The trial was harvested after 127 days and the results are summarized in **Table 7**. In general, the yield was good in this trial and internal defects were low. Four of the 11 lines have late blight resistance and 5 lines have moderate to strong scab resistance. MSP408-14Y was the highest yielding line and has foliar late blight resistance and moderate scab resistance; Boulder and MSK498-1 also yielded well and have moderate scab resistance. MSE221-1 and MSP239-1 are two other tablestock lines with good scab resistance. Promising lines with attractive type for the tablestock market and strong foliar late blight resistance include MSP408-14Y, MSL082-A, MSL183-AY, and MSM148-A. Another line that has a very attractive, smooth type and bright skin is MSN084-3.

G. Preliminary Trial (Tables 8 and 9)

The Preliminary trial is the first replicated trial for evaluating new advanced selections from the MSU potato breeding program. The division of the trials was based upon chip-processing and tablestock utilization. The chip-processing Preliminary Trial had 41 advanced selections and three check varieties (Atlantic, Snowden and Pike). The chip-processing trial that is summarized in **Table 8** was harvested after 136 days. Most lines chip-processed well from the field although the range included some darker chips than average. Specific gravities values and yields were average for the trial. Fifteen of the lines were also classified to be resistant or moderately resistant to scab. Ten lines have demonstrated late blight resistance and 6 are potentially late blight resistant. The two highest yielding lines (MSQ089-1 and MSQ279-7) both had good scab resistance, as well as MSQ089-1 having possible late blight resistance. MSQ070-1 combines scab resistance and foliar late blight resistance with an above average specific gravity and yield. Both MSP459-5 and MSN313-A have excellent chip quality and above average yield potential. MSQ289-1 has strong resistance to scab and an early maturity. The strengths of MSQ047-1 are scab resistance and high specific gravity. Chip quality and late blight resistance are found in MSQ245-1, MSQ214-1, MSQ029-1, and MSP516-A.

Table 9 summarizes the Preliminary Trial tablestock lines, including material from South Africa and Mexico. This tablestock trial was harvested and evaluated after 134 days. Eleven of the 26 lines were late blight resistant, and 4 are possibly late blight resistant. Despite the late blight resistance, the vine maturities were not late in all cases. Six of the lines had chip scores to be considered for chip-processing. MSQ176-6 was the highest yielding line and also has late blight resistance. It sister line, MSQ176-5 has both scab and lat blight resistance and an attractive type for the fresh market. Other tablestock lines with above average yield and late blight resistance are the yellow-fleshed MSQ181-1Y and the red MSQ441-6R. MSQ244-1 is both scab and late blight resistant. The Mexican lines Malinche and Monserrat were of interest due to their late blight resistance. Interestingly, the South African lines grouped together at the low end for yield: Devlin, Caren, Darius, BP1, Eden, Vanderplank, Esco, and Karna.

H. Transgenic Trial (Table 10)

A field trial was conducted to continue to evaluate *Bt-cry1Ia1* transgenic potato lines. The results are summarized in **Table 10.**   The trial this year (129 days) produced smaller tuber sizes yields that were below average. In general, Spunta G2 and Spunta G3 had good overall agronomic performance and good type, consistent with the untransformed parent line Spunta. We are in the process of commercializing Spunta G2 in South Africa. Due to the potato tuber moth problem in the Pacific Northwest, we have tested these lines in Washington State and the resistance is complete in the field. We also have a transgenic line of Jacqueline Lee (MSG274-35.1) that is agronomically similar to Jacqueline Lee. This line also has demonstrated resistance to the potato tuber moth.

I. Potato Scab Evaluation (Table 11)

Each year a replicated field trial at the MSU Soils Farm is conducted to assess resistance to common scab. We are using a modified scale of a 0-5 ranking based upon a combined score for scab coverage and lesion severity. Usually examining one year's data does not indicate which varieties are resistant but it should begin to identify ones that can be classified as susceptible to scab. Our goal is to evaluate important advanced selections and varieties in the study at least three years to obtain a valid estimate of the level of resistance in each line. **Table 11** categorizes many of the varieties and advanced selections tested in 2006 at the MSU Soils Farm Scab Nursery over a three-year period. The varieties and lines are placed into six arbitrary categories based upon scab infection level and lesion severity. A rating of 0 indicates zero infection. A score of 1.0 indicates a trace amount of infection.   A moderate resistance (1.2 – 1.8) correlates with <10% infection. Scores of 4.0 or greater are found on lines with >50% infection and severe pitted lesions.

The check varieties Russet Burbank, Russet Norkotah, Red Norland, NorValley, Pike, Atlantic and Snowden can be used as references (bolded in **Table 11**). In general, most russet lines were scab resistant. This year's results, like 2005, indicate that we have been able to breed numerous lines for the chip-processing and tablestock markets with resistance to scab. A total of 51 lines had a scab rating of 1.5 or better in 2006. Most notable scab resistant MSU lines are MSA8254-2BRUS, MSL007-B, MSK409-1, MSM058-A, MSN215-2P, MSP239-1, MSJ036-A, MSN073-2, MSN099-B, MSH228-6, MSE221-1, MSJ126-9Y, and MSN238-A; as well as some earlier generation lines MSQ289-5, MSQ334-3, MSQ283-2, MSQ293-2, MSQ047-1, MSQ335-2, MSQ461-

1RR, and MSQ493-1. A number of lines with scab resistance also have late blight resistance, including MSP516-A, MSQ086-3, MSM171-A, MSN105-1, MSQ023-5, MSQ039-5. The greater number of MSU lines in the resistant and moderately resistant categories indicates we are making progress in breeding more scab resistant lines for the chip-processing and tablestock markets. Scab results from the disease nursery are also found in the Trial Summaries (**Tables 2-10**).

J. Late Blight Trial

In 2006, a late blight trial was conducted at the Muck Soils Research Farm. As in previous years, over 100 entries were planted for evaluation in replicated plots. The field was planted on June 15 and inoculated July 26 with a combination of isolates. Over the next week, almost seven inches of rain fell at the farm. The flooding from these and subsequent rains damaged the plants beyond recovery. Unfortunately, all plots were destroyed and no data was taken. Fortunately, we are able to continue to test tuber late blight resistance in many of the selections with foliar late blight resistance from past years. We will try again for a successful late blight disease field test in 2007.

K. Blackspot Susceptibility (Table 12)

Increased evaluations of advanced seedlings and new varieties for their susceptibility to blackspot bruising have been implemented in the variety evaluation program over the past decade. Based upon the results collected over the past years, we decided to eliminate the check sample from our bruise assessment. Therefore, a composite bruise sample of each line in the trials was collected. The sample consisted of 25 tubers (a composite of 4 reps) from each line at the time of grading. The 25 tuber sample was held in 50°F storage overnight and then was placed in a hexagon plywood drum and tumbled 10 times to provide a simulated bruise. The samples were peeled in an abrasive peeler in October and individual tubers were assessed for the number of blackspot bruises on each potato. These data are shown in **Table 12**. The bruise data are represented in two ways: percentage of bruise free potatoes and average number of bruises per tuber. A high percentage of bruise-free potatoes is the desired goal; however, the numbers of blackspot bruises per potato is also important. Cultivars which show blackspot incidence greater than Atlantic are approaching the bruise-susceptible rating. In addition, the data is grouped by trial, since the bruise levels can vary between trials. Conducting the simulated bruise on 50°F tubers is helping to standardize the bruise testing. We are observing less variation between trials since we standardized the handling of the bruise sample.

In 2006, the bruise levels were comparable to previous years. The most bruise resistant lines this year from the advanced trials were FL1922, MSM037-3, MSJ126-9Y, MSN105-1, MSM058-A, MSP270-1, MSP335-1, MSP292-7, MSN073-2, MSL292-A, MSN238-A, W2982-1, MSI005-20Y, NY137, MSJ461-1, Stampede Russet, MSA8254-2BRUS, ND5002-3R, MSL228-1, Michigan Purple, MSN215-2P, MSN084-3, MSL183-AY, MSE221-1, MSP197-1, MSP239-1. The most susceptible lines from the advanced trials were Beacon Chipper, FL2048, CO95051-7W, W2324-1, W2133-1, A93157-6LS, W2683-2RUS, Monticello, MSP408-14Y, and MSP498-1Y. From the earlier generation trials, the most bruise resistant lines were MSQ461-1RR, MSQ089-1, MSQ237-2, MSQ029-1, MSQ441-6R, MSQ440-2, and MSQ181-1Y. The most bruise susceptible of this material was MSN313-A, MSP516-A, MSQ293-2, and Malinche. The bruise resistant MSU entries in the US Potato Board/Snack Food Association Trial were MSJ316-A, MSJ461-1, MSJ147-1. Beacon Chipper and Atlantic were the most bruise susceptible in this trial.

Table 1

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

DATE OF HARVEST TRIAL: EARLY HARVEST
MONTCALM RESEARCH FARM
May 8 to August 9, 2006 (94 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	PERCENT (%) TUBER QUALITY[3] HH	VD	IBS	BC	3-YR AVG US#1 CWT/A
FL1879	274	291	94	5	85	10	1	1.078	1.0	45	10	0	0	234
FL2053	262	309	85	12	85	0	3	1.092	1.0	0	0	0	0	-
MSM171-A[LBR]	243	261	93	7	92	1	0	1.064	1.0	0	0	0	0	-
MSJ036-A	240	273	88	12	87	0	0	1.076	2.0	0	0	0	0	204*
MSJ147-1	220	247	89	11	88	1	0	1.078	1.0	0	0	0	0	220
Beacon Chipper	210	233	90	9	88	2	1	1.075	1.5	3	0	0	0	213
MSJ461-1[LBR]	200	246	81	19	81	0	0	1.066	1.0	0	0	0	0	192
MSL007-B	195	229	85	15	85	0	0	1.076	1.0	0	0	0	0	-
MSM051-3	194	215	90	10	88	3	0	1.076	1.0	0	3	0	0	244*
Snowden	**190**	**229**	**83**	**17**	**83**	**0**	**0**	**1.080**	**1.0**	**0**	**15**	**0**	**0**	**216**
Atlantic	**188**	**209**	**90**	**10**	**86**	**4**	**0**	**1.085**	**1.0**	**23**	**0**	**0**	**0**	**241**
MSJ126-9	188	215	87	13	87	1	0	1.072	1.0	0	0	0	0	-
MSL211-3[LBR]	180	207	87	12	86	0	2	1.071	2.5	0	0	0	0	182*
FL1922	174	223	78	22	75	3	0	1.075	1.0	3	0	0	0	151
MSM182-1[LBR]	169	242	70	30	70	0	0	1.067	1.0	0	3	0	0	-
MSK409-1	169	207	82	17	80	1	1	1.078	1.0	3	5	0	0	-
MSH228-6	164	181	91	9	91	0	0	1.074	1.0	0	3	0	0	159
MSM037-3	156	183	86	14	86	0	1	1.065	1.0	0	3	0	0	-
MSK061-4	156	191	81	19	81	0	0	1.083	1.0	0	5	0	0	121*
FL2048	151	174	87	13	87	0	0	1.081	1.0	0	3	0	0	-
Pike	**125**	**154**	**81**	**19**	**81**	**0**	**0**	**1.078**	**1.0**	**0**	**0**	**0**	**0**	**138***
MSN105-1[LBMR]	116	135	86	12	86	0	1	1.076	1.0	0	0	0	0	-
MSJ316-A	104	126	82	17	82	0	0	1.069	1.0	0	0	0	0	95*
MEAN	186	217						1.075						
$LSD_{0.05}$	41	39						0.004						

* Two-Year Average

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.

[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

Table 2

DATE OF HARVEST TRIAL: LATE HARVEST
MONTCALM RESEARCH FARM
May 8 to October 6, 2006 (152 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	PERCENT (%) TUBER QUALITY[3] HH	VD	IBS	BC	SCAB[4]	MAT[5]	3-YR AVG US#1 CWT/A
MSJ036-A	317	391	81	19	80	1	0	1.078	2.0	0	18	3	0	1.2	2.5	301*
FL1879	315	347	91	8	84	7	1	1.078	1.5	55	28	5	0	2.6	1.8	300
Beacon Chipper	299	330	90	9	83	7	1	1.080	1.5	8	45	5	0	1.8	3.0	328
MSJ461-1[LBR]	297	374	79	20	78	2	0	1.073	1.5	5	0	0	0	1.8	3.0	307
MSM037-3	284	334	85	15	84	1	0	1.071	2.0	5	23	0	0	1.6	3.5	-
Atlantic	**272**	**308**	**88**	**11**	**82**	**6**	**1**	**1.087**	**2.0**	**38**	**30**	**13**	**0**	**2.8**	**2.5**	**324**
MSJ316-A	267	311	86	14	80	6	0	1.082	1.5	18	3	0	0	1.6	4.3	286*
MSL007-B	259	315	82	18	80	2	0	1.078	1.5!	0	23	5	0	0.8	2.8	-
Snowden	**258**	**319**	**81**	**18**	**77**	**4**	**1**	**1.081**	**2.0**	**10**	**48**	**5**	**0**	**2.8**	**2.5**	**291**
FL2053	253	329	77	19	74	3	5	1.091	1.5	3	13	0	0	2.5	1.0	-
MSM171-A[LBR]	245	280	87	12	80	7	0	1.061	n/a	0	13	0	0	1.3	1.0	-
MSH228-6	240	273	88	11	83	5	0	1.076	1.5	23	33	5	0	1.4	2.0	228
MSJ126-9Y	222	275	81	19	79	2	1	1.077	1.5	3	28	3	0	1.5	1.3	-
MSM051-3	219	254	86	14	79	8	0	1.072	2.0	5	15	0	0	1.5	1.5	282*
MSJ147-1	217	277	78	21	76	2	0	1.081	1.5	3	13	0	3	1.8	2.8	271
MSM182-1[LBR]	203	326	62	38	61	1	0	1.072	n/a	0	25	8	0	2.7	2.8	-
MSL211-3[LBR]	194	256	76	22	74	2	2	1.079	n/a	0	5	3	0	2.3	2.0	230*
FL2048	191	228	83	16	83	1	1	1.081	2.0	0	40	3	0	3.1	2.5	-
MSK409-1	189	255	74	26	73	1	0	1.076	2.0	3	25	3	0	1.0	1.3	-
FL1922	183	251	73	26	73	0	1	1.077	2.0	0	5	0	0	1.5	1.0	195
MSN105-1[LBMR]	179	237	75	17	74	1	7	1.083	n/a	0	10	0	0	1.5	1.8	-
MSK061-4	166	219	76	24	75	1	0	1.089	1.5	0	50	0	0	1.3	2.8	196*
Pike	**165**	**214**	**77**	**23**	**77**	**0**	**0**	**1.083**	**2.0**	**3**	**33**	**0**	**0**	**1.4**	**3.0**	**192***
MSM053-4	105	154	69	31	69	0	0	1.082	n/a	15	15	10	13	1.7	3.8	-
MEAN	231	286						1.079								
$LSD_{0.05}$	50	48						0.004								

* Two-Year Average

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.

[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

[4]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[5]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 3

ROUND WHITE TRIAL
MONTCALM RESEARCH FARM
May 8 to Septmeber 18, 2006 (134 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	PERCENT (%) TUBER QUALITY[3] HH	VD	IBS	BC	SCAB[4]	MAT[5]	3-YR AVG US#1 CWT/A
W2324-1[NCR]	533	565	94	4	83	11	2	1.084	1.0	0	8	0	0	2.6	3.0	-
ND5775-3[NCR]	489	521	94	5	88	6	1	1.086	1.5	53	0	0	10	2.0	3.0	-
MSJ461-1[LBR NCR]	411	459	90	10	85	5	0	1.075	1.0	0	0	0	0	1.8	3.0	405*
Snowden[NCR]	**385**	**421**	**91**	**7**	**88**	**4**	**1**	**1.080**	**2.0**	**5**	**8**	**0**	**0**	**2.8**	**2.8**	**383***
VC1123-2W/Y	369	415	89	10	86	3	2	1.069	1.0	5	30	3	0	2.2	3.5	-
VC1009-1W/Y	368	426	87	11	83	4	3	1.070	1.5	10	3	0	0	1.9	3.3	-
VC1002-3W/Y	360	413	87	10	85	2	3	1.076	1.5	0	13	10	0	1.8	2.3	-
Atlantic[NCR]	**339**	**368**	**92**	**6**	**81**	**11**	**2**	**1.087**	**2.0**	**58**	**0**	**5**	**0**	**2.8**	**2.0**	**360***
W2982-1	339	382	89	10	86	3	1	1.071	1.0	0	15	3	0	2.4	1.5	-
MSI005-20Y[NCR]	337	391	86	13	81	5	1	1.069	1.5	0	5	0	0	2.5	2.3	368*
NY41-67	334	359	93	5	82	11	2	1.071	1.0	0	13	0	0	1.8	1.5	-
NorValley[NCR]	**327**	**371**	**88**	**9**	**79**	**9**	**3**	**1.072**	**1.0**	**3**	**0**	**3**	**0**	**3.0**	**1.5**	**-**
W2133-1[NCR]	318	359	89	9	84	5	2	1.084	1.5	5	5	5	0	2.0	3.5	294*
W2438-3	311	325	96	4	86	10	1	1.069	2.0	8	25	5	0	2.4	1.3	-
NY137	302	340	89	11	84	4	0	1.059	1.0	0	0	0	0	1.5	1.3	-
MSL268-D[LBR]	302	363	83	14	83	1	2	1.079	1.5	0	15	0	0	2.3	2.0	-
ND7818-1Y[NCR]	300	376	80	16	79	1	5	1.060	1.0	0	10	3	0	3.3	1.0	-
W2717-5	248	288	86	13	84	2	1	1.085	1.0	13	18	0	0	2.5	1.5	237*
MN00307-1[NCR]	232	276	84	16	84	0	0	1.063	2.0	0	0	0	0	1.0	1.8	-
W2310-3	226	259	87	9	85	2	4	1.087	1.0	0	0	0	0	1.8	2.0	223*
W4013-1	212	270	79	20	79	0	1	1.082	1.0	0	3	0	0	2.6	1.0	182
CO95051-7W	189	221	86	14	85	0	1	1.085	1.0	0	0	0	3	1.4	3.3	210*
W2309-7	160	207	77	22	77	0	1	1.083	1.5	18	8	0	0	2.0	1.0	130*
MEAN	321	364						1.076								
$LSD_{0.05}$	71	70						0.004								

* Two-Year Average

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.
[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.
[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[4]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[5]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 4

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

RUSSET and LONG TYPES TRIAL
MONTCALM RESEARCH FARM
May 8 to September 11, 2006 (127 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	PERCENT (%) TUBER QUALITY[2] HH	VD	IBS	BC	SCAB[3]	MAT[4]	3-YR AVG US#1 CWT/A
MSL794-BRUS[LBR]	369	447	83	13	59	24	4	1.080	0	8	5	0	2.5	2.5	315
AND98324-1RUS[NCR]	343	410	84	14	71	12	2	1.084	35	5	0	0	3.0	1.5	-
MSA8254-2BRUS[NCR]	330	437	76	19	62	13	6	1.074	33	3	0	10	0.0	2.5	299
W3328-1RUS	329	416	79	18	74	6	2	1.076	0	0	3	0	1.5	3.0	-
W3140-3RUS[NCR]	305	409	74	25	71	4	1	1.069	0	0	0	0	2.0	1.8	-
W2683-2RUS[NCR]	275	379	73	25	69	4	2	1.074	0	3	0	0	0.3	2.5	281*
W2466-5RUS	274	399	69	31	64	5	0	1.070	3	3	0	0	1.5	2.0	-
CO95086-8RU	272	350	78	20	69	8	2	1.073	5	0	0	0	0.3	1.7	-
A95409-1	269	353	76	19	66	11	4	1.082	0	0	0	0	2.5	2.6	-
A95109-1	262	318	82	16	71	11	2	1.073	3	15	0	0	1.5	2.0	-
CO95172-3RU	250	345	72	26	68	4	1	1.082	0	5	0	0	1.8	2.6	-
ND7882b-7RUS[NCR]	247	362	68	28	67	1	4	1.078	0	3	0	0	1.0	1.3	186*
Russet Burbank[NCR]	**243**	**379**	**64**	**30**	**63**	**1**	**6**	**1.076**	**3**	**0**	**0**	**3**	**2.3**	**2.3**	**195***
A9305-10	240	332	72	21	64	9	7	1.079	0	25	0	0	1.5	2.8	-
A93157-6LS	233	341	69	28	64	5	3	1.090	38	3	0	0	1.5	3.5	-
Stampede Russet	224	316	71	26	68	3	4	1.055	0	10	0	0	1.0	1.0	181
MN18710RUS[NCR]	196	294	67	33	60	7	1	1.076	3	0	0	0	0.8	2.8	-
Superior	193	209	92	6	92	0	1	1.067	3	3	3	0	1.0	1.0	-
Russet Norkotah[NCR]	**162**	**235**	**69**	**29**	**66**	**3**	**2**	**1.066**	**8**	**3**	**0**	**0**	**2.3**	**1.0**	**141**
AOTX95265-3RU	148	255	58	41	56	2	1	1.071	20	5	8	0	2.0	1.3	-
W1879-1RUS[NCR]	146	271	54	46	54	0	0	1.074	0	3	0	0	0.3	1.0	138*
AC96052-1RUS	140	244	57	42	57	0	1	1.080	3	3	5	0	0.8	3.5	-
AOTX95295-3RU	71	185	39	61	39	0	1	1.071	8	3	3	3	1.5	1.0	-
MEAN	240	334						1.075							
$LSD_{0.05}$	54	63						0.003							

* Two-Year Average

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 4 oz.; A: 4-10 oz.; OV: > 10 oz.; PO: Pickouts.

[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[4]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 5

MICHIGAN STATE UNIVERSITY

POTATO BREEDING and GENETICS

RED-SKINNED TABLESTOCK TRIAL
MONTCALM RESEARCH FARM
May 8 to September 18, 2006 (134 days)

	CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]
Michigan Purple	433	451	96	3	76	20	1	1.066	3	5	0	0	2.8	1.8
ND5002-3R[NCR]	332	379	87	12	86	2	0	1.065	0	8	0	0	1.0	3.3
ATTX961014-1RY	275	331	83	17	82	1	0	1.067	0	0	0	0	3.6	1.8
MSN109-6RR	270	373	72	25	72	0	3	1.062	0	0	0	0	2.3	4.0
Red Norland[NCR]	**258**	**280**	**92**	**8**	**90**	**1**	**0**	**1.054**	**0**	**10**	**0**	**0**	**1.0**	**1.0**
MN99460-14R[NCR]	256	314	81	18	78	3	1	1.070	18	30	0	0	2.0	1.8
COTX00104-7R	256	316	81	10	76	5	9	1.058	0	8	0	0	1.6	3.5
ND4659-5R[NCR]	232	277	84	16	82	2	0	1.064	0	0	0	0	1.3	1.4
MSL228-1	231	257	90	8	86	4	3	1.074	3	10	0	0	2.6	2.3
MSN215-2P	217	282	77	20	76	0	4	1.068	0	3	0	0	1.1	1.3
MSN230-1RY[LBR]	211	278	76	24	76	0	0	1.082	0	0	0	0	1.9	3.7
MN00177-6R[NCR]	80	210	38	61	38	0	1	1.064	0	0	0	0	0.9	1.8
MEAN	254	313						1.066						
$LSD_{0.05}$	52	51						0.002						

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[4]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 6

MICHIGAN STATE UNIVERSITY

POTATO BREEDING and GENETICS

ADAPTATION TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH FARM
May 8 to September 25, 2006 (141 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	PERCENT (%) TUBER QUALITY[3] HH	VD	IBS	BC	SCAB[4]	MAT[5]
Monticello	362	413	88	12	87	1	0	1.082	1.5	5	15	0	0	2.3	2.3
MegaChip	350	373	94	5	87	7	1	1.087	2.0	5	28	0	0	1.5	2.3
Atlantic	**345**	**365**	**95**	**5**	**91**	**3**	**1**	**1.086**	**1.5**	**13**	**18**	**0**	**0**	**3.0**	**1.8**
MSM246-B	331	345	96	4	84	12	0	1.085	1.0	5	20	0	0	2.5	2.7
Snowden	**313**	**353**	**89**	**11**	**87**	**1**	**1**	**1.081**	**1.5**	**5**	**5**	**0**	**0**	**3.0**	**2.8**
MSP335-1	309	342	90	10	88	2	0	1.070	1.5	0	15	0	0	2.5	1.0
MSN099-B	307	340	90	8	84	6	2	1.076	2.0	3	5	0	0	1.3	1.0
MSN180-3	302	332	91	9	86	5	0	1.078	1.5	3	13	0	0	3.0	1.3
MSL603-319Y[LBR]	292	332	88	11	85	3	1	1.077	1.5	8	5	0	0	2.8	2.3
MSM058-A	292	332	88	10	86	2	2	1.070	1.5	0	5	0	0	1.0	2.5
MSL292-A	284	310	92	8	86	6	1	1.077	1.5	5	8	0	0	2.5	1.0
MSN238-A	281	293	96	4	92	4	0	1.083	1.5	20	8	0	0	1.5	2.3
MSN191-2Y	272	302	90	10	89	1	0	1.090	1.5	0	3	0	0	2.5	2.5
MSP270-1	260	290	90	9	84	6	1	1.069	1.0	3	3	0	0	2.3	3.8
MSM108-A	259	306	85	15	84	1	0	1.083	1.5	23	8	0	0	2.5	2.0
MSN184-2	257	293	88	8	82	5	4	1.069	1.5	0	3	0	0	2.0	2.8
MSN073-2	254	288	88	11	87	1	1	1.076	1.5	3	3	0	0	1.3	1.3
MSN190-2	252	284	89	10	87	2	1	1.082	1.5	5	8	3	0	1.8	1.5
MSM060-3	247	301	82	16	81	1	2	1.085	2.0	8	15	0	0	1.8	2.0
Pike	**233**	**260**	**90**	**10**	**87**	**3**	**0**	**1.083**	**1.0**	**0**	**5**	**0**	**0**	**1.3**	**3.0**
MSN135-A	224	297	76	22	74	1	2	1.083	1.0	0	5	0	0	3.0	1.5
MSP292-7	213	251	85	14	81	4	1	1.079	2.0	5	3	0	0	1.8	1.0
MSM102-A	202	239	84	14	80	4	2	1.084	1.0	0	3	0	0	1.5	2.5
MSM046-E	156	179	87	12	87	1	0	1.069	1.5	0	0	0	0	2.3	1.5
MEAN	275	309						1.079							
$LSD_{0.05}$	59	59						0.003							

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.

[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

[4]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[5]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 7

ADAPTATION TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH FARM
May 8 to September 11, 2006 (127 days)

	CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]
MSP408-14Y[LBR]	421	460	92	5	77	14	3	1.068	0	3	0	0	2.0	2.8
Boulder	398	401	99	1	44	55	0	1.079	0	0	0	0	1.8	3.3
MSK498-1	393	421	93	7	92	2	0	1.076	0	0	0	0	2.0	3.0
MSP197-1	352	367	96	3	77	18	1	1.067	30	5	0	0	3.0	1.0
MSL082-A[LBR]	344	415	83	14	81	2	3	1.078	5	0	0	0	3.0	2.3
Saginaw Gold	**301**	**336**	**90**	**10**	**88**	**1**	**0**	**1.071**	**0**	**0**	**0**	**0**	**2.3**	**1.0**
MSE221-1	265	286	92	3	80	12	5	1.069	5	20	0	0	1.5	1.5
MSL183-AY[LBR]	257	289	89	11	84	5	0	1.065	0	0	0	0	3.0	1.3
MSN084-3	256	266	96	4	87	9	0	1.064	5	5	0	0	2.5	1.8
MSP239-1	227	244	93	7	89	4	0	1.072	0	5	3	0	1.3	1.5
MSM148-A[LBR]	224	294	76	20	75	1	4	1.078	0	15	0	0	2.3	2.5
MSN032-A	212	334	63	34	63	0	2	1.077	3	0	0	0	3.0	1.5
MEAN	304	343						1.072						
$LSD_{0.05}$	48	53						0.002						

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.

[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[4]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 8

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

PRELIMINARY TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH FARM
May 8 to Septmeber 20, 2006 (136 days)

	CWT/A		PERCENT OF TOTAL[1]							PERCENT (%) TUBER QUALITY[3]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	HH	VD	IBS	BC	SCAB[4]	MAT[5]
MSQ089-1[LBR?]	409	452	91	8	83	8	1	1.068	1.0	0	0	5	0	1.0	3.0
MSQ279-7	397	414	96	4	80	16	0	1.086	2.5	0	0	10	0	1.0	3.5
MSQ245-1[LBR]	386	459	84	15	82	2	1	1.079	1.5	20	5	0	0	3.0	3.0
MSQ035-2[LBR]	376	423	89	11	87	2	0	1.061	1.0	0	15	0	0	3.0	5.0
MSP524-C	370	444	83	15	78	5	2	1.076	3.0	0	0	0	0	3.0	2.0
MSQ245-2[LBR?]	363	446	81	17	80	2	1	1.080	1.5	5	15	0	0	2.5	3.3
MSQ082-3[LBR?]	360	393	92	8	89	2	1	1.083	1.0	40	0	0	0	2.0	4.0
MSP459-5	355	387	92	8	91	1	1	1.075	1.0!	10	5	0	0	2.0	1.0
MSQ461-1RR	347	382	91	9	80	11	0	1.069	2.0	0	0	0	0	1.5	4.5
MSN313-A	344	411	84	15	83	1	1	1.088	1.0	15	0	0	0	3.0	4.0
MSQ070-1[LBR]	334	365	92	8	92	0	0	1.088	2.0	0	0	0	0	1.0	4.0
MSQ214-1[LBR]	330	368	90	10	88	2	0	1.083	2.0	25	0	0	0	2.0	4.0
Atlantic	**326**	**350**	**93**	**6**	**87**	**6**	**1**	**1.086**	**1.5**	**35**	**5**	**0**	**0**	**3.0**	**1.5**
Snowden	**325**	**354**	**92**	**8**	**90**	**2**	**1**	**1.076**	**1.5**	**15**	**50**	**0**	**0**	**3.0**	**1.0**
MSQ039-5[LBR?]	311	327	95	5	77	18	0	1.083	2.5	10	0	5	0	1.5	4.0
MSQ363-2	311	331	94	6	88	6	0	1.074	1.5	25	0	0	0	2.5	1.0
MSQ293-2	311	340	91	9	87	4	0	1.081	2.0	5	0	5	5	1.3	2.0
MSQ029-1[LBR]	303	334	91	8	84	6	1	1.071	1.5	5	10	0	0	2.0	5.0
MSP542-4	297	332	89	11	83	6	0	1.077	2.0	25	5	0	0	3.0	2.0
MSQ201-1[LBR?]	293	336	87	13	87	0	0	1.079	2.0	10	0	0	0	3.0	2.5
MSQ108-1[LBR]	289	302	96	4	90	6	0	1.075	2.0	0	0	0	0	2.5	2.0
MSQ335-2	286	322	89	11	89	0	0	1.073	1.5	0	10	0	0	1.5	1.0
MSQ289-5	281	291	97	3	90	7	0	1.079	1.5	0	20	10	0	0.5	1.0
MSQ047-1	277	327	85	15	85	0	0	1.089	2.0	0	5	0	0	1.5	3.5
MSQ060-5[LBR?]	270	326	83	17	83	0	0	1.074	2.5	0	0	0	0	2.0	3.5

continued on next page:

PRELIMINARY TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH FARM
May 8 to Septmeber 20, 2006 (136 days)

	CWT/A		PERCENT OF TOTAL[1]						CHIP	PERCENT (%) TUBER QUALITY[3]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[2]	HH	VD	IBS	BC	SCAB[4]	MAT[5]
continued:															
MSQ490-3	270	305	89	11	86	2	0	1.076	1.5	15	0	0	0	2.5	4.0
MSP542-11	269	334	81	19	81	0	0	1.080	2.0	0	0	0	0	3.0	3.0
MSQ001-1	269	310	87	13	86	1	0	1.078	1.5	15	0	15	0	3.0	2.0
MSP368-1	268	318	84	14	82	2	2	1.081	1.0	10	10	0	0	2.8	2.0
MSP516-A[LBR]	264	298	89	11	89	0	0	1.076	1.5	0	0	0	0	1.0	3.5
MSQ237-2	261	277	94	6	88	7	0	1.070	1.0	0	10	0	0	ND	4.0
Pike	**257**	**290**	**89**	**11**	**87**	**2**	**0**	**1.083**	**1.0**	**5**	**5**	**0**	**0**	**1.3**	**3.5**
MSQ283-2	254	278	92	7	87	4	1	1.074	1.5	10	5	0	0	1.3	1.0
MSP557-B[LBR]	250	306	82	16	82	0	2	1.080	1.0	0	0	0	0	2.5	4.0
MSQ023-5[LBR]	241	265	91	9	87	4	0	1.086	1.0	10	10	0	0	1.5	4.5
MSQ492-2[LBR]	237	270	88	12	85	2	0	1.072	2.0	0	10	5	0	1.8	4.5
MSQ334-3	235	264	89	11	82	7	0	1.059	2.5	20	5	15	0	1.0	2.0
MSM080-1	226	251	90	8	90	0	2	1.075	1.0	5	0	0	0	2.5	1.0
MSQ493-1	210	237	89	10	87	1	1	1.083	1.5	5	0	0	0	1.5	2.5
MSQ383-2	205	244	84	15	80	4	1	1.077	1.5	10	5	5	0	2.5	2.0
MSQ393-11	204	238	86	13	84	3	1	1.072	1.5	0	30	10	0	2.5	2.5
MSP346-5	197	246	80	18	80	0	2	1.083	1.0	5	10	10	0	2.5	3.0
MSN236-A	156	244	64	36	64	0	0	1.071	2.0	0	20	0	0	3.0	2.0
MSQ405-1PP	110	200	55	44	55	0	1	1.066	2.0	0	0	0	0	3.0	4.5
MEAN	287	327						1.077							
$LSD_{0.05}$	78	90						0.005							

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.

[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 20 Oversize and/or A-size tubers cut.

[4]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[5]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 9

PRELIMINARY TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH FARM
May 8 - September 18, 2006 (134 days)

	CWT/A		PERCENT OF TOTAL[1]						CHIP	PERCENT (%) TUBER QUALITY[3]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[2]	HH	VD	IBS	BC	SCAB[4]	MAT[5]
MSQ176-6[LBR]	398	436	91	8	84	8	1	1.073	1.0	40	0	0	0	3.0	4.0
MSQ434-4P	393	414	95	3	67	28	2	1.063	3.0	0	20	0	0	2.0	2.5
MSQ181-1Y[LBR?]	362	409	88	6	80	8	6	1.061	1.5	0	5	5	0	2.0	3.5
MSQ176-5[LBR]	339	362	94	5	78	16	1	1.068	2.5	10	0	5	0	2.5	1.5
MSQ441-6R[LBR]	325	350	93	7	89	3	0	1.055	3.0	5	5	0	0	3.0	1.0
MSQ410-4P	322	377	85	14	85	0	1	1.076	2.0	0	5	0	0	2.0	2.0
Malinche[LBR]	301	381	79	18	79	0	3	1.087	2.0	0	10	5	0	ND	5.0
MSQ244-1[LBR]	297	325	91	7	90	1	2	1.083	3.0	0	0	10	0	1.0	4.5
MSN111-4PP	286	331	86	13	86	0	0	1.070	2.0	0	0	0	0	2.5	1.0
MSQ086-3[LBR]	269	284	95	4	85	10	1	1.079	2.5	25	5	0	0	1.0	3.5
MSE69.6[LBR]	267	310	86	14	86	0	0	1.066	2.0	10	5	10	0	2.5	2.0
Spunta RB[LBR]	265	319	83	14	80	3	3	1.064	4.0	5	0	0	5	ND	3.0
MSQ087-3[LBR?]	262	283	92	6	92	0	1	1.069	3.0	0	5	0	0	1.0	1.5
MSQ134-5[LBR?]	256	283	90	9	89	1	0	1.069	1.5	0	5	0	0	1.0	2.5
MSQ440-2[LBR?]	246	263	94	6	86	7	1	1.056	4.0	0	30	0	0	1.8	1.5
Teena[LBR]	245	396	62	22	62	0	17	1.071	3.0	0	20	80	0	1.8	4.5
Devlin	243	286	85	11	83	2	3	1.078	1.5	50	20	0	0	2.0	3.0
Caren	220	332	66	20	66	0	14	1.080	4.0	15	5	10	0	2.0	4.0
Darius	182	240	76	21	76	0	3	1.077	2.5	25	15	0	0	2.5	3.5
BP1	175	248	70	22	70	0	8	1.069	2.5	10	0	5	0	2.3	5.0
Eden	174	256	68	21	68	0	11	1.080	1.5	15	50	0	0	2.5	5.0
Vanderplank	134	175	76	17	76	0	6	1.058	4.0	25	40	5	0	ND	2.0
Esco	128	188	68	23	68	0	8	1.067	1.5	5	10	0	0	2.0	5.0
Kufri Jeeven[LBR]	126	209	60	33	60	0	6	1.061	4.0	0	35	5	0	ND	2.5
Monserrat[LBR]	115	244	47	34	47	0	19	1.078	4.0	20	0	100	0	ND	5.0
Karna	12	84	15	75	15	0	10	1.079	ND	0	0	0	0	2.3	5.0
MEAN	244	300						1.071							
$LSD_{0.05}$	69	72						0.004							

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.

[2]CHIP SCORE: Snack Food Association Scale (Out of the field); Ratings: 1-5; 1: Excellent, 5: Poor.

[3]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 20 Oversize and/or A-size tubers cut.

[4]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

[5]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 10

Bt TRANSGENIC TRIAL
MONTCALM RESEARCH FARM
May 8 - September 13, 2006 (129 days)

	CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]					
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]
G274-3.5.1	126	399	32	65	32	0	4	1.076	0	8	0	0	ND	1.8
Jacqueline Lee	**186**	**405**	**46**	**51**	**44**	**2**	**3**	**1.079**	**0**	**5**	**0**	**0**	**ND**	**2.8**
Spunta	**289**	**357**	**81**	**14**	**58**	**23**	**5**	**1.055**	**23**	**3**	**8**	**0**	**ND**	**3.0**
Spunta G2	286	367	78	17	66	12	5	1.062	8	18	0	0	ND	2.5
Spunta G3	316	396	80	14	69	11	7	1.061	3	13	0	0	ND	3.0
MEAN	241	385						1.067						
$LSD_{0.05}$	90	NS						0.003						

[1]SIZE: B: < 2 in.; A: 2-3.25 in.; OV: > 3.25 in.; PO: Pickouts.
[2]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[3]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[4]MATURITY RATING: August 30, 2006; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

Table 11

2004-2006 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, EAST LANSING, MI

	2006	2006	2006	2005	2005	2005	2004	2004	2004
LINE	RATING	WORST	N	RATING	WORST	N	RATING	WORST	N
Sorted by ascending 2006 Rating;									
MSA8254-2BRUS[NCR]	0.0	0	4	0.0	0	5	0.0	0	4
CO95086-8RU	0.3	1	4	1.0	1	3	-	-	-
ND7994-1RUS	0.3	1	4	0.8	1	4	0.0	0	4
W1879-1RUS[NCR]	0.3	3	4	0.3	1	3	-	-	-
W2683-2RUS[NCR]	0.3	1	4	0.3	1	6	-	-	-
MSQ289-5	0.5	1	4	-	-	-	-	-	-
AC96052-1RUS	0.8	2	4	-	-	-	-	-	-
MN18710RUS[NCR]	0.8	1	4	-	-	-	-	-	-
MSL007-B	0.8	1	4	0.8	1	4	2.0	3	4
ND7882b-7RUS[NCR]	0.8	1	4	-	-	-	-	-	-
MN00177-6R[NCR]	0.9	2	4	-	-	-	-	-	-
MN00307-1[NCR]	1.0	1	4	-	-	-	-	-	-
MSK409-1	1.0	1	4	0.7	1	3	1.3	2	3
MSM058-A	1.0	1	4	0.8	1	4	-	-	-
MSP516-A[LBR]	1.0	1	1	-	-	-	-	-	-
MSQ086-3[LBR]	1.0	1	4	-	-	-	-	-	-
MSQ334-3	1.0	1	3	-	-	-	-	-	-
ND5002-3R[NCR]	1.0	1	4	-	-	-	-	-	-
Red Norland[NCR]	**1.0**	**2**	**4**	-	-	-	-	-	-
Stampede Russet	1.0	1	4	1.0	1	4	0.5	1	2
Superior	1.0	1	4	-	-	-	-	-	-
MSN215-2P	1.1	2	4	1.0	1	4	-	-	-
MSP239-1	1.1	2	4	1.0	1	3	-	-	-
MSJ036-A	1.2	2	3	0.8	1	4	0.8	1	4
CO95172-3RU	1.3	2	4	-	-	-	-	-	-
MSM171-A[LBR]	1.3	2	4	1.0	1	3	2.5	4	4
MSN073-2	1.3	2	4	1.5	2	2	-	-	-
MSN099-B	1.3	2	4	1.3	2	4	-	-	-
MSQ283-2	1.3	2	4	-	-	-	-	-	-
MSQ293-2	1.3	2	4	-	-	-	-	-	-
MSQ480-7RR	1.3	2	4	-	-	-	-	-	-
ND4659-5R[NCR]	1.3	3	4	-	-	-	-	-	-
MSK061-4	1.3	2	3	0.8	1	4	1.3	2	4
Pike	**1.4**	**2**	**7**	**1.0**	**1**	**8**	**0.9**	**1**	**7**
A93157-6LS	1.4	3	4	0.8	2	4	-	-	-
CO95051-7W	1.4	2	4	0.5	1	2	-	-	-
MSH228-6	1.4	2	4	1.0	1	4	1.3	2	4
FL1922	1.5	2	4	1.0	1	4	1.0	1	4
MegaChip	1.5	2	4	1.0	2	4	-	-	-
MSE221-1	1.5	2	4	1.0	1	4	-	-	-

2004-2006 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, EAST LANSING, MI

	2006	2006	2006	2005	2005	2005	2004	2004	2004
LINE	RATING	WORST	N	RATING	WORST	N	RATING	WORST	N
Sorted by ascending 2006 Rating;									
MSJ126-9Y	1.5	2	4	1.0	1	3	1.3	2	3
MSM051-3	1.5	3	4	0.7	1	3	1.0	1	4
MSN105-1[LBMR]	1.5	2	2	1.0	1	3	1.3	2	3
MSN238-A	1.5	2	4	1.0	1	4	-	-	-
MSQ023-5[LBR]	1.5	2	2	-	-	-	-	-	-
MSQ039-5[LBR?]	1.5	2	4	-	-	-	-	-	-
MSQ047-1	1.5	2	2	-	-	-	-	-	-
MSQ335-2	1.5	2	3	-	-	-	-	-	-
MSQ461-1RR	1.5	2	1	-	-	-	-	-	-
MSQ493-1	1.5	2	2	-	-	-	-	-	-
NY137	1.5	2	4	-	-	-	-	-	-
W2466-5RUS	1.5	2	3	-	-	-	-	-	-
W3328-1RUS	1.5	2	4	-	-	-	-	-	-
Boulder	1.6	2	4	-	-	-	-	-	-
COTX00104-7R	1.6	2	4	-	-	-	-	-	-
MSJ316-A	1.6	2	4	1.0	1	4	-	-	-
MSM037-3	1.6	3	4	1.0	1	4	1.3	2	4
MSM102-A	1.6	2	4	1.0	1	4	-	-	-
MSN190-2	1.6	2	4	1.3	2	4	-	-	-
A95109-1	1.7	3	3	0.0	0	4	1.8	2	4
AOTX95295-3RU	1.7	3	6	-	-	-	-	-	-
MSM053-4	1.7	2	3	1.5	2	4	2.0	3	4
MSP292-7	1.7	2	3	1.0	1	4	-	-	-
Beacon Chipper	1.8	2	4	1.0	1	4	1.5	2	4
MSJ147-1	1.8	2	4	2.0	2	4	1.8	2	4
MSJ461-1[LBR NCR]	1.8	2	4	1.3	2	7	1.8	2	4
MSQ440-2[LBR?]	1.8	2	4	-	-	-	-	-	-
NY41-67	1.8	2	4	-	-	-	-	-	-
Teena[LBR]	1.8	2	4	-	-	-	-	-	-
VC1002-3W/Y	1.8	3	4	-	-	-	-	-	-
W2310-3	1.8	3	4	1.5	2	4	-	-	-
MSM060-3	1.8	2	3	1.0	1	4	1.0	1	4
MSP408-10Y	1.8	2	3	1.0	2	4	-	-	-
MSQ383-2	1.8	3	3	-	-	-	-	-	-
MSQ492-2[LBR]	1.8	2	3	-	-	-	-	-	-
A9305-10	1.9	3	7	-	-	-	-	-	-
MSE202-3RUS	1.9	3	4	-	-	-	-	-	-
MSN230-1RY[LBR]	1.9	3	4	0.8	1	4	-	-	-
MSQ434-4P	1.9	2	4	-	-	-	-	-	-
VC1009-1W/Y	1.9	3	4	-	-	-	-	-	-
W3140-3RUS[NCR]	1.9	2	4	-	-	-	-	-	-
Caren	2.0	2	4	-	-	-	-	-	-

2004-2006 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, EAST LANSING, MI

	2006	2006	2006	2005	2005	2005	2004	2004	2004
LINE	RATING	WORST	N	RATING	WORST	N	RATING	WORST	N
Sorted by ascending 2006 Rating;									
Esco	2.0	2	1	-	-	-	-	-	-
MN99460-14R[NCR]	2.0	3	4	-	-	-	-	-	-
MSK498-1	2.0	2	4	1.8	2	4	1.5	2	4
MSN108-3	2.0	2	1	-	-	-	-	-	-
MSN184-2	2.0	3	4	1.0	1	4	1.8	2	4
MSP346-5	2.0	3	4	-	-	-	-	-	-
MSP408-14Y[LBR]	2.0	2	4	2.0	3	3	-	-	-
MSP459-5	2.0	2	4	1.3	2	3	-	-	-
MSQ029-1[LBR]	2.0	2	1	-	-	-	-	-	-
MSQ060-5[LBR?]	2.0	3	3	-	-	-	-	-	-
MSQ082-3[LBR?]	2.0	3	2	-	-	-	-	-	-
MSQ181-1Y[LBR?]	2.0	2	2	-	-	-	-	-	-
ND5775-3[NCR]	2.0	3	3	-	-	-	-	-	-
W2133-1[NCR]	2.0	2	4	1.0	1	4	1.5	2	4
W2309-7	2.0	2	3	1.3	2	3	-	-	-
W2438-5	2.0	2	1	-	-	-	-	-	-
MSM148-A[LBR]	2.1	3	4	0.8	1	4	1.0	1	2
MSN106-2	2.1	3	4	1.0	1	3	-	-	-
Devlin	2.2	3	3	-	-	-	-	-	-
Russet Norkotah[NCR]	**2.2**	**3**	**3**	**1.3**	**2**	**4**	**1.3**	**2**	**4**
VC1123-2W/Y	2.2	1	3	-	-	-	-	-	-
A95409-1	2.2	3	5	-	-	-	-	-	-
BP1	2.3	3	4	-	-	-	-	-	-
Karna	2.3	3	4	-	-	-	-	-	-
Monticello	2.3	3	4	1.0	1	4	-	-	-
MSL072-C	2.3	3	4	2.0	3	4	2.0	2	2
MSL211-3[LBR]	2.3	3	4	1.0	1	4	1.3	2	4
MSL268-D	2.3	3	4	1.0	2	4	2.0	3	3
MSM046-E	2.3	3	4	-	-	-	-	-	-
MSN109-6RR	2.3	3	4	0.0	0	1	-	-	-
MSQ410-4P	2.3	3	2	-	-	-	-	-	-
MSQ490-3	2.3	3	2	-	-	-	-	-	-
Russet Burbank[NCR]	**2.3**	**2**	**4**	-	-	-	-	-	-
Saginaw Gold	2.3	3	4	-	-	-	-	-	-
MSP270-1	2.3	3	3	1.0	1	4	-	-	-
MSQ108-1[LBR]	2.3	3	3	-	-	-	-	-	-
MSM080-1	2.4	3	4	-	-	-	-	-	-
MSM246-B	2.4	4	4	1.0	2	4	-	-	-
W2438-3	2.4	2	4	-	-	-	-	-	-
W2982-1	2.4	3	4	-	-	-	-	-	-
Darius	2.5	3	2	-	-	-	-	-	-
Eden	2.5	3	4	-	-	-	-	-	-

2004-2006 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, EAST LANSING, MI

LINE	2006 RATING	2006 WORST	2006 N	2005 RATING	2005 WORST	2005 N	2004 RATING	2004 WORST	2004 N
Sorted by ascending 2006 Rating;									
FL2053	2.5	3	4	-	-	-	-	-	-
MSI005-20Y[NCR]	2.5	3	4	1.3	2	4	1.3	2	4
MSL292-A	2.5	3	4	1.0	1	3	2.0	3	3
MSL794-BRUS[LBR]	2.5	3	4	1.3	2	4	2.0	3	4
MSM108-A	2.5	3	4	1.5	3	4	-	-	-
MSN084-3	2.5	3	4	2.3	3	4	-	-	-
MSN111-4PP	2.5	3	4	2.0	3	4	-	-	-
MSN191-2Y	2.5	3	4	1.5	2	2	-	-	-
MSP232-B	2.5	3	2	-	-	-	-	-	-
MSP335-1	2.5	3	2	-	-	-	-	-	-
MSP557-B[LBR]	2.5	3	3	-	-	-	-	-	-
MSQ176-5[LBR]	2.5	3	2	-	-	-	-	-	-
MSQ245-1[LBR]	2.5	2	2	-	-	-	-	-	-
MSQ393-11	2.5	3	2	-	-	-	-	-	-
W2717-5	2.5	3	4	1.8	3	4	-	-	-
FL1879	2.6	3	4	2.3	3	3	2.5	3	4
MSE69.6[LBR]	2.6	4	4	-	-	-	-	-	-
MSL228-1	2.6	3	4	2.0	3	4	1.8	3	4
MSN135-A	2.6	3	4	-	-	-	-	-	-
W2324-1[NCR]	2.6	3	4	-	-	-	-	-	-
W4013-1	2.6	3	4	2.0	2	4	-	-	-
MSM182-1[LBR]	2.7	3	3	1.8	2	4	-	-	-
Michigan Purple	2.8	3	4	1.5	2	6	3.3	4	4
MSL603-319Y[LBR]	2.8	3	4	1.7	2	3	-	-	-
MSP368-1	2.8	3	4	1.0	1	4	-	-	-
Atlantic[NCR]	**2.8**	**3**	**16**	**1.6**	**2**	**11**	**2.1**	**3**	**15**
MSN180-3	2.8	4	3	2.3	3	4	-	-	-
Snowden[NCR]	**2.8**	**3**	**16**	**2.0**	**3**	**12**	**1.9**	**3**	**8**
MSL082-A[LBR]	2.9	3	4	1.0	2	3	-	-	-
AND98324-1RUS[NCR]	3.0	4	4	-	-	-	-	-	-
AOTX95265-3RU	3.0	3	2	-	-	-	-	-	-
MSL183-AY[LBR]	3.0	3	3	2.0	2	4	2.0	2	2
MSN032-A	3.0	3	4	-	-	-	-	-	-
MSN236-A	3.0	3	4	2.0	2	2	-	-	-
MSN313-A	3.0	3	4	1.0	2	4			
MSP197-1	3.0	3	4	1.5	2	4	-	-	-
MSP403-2	3.0	3	4	0.5	1	2	-	-	-
MSP524-C	3.0	3	2	-	-	-	-	-	-
MSP542-11	3.0	3	4	2.0	3	4	-	-	-
MSP542-4	3.0	3	3	1.3	2	4	-	-	-
MSQ001-1	3.0	3	2	-	-	-	-	-	-

2004-2006 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, EAST LANSING, MI

	2006	2006	2006	2005	2005	2005	2004	2004	2004
LINE	RATING	WORST	N	RATING	WORST	N	RATING	WORST	N
Sorted by ascending 2006 Rating;									
MSQ035-2[LBR]	3.0	3	2	-	-	-	-	-	-
MSQ176-6[LBR]	3.0	3	2	-	-	-	-	-	-
MSQ201-1[LBR?]	3.0	3	2	-	-	-	-	-	-
MSQ363-2	3.0	3	1	-	-	-	-	-	-
MSQ405-1PP	3.0	3	1	-	-	-	-	-	-
MSQ441-6R[LBR]	3.0	3	2	-	-	-	-	-	-
NorValley[NCR]	3.0	3	4	-	-	-	-	-	-
FL2048	3.1	4	4	-	-	-	-	-	-
ND7818-1Y[NCR]	3.3	4	4	-	-	-	-	-	-
MSK128-A	3.6	4	5	2.0	3	3	2.8	4	4
ATTX961014-1RY	3.6	5	4	-	-	-	-	-	-

*SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.

$LSD_{0.05}$ = 0.9

[LBR] Line(s) demonstrated foliar resistance to Late Blight (*Phytopthora infestans*) in inoculated field trials at the MSU Muck Soils Research Farm.

[NCR] North Central Regional Entry

N = Number of replications (observations).

Table 12

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
DATE OF HARVEST: LATE HARVEST								
FL1922	14	5					74	0.3
MSM037-3	14	5	1				70	0.4
MSJ126-9Y	13	6	1				65	0.4
MSN105-1	13	5	2				65	0.5
MSJ316-A	9	8	2				47	0.6
MSM051-3	10	6	1		1		56	0.7
MSH228-6	9	8	3				45	0.7
MSK409-1	9	8	3				45	0.7
MSK061-4	8	8	3				42	0.7
MSM182-1	7	11	2				35	0.8
Pike	**11**	**5**	**3**		**1**		**55**	**0.8**
FL1879	8	8	4				40	0.8
MSM171-A	7	7	2	1			41	0.8
FL2053	8	6	5				42	0.8
MSJ147-1	8	6	2	4			40	1.1
MSJ036-A	3	11	6				15	1.2
MSL211-3	6	5	7	2			30	1.3
MSJ461-1	7	4	4	4			37	1.3
MSL007-B	6	5	6	3			30	1.3
Snowden	**4**	**8**	**2**	**5**			**21**	**1.4**
Atlantic	**3**	**5**	**4**	**5**	**2**		**16**	**1.9**
Beacon Chipper	1	6	4	7			**6**	**1.9**
FL2048	0	7	7	4		1	0	2.0
ROUND-WHITE TRIAL								
NY41-67	19	1					95	0.1
VC1009-1W/Y	18	2					90	0.1
ND7818-1Y	17	3					85	0.2
W2982-1	16	4					80	0.2
MN00307-1	15	2	1				83	0.2
MSI005-20Y	15	5					75	0.3
NY137	16	3	1				80	0.3
VC1002-3W/Y	15	5					75	0.3
VC1123-2W/Y	13	6					68	0.3
W2438-3	14	5	1				70	0.4
ND5775-3	13	6	1				65	0.4
W2309-7	13	6	1				65	0.4
W2717-5	12	7	1				60	0.5
MSJ461-1	13	5	1	1			65	0.5
W2310-3	10	9	1				50	0.6

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
Snowden	**7**	**9**	**4**				**35**	**0.9**
MSL268-D	6	8	4	1			32	1.0
NorValley	6	10	2	2			30	1.0
W4013-1	2	15	3				10	1.1
Atlantic	**8**	**4**	**3**	**2**	**1**		**44**	**1.1**
CO95051-7W	5	8	5	2			25	1.2
W2324-1	5	6	7	2			25	1.3
W2133-1	3	7	9				16	1.3
RUSSET TRIAL								
AOTX95265-3RU	18	2					90	0.1
CO95086-8RU	18	2					90	0.1
Stampede Russet	18	2					90	0.1
Russet Norkotah	**17**	**3**					**85**	**0.2**
A9305-10	16	4					80	0.2
AOTX95295-3RU	18	1		1			90	0.2
MSA8254-2BRUS	16	4	1				76	0.3
W3140-3RUS	14	5	1				70	0.4
MN18710RUS	12	6	2				60	0.5
CO95172-3RU	13	4	2	1			65	0.6
ND7882b-7RUS	11	7	2				55	0.6
ND7994-1RUS	8	4	1	1			57	0.6
Russet Burbank	**10**	**7**	**3**				**50**	**0.7**
W1879-1RUS	9	8	3				45	0.7
W2466-5RUS	9	7	4				45	0.8
Superior	8	9	2	1			40	0.8
AND98324-1RUS	9	9	3	1			41	0.8
A95109-1	8	7	4	1			40	0.9
AC96052-1RUS	7	8	3	2			35	1.0
W3328-1RUS	7	6	6	1			35	1.1
MSL794-BRUS	4	4	7	4			21	1.6
A95409-1	4	4	7	5			20	1.7
A93157-6LS	4	5	3	6	2		20	1.9
W2683-2RUS	0	5	6	6	2	1	0	2.4

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
RED TRIAL								
ND5002-3R	19	1					95	0.1
MSL228-1	18	2					90	0.1
Red Norland	**18**	**2**					**90**	**0.1**
COTX00104-7R	17	3					85	0.2
MN00177-6R	16	4					80	0.2
ND4659-5R	16	4					80	0.2
ATTX961014-1RY	15	5					75	0.3
Michigan Purple	15	3	2				75	0.4
MSN215-2P	13	6	1				65	0.4
MN99460-14R	13	4	3				65	0.5
MSN109-6RR	11	8	1				55	0.5
MSN230-1RY	6	9	4	1			30	1.0
ADAPTATION TRIAL, CHIP-PROCESSING LINES								
MSM058-A	16	4					80	0.2
MSP270-1	16	4					80	0.2
MSM046-E	15	5					75	0.3
MSN135-A	16	3	1				80	0.3
MSP335-1	16	3	1				80	0.3
MSP292-7	15	4	1				75	0.3
MSN073-2	13	6					68	0.3
MSL292-A	13	6	1				65	0.4
MSN238-A	13	6	1				65	0.4
MSM060-3	13	5	2				65	0.5
MSL603-319Y	11	7	2				55	0.6
MSM246-B	9	8	1				50	0.6
MSN184-2	12	4	2	2			60	0.7
MSN190-2	10	6	4				50	0.7
MSN191-2Y	9	6	5				45	0.8
MSM102-A	7	9	2	1			37	0.8
MSN099-B	9	6	4	1			45	0.9
MSN180-3	7	9	1	3			35	1.0
Pike	**8**	**7**	**3**	**1**	**1**		**40**	**1.0**
Snowden	**4**	**11**	**3**	**1**	**1**		**20**	**1.2**
MSM108-A	4	7	6	3			20	1.4
MegaChip	6	4	6	3	1		30	1.5
Atlantic	**1**	**10**	**6**	**3**			**5**	**1.6**
Monticello	2	2	4	6	1	2	12	2.5

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

	NUMBER OF SPOTS PER TUBER						PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
ENTRY	0	1	2	3	4	5+		
ADAPTATION TRIAL, TABLESTOCK LINES								
MSN084-3	17	4	1				77	0.3
MSL183-AY	16	4	1				76	0.3
MSE221-1	14	4	1				74	0.3
MSP197-1	17	4		1			77	0.3
MSP239-1	13	13					50	0.5
MSM148-A	12	5	4				57	0.6
MSL082-A	10	7	3				50	0.7
MSN032-A	9	8	3				45	0.7
Boulder	6	11	2				32	0.8
Saginaw Gold	**7**	**7**	**5**	**3**			**32**	**1.2**
MSP408-14Y	2	4	9	4			11	1.8
MSK498-1Y	3	11	5	11			10	1.8
PRELIMINARY TRIAL, CHIP-PROCESSING LINES								
MSQ461-1RR	19	1					95	0.1
MSQ035-2	17	2	1				85	0.2
MSQ039-5	15	5					75	0.3
MSQ089-1	15	5					75	0.3
MSQ237-2	16	3	1				80	0.3
MSQ001-1	14	6					70	0.3
PMS542-4	13	5	1				68	0.4
MSM080-1	14	5		1			70	0.4
MSQ029-1	12	8					60	0.4
MSP557-B	11	8					58	0.4
MSP542-11	11	8	1				55	0.5
MSQ490-3	12	6	2				60	0.5
Pike	**11**	**6**	**2**				**58**	**0.5**
MSP459-5	10	8	2				50	0.6
MSP524-C	9	9	2				45	0.7
MSQ060-5	10	7	1	2			50	0.8
MSQ108-1	10	5	5				50	0.8
MSQ201-1	11	5	2	2			55	0.8
MSQ283-2	10	6	3	1			50	0.8
MSQ393-11	8	9	3				40	0.8
MSQ334-3	3	6	1				30	0.8
MSQ363-2	9	7	2	2			45	0.9
MSQ023-5	7	12	1		1		33	0.9
MSQ383-2	8	8	5				38	0.9
MSN236-A	8	6	5	1			40	1.0
MSP346-5	7	9	2	2			35	1.0

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSQ289-5	10	4	3	3			50	1.0
Snowden	**7**	**9**	**6**				**32**	**1.0**
MSQ047-1	7	7	4	2			35	1.1
MSQ279-7	6	8	5	1			30	1.1
MSQ492-2	3	11	3	1			17	1.1
MSQ245-1	4	10	5	1			20	1.2
MSQ070-1	6	6	5	3			30	1.3
MSQ214-1	4	9	5	2			20	1.3
MSQ245-2	6	7	3	4			30	1.3
MSP368-1	6	7	4	4			29	1.3
MSN313-A	2	8	7	3			10	1.6
Atlantic	**1**	**7**	**7**	**4**	**1**		**5**	**1.9**
MSQ082-3	1	4	8	4	2	1	5	2.3
MSP516-A	1	6	4	6	1	2	5	2.3
MSQ293-2	0	4	4	5	5	2	0	2.9
PRELIMINARY TRIAL, TABLESTOCK LINES								
MSQ441-6R	19	1					95	0.1
Spunta RB/CSPAG.13	19	1					95	0.1
Vanderplank	18	1	1				90	0.2
Caren	17	2	1				85	0.2
Esco	16	4					80	0.2
BP 1	15	4	1				75	0.3
MSQ440-2	12	6					67	0.3
Eden	14	5	1				70	0.4
Kufri Jeeven	14	6	1				67	0.4
MSQ181-1Y	14	6	1				67	0.4
Devlin	12	8					60	0.4
MSN111-4PP	12	8					60	0.4
MSQ434-4P	8	7					53	0.5
MSQ134-5	11	7	1				58	0.5
MSQ176-5	10	7	3				50	0.7
Darius	10	6	4				50	0.7
MSQ410-4P	7	9	3				37	0.8
E69.6	8	9	2	1			40	0.8
Teena	4	4	2				40	0.8
MSQ086-3	10	6	3	3			45	1.0
MSQ244-1	7	7	4	2			35	1.1
MSQ087-3	7	6	5	2			35	1.1
MSQ176-6	6	4	6	3	1		30	1.5
Monserrat	2	8	9	2			10	1.5
Malinche	0	5	6	5	2	3	0	2.6

2006 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
USPB/SFA TRIAL CHECK SAMPLES								
A91814-5	25						100	0.0
Beacon Chipper	25						100	0.0
MSJ316-A	25						100	0.0
W2324-1	25						100	0.0
MSJ461-1	25						100	0.0
Snowden	**25**						**100**	**0.0**
W2133-1	25						100	0.0
AF2211-9	24	1					96	0.0
Atlantic	**24**	**1**					**96**	**0.0**
CO95051-7W	24	1					96	0.0
MSJ147-1	24	1					96	0.0
NY132	23	2					92	0.1
USPB/SFA TRIAL BRUISE SAMPLES								
MSJ316-A	21	4					84	0.2
CO95051-7W	19	6					76	0.2
AF2211-9	19	6					76	0.2
MSJ461-1	17	8					68	0.3
MSJ147-1	17	6	2				68	0.4
W2324-1	17	8	1				68	0.4
W2133-1	12	8	3		1		48	0.7
A91814-5	7	8	6	2			28	1.0
Snowden	**6**	**7**	**8**	**4**	**1**		**24**	**1.6**
Beacon Chipper	6	6	6	6	1		24	1.6
NY132	6	4	7	5	1	2	24	1.9
Atlantic	**3**	**3**	**7**	**7**	**3**	**2**	**12**	**2.4**

* Twenty or twenty-five A-size tuber samples were collected at harvest, held at 50 F at least 12 hours, and placed in a six-sided plywood drum and rotated ten times to produce simulated bruising. Samples were abrasive-peeled and scored.
The table is presented in ascending order of average number of spots per tuber.

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2006 On-Farm Potato Variety Trials

Chris Long, Dr. Dave Douches, Fred Springborn (Montcalm), Dave Glenn (Presque Isle), Dr. Doo-Hong Min and Chris Kapp (Upper Peninsula)

Introduction

On-farm potato variety trials were conducted with 13 growers in 2006 at a total of 15 locations. Eight of the locations evaluated processing entries and seven evaluated fresh market entries. The processing cooperators were Crooks Farms, Inc. (Montcalm), Walther Farms, Inc. (St. Joseph), Lennard Ag. Co. (Monroe), 4-L Farms, Inc. (Allegan) and Main Farms (Montcalm). The United States Potato Board/Snack Food Association (USPB / SFA) chip trial was at Sandyland Farms LLC (Montcalm). Fresh market trial cooperators were Crawford Farms, Inc. (Montcalm), DuRussel's Potato Farms, Inc. (Washtenaw), Wilk Farms (Presque Isle), Horkey Bros. (Monroe), VanDrese Farms (Marquette), Lennard Ag. Co. (Cass) and Walther Farms, Inc. (St. Joseph).

Procedure

There were two types of processing trials conducted this year. The first type contained 16 entries which were compared with check varieties Atlantic, Snowden, Pike and FL1879. This trial type was conducted at Main Farms, Lennard Ag. Co., 4-L Farms, and Walther Farms, Inc. Varieties in these trials were planted in 100' strip plots. Seed spacing was grower dependent, but in general ranged from 8 to 11 inches. The Walther trial was not harvested in 2006 due to a severe late blight infection which resulted in the plot being vine killed before the plot matured.

The second type of processing trial, referred to as a "Select" trial, contained from six to eight lines which were compared to the variety in the field. In these trials each variety was planted in a 15' row plot. Seed spacing and row width was 10" and 34", respectively. On Crooks farm, a small common scab trial was also planted to screen the scab tolerance of the varieties being tested in the Select trials. The plots were seven feet long and total yield, specific gravity, scab rating and vine maturity was recorded. Seed spacing was also ten inches in these plots.

Within the fresh market trials, there were 34 entries evaluated. There were 6-24 lines planted at each of the following locations: Cass, Marquette, Monroe, Montcalm, Presque Isle, St. Joseph, and Washtenaw counties. The varieties in each trial ranged from mostly round white varieties to mostly russet varieties. These varieties were planted in 100' strip plots. Again, spacing varied from 8 to 12 inches depending upon grower production practices and variety. At Walther Farms a 20 variety by three replication trial was evaluated. At Lennard Farms in Cass County 6 varieties were evaluated in 300 foot by 6 row block plantings.

For procedural details on the USPB / SFA trial, reference the 2006 annual report published by the United States Potato Board.

Results

A. Processing and "Select" Processing Variety Trial Results

A description of the processing varieties, their pedigree and scab ratings are listed in Table 1. The overall averages of the three locations of Allegan, Montcalm and Monroe counties are shown in Table 2. The data from Walther Farms, Inc. in St. Joseph County is not available. The overall averages of the "Select" processing trial, which are averaged across two locations, are in Table 3 and Crooks Farm "Scab Trial" is in Table 4.

Processing Variety Highlights

Beacon Chipper; this variety continues to exhibit a strong yield performance and size profile. In 2006, Beacon Chipper was the second highest yielding line at 428 cwt/A US#1 in the Processing Variety Trial Overall Average (Table 2). Beacon Chipper also performed well in the USPB/SFA trial at 378cwt/A yield of US#1 size tubers (Table 5). The specific gravity for this clone was generally average. Tuber type was excellent, with moderate scab tolerance and a small amount of internal defects. This variety had good storage chip quality in mid-February when stored at 50 ºF.

Monticello; this variety was an average yielding line with a heavy set of medium size tubers. The US#1 overall average in 2006 was 379 cwt/A with a slightly above average specific gravity (Table 2). Scab resistance was slight. The number of internal defects were minimal. This variety has the greatest potential to make an impact as a late storage variety. Monticello exhibits the ability to store well into May and June.

MSJ036-A; this Michigan State University developed clone had above average yield of uniform round tubers. In 2006 On-Farm trials this variety had excellent resistance to common scab. In 2006, MSJ036-A yielded 363 cwt/A US#1 with an average specific gravity (Table 2). This variety exhibited a short term storage profile and can be stored until January.

W2324-1; this clone was developed at the University of Wisconsin and has excellent yield and tuber type. In the 2006 USPB/SFA trial this clone yielded 488 cwt/A US#1 yield (Table 5). The size profile was good and the gravity was average. The variety appears to be susceptible to common scab. In the 2006 "Select" trials this variety was also the top yielding line (Table 3).

B. USPB / SFA Chip Trial Results

The Michigan location of the USPB / SFA chip trial was on Sandyland Farms LLC in Montcalm County in 2006. Table 5 shows the yield, size distribution and specific gravity of the entries when compared with Atlantic and Snowden. Table 6 shows the at harvest raw tuber quality results. Table 7 shows the out of the field chip quality evaluations from samples processed and scored by Herr Foods, Inc., Nottingham, PA and Table 8 provides the blackspot bruise susceptibility of each entry.

USPB / SFA Chip Trial Highlights

The varieties in the 2006 trial that displayed the greatest potential for commercialization were W2324-1, W2133-1, Beacon Chipper and MSJ147-1. Yield potential and specific gravity were excellent for W2324-1 (Table 5). W2133-1 and Beacon Chipper both had comparable yields and specific gravity (Table 5). Beacon Chipper had a slight amount of hollow heart recorded (Table 6). MSJ147-1 exhibited excellent long-term storage quality. MSJ147-1 displayed the best post harvest chip quality at Herr Foods (Table 7) and a low amount of black spot bruising (Table 8).

C. Fresh Market and Variety Trial Results

A description of the fresh pack varieties, their pedigree and scab ratings are listed in Table 9. Table 10 shows the overall average of five locations: Delta, Monroe, Montcalm, Presque Isle and Washtenaw counties. Table 11 provides the results from the Lennard Ag. Co. location in Cass County and Table 12 provides the averaged data from the Walther location in St. Joseph County.

Fresh Market Variety Highlights

One round white and two russet lines are worthy of mention from the 2006 variety trials. They are MSN105-1 (the round white) and the russets, Freedom Russet and A93157-6LS.

MSN105-1; this is a new, very promising, selection for the Michigan State University potato breeding program. This variety had an above average yield of 351 cwt/A US#1 (Table 10). This clone had foliar late blight resistance, strong common scab tolerance and an excellent bright appearance. The specific gravity may be slightly higher than desired for the table stock market.

Freedom Russet (W1836-3Rus); this is a University of Wisconsin selection. This variety has been in the On-farm trials in years past and was on one location again this season. The variety has a very full maturity, possibly 140 days. The US#1 yield was excellent at 378 cwt/A (Table 10). There were no recorded internal defects and the specific gravity was in line for the tablestock market.

A93157-6LS; is a USDA Aberdeen release with processing potential. In Michigan this variety had a 326 cwt/A US#1 yield with a 1.079 specific gravity and a nice blocky russet type (Table 10). A slight amount of hollow heart was observed (Table 10). The overall type and appearance of this variety make it a candidate for further testing. This variety also performed well in Cass County at the Lennard Ag. location (Table 11).

Table 1.

2006 MSU Processing Potato Variety Trials

Entry	Pedigree	2006 Scab Rating*	Characteristics
Atlantic (B6987-56)	Wauseon X Lenape	2.8	Early maturing, high yield check variety.
Beacon Chipper (UEC)	Unknown	1.8	Mid-season maturity, high yield, some heat stress and scab tolerance.
Dakota Diamond (ND5822C-7)	ND4103-2 X Dakota Pearl	0.5	Late maturing, high yield, CPB repelling, hollow heart in oversize tubers, bright appearance, masks PVY.
Megachip (W1201)	Wischip X FYF 85	1.5	Late maturing, high yield, cold chipper 45 °F, slight deep eyes, early bulking.
Monticello (NY102 or K9-29)	Steuben X Kanona	2.3	Mid-season maturity, average yield, medium specific gravity, good long-term storability, low internal defects, black spot susceptible.
Pike (NYE55-35)	Allegany X Atlantic	1.4	Early maturing, early storage check variety.
Snowden (W855)	B5141-6 X Wischip	2.8	Late maturing, late season storage check variety.
A91814-5	NDA2031-2 X Ivory Crisp	3.5	Mid-season maturity, medium high specific gravity, round to oblong tuber type, high yield potential, low internal defects, scab tolerance similar to Atlantic.
AF2211-9	Atlantic X Maine Chip	2.3	Mid-season maturity, high specific gravity, good tuber appearance, cold chipping potential, high yield.
CO95051-7W	AC88456-6W X BC0894-2W	1.4	Medium to late maturity, medium high yielding, high percent of US#1 tubers, low internal defects, high specific gravity.
FL1879	Snowden X FL1207	2.6	Late maturing, late season storage check variety.
FL1922	FL1533 X FL1207	1.0	Oval to oblong tubers, medium to low specific gravity, good chip quality out of late storage.

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible.

Entry	Pedigree	2006 Scab Rating*	Characteristics
FL2048	NA	3.1	Round to oblong tubers, high solids, excellent yield potential, full season storage, good sugar profile.
FL2053	NA	2.5	Round to oblong shape, very high solids, good yield potential, good bruise tolerance, fresh or early season storage.
MSH228-6	MSC127-3 OP	1.4	Mid-season maturity, slightly flattened tubers, shallow eyes, intermediate specific gravity, average yield.
MSJ036-A	A7961-1 X Zarevo	1.2	Mid-season maturity, high yield, nice round uniform tuber type, medium high specific gravity, scab resistant.
MSJ126-9Y	Penta OP	1.5	Average yield, cold chipper from 45 ºF, Uniform A-size tubers, attractive appearance, good internal quality.
MSJ147-1	Norvalley X S440	1.8	Mid-season maturity, good internal quality, very good chip quality late in storage, medium specific gravity.
MSJ316-A	Pike X B0718-3	1.6	Late maturing, medium specific gravity, round tubers, high yield, scab tolerant, good type.
MSJ461-1	Tollocan X NY88	1.8	Maturity slightly earlier than Snowden, round tubers with bright skin, low defects, strong foliar late blight resistance, intermediate specific gravity.
MSK061-4	MSC148-A X Dakota Pearl	1.3	Medium to late season maturity, high specific gravity, good chip color, average yield with low blackspot bruising.
MSK409-1	MSC148-A X Liberator	1.0	Storage chipper, early maturity, average yield and specific gravity.
MSM051-3	MSF099-3 X MSG227-2	1.5	High yield, early bulking.
NY132	Eva X Pike	1.3	Late maturity, medium low specific gravity, medium yield of uniformly round tubers, scab resistance, bright appearance.

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible.

Entry	Pedigree	2006 Scab Rating*	Characteristics
W2133-1	Snowden X RHL 167	2.0	Late maturity, scab resistant, good internal quality, high yield, nice tuber type, medium to low specific gravity, 42-45 ºF cold chipper.
W2309-7	ND2471-8 X W1242	1.3	Full season maturity, high specific gravity, high yielding, chipping from 42 ºF after 5 months.
W2324-1	Snowden X RHL166	2.6	Late maturity, medium high specific gravity, high yield potential, uniform tuber size, long-term storage at 48 ºF.
W2982-1	S440 X Dakota Crisp (ND2470-27)	2.4	Medium maturity, high yielding, oval tuber type, medium low specific gravity.
W4013-1	W2504-9 X Norvalley	2.6	Mid to early season maturity, average yielder, with an average specific gravity.

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible.

Table 2.

2006 Processing Potato Variety Trial
Overall Average - Three Locations
Allegan, Monroe, Montcalm Counties

	CWT/A		PERCENT OF TOTAL[1]						CHIP	TUBER QUALITY[2]				TOTAL		3-YR AVG US#1
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[3]	HH	VD	IBS	BC	CUT	COMMENTS	CWT/A
FL1879	440	452	97	3	74	23	0	1.073	1.3	0	4	0	0	10	Surface and pitted scab	389
Beacon Chipper	428	449	95	3	63	32	2	1.074	1.0	0	4	0	0	10	Large round type surface and pitted scab	404*
Snowden	**417**	**441**	**94**	**6**	**84**	**10**	**0**	**1.074**	**1.3**	**0**	**5**	**1**	**0**	**10**	**Pitted scab**	**435**
Atlantic	**384**	**413**	**93**	**6**	**80**	**13**	**1**	**1.080**	**1**	**1**	**2**	**2**	**0**	**10**	**Pitted scab**	**383**
MSM051-3	380	399	95	4	63	32	1	1.069	1.0	0	3	0	2	10	Large tuber size, sl pitted and surface scab	-
Monticello	379	420	90	9	87	3	1	1.077	1.0	0	3	0	0	10	Growth cracks, bright appearance, sl pitted and surface scab	360*
MSH228-6	375	405	92	6	68	24	2	1.071	1.3	0	4	0	0	10	Tr surface and pitted scab, flat oval type, internal heat stress	402
MSJ036-A	363	397	92	8	87	5	0	1.073	1.3	0	2	3	0	10	Nice type, tr surface scab, tr internal heat stress	417*
FL2048	350	375	93	6	77	16	1	1.076	1.3	0	7	0	0	10	Pitted and surface scab, growth cracks and misshapen	-
Pike	331	359	93	6	84	9	1	1.079	1.0	0	2	1	0	10	Misshapen, tr internal heat necrosis, tr surface scab	325
MSJ126-9Y	**327**	**355**	**92**	**8**	**83**	**9**	**0**	**1.073**	**1.0**	**0**	**1**	**1**	**0**	**10**	**Nice type, tr surface scab, tr internal heat necrosis**	**-**
MSK061-4	323	401	80	11	80	0	9	1.080	1.0	0	6	0	0	10	Tr heat sprouts, tr pitted and surface scab	377*
FL2053	291	333	87	10	80	7	3	1.081	1.0	0	2	0	0	10	Growth cracks, sl pitted scab, tr heat sprouts	-
MSK409-1	**291**	**333**	**87**	**10**	**83**	**4**	**3**	**1.076**	**1.0**	**0**	**3**	**0**	**0**	**10**	**Tr heat sprouts, knobs, sl pitted and surface scab**	**-**
MSJ147-1	287	333	87	9	77	10	4	1.075	1.3	0	2	0	0	10	Points, heat sprouts, tr pitted and surface scab	372
W2309-7	229	272	84	15	83	1	1	1.076	1.0	0	3	0	0	10	Growth crack, misshapen, pitted and surface scab	-
MEAN	350	384	91					1.075								

[1]SIZE
Bs: < 1 7/8"
As: 1 7/8" - 3.25"
OV: > 3.25"
PO: Pickouts

[2]TUBER QUALITY (number of tubers per total cut)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

[3]CHIP COLOR SCORE
Snack Food Assoc. Scale
(Out of the field)
Ratings: 1 - 5
1: Excellent
5: Poor

* Two-Year Average

sl = (slight)
tr = (trace)

Table 3.

2006 "Select" Processing Potato Variety Trial
Overall Average - Crooks Farms, Inc., Two Locations
Montcalm County, Musson & Peoples Roads

NUMBER OF LOCATIONS	LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	TUBER QUALITY[2] HH	VD	IBS	BC	TOTAL CUT	COMMENTS
2	W2324-1	506	539	95	5	86	9	0	1.082	1	0	0	0	10	Nice size profile, slight deep eye, tr pitted scab
2	FL2048	344	377	92	8	83	9	0	1.082	1	0	0	0	10	Pitted scab
2	MSK061-4	292	360	81	18	81	0	1	1.080	1	0	0	0	10	
2	FL2053	258	328	79	21	78	1	0	1.037	0	0	0	0	10	Tr pitted scab and small size profile
2	MSJ036-A	257	344	72	28	71	1	0	1.078	1	0	0	0	10	Uniform type
2	W2309-7	212	253	83	17	79	4	0	1.081	1	0	0	0	10	Tr pitted scab, small size and tuber set
	MEAN	311	367	83					1.073						

[1]SIZE
Bs: < 1 7/8"
As: 1 7/8" - 3.25"
OV: > 3.25"
PO: Pickouts

[2]TUBER QUALITY (number of tubers per total cut)
HH: Hollow Heart
BC: Brown Center
VD: Vascular Discoloration
IBS: Internal Brown Spot

sl = (slight)
tr = (trace)

Table 4.

2006 "SCAB"
Processing Potato Variety Trial
Crooks Farms - Montcalm County
September 14, 2006 Harvest / 133 Days

LINE	Total Yield CWT/A	SP GR	SCAB[1] SCORE	VINE[2] MATURITY
W2324-1	834	1.087	0.5	4
FL2048	567	1.085	1.0	5
MSJ036-A	561	1.084	0.0	4
MSK061-1	500	1.082	0.5	4
MSJ147-1	428	1.076	0.5	3
PIKE	**400**	**1.082**	**0.0**	**3**
FL2053	319	1.085	0.0	4
W2309-7	195	1.083	0.0	5
MEAN	476	1.083		

[1] Common Scab
0: No Infection
3: Intermediate
5: Highly Susceptible

[2] Vine Maturity Read on 7.28.06
1: Early (Dead Vines)
5: Late (Vigorous Vine)

Planted: May 5, 2006
Vines Killed: None
Days After Vine Kill: 0
Seed Spacing : 10"

Table 5. Yield ,Size Distribution*, Specific Gravity									
	Yield (cwt/A)		**Percent Size Distribution**						
Entry	**US#1**	**TOTAL**	**US#1**	**Small**	**Mid-Size**	**Large**	**Culls**	**Specific Gravity**	
W2324-1	488	515	95	4	90	5	1	1.083	
MSJ461-1	441	478	92	8	89	3	0	1.077	
A91814-5	431	493	87	8	86	1	5	1.085	
MSJ316-A	411	437	94	5	82	12	1	1.083	
W2133-1	401	442	91	8	88	3	1	1.084	
Beacon Chipper	378	391	97	2	82	15	1	1.083	
AF2211-9	358	380	94	5	90	4	1	1.081	
NY132	357	394	91	9	89	2	0	1.091	
Atlantic	**347**	**361**	**96**	**4**	**87**	**9**	**0**	**1.087**	
Snowden	**335**	**380**	**88**	**12**	**87**	**1**	**0**	**1.081**	
MSJ147-1	311	379	82	17	81	1	1	1.084	
CO95051-7W	292	322	91	8	90	1	1	1.081	
Average	379	414	92					1.083	

*small <1 7/8"; mid-size 1 7/8"-3 1/4"; large >3 1/4"

Table 6. At Harvest Tuber Quality. Sandyland Farms, Howard City, Michigan.					
	Internal Defects[1]				
Entry	**HH**	**VD**	**IBS**	**BC**	**Total Cut**
W2324-1	0	1	0	0	30
MSJ461-1	0	1	0	0	30
A91814-5	0	1	0	0	30
MSJ316-A	0	0	1	0	30
W2133-1	0	0	0	0	30
Beacon Chipper	1	4	0	0	30
AF2211-9	1	1	0	0	30
NY132	0	2	0	0	30
Atlantic	**1**	**0**	**0**	**1**	**30**
Snowden	**0**	**4**	**0**	**0**	**30**
MSJ147-1	0	1	0	0	30
CO95051-7W	0	1	0	1	30

[1]Internal Defects. HH = hollow heart, VD = vascular discoloration, IBS = internal brown spot, BC = brown center.

Table 7. 2006 Post-Harvest Chip Quality[1].

Entry	Agtron Color	SFA[2] Color	Specific Gravity	Percent Chip Defects[3] Internal	External	Total
W2324-1	55.1	2.0	1.085	12.6	8.6	21.2
MSJ461-1	55.4	2.5	1.068	28.2	7.8	36.0
A91814-5	55.7	2.5	1.082	27.8	11.5	39.3
MSJ316-A	58.8	2.0	1.075	36.1	7.8	43.9
W2133-1	57.2	1.0	1.075	4.9	7.5	12.4
Beacon Chipper	57.8	2.0	1.076	37.7	7.5	45.2
AF2211-9	55.4	2.5	1.075	43.4	0.6	44.0
NY132	54.3	2.0	1.080	19.8	7.2	27.0
Atlantic	53.3	2.5	1.088	27.9	12.2	40.1
Snowden	57.3	3.0	1.073	40.0	5.5	45.5
MSJ147-1	56.5	1.0	1.078	3.5	4.3	7.8
CO95051-7W	60.3	1.0	1.075	5.5	11.6	17.1

[1] Samples collected at harvest September 28th and processed by Herr Foods Inc., Nottingham, PA on October 4, 2005 (7 days).

Chip defects are included in Agtron and SFA samples.

[2] SFA Color: 1 = lightest, 5 = darkest

[3] Percent Chip Defects are a percentage by weight of the total sample; comprised of undesirable color, greening, internal defects and external defects.

Table 8. Black spot Bruise Test

	A. Check Samples[1]										B. Simulated Bruise Samples[2]								
	# of Bruises Per Tuber							Percent	Average	# of Bruises Per Tuber								Percent	Average
Entry	0	1	2	3	4	5	Total Tubers	Bruise Free	Bruises Per Tuber	0	1	2	3	4	5	Total Tubers	Bruise Free	Bruises Per Tuber
W2324-1	25						25	96	0.0	17	8	1				25	68	0.4
MSJ461-1	25						25	100	0.0	17	8					25	68	0.3
A91814-5	25						25	100	0.0	7	8	6	2			25	28	1.0
MSJ316-A	25						25	100	0.0	21	4					25	84	0.2
W2133-1	25						25	100	0.0	12	8	3		1		25	48	0.7
Beacon Chipper	25						25	100	0.0	6	6	6	6	1		25	24	1.6
AF2211-9	24	1					25	96	0.0	19	6					25	76	0.2
NY132	23	2					25	92	0.1	6	4	7	5	1	2	25	24	1.9
Atlantic	24	1					25	96	0.0	3	3	7	7	3	2	25	12	2.4
Snowden	25	1					25	96	0.0	6	7	8	4	1		25	24	1.6
MSJ147-1	24	1					25	96	0.0	17	6	2				25	68	0.4
CO95051-7W	24	1					25	96	0.0	19	6					25	76	0.2

[1]Tuber samples collected at harvest and held at room temperature for later abrasive peeling and scoring.

[2]Tuber samples collected at harvest, held at 50ºF for at least 12 hours, then placed in a 6 sided plywood drum and rotated 10 times to produce simulated bruising. They were then held at room temperature for later abrasive peeling and scoring.

Table 9.

2006 MSU Fresh Pack Potato Variety Trials

Entry	Pedigree	2006 Scab Rating*	Characteristics
Boulder (MSF373-8)	MS702-80 X NY88	1.6	High yield, large tubers, low internal defects, med. deep eyes.
Chieftain (Iowa 57410)	La1354 X Ia1027-18	-	High yielding, red skin variety.
Dakota Jewel (ND3196-1R)	ND2223-8R X ND649-4R	1.0	Early maturity, average yield, smooth round tubers, white flesh, shallow eyes, stores well, some brown center noted, nice red color out of the field.
Fabula	Monalisa X Hudson	-	Mid to late season maturity, oval tuber type, light yellow flesh, high yield, resistance to potato cyst nematodes, tolerance to common scab, PVY and tuber late blight.
Goldrush (ND1538-1 Rus)	ND450-3 Rus X Lemhi Russet	0.3	Long to oval tubers, heavy russet, check variety.
Green Mountain	Dunmore X Excelsior	-	High yield, stores well, grows well in light soils.
Katahdin (USDA42667)	USDA40568 X USDA24642	-	High yielding, round white, tablestock, check variety.
Michigan Purple	W870 X Maris Piper	2.8	Mid-season, attractive purple skin, white flesh, high yield potential, low incidence of internal defects.
Onaway	USDA X96-56 X Katahdin	1.0	Early maturing, high yielding check variety.
Reba (NY 87)	Monona X Allegany	2.5	High yield, bright tubers, low incidence of internal defects, mid to late season maturity.
Red La Soda	Triumph X Katahdin	-	Red skin, tablestock variety, with heat tolerance.

*Scab rating based on a 0-5 rating; 0 = most resistant and 5 = most susceptible.

Entry	Pedigree	2006 Scab Rating*	Characteristics
Russet Norkotah (ND534-4 Rus)	ND9526-4 Rus X ND9687-5 Rus	2.2	Mid-season maturity, average yield, long to oval tubers, heavy russet skin, check variety.
Stampede Russet (TXAV657-27Rus)	BR7091-1 X Lemhi Russet	1.0	Early season maturity, oblong to long, heavy russeting, average yield potential, fresh market.
A9305-10	A83043 X A85103-3	1.9	Dual purposes, late maturing, light russet skin, high yield, long term storability, tolerant to common scab.
Primer Russet (A93157-6LS)	A87149-4 X A88108-7	1.4	Maintains low levels of reducing sugars even after extended storage, Med to late maturity, dual purpose usage, PVY resistant, high specific gravity.
A95109-1	Blazer Russet X Summit Russet	1.7	Early maturity, attractive appearance, fresh market use.
AC96052-1Rus	A81386-1 X A9014-2	0.8	Medium maturity, good fry potential, moderate specific gravity, oblong to long, heavy russeting
CO95086-8Rus	CO87009-4Rus X Silverton Russet	0.3	Early maturity, medium high specific gravity, resistant to black spot bruise, no internal defects, good size profile, medium yield potential, dual purpose russet, good processing from storage.
CO95172-3Rus	Russet Nugget X AC88165-3Rus	1.3	Medium maturity, medium to high specific gravity, high yield potential, few external defects, resistant to hollow heart, fresh market russet.
MSA8254-2BRus	Unknown	0.0	Late season maturity, dual purpose, medium specific gravity, good yield.
MSE192-8 Rus	A81163 X Russet Norkotah	1.2	Long russet tubers, low internal defects, bright white flesh, good cooking quality, specific gravity similar to R. Norkotah, PVY expression good.
MSE202-3 Rus	Frontier Russet X A8469-5	1.9	Long russet, lighter russet like R. Burbank.

*Scab rating based on a 0-5 rating; 0 = most resistant and 5 = most susceptible.

Entry	Pedigree	2006 Scab Rating*	Characteristics
MSE221-1	Superior X Spartan Pearl	1.0	Medium maturity, medium yield, scab tolerant, netted round tubers, low internal defects.
MSI005-20Y	MSA097-1Y X Penta	1.5	Early to mid-season maturity, high yielding, low internal defects, strong yellow flesh color.
MSJ461-1	Tollocan X NY88	1.8	Maturity slightly earlier than Snowden, round, bright skin, low defects, strong foliar late blight resistance, nice flavor, intermediate specific gravity.
MSK498-1Y	Saginaw Gold X Brodick	2.0	Late maturity, uniform sizing, moderate scab resistance, light yellow flesh.
MSL211-3	MSG301-9 X Jacqueline Lee	2.3	Early maturing, bright skin, late blight resistance.
MSL228-1	MSH361-1 X Picasso	2.6	Splashes of purple on skin.
MSM171-A	Stirling X MSE221-1	1.3	Smooth shape, Superior skin type, late blight resistant.
MSN105-1	MSG141-3 X Jacqueline Lee	1.5	Early maturity, bright skin, moderate late blight resistance.
MSN184-2	MSI172-2 X MSH098-2	2.0	Bright skin, round white.
MSN215-2P	Michigan Purple X Norland	1.1	Heavy purple skin, smooth shape.

*Scab rating based on a 0-5 rating; 0 = most resistant and 5 = most susceptible.

Entry	Pedigree	2006 Scab Rating*	Characteristics
W2466-5Rus	W1005Rus X W1151Rus	1.5	Bright skinned, light russeting.
W3328-1Rus	W1099Rus X AC88064-6Rus	1.5	Heavy russet skin.

*Scab rating based on a 0-5 rating; 0 = most resistant and 5 = most susceptible.

Table 10.

2006 Freshpack Potato Variety Trial
Overall Averages - Five Locations
Delta, Monroe, Montcalm, Presque Isle, Washtenaw Counties

NUMBER OF LOCATIONS	LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	TUBER QUALITY[2] HH	VD	IBS	BC	TOTAL CUT	COMMENTS	3-YR AVG US#1 CWT/A
3	MSK498-1Y	446	484	92	7	91	1	1	1.072	0	2	1	0	10	Good appearance, surface scab, netted skin	393*
3	**Reba**	**422**	**451**	**94**	**4**	**81**	**13**	**2**	**1.072**	**0**	**0**	**0**	**1**	**10**	**Sl scab**	**439**
1	MSI005-20Y	409	428	96	3	89	7	1	1.081	0	0	0	0	10		400
1	**Katahdin**	**399**	**420**	**95**	**5**	**82**	**13**	**0**	**1.062**	**0**	**1**	**0**	**1**	**10**	**Good size, tr surface scab**	**401***
2	**Onaway**	**390**	**470**	**82**	**10**	**70**	**12**	**8**	**1.059**	**0**	**4**	**0**	**0**	**10**	**Misshapen and knobs**	**482**
2	Boulder	389	412	94	3	64	30	3	1.074	4	1	0	0	10	Tr surface scab, large size profile	438*
1	Freedom Russet	378	433	87	9	67	20	4	1.070	0	0	0	0	10	Blocky not uniform type	-
3	MSN105-1	351	407	86	12	78	8	2	1.078	0	0	0	2	10	Bright appearance, tr surface scab	-
3	MSJ461-1	349	435	82	17	76	6	1	1.071	0	1	1	0	10	Uniform round type	377
4	MSE221-1	344	385	90	3	71	19	7	1.067	1	1	0	0	10	Misshapen heavy netting, growth cracks	362*
2	Fabula	328	380	83	9	71	12	8	1.057	0	3	1	0	10	Oblong to long type, growth cracks and surface scab	-
2	A93157-6LS	326	432	77	19	69	8	4	1.079	1	1	0	0	10	Uniform blocky type, oval to oblong	305*
2	MSN184-2	305	374	82	14	66	16	4	1.067	0	0	1	0	10	Poor skin set, heat sprouts	-
2	MSN215-2P	280	366	75	11	74	1	14	1.072	0	0	0	0	10		-
4	MSL228-1	274	317	85	10	76	9	5	1.073	0	2	0	1	10	Growth cracks, some off types, blocky shoulders	-
2	W2466-5 Rus	271	422	65	29	54	11	6	1.068	0	0	0	0	10	Bright skin	-
1	Green Mountain	265	462	58	23	47	11	19	1.078	1	1	0	0	10	Deep Eyes	-
3	MSA8254-2BRus	256	367	70	23	56	14	7	1.071	1	1	0	0	10	Misshapen	254*
2	A95109-1Rus	237	318	76	11	63	13	13	1.071	0	4	0	0	10	Nice type, good appearance, medium russet skin	241*
2	MSM171-A	224	255	88	8	75	13	4	1.053	0	2	0	0	10	Growth cracks, misshapen and netted skin	-
2	CO95172-3Rus	214	410	54	42	54	0	4	1.070	1	1	0	0	10	Misshapen, small size profile	274*
1	**Goldrush**	**214**	**371**	**58**	**42**	**55**	**3**	**0**	**1.070**	**0**	**2**	**0**	**0**	**10**	**Oval to oblong, dark russet**	**212***
1	Snowbird	203	243	84	13	82	2	3	1.068	0	3	0	0	10	Bright oval to oblong, small size	-
3	A9305-10Rus	203	410	51	23	41	10	26	1.072	0	1	0	1	10	Misshapen, long to oblong, heavy russet	-
2	CO95086-8Rus	194	337	59	38	52	7	3	1.067	4	1	0	0	10	Nice blocky type	232*
1	Dakota Pearl	194	248	78	21	78	0	1	1.075	0	2	0	2	10	Bright, small size, knobs	-
2	W3328-1	186	329	59	12	47	12	29	1.072	0	1	0	0	10	Blocky oval to round type	-
2	AC96052-1Rus	159	258	61	35	51	10	4	1.077	1	1	0	0	10	Small Size	-
1	**Russet Norkotah**	**119**	**216**	**55**	**42**	**53**	**2**	**3**	**1.055**	**0**	**1**	**1**	**0**	**10**	**Good type**	**247**
	MEAN	287	374	76					1.070							

[1]SIZE
Bs: < 1 7/8" or < 4 oz.
As: 1 7/8" - 3.25" or 4 - 10 oz.
OV: > 3.25" or > 10 oz.
PO: Pickouts

[2]TUBER QUALITY (number of tubers per total cut)
HH: Hollow Heart
BC: Brown Center
VD: Vascular Discoloration
IBS: Internal Brown Spot

* Two-Year Average

sl = (slight)
tr = (trace)

Table 11.

2006 Freshpack Potato Variety Trial
Lennard Ag. Co. - Cass County
Harvest 5-Oct-06 133 Days

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	TUBER QUALITY[2] HH	VD	IBS	BC	TOTAL CUT	COMMENTS
R. N. #3	571	750	76	19	60	16	5	1.071	0	2	1	0	10	Knobs, two glassy ends
A93157-6LS	410	523	78	16	62	16	6	1.081	0	0	0	0	10	Good blocky shape, heavy russeted skin
Texas #112	336	506	67	32	62	5	1	1.063	0	2	1	0	10	Heavy russeted skin, four glassy ends
CO95172-3Rus	318	449	71	26	63	8	3	1.076	0	1	0	0	10	Tr heat sprout, 4 tubers with pythium leak
AC92009-4Rus	294	407	73	23	67	6	4	1.075	0	2	1	0	10	Heavy russeted skin
RioGrande	281	477	59	35	54	5	6	1.064	0	0	0	0	10	Heavy russeted skin, one glassy end
CO95086-8Rus	251	351	71	29	53	18	0	1.067	0	0	1	0	10	One glassy end, heavy russeted skin
MEAN	352	495	71					1.071						tr = (trace) sl = (slight)

[1]SIZE
Bs: < 1 7/8" or < 4 oz.
As: 1 7/8" - 3.25" or 4 - 10 oz.
OV: > 3.25" or > 10 oz.
PO: Pickouts

[2]TUBER QUALITY (number of tubers per total cut)
HH: Hollow Heart
VD: Vascular Discoloration
IBS: Internal Brown Spot
BC: Brown Center

Planted: 20-Apr-06
Vines Killed: None
Days from Planting to Vine Kill None
Seed Spacing : 12"
No Fumigation

Table 12.

2006 Tablestock Potato Variety Trial
Walther Farms - St. Joseph County
Harvest 25-Sept-06 127 Days

	Averaged Total Plot Yield	
LINE	lbs.	cwt/A
MSI005-20Y	125.7	842
MSK498-1Y	116.7	782
Onaway	**113.2**	**758**
Red LaSoda	110.5	741
MI Purple	109.2	732
Chieftain	**100.4**	**673**
Reba	**89.1**	**597**
Boulder	89.0	596
R. Norkotah	**82.5**	**553**
MSE221-1	80.3	538
MSE202-3Rus	77.4	519
W2466-5Rus	74.9	502
CO95086-6Rus	72.3	485
A93157-6LS	71.7	481
W3328-1Rus	71.1	477
CO95172-3Rus	65.6	440
MSA8254-2BRus	60.7	407
MSE192-8Rus	60.2	403
Stampede Rus	59.2	397
MSL228-1	54.9	368
MEAN	84	564

Planted May 22, 2006

Seed spacing
Russet type 12"
Round type 8"

General Pathology Report for 2006 growing season in Michigan and Meteorological conditions at the Muck Soils Research Farm, Laingsburg, MI; 2006.

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Weather conditions strongly influence crop and pathogen development in potato crops. For example, Rhizoctonia stem canker and black scurf appears to be favored by cool wet soil wet conditions early in the season and dry rot seed-borne disease is favored by wet soil conditions at temperatures about 50F. Both diseases were evident in MI during 2006. Potato early die is favored by soil temperatures in excess of 80F especially in some susceptible varieties and was a problem in Montcalm in 2006 after the heavy rains and high temperatures in late Jul and early Aug experienced in the region. Another interesting development in 2006 was that early blight appeared in some regions but on closer analysis turned out to be leaf brown spot a disease cause by *Alternaria alternata* (a relative of the early blight pathogen *Alternaria solani*). In addition, some growers experienced severe potato common scab in susceptible varieties in 2006 which is favored by dry soils during tuber initiation, although it also appeared in crops that were well-watered. Finally late blight of potato caused by *Phytophthora infestans* appeared again some regions of Michigan. Late blight spreads in potato canopies by continuous leaf and stem infection when inoculum is present and favorable environmental conditions, typically moist cool weather, exist. Prior to 1992, North American populations of *P. infestans* (A_1 mating type) were easily controlled by metalaxyl-based fungicide applications, but a new aggressive genotype (US8, A2 mating type, metalaxyl-insensitive) has replaced the previous clonal lineage. The foliage of all available commercial potato varieties is highly susceptible to current *P. infestans* populations and the cost of protecting potato crops continues to increase. The disease is normally tuber-borne and can be seed-borne or volunteer-borne.

On July 7th 2006, a leaf sample of suspected potato late blight was found and collected in a field of FL1922, 2 miles north of Centreville. The blighted area was at an exposed edge of the field and lesions of the disease could be found on the upper foliage of plants about 300 ft from the initial locus of the disease. The field had been scouted regularly since planting and all rock piles and field edges had been carefully inspected for volunteer plants. Volunteer potatoes had been reported in south west MI in 2006 and scouts had been advised of the possible appearance of potato late blight from these sources and such sources were included in scouting efforts by IPM scouts. No potato late blight had been reported form these potential sources prior to the initial discovery of potato late blight in this field. Subsequent tests confirmed that the pathogen responsible for the disease symptoms was *Phytophthora infestans* (potato late blight). Further tests confirmed that the pathogen was the US8 genotype which is predominant in North America. Being so early in the season, drastic remedial measures were recommended and taken to destroy the infected and the potentially infected area in the field. A Reglone spot spray (1 pt/A) was used and about ¾ acre was killed on July 7th. The entire field was sprayed by ground rig with a fungicide mixture during the early morning on July 8th. The field was revisited and scouted on Monday July 10th and a further 2 acres destroyed with Reglone including a five foot strip on either side of the pivot wheel lines. Thunderstorms had occurred over the area during early July with strong and persistent winds over the next weeks. Over this period 9 Potato Late Blight DSV (Disease Severity Values) were recorded indicating conducive conditions for production of sporangia, spread and re-infection of potato foliage (Table 1). Conditions had been sporadically conducive for the development of potato late blight since June 26th although no continuous high risk periods occurred until early July. Similar conditions occurred in the Saginaw and Tuscola areas and potato late blight was also confirmed there. So far during the storage season some storages have been processed and/or destroyed due to tuber rots.

Table 1. DSV accumulations (from 1 May); Results for station at Mendon, St. Joseph County.

Date	DSVs	Cumulative DSVs from May 1
2006-08-04	4	100
2006-08-03	1	96
2006-08-02	0	95
2006-08-01	0	95
2006-07-31	3	95
2006-07-30	2	92
2006-07-29	3	90
2006-07-28	4	87
2006-07-27	4	83
2006-07-26	3	79
2006-07-25	1	76
2006-07-24	0	75
2006-07-23	2	75
2006-07-22	2	73
2006-07-21	4	71

At the Muck Soils research Farm where potato late blight and other disease trials are carried out weather conditions in 2006 were conducive for development of potato late blight up until late Jul. Meteorological variables were measured with a Campbell weather station located at the farm, latitude 42.8269 and longitude -84.365deg. Maximum and minimum air temperature (^{o}F) were 92.0 and 36.3 and 1-d with maximum temperature >90^{o}F (Jun), 92.0 and 42.7 and 3-d with maximum temperature >90^{o}F (Jul), 95.2 and 41.6 and 3-d with maximum temperature >90^{o}F (Aug) and 82.3 and 45.5 (Sep). Maximum and minimum soil temperature (^{o}F) were 87.8 and 56.0 (Jun), 89.9 and 53.1 (Jul), 92.2 and 59.4 (Aug) and 67.3 and 57.5 (Sep). Maximum and minimum soil moisture (% of field capacity) was 78.3 and 64.9 (Jun); 116.6 and 66.7 (Jul), 119.1 and 80.4 (Aug) and 85.8 and 79.1 (Sep). Precipitation was 2.93 in. (Jun), 6.77 in. (Jul), 3.47 in. (Aug) and 0.68 in. (Sep). The total number of early blight disease severity values (P-values) over the growing season was 2036 (45^{o}F base for accumulation). Flooding occurred during late Jul and early Aug with 6 days when the maximum air temperature was in excess of 90F (Figs 1 and 2). The main pump at the Muck Farm failed during this period and the root systems of the potato plants in the potato late blight variety trials and the fungicide efficacy trials were compromised. Despite efforts to revive the plants after the floods receded and after a second inoculation with potato late blight only a few plants developed lesions and not enough to collect meaningful data. The problem has now been resolved with the pump and it is anticipated that under similar circumstances in the future the trials will not be compromised.

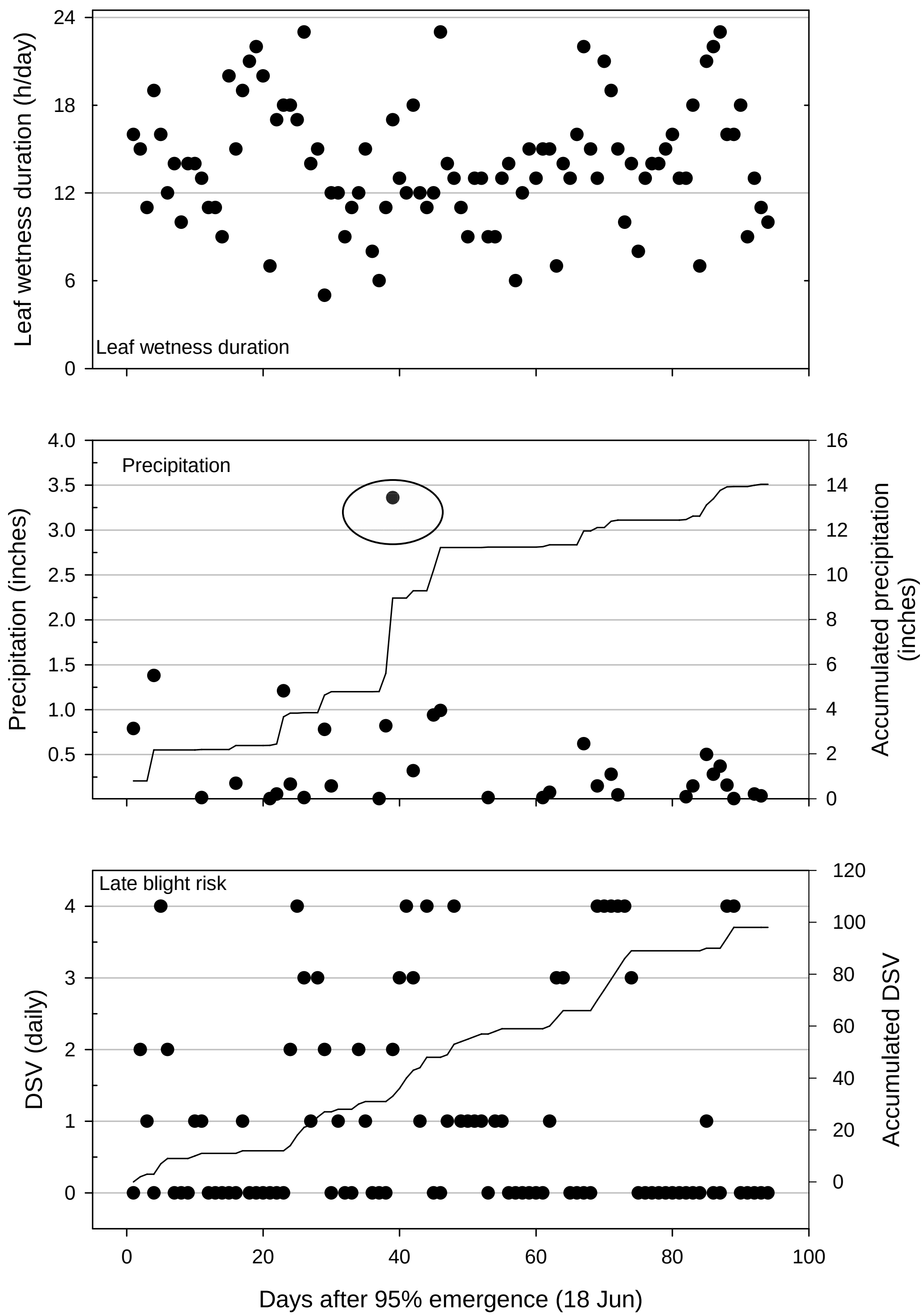

Figure 1. Leaf wetness duration, precipitation and potato late blight disease severity values (DSV) from 95% emergence to late senescence at the Muck Soils research Farm, Laingsburg, MI, 2006.

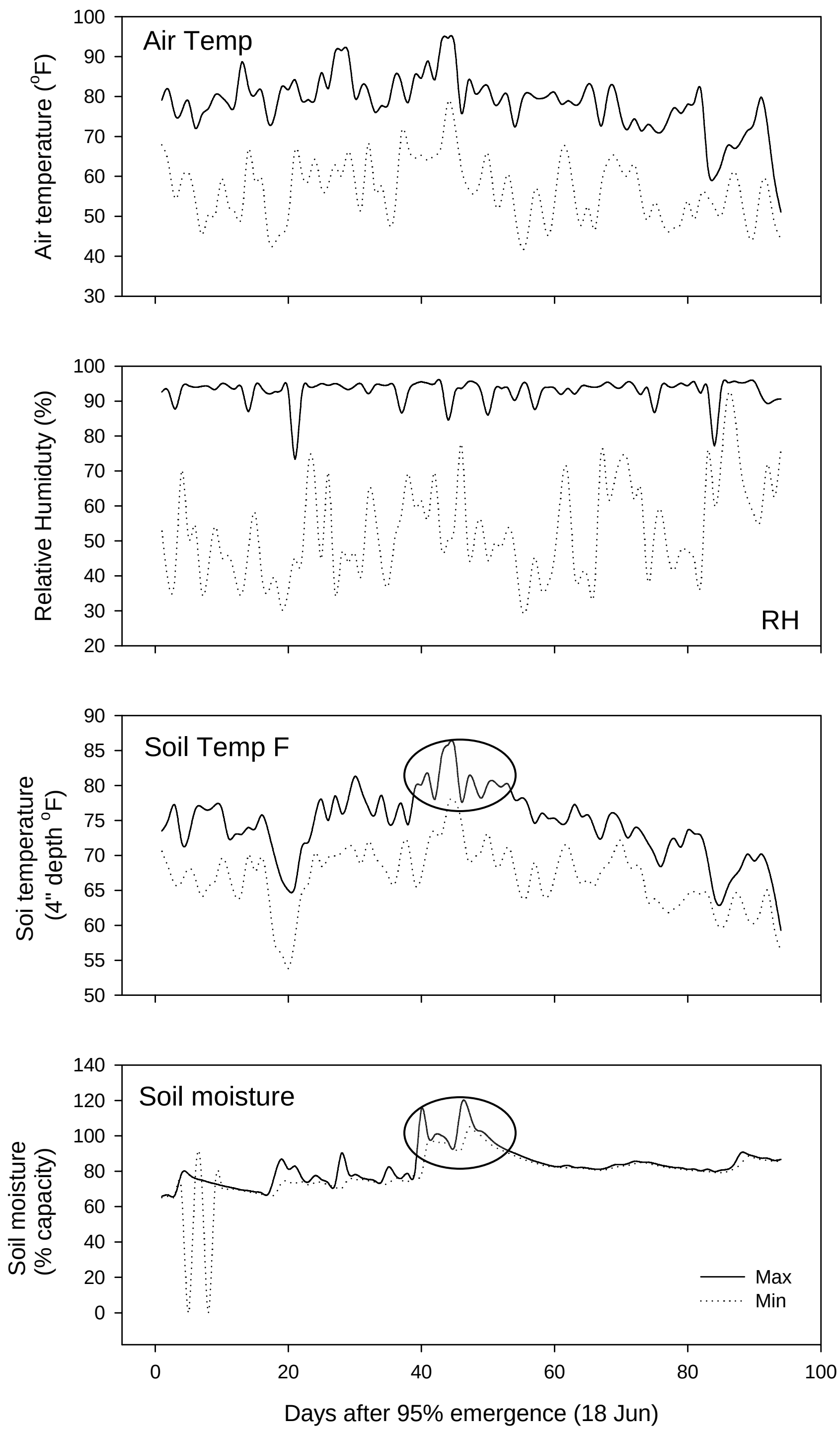

Figure 2. Maximum and minimum air temperature, relative humidity, soil temperature and soil moisture from 95% emergence to late senescence at the Muck Soils research Farm, Laingsburg, MI, 2006.

Pre-planting application of chloropicrin for control of common scab in potato, 2006.

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Seed (FL1879)was planted at Hemlock Farm, Saginaw, MI on 5 May into eight-row by 50-ft plots (ca. 9-in. between plants at 34-in. row spacing) replicated four times in a randomized complete block design. Fertilizer was drilled into plots before planting, formulated according to results of soil tests. Additional nitrogen (final N 28 lb/A) was applied to the growing crop with irrigation 45 DAP (days after planting). Plots were irrigated to supplement precipitation to about 0.5 in. /A/5 day period with overhead pivot irrigation. Bravo WS 6SC was applied at 1.5 pt/A, 5 gal/A by air on a seven-day interval (ten applications), starting after the canopy was about 50% closed. Chloropicrin was applied as Pic Plus Fumigant 85.5% active ingredient into pre-made rows 30 days prior to planting when soil temperature reached 45°F. Weeds were controlled by hilling and with Dual 8E at 2 pt/A 10 DAP, and Poast at 1.5 pt/A 40 DAP. Insects were controlled with Admire 2F at 1.25 pt/A at planting and as needed thereafter. Vines were killed with Reglone 2EC (1 pt/A on 2 Sep). Plots (8 x 50-ft row) were harvested on 29 Sep. Individual treatments were weighed, tuber number determined per 10 ft row and specific gravity determined. All tubers in each plot were harvested 14 days after desiccation (approximately 135 DAP). Tubers were washed and assessed for common scab (*S. scabies*) incidence (%) and severity at harvest. Severity of common scab was measured as an index calculated by counting the number of tubers (n = 200) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 - 15; 4 >16% surface area of tuber covered with tuber lesions (surface and pitted). The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with lesions.

Treatments with tuber number from 161.3 to 186.0 and 184.0 to 198.3 tubers/10 ft row were not significantly different. There was no significant difference among treatments on specific gravity which ranged from 1.0815 to 1.0846. There was no significant difference among treatments on common scab and the index ranged from 22.1 (Pic Plus 85.5AP 100 lb) to 42.9 (Pic Chlor 85.5AP 100 lb) and the untreated check had an index of 38.5. There was no significant difference among treatments on total yield which ranged from 447.3 (untreated check) to 518.8 cwt/A (Pic Plus 85.5AP 100 lb; Table 1). No phytotoxicity was observed in this trial.

Table 1. Efficacy of in-furrow at-planting fungicide application of **chloropicrin** on incidence and severity of common scab and yield in two potato cultivars.

Treatment and rate/A	tuber number		specific gravity	Common scab[z] (% in class) class 0	class 1	class 2	class 3	class 4	class 5	Scab Index	yield cwt/A
Pic Plus 85.5AP 100 lb	195.3	a[y]	1.0815	25.3	45.3	21.3	6.7	0.7	0.0	22.1	518.8
Pic Plus 85.5AP 120 lb	161.3	b	1.0841	21.3	44.0	20.0	13.3	2.7	0.7	27.6	488.5
Pic Chlor 85.5AP 100 lb	186.3	a	1.0846	8.0	29.3	29.3	20.7	15.3	0.7	42.9	489.6
Pic Chlor 85.5AP 120 lb	198.3	a	1.0838	18.0	34.7	28.7	16.7	5.3	2.0	34.7	498.7
Vapam 32.7EC 38 gal	186.0	ab	1.0836	18.0	37.3	36.7	11.3	0.0	0.0	28.9	457.2
Untreated Check	184.0	ab	1.0842	13.3	32.7	24.7	14.0	11.3	4.7	38.5	447.3
LSD[x] p = 0.05	24.78		0.00720	21.648	33.91	24.556	16.404	16.89	5.958	23.899	78.28

[z] Severity of common scab was measured as an index calculated by counting the number of tubers (n = 200) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 - 15; 4 >16% surface area of tuber covered with tuber lesions (surface and pitted). The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with lesions.

[y] Values followed by the same letter are not significantly different at P = 0.05 (Tukey Multiple Comparison). Varieties were analyzed together as there was no significant difference between varieties in incidence or severity of common scab.

[x] $LSD_{p=0.05}$ included if no significant difference among mean values.

Evaluation of novel fungicide seed treatments in combination with management practices for the control of seed-borne diseases of potato.

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Introduction

Seed-borne diseases of potato represent a significant constraint to potato production in the US. The major diseases of potato, late blight, *Fusarium* dry rot, and black scurf are all readily transmitted by seed-borne inoculum. During recent growing seasons, three factors have enhanced seed-borne potato disease problems in Michigan; 1) lack of information on effective fungicides for both post-harvest and pre-planting use against seed-borne pathogens; 2) an increase in the area of potatoes grown by fewer growers leading to management issues such as timing of pre-cutting of seed prior to planting; and 3) climatic factors such as increased frequencies of rain events during planting. In combination, these factors can delay planting and increase the impact of fungal and secondary bacterial seed piece decay and sprout rot during the early part of the growing season, subsequently affecting yield and quality of the crop. The most effective control of seed-borne diseases such as late blight and *Fusarium* dry rot is achieved by the application of an effective fungicide seed treatment prior to planting. However, many of the fungal isolates that contribute to seed-borne diseases are now resistant to the fungicides traditionally used to control them, resulting in poor control of these diseases. Thus, the use of an effective seed treatment in combination with good management practices during the cutting process and storage of cut seed prior to planting are essential to reducing these diseases in cut seed prior to planting. This project sought to evaluate two new biofungicides and a reduced risk fungicide for control of seed-borne diseases, and determine the best conditions to store seed after cutting and treating.

Objectives

The objectives of this proposal were to a) evaluate *in vitro* the effectiveness of fungicidal seed treatments and different storage conditions prior to planting for controlling seed piece decay (*Fusarium*) and sprout rot caused by *P. infestans*, *F. sambucinum*, and *R. solani* and b) carry out *in vivo* field experiments to evaluate the agronomical effects of fungicidal seed treatments and storage conditions before planting on crop health.

Results and accomplishments

Results of the *in vitro* experiments on the effectiveness of fungicidal seed treatments and different storage conditions prior to planting for controlling seed piece decay and sprout rot are shown in Tables 1-3. The results show that storage of seed pieces under sub-optimal conditions (at 25°C in the dark without ventilation) significantly increased the levels of seed piece decay and sprout rot (Tables 1-3). In experiments inoculated with *Fusarium sambucinum,* all treatments had significantly fewer diseased sprouts (sprout rot) and a lower incidence of seed piece decay than the inoculated/non-treated controls (positive controls). Seed treatment with the biofungicides Serenade Max, and T-22 Planter Box and storage under optimal conditions (between 12 and 18°C at 95% RH and with forced air ventilation at 5950 l min^{-1}) provided good control of sprout rot and seed piece decay caused by *F. sambucinum* (Table 1). In the late blight experiments treatment with the biofungicides significantly lowered the incidence of seed piece decay and the percentage of seed piece decay per tuber when seed pieces were stored under optimal conditions or treated on the day of planting (Table 2). The amount of seed piece decay in seed pieces treated with T-22 Planter Box and stored under optimal conditions was equivalent to that in treatments with Maxim MZ. In treatments where the biofungicides were applied on the day of planting the amount of seed piece decay was not significantly different from the non-inoculated/non-treated control (negative control). Neither of the biofungicides or the commercial seed treatment Maxim MZ provided effective control of seed piece decay when the tubers were stored under sub-optimal conditions (Table 2). In the *Rhizoctonia* experiments, none of the seed treatments were effective against sprout rot, as there was no significant differences between any of the treatments and the positive controls (Table 3).

Results of the *in vivo* field experiments to evaluate the agronomical effects of fungicidal seed treatments and storage conditions before planting on crop health are shown in Tables 4-6. In all experiments, treatment with the biofungicides did not significantly enhance the rate of emergence of sprouts (RAUEPC) or the final plant stand compared to the positive control (Tables 4-6). In experiments inoculated with *F. sambucinum* , there were no significant differences between the two types of storage regime. However, in all treatments there was a lower rate of emergence and lower final plant stand in treatments treated and inoculated on the day of planting (Table 4). There were no significant differences between treatments in terms of the number of diseased stems. In late blight experiments, the non-inoculated treatments where the biofungicides were applied on the day of planting showed a significant reduction in the rate of emergence and final plant stand, suggesting that the biofungicides may be having a phytotoxic effect on emerging sprouts (Table 5). In experiments inoculated with *R. solani,* the type of storage did not significantly affect the rate of emergence compared to the negative controls. However, as with late blight, in the non inoculated treatments where the biofungicides were applied on the day of planting the rate of emergence and final plant stand were much lower compared to treatments which were stored (Table 6). However, these treatments were not significantly different from both the negative and positive controls (Table 6). Seed treatment with the biofungicides Serenade Max, and T-22 Planter Box provided good control of black scurf and was equivalent to that obtained with Maxim MZ (Table 6).

Impacts

Seed-borne diseases of potato represent a significant constraint to potato production in the US and are consistently rated as high priority research topics. Studies have shown that cut potato tuber seed pieces are particularly susceptible to the development of seed piece decay during the period between cutting and planting. Also after planting over 50% of sprouts developing on infected tubers may become diseased and killed outright before emergence. With the increasing resistance of potato seed-borne pathogens to conventional fungicidal seed treatments any new means of controlling or preventing the spread of seed-borne pathogens should be of keen interest to the potato industry. Biofungicides are an economically attractive alternative to conventional seed treatment products since one application can provide prolonged protection (up to 61 days in the case of *Bacillus* spp.) reducing the number of fungicide sprays needed in the field. A single fungicide spray typically costs $15 per acre, thus the elimination of even a single spray may result in savings of over $4500 to a grower who may have more than 300 acres under cultivation. A reduction in the use of traditional chemical fungicides will also lessen the likelihood of fungicide resistance developing in the pathogen populations. This project has demonstrated that new biofungicides may have the potential to become an alternative to conventional seed treatments for the control of seed borne diseases as they provided control of seed piece decay caused by late blight and Fusarium dry rot. However, further studies are needed to confirm these results.

New regulations governing pesticides, concerns about worker safety, and the public's interest in environmental stewardship, including reduced use of fungicides, have further heightened the potato industries desire to increase its reliance on newer, biofungicide and reduced risk chemistries, technologies and management practices.

Summary Statement

Seed-borne diseases of potato represent a significant constraint to potato production in the US. Using a systematic experimental approach through a combination of lab based and field experimentation, results from this project suggest that applying seed treatments and storing seed pieces at high temperatures (25°C) without sufficient ventilation is less effective in controlling seed piece decay and sprout rot than applying a seed treatment and storing at lower temperature (12°C), at 95%RH with forced air ventilation at 5950 l min^{-1} until planting. Seed pieces stored under these optimal conditions had less seed piece decay, increased tuber, stem, and stolon numbers, a higher rate of emergence and final plant stand.

Table 1. Effect of storage method, seed treatment application and inoculation with *Fusarium sambucinum* on sprout development, and sprout and seed piece health of potato stored for 14 days in controlled environments after the scheduled time of planting.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	Diseased sprouts (%)		Incidence of seed piece decay (%)[4]		Seed piece decay (%)[5]	
None	–	A	32.8	defg[6]	35.0	defg	5.1	e
	–	B	37.5	defg	25.0	fg	4.6	e
	–	C	27.7	fg	57.5	bcde	14.0	e
	+	A	89.4	a	97.5	a	68.9	ab
	+	B	96.9	a	100	a	85.1	a
	+	C	91.2	a	97.5	a	60.4	bc
Serenade Max (250g)	–	A	45.0	cdefg	40.0	cdefg	8.5	e
	–	B	42.4	defg	45.0	cdef	11.6	e
	–	C	35.6	defg	42.5	cdefg	6.9	e
	+	A	47.2	cdef	50.0	bcdef	43.5	cd
	+	B	66.1	bc	77.5	ab	55.5	bc
	+	C	53.4	cde	45.0	cdef	40.0	cd
T-22 Planter Box (125g)	–	A	33.5	defg	27.5	fg	15.0	e
	–	B	37.5	defg	32.5	defg	11.0	e
	–	C	41.6	defg	30.0	efg	11.9	e
	+	A	54.0	cd	57.5	bcde	40.8	cd
	+	B	84.2	ab	67.5	bc	52.5	bc
	+	C	65.4	bc	60.0	bcd	43.8	cd
Maxim MZ (500g)	–	A	31.2	efg	15.0	g	3.4	e
	–	B	33.0	defg	40.0	cdefg	6.9	e
	–	C	30.1	fg	27.5	fg	6.9	e
	+	A	33.4	defg	32.5	defg	4.9	e
	+	B	38.2	defg	30.0	efg	22.8	de
	+	C	24.4	g	22.5	fg	4.1	e

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] Incidence of seed piece decay was calculated as the mean number of seed pieces showing symptoms of Fusarium dry rot.
[5] Seed piece decay was calculated as the percentage volume of decay per tuber.
[6] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 2. Effect of storage method, seed treatment application and inoculation with *Phytophthora infestans* on seed piece health of potato stored for 14 days in controlled environments after the scheduled time of planting.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	Incidence of seed piece decay (%)[4]		Seed piece decay (%)[5]	
None	–	A	0.0	g	0.0	e
	–	B	0.0	g	0.0	e
	–	C	0.0	g	0.0	e
	+	A	87.5	ab	74.5	ab
	+	B	100.0	a	81.6	ab
	+	C	50.0	cd	25.3	de
Serenade Max (250g)	–	A	0.0	g	0.0	e
	–	B	0.0	g	0.0	e
	–	C	0.0	g	0.0	e
	+	A	55.0	cd	43.1	cd
	+	B	92.5	a	85.4	ab
	+	C	30.0	def	8.3	e
T-22 Planter Box (125g)	–	A	5.0	fg	1.4	e
	–	B	10.0	efg	1.8	e
	–	C	2.5	g	0.3	e
	+	A	32.5	de	18.5	de
	+	B	100.0	a	95.5	ab
	+	C	12.5	efg	2.9	e
Maxim MZ (500g)	–	A	0.0	g	0.0	e
	–	B	0.0	g	0.0	e
	–	C	0.0	g	0.0	e
	+	A	32.5	de	18.6	de
	+	B	65.0	bc	61.5	bc
	+	C	10.0	efg	1.1	e

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Phytophthora infestans* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] Incidence of seed piece decay was calculated as the mean number of seed pieces showing symptoms of late blight.
[5] Seed piece decay was calculated as the percentage volume of decay per tuber.
[6] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 3. Effect of storage method, seed treatment application and inoculation with *Rhizoctonia solani* on sprout development, and sprout and seed piece health of potato stored for 14 days in controlled environments after the scheduled time of planting.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	Diseased sprouts (%)	
None	–	A	82.2	abcd[4]
	–	B	85.2	abcd
	–	C	67.4	cdefg
	+	A	77.3	abcde
	+	B	90.0	abc
	+	C	73.4	abcdef
Serenade Max (250g)	–	A	74.8	abcde
	–	B	50.4	fg
	–	C	85.2	abcd
	+	A	71.3	bcdef
	+	B	85.2	abcd
	+	C	62.4	defg
T-22 Planter Box (125g)	–	A	89.0	abc
	–	B	56.8	efg
	–	C	51.4	fg
	+	A	90.8	ab
	+	B	95.0	a
	+	C	45.9	g
Maxim MZ (500g)	–	A	90.1	abc
	–	B	65.5	defg
	–	C	19.0	h
	+	A	90.0	abc
	+	B	83.6	abcd
	+	C	78.5	abcde

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Rhizoctonia solani* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 4. Effect of timing of seed treatment application and inoculation with *Fusarium sambucinum* on emergence, final plant stand, and number of diseased stems of potato.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	RAUEPC (%)[4]		Final plant stand (%)[5]		Diseased stems (%)[6]	
None	–	A	15.5	a[7]	89.2	abc	20.7	a
	–	B	14.7	abcd	85.8	abc	20.8	a
	–	C	6.5	g	44.2	d	37.8	a
	+	A	14.4	abcde	84.2	abc	24.3	a
	+	B	11.5	abcdefg	70.0	abcd	33.2	a
	+	C	8.2	efg	52.5	cd	34.5	a
Serenade Max (250g)	–	A	14.7	abcd	86.7	abc	13.2	a
	–	B	14.8	abcd	85.0	abc	24.3	a
	–	C	8.6	defg	58.3	bcd	24.1	a
	+	A	13.4	abcdef	80.0	abcd	24.5	a
	+	B	9.1	bcdefg	52.5	cd	27.1	a
	+	C	8.8	cdefg	58.3	bcd	31.2	a
T-22 Planter Box (125g)	–	A	15.1	abc	88.3	abc	31.2	a
	–	B	14.4	abcde	85.0	abc	41.8	a
	–	C	14.3	abcde	85.8	abc	34.8	a
	+	A	15.4	ab	91.7	ab	24.1	a
	+	B	12.6	abcdefg	75.8	abcd	36.0	a
	+	C	7.5	fg	51.7	cd	29.7	a
Maxim MZ (500g)	–	A	17.0	a	98.3	a	28.0	a
	–	B	15.8	a	94.2	ab	20.9	a
	–	C	13.7	abcdef	83.3	abc	35.5	a
	+	A	16.1	a	94.2	ab	26.9	a
	+	B	15.0	abc	86.7	abc	11.5	a
	+	C	11.2	abcdefg	71.7	abcd	12.6	a

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] RAUEPC, relative area under the plant emergence progress curve, calculated from the day of planting to full emergence 28 days after planting (max = 100).
[5] Final plant stand, was expressed as the percentage of emerged plants divided by the expected number based on the planting rate.
[6] Diseased stems, the number of stems showing symptoms of vascular wilt when cut open.
[7] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 5. Effect of timing of seed treatment application and inoculation with *Phytophthora infestans* on emergence and final plant stand of potato.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	RAUEPC (%)[4]		Final plant stand (%)[5]	
None	–	A	15.2	a[6]	89.2	a
	–	B	13.9	ab	80.0	abcd
	–	C	6.8	def	49.2	efgh
	+	A	7.7	cdef	45.8	fgh
	+	B	7.7	cdef	45.0	fgh
	+	C	7.8	cdef	40.0	gh
Serenade Max (250g)	–	A	14.5	ab	85.0	abc
	–	B	13.9	ab	81.7	abcd
	–	C	8.2	cdef	57.5	bcdefgh
	+	A	9.4	bcdef	56.7	bcdefgh
	+	B	6.0	ef	34.2	h
	+	C	7.7	cdef	55.8	cdefgh
T-22 Planter Box (125g)	–	A	14.8	a	86.7	ab
	–	B	13.4	ab	78.3	abcde
	–	C	4.4	f	31.7	h
	+	A	12.1	abc	72.5	abcdef
	+	B	9.4	bcdef	53.3	defgh
	+	C	6.1	def	44.2	fgh
Maxim MZ (500g)	–	A	16.0	a	93.3	a
	–	B	15.1	a	86.7	ab
	–	C	10.9	abcde	71.7	abcdef
	+	A	12.1	abc	70.0	abcdefg
	+	B	6.7	def	40.8	gh
	+	C	11.3	abcd	70.0	abcdefg

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] RAUEPC, relative area under the plant emergence progress curve, calculated from the day of planting to full emergence 28 days after planting (max = 100).
[5] Final plant stand, was expressed as the percentage of emerged plants divided by the expected number based on the planting rate.
[6] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 6. Effect of timing of seed treatment application and inoculation with *Rhizoctonia solani* on emergence and final plant stand of potato.

Fungicide treatment and rate/100kg seed[1]	Inoculation[2]	Storage type[3]	RAUEPC (%)[4]		Final plant stand (%)[5]		Stem canker (%)		Stolon canker (%)		Black scurf on tubers[6] Severity[7]		Incidence (%)	
None	–	A	15.7	a[8]	90.8	ab	70.3	ab	38.9	ab	11.6	ab	37.5	ab
	–	B	16.0	a	94.2	a	72.4	ab	54.6	ab	5.1	ab	18.5	ab
	–	C	8.8	efg	57.5	ef	57.3	ab	43.9	ab	4.6	ab	14.5	bc
	+	A	14.5	ab	90.8	ab	90.8	a	56.5	ab	6.9	ab	20.5	abc
	+	B	14.5	ab	85.0	abc	77.4	a	53.2	ab	13.0	ab	30.0	abc
	+	C	5.8	g	46.7	f	90.6	a	51.6	ab	5.4	ab	17.0	bc
Serenade Max (250g)	–	A	15.3	a	89.2	ab	64.9	ab	48.5	ab	3.8	ab	8.5	bc
	–	B	15.1	a	88.3	ab	62.2	ab	52.0	ab	5.1	ab	13.5	bc
	–	C	9.4	defg	60.8	cdef	79.0	a	69.0	a	17.0	a	53.5	a
	+	A	12.1	abcde	70.8	abcdef	26.1	b	31.4	b	1.9	b	6.5	bc
	+	B	9.3	defg	55.0	ef	73.4	ab	36.4	ab	0.0	b	0.0	c
	+	C	8.5	efg	58.3	def	83.8	a	44.6	ab	7.1	ab	23.5	abc
T-22 Planter Box (125g)	–	A	14.7	ab	84.4	abc	81.3	a	59.7	ab	5.1	ab	13.5	bc
	–	B	15.5	a	90.8	ab	81.6	a	60.3	ab	4.5	ab	12.0	bc
	–	C	7.6	fg	51.7	f	55.1	ab	48.7	ab	10.0	ab	28.0	abc
	+	A	13.4	abcd	79.2	abcde	74.8	ab	41.1	ab	2.4	b	6.0	bc
	+	B	14.2	abc	82.5	abcd	54.6	ab	38.8	ab	5.9	ab	16.5	bc
	+	C	7.6	fg	50.0	f	70.3	ab	48.4	ab	9.5	ab	24.5	abc
Maxim MZ (500g)	–	A	14.6	ab	85.8	ab	43.7	ab	32.2	b	7.8	ab	21.5	abc
	–	B	15.0	a	86.7	ab	66.3	ab	40.0	ab	3.6	ab	12.0	bc
	–	C	10.8	bcdef	78.3	abcde	73.5	ab	51.3	ab	2.4	b	9.0	bc
	+	A	15.6	a	93.3	ab	52.1	ab	41.2	ab	2.5	b	8.0	bc
	+	B	15.8	a	90.0	ab	69.7	ab	47.9	ab	3.3	ab	9.5	bc
	+	C	10.1	cdef	69.2	bcdef	49.0	ab	35.3	ab	7.0	ab	18.5	abc

[1] Seed pieces were treated with the seed treatment 30 min after inoculation. All rates are manufacturers recommended rate.
[2] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[3] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[4] RAUEPC, relative area under the plant emergence progress curve, calculated from the day of planting to full emergence 28 days after planting (max = 100).
[5] Final plant stand, was expressed as the percentage of emerged plants divided by the expected number based on the planting rate.
[6] Samples of 50 tubers per plot were harvested 14 days after desiccation (approximately 135 DAP) and assessed for black scurf (*R. solani*) incidence (%) and severity 40 days after harvest.
[7] Severity of black scurf was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 - 15; 4 >15% surface area of tuber covered with sclerotia. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with sclerotia.
[8] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Evaluation of fungicides for use in potato seed piece health management.

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Introduction

During recent seasons in the potato growing regions of the mid-western states of the US, three factors have enhanced seed piece decay problems; 1) lack of information on effective fungicides for both post-harvest and pre-planting use against the primary seed piece decay pathogen *Fusarium* dry rot; 2) an increase in the area of potatoes grown by fewer growers (MPIC, 1995 – 1999, pesticide survey) leading to management issues such as timing of pre-cutting of seed prior to planting; and 3) climatic factors such as increased frequencies of precipitation events during the planting phase of the season [1, 2]. In combination, these factors can delay planting and increase the impact of seed piece decay during the early portion of the growing season and subsequently may affect yield and quality of the crop. Current recommendations for seed cutting describe some guidelines for the cutting process [3] but do not indicate a time period or management strategy for storage of cut seed. Some level of *Fusarium* dry rot is almost always present in commercially available seed [4] and tubers infected with *Fusarium* dry rot are particularly susceptible to the development of seed piece decay during this phase. In severe disease cases seed pieces may completely rot before planting. Alternatively after planting, over 50% of sprouts developing on infected tubers may become diseased and may be killed outright before emergence. The most effective control of *Fusarium* dry rot is achieved by the application of an effective fungicide, such as fludioxinil, prior to planting. Many of the isolates of *Fusarium* sp. that contribute to seed piece decay are resistant to the benzimidazole fungicides such as thiabendazole and thiophanate-methyl, resulting in poor control of dry rot [5, 6]. Thus, the use of an effective seed treatment such as fludioxinil in combination with good management practices during the cutting process and storage of cut seed prior to planting are essential to reducing *Fusarium* dry rot and secondary bacterial soft rot in cut seed prior to planting. However, studies at Michigan State University have shown that the effect of the timing of pre-cutting potato seed and timing of application of seed-piece fungicides prior to planting on seed piece decay, plant establishment, subsequent vigor and early crop development is complex and can be affected not just by the presence of inoculum but also by seed storage conditions after seed cutting and prior to planting. This project seeks to evaluate the best conditions to store seed after cutting and treating with a seed treatment in a selection of commonly grown varieties in order to minimize seed piece decay and maximize early plant development and vigor. Results from the first year of the project indicated that treatment with a fungicidal seed treatment and storage of cut seed under optimal conditions (see below) was effective in reducing levels of disease in cut seed.

Research Objectives

The application of fungicidal seed piece treatments to cut seed may provide an effective means of controlling *Fusarium* dry rot prior to planting. However, there is little information on the use and effectiveness of seed treatments for control of *Fusarium* seed piece decay, the pre-planting phase of dry rot, and sprout rot, the post-planting phase of the disease. Thus, the objectives of this investigation are:

1. To evaluate *in vitro* the effectiveness of fungicidal seed treatments and different storage conditions prior to planting for controlling *Fusarium* seed piece decay and sprout rot.
2. *In vivo* field experiments to evaluate the agronomical effects of fungicidal seed treatments and storage conditions before planting on crop health.

Materials & Methods

Four potato varieties “Pike”, “Atlantic”, “Russet Norkotah” and “FL1879” which are susceptible to seed piece decay caused by *Fusarium sambucinum* were used. Tubers were selected from certified seed crops grown in Michigan. The tubers were stored in the dark at 3^{o}C and 95% RH until used. Tubers free from *Fusarium* dry rot (and other diseases) were selected for experiments.

Fusarium sambucinum, (isolate ATTC S602), which produces dry rot symptoms in potato tuber tissue, were used for inoculation. Conidia were harvested from cultures of *F. sambucinum* grown on PDA in the dark at 8°C for 14 days prior to the inoculation date. A comparison between two simulations of cutting/treating/planting regimes was made; a) cutting and treating seed with a delay in planting of 10 days and b) cutting and treating on the day of planting. The controls included seed that was cut and inoculated with *F. sambucinum* and cut but not inoculated at each of the two cutting times. The two fungicide treatments included the controls (as above) plus or minus application of a seed treatment (see below).

For each treatment, tubers were removed from storage and warmed to 8^{o}C in the dark in controlled environment chambers with forced air ventilation at 5950 l min^{-1} for 10 days prior to treatment. Whole tubers were cut in half with a sterile knife and the cut surfaces (160 per treatment) were spray inoculated with 200 ml of the conidial suspension (described above) to give a final dosage of about 1 ml per tuber. Approximately 30 minutes after inoculation, seed pieces were treated with the commercial seed protectant Maxim® MZ (active ingredients: fludioxonil 5 g kg^{-1} + mancozeb 96 g kg^{-1}) at the manufacturers recommended rate (500g per 100 kg potato seed). Dust formulations of seed treatments were measured and added to cut seed pieces in a Gustafson revolving drum seed treater and mixed for two minutes to ensure even spread of the fungicide. The pre-planting re-storage treatments followed current guidelines for recommended pre-planting practices (MSU); cut tubers were returned to the controlled environment chamber and held at 8^{o}C for 2 days and over the next 10 days the temperature were increased every 2 days by 2^{o}C intervals to 18^{o}C in a 14/10 h photoperiod and 95%RH with forced air ventilation at 5950 l min^{-1} until planting. To simulate non-recommended pre-planting practices, the second storage treatment was in the dark at 25°C, without added humidity or ventilation. To evaluate the effect of seed treatment and storage conditions on the development of dry rot on the seed pieces and its effect on sprout health, samples from each treatment (n = 50) were removed prior to planting and incubated at 8^{o}C (95% RH) in controlled environment chambers for 14 days. The treated seed tuber samples were held in storage post-treatment for 24 and 14 days (10 and 0 days pre-planting treatments, respectively) to allow equal incubation time. The total number of healthy and dry rot affected sprouts were counted and development of dry rot on the seed piece was estimated as percent decay by comparing depth of penetration of darkening through the tuber after cutting four transverse sections through the seed piece. To evaluate the agronomical effects of fungicidal seed treatments and storage conditions before planting on crop health, the treated seed-pieces were planted at the Montcalm Potato Research Farm, Entrican, MI into two-row by 9 m plots (ca. 22 cm between plants to give a target population of 80 plants at 86 cm row spacing) replicated four times in a randomized complete block design. Stand count, rate of emergence, final plant stand, and yield were measured.

Results

Results of the *in vitro* experiments on the effectiveness of the fungicidal seed treatment and different storage conditions prior to planting for controlling seed piece decay and sprout rot are shown in Table 1. The results show that in general, storage of seed pieces under sub-optimal conditions (at 25°C in the dark without ventilation) significantly increased the levels of seed piece decay and sprout rot (Table 1). In general, treatments inoculated with *Fusarium sambucinum* and treated with a seed piece treatment, had significantly fewer diseased sprouts (sprout rot) and a lower incidence of seed piece decay than the inoculated/non-treated controls (positive controls). The varieties “Russett Norkotah” and “FL1879” had the least disease of the four varieties tested, with the seed treatment providing effective control of dry rot under both storage regimes. However, in all varieties tested, the most effective control was always obtained in treatments where the seed was treated and planted on the same day (treatments labeled C in Table 1). In “FL1879”, the incidence of seed piece decay was significantly lower in non fungicide treated seed that were stored under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}) compared to non-fungicide treated seed that was stored under sub-optimal conditions (Table 1).

Results of the *in vivo* field experiments to evaluate the agronomical effects of fungicidal seed treatment and storage conditions before planting on crop health are shown in Table 2. In general, in treatments inoculated with *F. sambucinum* and treated with a seed piece treatment, there were no significant differences in RAUEPC (rate of emergence) between the two types of storage regimes. However, in the varieties “Pike”, “Atlantic”, and “Russett Norkotah”, in the inoculated/non-fungicide treated treatments, storage under optimal conditions significantly enhanced the rate of emergence, compared to storage under sub-optimal conditions (Table 2). In general for all varieties, there was no significant difference between any of the treatments in terms of mean shoot number, final plant stand and yield. However, in “Pike” and “Atlantic”, in the inoculated/non-fungicide treated treatments, storage under optimal conditions significantly enhanced the final plant stand, compared to storage under sub-optimal conditions (Table 2).

Table 1. Effect of storage method, seed treatment application and inoculation with *Fusarium sambucinum* on sprout development, and seed piece health in four cultivars of potato stored for 14 days in controlled environments after the scheduled time of planting.

Cultivar[1]	Storage type[2]	Inoculation[3]	Fungicide treatment[4]	Diseased sprouts (%)		Seed piece decay (%)	
Pike	A	–	–	47.5	abc[5]	77.5	ab
	B	–	–	52.7	ab	82.5	a
	C	–	–	47.9	abc	15.0	d
	A	+	–	51.3	ab	65.0	abc
	B	+	–	63.5	a	77.5	ab
	C	+	–	44.2	abc	40.0	abcd
	A	–	+	42.9	abc	7.5	d
	B	–	+	46.6	abc	47.5	abcd
	C	–	+	23.4	c	17.5	d
	A	+	+	41.8	abc	30.0	cd
	B	+	+	54.1	ab	37.5	bcd
	C	+	+	34.4	bc	5.0	d
Atlantic	A	–	–	56.5	abc	37.5	ab
	B	–	–	71.8	a	72.5	a
	C	–	–	38.4	c	47.5	ab
	A	+	–	62.5	ab	77.5	a
	B	+	–	67.0	ab	80.0	a
	C	+	–	38.1	c	75.0	a
	A	–	+	46.8	bc	22.5	ab
	B	–	+	58.3	abc	42.5	ab
	C	–	+	52.5	abc	7.5	b
	A	+	+	49.6	bc	45.0	ab
	B	+	+	55.6	abc	55.0	ab
	C	+	+	38.4	c	0	b
Russett Norkotah	A	–	–	65.5	bcd	72.5	a
	B	–	–	81.2	ab	75.0	a
	C	–	–	53.3	def	55.0	ab
	A	+	–	72.0	abcd	40.0	abc
	B	+	–	85.1	a	47.5	abc
	C	+	–	33.9	g	35.0	abc
	A	–	+	53.8	def	15.0	bc
	B	–	+	58.8	cde	22.5	bc
	C	–	+	39.7	fg	15.0	bc
	A	+	+	68.5	abcd	10.0	bc
	B	+	+	74.1	abc	10.0	bc
	C	+	+	46.4	efg	5.0	c
FL1879	A	–	–	53.3	abc	7.5	bc
	B	–	–	71.5	a	20.0	abc
	C	–	–	36.8	cde	5.0	bc
	A	+	–	42.9	bcde	12.5	bc
	B	+	–	61.0	ab	50.0	a
	C	+	–	59.5	ab	0	c
	A	–	+	31.6	de	2.5	c
	B	–	+	32.8	de	2.5	c
	C	–	+	26.6	e	0	c
	A	+	+	44.9	bcd	22.5	abc
	B	+	+	47.8	bcd	35.0	ab
	C	+	+	35.9	cde	0	c

[1] Data for each cultivar were analyzed separately.
[2] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[3] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[4] Seed pieces were treated with the seed treatment 30 min after inoculation.
[5] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Table 2. Effect of timing of seed treatment application and inoculation with *Fusarium sambucinum* on emergence, final plant stand, shoot number and yield in four cultivars of potato.

Cultivar[1]	Storage type[2]	Inoculation[3]	Fungicide treatment[4]	RAUEPC (%)[5]	Mean Shoot number	Final plant stand (%)	Yield (lb)
Pike	A	–	–	11.2 a	2.5 a[6]	79.5 ab	41.2 ab
	B	–	–	10.5 a	2.4 a	68.0 ab	32.8 bc
	C	–	–	11.9 a	2.6 a	85.5 ab	46.2 ab
	A	+	–	10.9 a	2.4 a	69.0 ab	37.5 abc
	B	+	–	5.8 b	2.3 a	60.7 b	24.8 c
	C	+	–	10.7 a	2.6 a	81.0 ab	43.3 ab
	A	–	+	11.7 a	2.2 a	76.0 ab	45.8 ab
	B	–	+	10.0 a	2.2 a	74.0 ab	44.5 ab
	C	–	+	12.6 a	2.8 a	88.5 a	47.4 a
	A	+	+	11.4 a	2.6 a	77.0 ab	39.8 ab
	B	+	+	11.3 a	2.3 a	71.5 ab	38.3 ab
	C	+	+	11.4 a	2.8 a	81.5 ab	46.0 ab
Atlantic	A	–	–	16.4 a	3.3 ab	94.0 ab	56.1 a
	B	–	–	12.2 ab	2.1 b	75.5 ab	49.8 a
	C	–	–	16.6 a	3.3 ab	95.5 a	60.4 a
	A	+	–	13.4 ab	2.4 ab	78.0 ab	49.5 a
	B	+	–	9.7 b	2.2 ab	62.0 b	35.9 a
	C	+	–	13.5 ab	3.2 ab	86.5 ab	51.3 a
	A	–	+	13.2 ab	2.9 ab	97.2 a	55.1 a
	B	–	+	12.7 ab	2.2 ab	82.5 ab	53.1 a
	C	–	+	16.8 a	3.6 a	97.5 a	58.9 a
	A	+	+	14.7 ab	3.2 ab	84.5 ab	53.2 a
	B	+	+	13.3 ab	2.2 ab	82.5 ab	49.1 a
	C	+	+	16.0 a	3.3 ab	94.0 ab	60.6 a
Russett	A	–	–	15.6 a	4.9 a	97.0 a	41.0 a
	B	–	–	15.0 ab	4.9 a	95.5 a	37.1 a
	C	–	–	15.5 a	4.8 a	98.0 a	41.1 a
	A	+	–	14.4 ab	4.2 a	97.0 a	40.2 a
	B	+	–	11.8 b	4.2 a	94.0 a	35.3 a
	C	+	–	15.8 a	4.8 a	97.1 a	36.0 a
	A	–	+	14.9 ab	4.4 a	95.0 a	39.8 a
	B	–	+	14.6 ab	4.0 a	92.5 a	38.2 a
	C	–	+	15.4 a	5.1 a	95.5 a	47.7 a
	A	+	+	15.0 ab	4.6 a	92.5 a	37.8 a
	B	+	+	14.3 ab	4.1 a	91.5 a	34.9 a
	C	+	+	15.0 ab	5.1 a	95.0 a	45.6 a
FL1879	A	–	–	16.2 ab	3.7 b	98.5 a	59.6 a
	B	–	–	15.7 ab	3.3 b	99.5 a	57.2 a
	C	–	–	16.6 ab	3.8 b	98.0 a	62.6 a
	A	+	–	16.2 ab	3.9 b	97.0 a	59.9 a
	B	+	–	15.3 ab	3.8 b	94.0 a	56.5 a
	C	+	–	17.0 a	4.6 ab	98.5 a	64.1 a
	A	–	+	16.2 ab	3.8 b	95.5 a	59.5 a
	B	–	+	15.5 ab	3.4 b	94.0 a	57.1 a
	C	–	+	16.4 ab	4.5 ab	98.0 a	68.6 a
	A	+	+	16.1 ab	4.5 ab	97.5 a	62.0 a
	B	+	+	15.2 b	4.3 ab	94.5 a	61.5 a
	C	+	+	16.9 ab	5.3 a	97.5 a	62.7 a

[1] Data for each cultivar were analyzed separately.
[2] Storage types were: A, stored for 10 DBP under optimal conditions (12 - 18°C at 95% RH with forced air ventilation at 5950 l min^{-1}); B, stored for 10 DBP under poor conditions (25°C in dark with no ventilation); C, treated and inoculated on the day of planting.
[3] Seed pieces were inoculated with *Fusarium sambucinum* = "+"; seed pieces were not inoculated = "–"; seed pieces were inoculated immediately after cutting 14 days prior to planting.
[4] Seed pieces were treated with the seed treatment 30 min after inoculation.
[5] RAUEPC, relative area under the plant emergence progress curve, calculated from the day of planting to full emergence 28 days after planting (max = 100).
[6] Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (Tukey multiple comparison method).

Seed treatments and seed plus foliar treatments for control of seed- and soil-borne Rhizoctonia, 2006.

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Potatoes with R*hizoctonia solani* (black scurf), 2- 5% tuber surface area infected, were selected for the trials. Potato seed was prepared for planting by cutting and treating with fungicidal seed treatments two days prior to planting. Seed were planted at the Michigan State University Muck Soils Experimental Station, Bath, MI on 24 May into two-row by 20-ft plots (ca. 10-in between plants to give a target population of 50 plants at 34-in row spacing) replicated four times in a randomized complete block design. The two-row beds were separated by a five-foot unplanted row. Dust formulations were measured and added to cut seed pieces in a Gustafson revolving drum seed treater and mixed for two minutes to ensure even spread of the fungicide. Fungicides applied as pre-planting potato seed liquid treatments were applied in water suspension at a rate of 0.2 pt/cwt onto the exposed seed tuber surfaces, with the entire seed surface being coated in the Gustafson seed treater. Foliar applications were applied with a R&D spray boom delivering 25 gal/A (80 p.s.i.) and using three XR11003VS nozzles per row. Fertilizer was drilled into plots before planting, formulated according to results of soil tests. Additional nitrogen (final N 28 lb/A) was applied to the growing crop with irrigation 45 DAP (days after planting). Previcur Flex was applied at 0.7 pt/A on a seven day interval, total of four applications, starting 1 day after inoculation of adjacent plots with *Phytophthora infestans*. A permanent irrigation system was established prior to the commencement of fungicide sprays and the fields were maintained at soil moisture capacity throughout the season by frequent (minimum 5 day) irrigations. Weeds were controlled by hilling and with Dual 8E at 2 pt/A 10 DAP, Basagran at 2 pt/A 20 and 40 DAP and Poast at 1.5 pt/A 58 DAP. Insects were controlled with Admire 2F at 1.25 pt/A at planting, Sevin 80S at 1.25 lb/A 31 and 55 DAP, Thiodan 3 EC at 2.33 pt/A 65 and 87 DAP and Pounce 3.2EC at 8 oz/A 48 DAP. Vines were killed with Reglone 2EC (1 pt/A on 20 Sep). Plots (20-ft row) were harvested on 29 Oct and individual treatments were weighed and graded. Samples of 50 tubers per plot were harvested 14 days after desiccation (approximately 135 DAP). Four plants per plot were harvested 10-days after the final treatment application (13 Jul) and the percentage of stems and stolons with greater than 5% of the total surface area were counted. Tubers were washed and assessed for black scurf (*R. solani*) incidence (%) and severity 40 days after harvest. Severity of black scurf was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 - 15; 4 >15% surface area of tuber covered with sclerotia. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with sclerotia. Meteorological variables were measured with a Campbell weather station located at the farm, latitude 42.8269 and longitude -84.3650 deg. Maximum and minimum air temperature (^{o}F) were 92.0 and 36.3 and 1-d with maximum temperature >90^{o}F (Jun), 92.0 and 42.7 and 3-d with maximum temperature >90^{o}F (Jul), 95.2 and 41.6 and 3-d with maximum temperature >90^{o}F (Aug) and 82.3 and 45.5 (Sep). Maximum and minimum soil temperature (^{o}F) were 87.8 and 56.0 (Jun), 89.9 and 53.1 (Jul), 92.2 and 59.4 (Aug) and 67.3 and 57.5 (Sep). Maximum and minimum soil moisture (% of field capacity) was 78.3 and 64.9 (Jun); 116.6 and 66.7 (Jul), 119.1 and 80.4 (Aug) and 85.8 and 79.1 (Sep). Precipitation was 2.93 in. (Jun), 6.77 in. (Jul), 3.47 in. (Aug) and 0.68 in. (Sep). The field was flooded for a period of 5-days from 29 Jul to 3 Aug due to excessive rain and failure of the drainage pump at the farm.

No seed treatment or seed treatment plus fungicide applied after emergence was significantly different from the untreated control or from the Maxim MZ 0.5 lb (ST) commercial standard treatment in terms of stem (10.9 to 65%) or stolon (4.7 to 30.2%) canker. Black scurf was not severe in this trial due to extremely hot and wet soil conditions during tuber development and growth. The severe weather conditions affected disease development and yield. The incidence of black scurf on tubers ranged from 3 to 17.5% and there was no significant difference among treatments with 3.0 to 13.0 and 4.0 to 17.5% incidence. The severity index for tuber black scurf ranged from 0.8 to 8.1 and treatments with indices from 0.8 to 5.6, and 1.6 to 8.1 were not significantly different. Marketable yield ranged from 111 to 182 cwt/A (not-treated check = 154 cwt/A) and treatments with 111 to 169 and 125 to 182 cwt/A were not significantly different. G-grade yield ranged from 15 to 27 cwt/A (not-treated check = 17 cwt/A) and treatments with 14.7 to 23.0 and 18.5 to 26.7 cwt/A were not significantly different. Seed treatments and seed treatment plus fungicide applications of fungicides were not phytotoxic.

Treatment and rate/A and rate/cwt potato seed[z]	Rhizoctonia incidence stems[y]		Rhizoctonia incidence stolons[x]		Black scurf on tubers[w] Incidence (%)		Black scurf on tubers[w] Severity[v]		Yield (cwt/A) US1		Yield (cwt/A) b-grade	
Untreated Check…………………………	65.0	a[u]	23.3	a	7.0	ab	2.4	ab	154.2	ab	16.8	b
Serenade ASO 1.34SC 0.4 fl oz/cwt (A[t]).	30.6	a	20.0	a	12.5	ab	5.6	ab	125.2	ab	18.5	ab
Serenade ASO 1.34SC 0.8 fl oz/cwt (A)...	45.0	a	19.9	a	5.0	ab	1.6	ab	157.4	ab	19.2	ab
Sonata 1.38SC 0.4 fl oz/cwt (A)…………	36.5	a	30.2	a	8.0	ab	3.5	ab	151.7	ab	21.0	ab
Sonata 1.38SC 0.8 fl oz/cwt (A)…………	53.0	a	21.1	a	17.5	a	8.1	a	120.8	b	23.0	ab
Maxim MZ 6.2DS 0.5 lb/cwt (A)………..	10.9	a	4.7	a	4.0	ab	1.8	ab	110.9	b	26.7	a
Mancozeb 6DS 1 lb/cwt (A)……………..	50.1	a	13.2	a	9.0	ab	3.6	ab	155.1	ab	22.5	ab
Mancozeb 6DS 1 lb/cwt + WECO 0250 (A)…………………………	44.4	a	19.0	a	3.0	b	0.8	b	168.7	ab	17.1	b
Dithane DF 75DF 2.0 lb + WECO 5006 (C) Dithane DF 75DF 2.0 lb + WECO 5006 (D)…………………………	42.5	a	22.0	a	10.5	ab	5.0	ab	181.7	a	14.7	b
Mancozeb 6DS 1 lb/cwt + WECO 0250+5006 (A) Dithane DF 75DF 2.0 lb + WECO 0250+5006 (C,D)……………….	28.5	a	11.2	a	5.5	ab	2.3	ab	129.4	ab	22.3	ab
Headsup 49.65WG 0.0002 lb/cwt (A)…...	33.8	a	25.0	a	13.0	ab	4.5	ab	157.9	ab	18.6	ab
Headsup 49.65WG 0.134 oz (B)………...	57.0	a	15.9	a	12.5	ab	5.1	ab	139.0	ab	21.2	ab
Headsup 49.65WG 0.0002 lb/cwt (A) Headsup 49.65WG 0.134 oz (B)………...	31.3	a	13.9	a	13.0	ab	5.3	ab	129.7	ab	23.0	ab
Tukey HSD p = 0.05	56.29		36.89		14.15		6.55		58.45		9.16	

[z] Application type; rate/A for broadcast fungicide applications; rate per cwt of potato seed-piece application prior to planting; liquid formulations for seed piece application at 0.2 pt/cwt.

[y] Stems with greater than 5% of area with stem canker due to *Rhizoctonia solani*.

[x] Stolons with greater than 5% of area with stolon canker due to *Rhizoctonia solani*.

[w] Samples of 50 tubers per plot were harvested 14 days after desiccation (approximately 135 DAP) and assessed for black scurf (*R. solani*) incidence (%) and severity 40 days after harvest.

[v] Severity of black scurf was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 - 15; 4 >15% surface area of tuber covered with sclerotia. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with sclerotia.

[u] Values followed by the same letter are not significantly different at $p = 0.05$ (Tukey Multiple Comparison).

[t] Application dates: A= 22 May; B= 21 Jun; C= 3 Jul.

Managing Rhizoctonia Diseases of Potato with Optimized Fungicide Applications and Varietal Susceptibility; Results from the 2006 Field Experiments.

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Introduction

The pathogen *Rhizoctonia solani* (AG-3) causes stem canker and black scurf of potatoes. Rhizoctonia diseases are initiated by seedborne or soilborne inoculum. Seedborne inoculum is carried on seed tubers in the form of sclerotia (black scurf) or as mycelium from the previous season. When contaminated seed is planted the fungus grows from the seed surface to the developing sprout and infection of root primordia, stolon primordia and leaf primordia can occur. The sprouts can be killed at this stage and emergence may be prevented or delayed. Mycelia and sclerotia of *R. solani* also survive in soil and on plant debris and can cause disease independently of seedborne inoculum. Soilborne inoculum can infect potato tissue at anytime when plant organs develop in the proximity of inoculum, however the plant is most severely impacted when immature sprouts, stolons and roots are infected early in the season. During early potato development in April in MI soil temperature is well within the optimal range (average about 10^{o}C) for infection by *R. solani*.

High temperature tends to minimize the impact of *R. solani* even when inoculum is abundant. Some potato varieties appear to be more sensitive than others to but there are none which exhibit high levels of resistance, however information on currently grown varieties is not available. Current recommendations for control of this disease are focused on reducing both seedborne and soilborne inoculum. It is known that minimizing the time between planting and emergence can minimize sprout infection. Crop rotation in warm climates to about three years can also reduce inoculum in the soil. As growers in MI are constrained by season length and rotation requirements it is necessary to include the application of fungicides effective against *R. solani* in a control program. Trials at MSU and elsewhere have indicated that there are several effective fungicides that can be used to manage *R. solani*, either applied as seed treatments or as in-furrow at-planting applications. These fungicides include fludioxonil-based seed treatments (Maxim products), strobilurin-based products applied in-furrow [azoxystrobin (Quadris, Amistar); pyraclostrobin (Headline), trifloxystrobin (Gem)], and flutolonil-based fungicides [Moncoat MZ (seed treatment); Moncut (in-furrow)]. Although products are available, new standards are being developed for avoidance of resistance in pathogen populations (not necessarily *R. solani*) to at-risk fungicide classes such as those in group 11 [QoI-fungicides (Quinone outside Inhibitors)] which includes all the strobilurines currently registered for use on potatoes. The broad spectrum of efficacy reported in strobilurines may lead to excessive use in the future as other products such as B2 carcinogens are at risk of further limitations in usage, and therefore a management plan for their use need to be developed which is compatible with potato production in MI. Currently there are many fungicide options available for control of Rhizoctonia diseases of potato however, to achieve optimal performance and preserve efficacy, a systematic approach of usage needs to be established. This approach also should address the climatic variability on the epidemiology of *R. solani* in potatoes to establish the threshold at which the application of fungicide intervention would have no effect.

The objective of this project therefore is to study the efficacy of some fungicides (identified below) applied, in combination with and without a seed treatment, at different times during early crop development, and its interaction with the effect of soil temperature at planting on two table stock cultivars and two chipping cultivars at the Muck Soils Research Farm.

Materials and Methods

The potato cultivars FL1833, FL1879, Russet Norkotah, and Superior were planted, at two separate times, at the Michigan State University Muck Soils Research farm near Bath, MI. Planting time was based upon soil temperature at a four inch depth reaching 8 C (5/9/2006) or 20 C (6/1/2006) for a five day average. All cultivars were tested for the control of Rhizoctonia disease symptoms under identical chemical regimes at two planting times. Within each regime two chemicals, Amistar (a.i. azoxystrobin) and Moncut (a.i. flutolonil) were examined for efficacy at two application times, at-planting in-furrow and 14 days after emergence. Also, the efficacy of the addition of a seed treatment, Maxim (a.i., fludioxonil), in combination with the fungicides was examined at each application timing (Table 1).

Table 1: Experimental layout for seed treatment and timing of application of fungicides in-furrow at-planting and 14 days post-emergence.

Seed treatment	In-furrow	14 day post-emergence	Seed treatment	In-furrow	14 day post-emergence
Yes	Amistar		No	Amistar	
Yes		Amistar	No		Amistar
Yes	Moncut		No	Moncut	
Yes		Moncut	No		Moncut
Yes			No		

Except for the cultivar Superior, which was cut prior to seed treatment, whole seed was treated with the Maxim seed treatment one day prior to planting. Seed pieces were planted in Houghton muck soil at the Michigan State University Muck Soils Research Farm, Bath, MI on 9 May (timing 1) and 1 June (timing 2), into two- row by 15 ft plots (approximately 12-in. between plants give a target population of 30 per plot at 34-in. row spacing) replicated three times in a strip block design. The seed treatment was applied, in a water suspension of at a rate of 0.8 fl. oz/cwt in 0.8 fl. oz/cwt of water for a total final solution of 0.16 fl. oz/cwt, onto the entire seed surface. In-furrow applications were made over the seed at-planting, applied with a single nozzle R&D spray boom delivering 5 gal/A (80 psi) and using one XR11003VS nozzle per row.

Fertilizer was drilled into plots before planting, formulated according to results of soil tests at the Bath, MI location. Previcur Flex was applied at 1.2 pt/A on a ten day interval, total of four applications, starting two weeks after the last application of experiment treatments. A permanent irrigation system was established prior to the commencement of fungicide sprays and the fields were maintained at soil moisture capacity throughout the season by frequent (minimum 5-day) irrigations. Weeds were controlled with Dual 8E at 1 pt/A and Sencor 75DF at .6 lbs/A at planting, Basagran at 2 pt/A 27 and 45 DAP (days after planting) and Poast at 1.5 pt/A 63 DAP. Insects were controlled with Platinum at 0.5 pt/A at-planting, Baythroid 2 at .125 pt/A 36 and 60 DAP.

Emergence was rated as the number of plants breaking the soil surface or fully emerged after planting. The rate of emergence was estimated as the area under the plant emergence curve (max=100) from the day of planting until 43 DAP for 'Superior. Tuber, stem, and stolon numbers, and percentages of stems and stolons with greater than 5% girdling caused by *Rhizoctonia solani* were measured via a destructive mid-season harvest (4 plants per replication) at 69 DAP (timing 1) and 61 DAP (timing 2). Vines were killed with Reglone 2EC (1 pt/A) on 25 August and 20 progeny tubers were harvested from each plot on 15 September and the individual treatment replications were washed and assessed for black scurf (*R.. solani*) incidence (%) and severity. Severity of black scurf was measured as an index calculated by counting the number of tubers (n = 20) falling in class 0 = 0%; 1 = 1 - 5%; 2 = 6 -10%; 3 = 11 – 15%; 4 = > 15% surface area of tuber covered with sclerotia. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 25 represent 0 - 5%; 26 - 50 represent 6 - 10%; 51 - 75 represent 11 - 15% and 75 - 100 >15% surface area covered with sclerotia.

Results

The effect of planting time on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* are shown in Table 2.

- Compared to planting time 1 (5/9/2006), planting time 2 (6/1/2006) had a significantly higher rate of emergence (RAUEPC), number of stems, the percentage of stems and stolons with Rhizoctonia canker, black scurf severity and incidence.
- There was no significant difference between the planting times for the number of stolons.

The effect of the cultivar grown on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* are shown in Table 3.

- Compared to the three other cultivars, Russet Norkotah had a significantly higher rate of emergence (RAUEPC), number of stems, percentage of stems and stolons with Rhizoctonia canker.
- Compared to the three other cultivars, FL1879 had a significantly higher number of stolons.
- There was no significant difference among the four cultivars for black scurf severity and incidence.

The effect of the seed treatment Maxim 4FS on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* are shown in Table 4.

- Compared to treatments with no seed treatment, the treatments with Maxim seed treatment had a significantly higher number of stems and stolons and a significantly lower percentage of stolons with Rhizoctonia canker.
- There was no significant difference between treatments with and without the Maxim seed treatment for the rate of emergence (RAUEPC), percentage of stems with Rhizoctonia canker, black scurf severity and incidence.

The effect of the fungicide applied on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* are shown in Table 5.

- Treatments with Amistar 80WDG had significantly lower number of stolons than the non-treated control.
- Treatments with Moncut 70DF had a significantly lower percentage of stolons with Rhizoctonia canker compared with the non-treated control.
- There was no significant difference among the treatments with either Amistar or Moncut and the non-treated control for the rate of emergence (RAUEPC), number of stems, percentage of stems with Rhizoctonia canker, black scurf severity and incidence.

The effect of the application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* are shown in Table 6.

- Treatments applied in-furrow at-planting had a significantly lower number of stolons compared to the non-treated control.
- Treatments applied 14 days post-emergence had a significantly lower percentage of stolons with Rhizoctonia canker compared to the non-treated control.
- There was no significant difference among application times for the rate of emergence (RAUEPC), number of stems, and the percentage of stems with Rhizoctonia canker, black scurf incidence and severity.

The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar FL1833 are shown in Table 7.

- All treatments with Amistar 80WDG, and all treatments with Moncut WDG applied at 14 days post-emergence had significantly lower number of stems than the treatment with Maxim seed treatment but no secondary fungicide treatment.
- The treatment with Maxim seed treatment and Amistar applied in furrow at-planting had a significantly lower percentage of stolons with Rhizoctonia canker compared to the treatment with Maxim seed treatment but no secondary fungicide treatment.

The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar FL1879 are shown in Table 8.

- The treatments with Maxim seed treatment and Amistar had a significantly lower rate of emergence compared to all treatments without Maxim seed treatment.
- The treatment with no seed treatment and Moncut applied 14 days post-emergence had a significantly higher percentage of stolons with Rhizoctonia canker compared to treatments with Maxim seed treatment and either Amistar or Moncut, and treatments applied in-furrow with no seed treatment.
- There were no significant differences among treatments for the number of stems, percentage of stems with Rhizoctonia canker, number of stolons, black scurf severity and incidence.

The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar Russet Norkotah are shown in Table 9.

- The treatment with no seed treatment and Moncut applied 14 days post-emergence had a significantly higher percentage of stems with Rhizoctonia canker than the treatment with Maxim seed treatment and Amistar applied in-furrow at-planting. However, there were no significant differences between these treatments and the non-treated controls.
- Treatments with no seed treatment and Amistar applied 14 days post-emergence, Moncut applied in-furrow at-planting, and the non-treated control all had significantly higher percentage of stolons with Rhizoctonia canker compared to all other treatments.
- There was no significant difference among treatments for the rate of emergence (RAUEPC), number of stems and stolons, black scurf severity and incidence.

The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar Superior are shown in Table 10.

- Treatments with Maxim seed treatment and either Amistar applied 14 days post-emergence or Moncut applied in-furrow had significantly higher rate of emergence (RAUEPC) compared to the treatment with no seed treatment and Moncut applied in-furrow at-planting. However, there were no significant differences between these treatments and the non-treated controls.
- The treatment with no seed treatment and Moncut applied in-furrow at-planting had a significantly higher percentage of stems with Rhizoctonia canker when compared with the treatment with only the Maxim seed treatment. However, there was no significant difference among other treatments.
- There was no significant difference among treatments for the number of stems and stolons, the percentage of stolons with Rhizoctonia canker, black scurf severity and incidence.

Table 2: The effect of planting time on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani*. Planting time was based upon soil temperature at a four inch depth reaching 8 C (5/9/2006) or 20 C (6/1/2006) for a five day average.

Planting Time	Rate of Emergence: RAUEPC [z]		Number of Stems [y]		Percentage of Stems with Rhizoctonia Canker [x]		Number of Stolons [y]		Percentage of Stolons with Rhizoctonia Canker [x]		Black Scurf Severity [w]		Black Scurf Incidence [v]	
5/9/2006	0.063	b [u]	2.9	b	30.0	b	19.4	a	16.8	b	4.0	b	13.4	b
6/1/2006	0.065	a	3.3	a	61.3	a	18.0	a	24.0	a	8.5	a	21.7	a

[z] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[y] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[x] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[w] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[v] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt .

[u] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 3: The effect of the cultivar grown on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani*.

Cultivar	Rate of Emergence: RAUEPC [z]		Number of Stems [y]		Percentage of Stems with Rhizoctonia Canker [x]		Number of Stolons [y]		Percentage of Stolons with Rhizoctonia Canker [x]		Black Scurf Severity [w]		Black Scurf Incidence [v]	
FL1833	0.066	b [u]	1.9	d	44.9	b	17.4	b	20.8	b	7.4	a	18.5	a
FL1879	0.066	b	3.3	b	40.3	b	32.3	a	16.0	c	7.8	a	21.3	a
Russet Norkotah	0.072	a	4.7	a	60.1	a	15.0	b	26.3	a	5.6	a	15.3	a
Superior	0.053	c	2.6	c	37.2	b	10.0	c	18.6	bc	4.0	a	14.9	a

[z] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[y] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[x] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[w] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[v] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[u] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 4: The effect of the seed treatment Maxim 4FS on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani*.

Seed Treatment	Rate of Emergence: RAUEPC [z]		Number of Stems [y]		Percentage of Stems with Rhizoctonia Canker [x]		Number of Stolons [y]		Percentage of Stolons with Rhizoctonia Canker [x]		Black Scurf Severity [w]		Black Scurf Incidence [v]	
Maxim 4FS [u]	0.065	a [t]	3.4	a	43.6	a	20.6	a	16.7	b	6.0	a	16.1	a
None	0.063	a	2.9	b	47.6	a	16.7	b	24.1	a	6.5	a	19.1	a

[z] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[y] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[x] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[w] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[v] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[u] Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[t] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 5: The effect of the fungicide applied on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani*.

Treatment Application (amount per 1000 ft)	Rate of Emergence: RAUEPC [z]		Number of Stems [y]		Percentage of Stems with Rhizoctonia Canker [x]		Number of Stolons [y]		Percentage of Stolons with Rhizoctonia Canker [x]		Black Scurf Severity [w]		Black Scurf Incidence [v]	
Amistar 80WDG 0.25 oz	0.064	a [u]	3.1	a	44.8	a	17.4	b	20.0	ab	7.2	a	20.2	a
Moncut 70DF 1.18 oz	0.063	a	3.0	a	46.4	a	18.9	ab	19.1	b	5.2	a	15.3	a
Non-treated check	0.065	a	3.4	a	45.8	a	20.9	a	23.9	a	6.4	a	16.7	a

[z] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[y] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[x] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[w] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[v] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[u] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 6: The effect of the application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani*.

Application Time	Rate of Emergence: RAUEPC [z]		Number of Stems [y]		Percentage of Stems with Rhizoctonia Canker [x]		Number of Stolons [y]		Percentage of Stolons with Rhizoctonia Canker [x]		Black Scurf Severity [w]		Black Scurf Incidence [v]	
In-Furrow At-Planting	0.063	a [u]	3.1	a	47.0	a	17.2	b	20.3	ab	5.8	a	16.9	a
14 Days Post-Emergence [t]	0.064	a	3.0	a	44.2	a	19.0	ab	18.8	b	6.7	a	18.6	a
Non-treated check	0.065	a	3.4	a	45.8	a	20.9	a	23.9	a	6.4	a	16.7	a

[z] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[y] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[x] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[w] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[v] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[u] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

[t] Emergence was considered the point at which 75% of the plants had broken the soil surface.

Table 7: The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar FL1833.

Seed Treatment	Treatment Application (amount per 1000 ft)	Application Time [z]	Rate of Emergence: RAUEPC [y]	Number of Stems [x]	Percentage of Stems with Rhizoctonia Canker [w]	Number of Stolons [x]	Percentage of Stolons with Rhizoctonia Canker [w]	Black Scurf Severity [v]	Black Scurf Incidence [u]
Maxim 4FS [t]	Amistar 80WDG 0.25 oz	IF	0.068 a [s]	1.8 a	50.0 a	2.6 b	15.6 b	11.0 a	23.3 a
		14 DPE	0.066 a	1.8 a	51.5 a	2.9 b	17.8 ab	7.3 a	14.2 a
	Moncut 70DF 1.18 oz	IF	0.068 a	2.0 a	53.6 a	4.3 ab	21.5 ab	12.5 a	28.3 a
		14 DPE	0.063 a	1.8 a	41.0 a	2.5 b	16.1 ab	8.3 a	23.0 a
	None	N/A	0.068 a	2.0 a	55.9 a	5.6 a	31.7 a	2.7 a	8.3 a
None	Amistar 80WDG 0.25 oz	IF	0.068 a	1.7 a	45.8 a	2.5 b	20.7 ab	9.6 a	20.0 a
		14 DPE	0.064 a	1.8 a	37.8 a	2.8 b	21.1 ab	7.7 a	20.8 a
	Moncut 70DF 1.18 oz	IF	0.067 a	2.0 a	24.3 a	3.5 ab	20.6 ab	5.8 a	17.5 a
		14 DPE	0.065 a	2.1 a	29.9 a	2.5 b	16.0 ab	7.1 a	18.3 a
	None	N/A	0.064 a	2.3 a	59.0 a	4.2 ab	26.8 ab	2.3 a	10.8 a

z Application timings: In-furrow at-planting (IF); 14 days post-emergence (14 DPE); Emergence was considered the point at which 75% of the plants had broken the soil surface.

y RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

x Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

w Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

v Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

u Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

t Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

s Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 8: The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar FL1879.

Seed Treatment	Treatment Application (amount per 1000 ft)	Application Time [z]	Rate of Emergence: RAUEPC [y]		Number of Stems [x]		Percentage of Stems with Rhizoctonia Canker [w]		Number of Stolons [x]		Percentage of Stolons with Rhizoctonia Canker [w]		Black Scurf Severity [v]		Black Scurf Incidence [u]	
Maxim 4FS [t]	Amistar 80WDG 0.25 oz	IF	0.055	b [s]	3.5	a	48.0	a	35.3	a	16.3	b	2.7	a	10.8	a
		14 DPE	0.055	b	3.5	a	27.8	a	38.3	a	11.1	b	13.1	a	33.3	a
	Moncut 70DF 1.18 oz	IF	0.062	ab	3.9	a	38.6	a	39.5	a	14.3	b	5.2	a	14.2	a
		14 DPE	0.065	ab	3.8	a	43.9	a	40.5	a	12.4	b	2.1	a	8.3	a
	None	N/A	0.067	ab	3.4	a	45.6	a	33.7	a	17.2	ab	9.8	a	20.0	a
None	Amistar 80WDG 0.25 oz	IF	0.072	a	3.4	a	22.0	a	29.5	a	10.7	b	10.4	a	31.2	a
		14 DPE	0.073	a	3.0	a	41.0	a	28.6	a	20.0	ab	7.1	a	25.0	a
	Moncut 70DF 1.18 oz	IF	0.068	a	2.7	a	34.3	a	23.8	a	11.0	b	11.5	a	32.5	a
		14 DPE	0.070	a	2.7	a	53.2	a	27.6	a	29.9	a	4.8	a	12.5	a
	None	N/A	0.068	a	3.1	a	48.6	a	26.3	a	17.1	ab	11.5	a	25.0	a

[z] Application timings: In-furrow at-planting (IF); 14 days post-emergence (14 DPE); Emergence was considered the point at which 75% of the plants had broken the soil surface.

[y] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[x] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[w] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[v] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[u] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[t] Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[s] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Table 9: The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar Russet Norkotah.

Seed Treatment	Treatment Application (amount per 1000 ft)	Application Time [z]	Rate of Emergence: RAUEPC [y]		Number of Stems [x]		Percentage of Stems with Rhizoctonia Canker [w]		Number of Stolons [x]		Percentage of Stolons with Rhizoctonia Canker [w]		Black Scurf Severity [v]		Black Scurf Incidence [u]	
Maxim 4FS [t]	Amistar 80WDG 0.25 oz	IF	0.071	a [s]	4.6	a	46.6	b	13.9	a	12.3	bc	1.0	a	3.3	a
		14 DPE	0.070	a	5.1	a	48.8	ab	17.5	a	17.3	bc	10.2	a	22.8	a
	Moncut 70DF 1.18 oz	IF	0.074	a	4.8	a	50.5	ab	18.7	a	19.0	bc	7.3	a	20.0	a
		14 DPE	0.071	a	5.3	a	54.0	ab	16.9	a	15.7	bc	1.9	a	10.2	a
	None	N/A	0.072	a	5.0	a	57.8	ab	16.7	a	17.6	bc	4.6	a	15.0	a
None	Amistar 80WDG 0.25 oz	IF	0.075	a	4.1	a	55.2	ab	13.1	a	18.0	bc	5.6	a	14.2	a
		14 DPE	0.071	a	4.9	a	70.1	ab	14.9	a	43.8	a	5.0	a	12.5	a
	Moncut 70DF 1.18 oz	IF	0.073	a	5.2	a	69.6	ab	14.8	a	41.9	a	6.9	a	17.5	a
		14 DPE	0.069	a	4.0	a	79.6	a	11.4	a	35.7	ab	9.8	a	23.3	a
	None	N/A	0.070	a	4.5	a	72.0	ab	11.8	a	42.5	a	4.2	a	14.5	a

[z] Application timings: In-furrow at-planting (IF); 14 days post-emergence (14 DPE); Emergence was considered the point at which 75% of the plants had broken the soil surface.

[y] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[x] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[w] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[v] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[u] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[t] Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[s] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Late Blight Risk Management in the Digital Age.

W. W. Kirk, P. S. Wharton, L. Duynslager and K. M. Baker

Potato late blight (*Phytophthora infestans*) spreads in potato canopies by continuous leaf and stem infection when inoculum is present and conditions are moist and cool. No potato cultivars are immune to potato late blight, and most cultivars planted in Michigan are susceptible. The cost of protecting potato crops in the United States against late blight is estimated at $287.8 million annually and can cost from $100 – 350/A in fungicides alone. Potato late blight occurs more sporadically in Michigan than in other U.S. production areas because of the variability of weather conditions throughout the growing season.

Potato late blight prediction models have been used to estimate when conditions have been favorable for epidemic development and for initiation of fungicide applications for more than 50 years. About 20 models have been developed that use temperature and moisture inputs from either in-canopy, on-site automated weather stations, or off-site regional stations. Traditionally, growers and other users have been expected to purchase their own weather station, the disease modeling software, or the risk data summary itself to take full advantage of measuring weather conditions in management decision making processes. This changed with the establishment of the statewide Michigan Automated Weather Network (MAWN) run by MSU. This is a joint partnership between the state's major commodity groups and food processors, the state government, the Michigan Agricultural Experiment Station, and Michigan State University. Weather data from MAWN has allowed us to establish a late blight disease prediction system in Michigan and make it available to Michigan growers through the internet.

The model first implemented in 1999 by MSU for extension and outreach to Michigan growers differed from traditional systems in several ways. Firstly, the system was web-based and interactive, allowing growers to access site specific, weather-based recommendations through their personal computer without the purchase or installation of additional equipment and/or software. Secondly, the weather network incorporated geographic proximity of known late blight infections and data from both in-canopy and off-site regional weather stations into daily risk estimates and management recommendations for approximately 30 locations in Michigan. Recommendations included application timing and spray rates for common fungicides.

Disease Models and Potato Late Blight

Potato late blight models are traditionally dependent on extended leaf wetness duration, which is approximated by 90 percent relative humidity, and air temperatures between thresholds of 45 and 80°F which are conducive for late blight infection. Microclimate-based late blight models were originally established in the 1940’s and fungicide spray programs and other management decisions have been based on the accumulation of ‘blight favorable days’, or thresholds of disease severity values (DSV’s), since the 1960’s. Disease severity values, ranging from 0 (no risk) to 4 (severe risk), became standard in estimating potato late blight risk using both the number of hours above the relative humidity threshold and the air temperature during that time (Fig. 1). This is generally known as the Wallin model, and MSU has been using a modified version of this model to predict late blight risk and give management recommendations to growers since 1999. The model takes hourly temperature and relative humidity data from MAWN and uses it to calculate DSV’s for each day during the growing season. Spray recommendations are then made based on the accumulation of these DSV’s (Fig. 1). All spray recommendations follow a typical seven day spray schedule, modifying the type and rate of fungicide application.

The original late blight risk management website

Depending on the station, hourly weather data was downloaded to the MAWN server twice daily as a text file. The Perl programming language was then used to integrate the weather data from MAWN into a single risk management website. A Perl program ran once daily for each weather station. The program retrieved the last 24 hours of data from the downloaded data file and a computer algorithm based on the Wallin model, then calculated a DSV for the day based on the relative humidity and temperature characteristics of the last 24 hours. The new DSV and the date were appended to a station specific risk file. This text file was used to calculate accumulated DSV's. The accumulated DSV's were then used to make a decision regarding corresponding fungicide application recommendations (Fig. 1). Accumulation of DSV's for all the stations was started on May 1st, but an additional interactive webpage allowed growers to input a start date for any station. This date was determined by the emergence of their potato crop. A script would then calculate the total number of accumulated DSV's for that station and give the grower a more personalized spray recommendation based on the time period they selected. If late blight was detected in a county, this information was recorded in another text file, with each station having their own text file. These files were updated manually once the disease was confirmed near a station. Each station had its own webpage, and DSV data for the stations text files was inserted dynamically into the web pages by the webserver software so that DSV's and corresponding spray recommendations were updated as soon as the Perl programs finished running each morning.

The original interactive web system employed by MSU was highly successful and limited grower investment in terms of both money and time while providing site-specific late blight risk information and recommendations for management decisions. However, it had several limitations, firstly because each of the 30 weather stations had their own web page, which had to be manually updated if late blight was detected near it. Secondly due to the fact that all the data was stored in text files, and data was transferred from one text file to another. Storing data in text files makes it difficult to manipulate and is also cumbersome for data retrieval, making activities such as being able to search it for patterns very difficult. It also meant that if there were gaps in the weather data for some reason it was very difficult to go back and correct for the missing data later at a time. Since the original implementation of the late blight website, database technology and tools to integrate databases with websites have improved drastically and allowed the creation of truly dynamic and interactive websites which can be updated in real-time, with web-pages being generated on demand. Since the inception of the late blight risk management site in 1999, the number of weather stations in the MAWN network has also grown from around 30 to 48 with additional stations being added annually. Furthermore, data from MAWN weather stations is now stored in a database instead of individual text files. Storing data in a database allows for rapid search and data retrieval. It also provides facilities for searching and easily updating records. Thus, in the spring of 2006 it was decided that it was time to update the lateblight.org website to take advantage of the new advances in database and web technology.

The new Lateblight.org website

The new late blight risk management site leverages the power of second generation web development tools that enables the integration of databases with the internet via web browsers, as described above. As with the original website, a Perl program runs once a day retrieving the last 24 hours of weather data from the MAWN server and then using this data to calculate DSV's for the day. However, with this new version, the Perl program connects to the MAWN server database to retrieve the data and then after performing the DSV calculations stores this data in a database on the lateblight.org server. This data is presented to users via the website in several different formats on different web pages as described below.

Front Page and Michigan Map

When users logon to the website, they are presented with a map of Michigan with colored markers on it, and a menu on the left hand side of the page with various headings (Fig. 2). The first two headings, "Home" and "News & Alerts" are not directly related to late blight risk management. "Home" links to the Potatodiseases.org homepage which contains up-to-date information on the identity, biology and disease-cycles, and current control methods for potato diseases. "News & Alerts" links to the page where important news and information relating to late blight and or other potato diseases is posted. Depending on the time of year this page may be updated with news on an almost daily basis. The next four menu items are directly related to late blight risk management. These are "Compare Stations", "Calculate DSV's", "Fungicide Rates", and "Help". Along with the map of Michigan these links allow the user to access data on late blight risk in the state with various levels of detail. For an overall summary of the levels of risk in the state the user can just refer to the map on the front page (Fig. 2). The map contains markers in various colors. These colors represent the various levels of late blight risk (Fig. 1), and may be green, yellow, orange, purple or red. The color of the markers are updated daily according to the late blight risk level for each station. When a user clicks on a marker it opens up an info window with a summary of details for that station. These details include the station name, county in which the station is based, risk level for the station, the DSV's accumulated over the last 10 days and the last time data was updated for that particular station. For further details the user can then click on the Details tab which shows the DSV's accumulated over the last 24 hours, last 7 and 10 days and the total DSV's accumulated to date.

Station Details pages

The information presented in the info window links directly to a webpage for the selected station. Each weather station has its own webpage. These web pages are dynamically generated using data from the lateblight.org database, and present the user with up-to-date DSV data for that particular weather station, and a spray recommendation based on the last 10 days worth of DSV's. At the bottom of each page is also a drop down menu which allows a user to get a personalized spray recommendation based on the date of emergence of their potato crop. When a user selects a date from the drop down box and hits the "Get Recommendation" button a new webpage is generated with a table listing the DSV's accumulated each day for the selected period, the total DSV's accumulated and a spray recommendation based on the total accumulated DSV's for the time period that was selected.

Compare Stations page

The map of Michigan on the front page allows a user to get an overview of the level of risk in the state. For a more detailed look at the levels of risk in the state a user can select the "Compare Stations" link from the menu. As suggested by the name, this menu item links to a dynamically generated page which lists all the weather stations in a table and displays daily, 7-day, 10-day, and total accumulated DSV's in a table. Like the map markers, the entries are color coded to indicate the risk level for each station. For further details on a particular station, a user can click on the station name, which will then open the station details described above. With the previous version of the website we could not update the DSV's for a particular station if there was missing weather data in the text file downloaded from the MAWN server. On the new site there is a program which runs behind the scenes 3 times a day and checks the lateblight.org database to make sure that the DSV data is up-to-date. If the script finds missing data, then it will access the MAWN weather database to check if the weather data has been updated. When it finds new data it then updates the DSV data to account for the missing data. This makes sure that data presented on the Compare Stations page is always up-to-date.

Calculate DSV's page

As mentioned above a user can generate a personalized spray recommendation for a particular station based on the date of emergence of his crop, by selecting a date from the drop down box at the bottom of the Station Details page. If a user knows the station closest to their location they can also do this directly by using the "Calculate DSV's" link in the menu on the front page. This takes them to a web form where they can select a particular station and emergence date from drop down boxes. Once the user has selected a station and a start date and pressed the "Calculate DSV's Now" button, a new webpage is generated with a table listing daily DSV's and accumulated DSV's and a spray recommendation as described above.

The fifth and six menu options "Fungicide Rates" and "Help" provide information to growers on what fungicides are available and rates to use for the control of late blight and a list of the 10 most frequently asked questions on how to use the late blight risk site. There is also an "Explanations" page which is shown at the bottom of every page on the website except for the main page. This page details the model used to calculate DSV's and how recommendations are derived.

Late blight reporting and monitoring

By migrating the late blight risk management website from using text files to store information to a database driven system, it has enabled us to provide users with a more interactive experience. In addition, it allows us to update the station details if late blight is detected in the state, as was the case this year. Once late blight is detected in a particular county the use of DSV's becomes irrelevant. Previously when late blight was reported in a particular county, the text files for the stations in that county had to be updated manually. With the new system, once we get a confirmed report of late blight we can fill out a web based form which allows us to post a report for the particular stations that are affected. As soon as this is done the recommendations for the affected stations are no longer automatically updated according to the DSV's, even though DSV's are still shown and accumulated. Instead the Station Details page recommendation is changed to orange, pink or red and a warning is placed on the page stating that late blight has been observed. If the late blight outbreak is limited to an individual field then the recommendation is changed to orange, if there are multiple but isolated outbreaks in a county then the recommendation is upgraded to pink, and if there are numerous outbreaks affecting over 1000 acres then the recommendation is upgraded to red.

Summary and conclusions

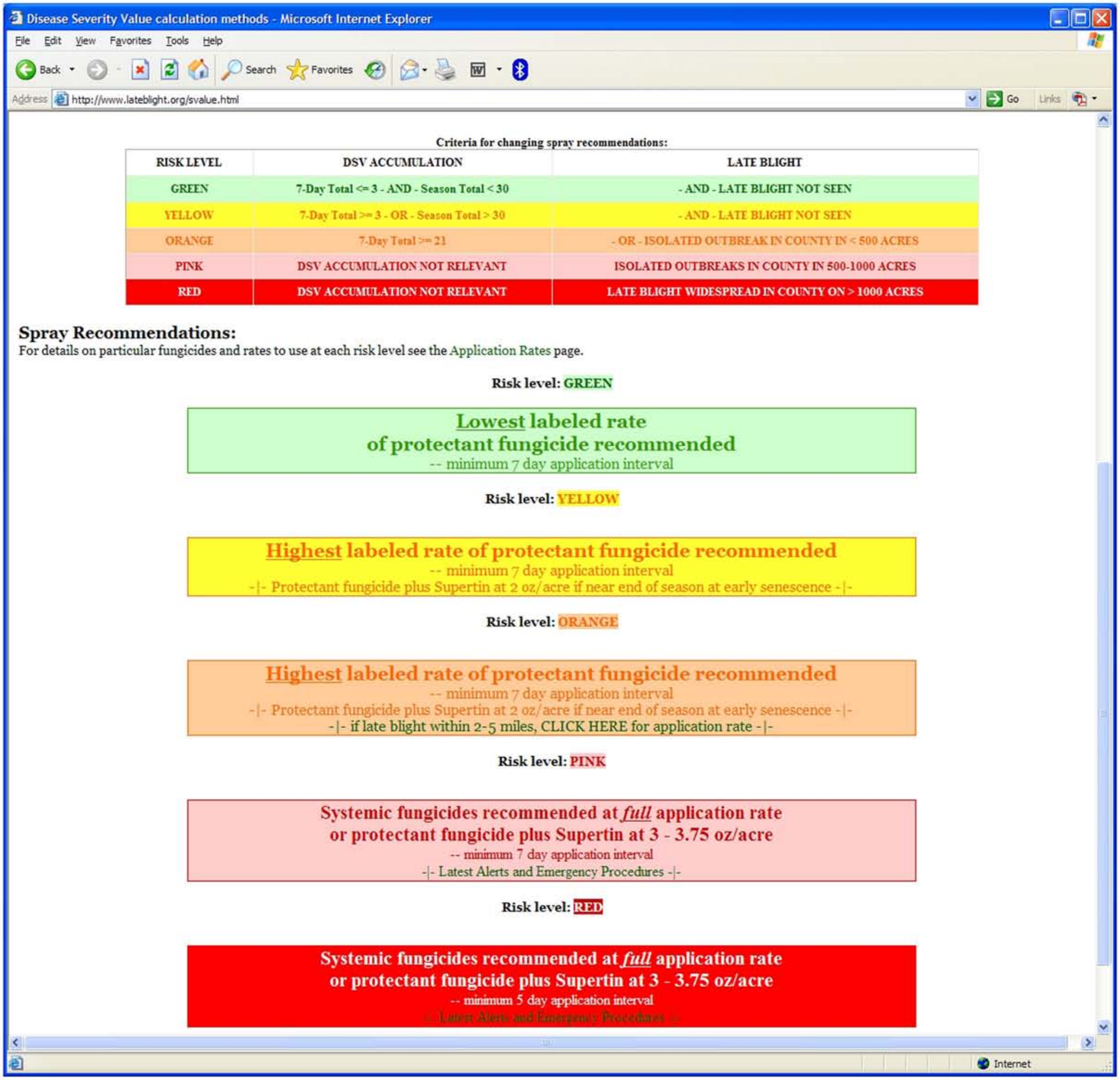
The control of potato late blight and estimation of associated field conditions throughout the growing season have continued to be top research priorities for the Michigan potato industry since 1995. Interest in the new website both in Michigan and around the world has been strong, with the site receiving over 4,000 visits a month since it was upgraded in May, with 1,600 of those from the USA and 700 from Michigan. The site is being continually updated and as more MAWN weather stations become available they can be easily added to the lateblight.org database.

The Late Blight Risk Management website is also an integral part of the main potato diseases website for Michigan (http://www.potatodiseases.org). This website has up-to-date bulletins, research articles and publications on all the major potato diseases found in Michigan. There are also links to other useful potato resources on the internet, and images of the symptoms of the main potato diseases found in Michigan. In the past year the site has been updated with several new bulletins on the diseases listed below. Links to the appropriate pages are provided next to each disease name:

Common Scab (http://www.potatodiseases.org/scab.html)
Early Blight (http://www.potatodiseases.org/earlyblight.html)
Fusarium Dry Rot (http://www.potatodiseases.org/dryrot.html)
Pink Rot (http://www.potatodiseases.org/pinkrot.html)
Black Scurf and Rhizoctonia Canker (http://www.potatodiseases.org/rhizoctonia.html)
Seed Piece Health Management (http://www.potatodiseases.org/seedpiecehealth.html)
White Mold (http://www.potatodiseases.org/whitemold.html)

In addition to these bulletins a new Pocket Guide to Scouting for Potato Diseases is in production and expected to be available for purchase from MSU extension by June 2007.

Figure 1. Criteria for developing spray recommendations, and associated spray recommendations.



Criteria for changing spray recommendations:

RISK LEVEL	DSV ACCUMULATION	LATE BLIGHT
GREEN	7-Day Total <= 3 - AND - Season Total < 30	- AND - LATE BLIGHT NOT SEEN
YELLOW	7-Day Total >= 3 - OR - Season Total > 30	- AND - LATE BLIGHT NOT SEEN
ORANGE	7-Day Total >= 21	- OR - ISOLATED OUTBREAK IN COUNTY IN < 500 ACRES
PINK	DSV ACCUMULATION NOT RELEVANT	ISOLATED OUTBREAKS IN COUNTY IN 500-1000 ACRES
RED	DSV ACCUMULATION NOT RELEVANT	LATE BLIGHT WIDESPREAD IN COUNTY ON > 1000 ACRES

Spray Recommendations:

For details on particular fungicides and rates to use at each risk level see the Application Rates page.

Risk level: GREEN

Lowest labeled rate of protectant fungicide recommended
-- minimum 7 day application interval

Risk level: YELLOW

Highest labeled rate of protectant fungicide recommended
-- minimum 7 day application interval
-|- Protectant fungicide plus Supertin at 2 oz/acre if near end of season at early senescence -|-

Risk level: ORANGE

Highest labeled rate of protectant fungicide recommended
-- minimum 7 day application interval
-|- Protectant fungicide plus Supertin at 2 oz/acre if near end of season at early senescence -|-
-|- if late blight within 2-5 miles, CLICK HERE for application rate -|-

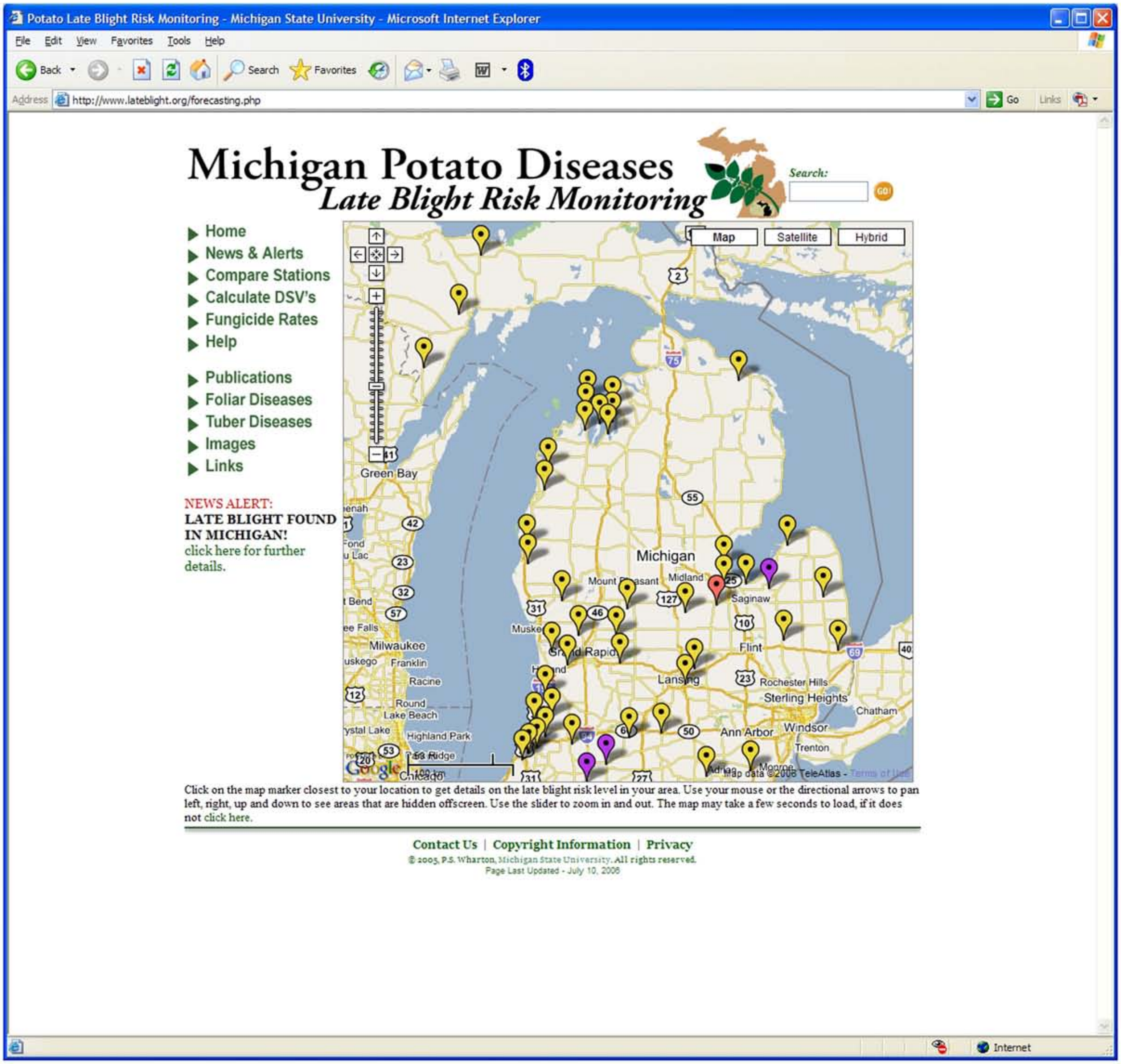
Risk level: PINK

Systemic fungicides recommended at *full* application rate or protectant fungicide plus Supertin at 3 - 3.75 oz/acre
-- minimum 7 day application interval
-|- Latest Alerts and Emergency Procedures -|-

Risk level: RED

Systemic fungicides recommended at *full* application rate or protectant fungicide plus Supertin at 3 - 3.75 oz/acre
-- minimum 5 day application interval
-|- Latest Alerts and Emergency Procedures -|-

Figure 2. The front page from the Late Blight Risk Management Website



Effect of different genotypes of *Phytophthora infestans* and temperature on tuber disease development.

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Potato late blight (*Phytophthora infestans* Mont. de Bary) is a significant global constraint to potato production and due to conducive climatic conditions and growing practices the mid western states of the US are particularly vulnerable. The emergence and spread of new genotypes of *P. infestans* in North America have resulted in significant economic loss to the potato industry. The mid-west states produce about 10 million tons of potato from 150,000 planted hectares, which represents about 40% of total US production. Potato late blight affects the health of foliage and tubers limiting profitable potato production. Significant financial costs in terms of crop protection (up to $700/ha) and crop losses (up to $5,000/ha) are incurred when intervention measures to control potato late blight are unsuccessful.

The newer genotypes have rapidly displaced the US-1 clonal lineage which previously had global occurrence (1, 2). In Michigan for example, the occurrence of diverse *P. infestans* genotypes (US-8, US-10, US-11 and US-14) has been documented in recent years (3). Rapid changes in the genetic diversity of the population of *P. infestans* are not predictable, but the sudden appearance and resultant predominance of the US-8 genotype, must pre-empt efforts in potato pathology and breeding to prepare for further genetic disturbance. Knowledge of competitive interactions among pathogen genotypes, fitness components and the role of resistant cultivars will enable us to develop a better understanding of the factors which govern strain selection and stability. The factors which affect frequency of occurrence of *P. infestans* genotypes and strain composition have not been adequately addressed. However, fungicide resistance clearly played an important role in genotype selection when phenylamide-resistant genotypes appeared globally in the 1990's (2). Other fitness components such as temperature tolerance have not been well evaluated but their importance has recently gained credibility (5). In previous field and growth chamber studies, late blight experiments were often inoculated with single or sequential pathogen genotypes, or epidemic development was monitored under field conditions prior to determination of fungal genotype composition. Therefore, this did not address the various host – pathogen genotype interactions. Furthermore, previous studies have not taken into account the susceptibility of potato tubers to different *P. infestans* genotypes. This is important as late blight is readily transmitted by seed-borne inoculum (6) and consequently, immature stems and leaves may be exposed to late blight from infected seed pieces. Recent work has indicated that the new immigrant clones, especially US-8, are more aggressive in tubers and sprouts. Research at MSU has shown that most of the commonly grown potato cultivars with foliar resistance to late blight are susceptible to tuber late blight. However, several advanced breeding lines (ABL) in the MSU potato breeding program have recently been identified with tuber late blight resistance. In 2005, we evaluated 104 ABL in replicated trials and 801 early generation lines in single observation plots which resulted in 41 and 98 lines, respectively being classified as having little to no late blight infection. The value of this advanced germplasm pool is that the resistance sources are diverse suggesting that we can now combine resistance sources.

The US-8 genotype of *P. infestans* displaced the US-1 genotype within five years of its appearance in North America, and it is vital that the industry is prepared for the supplanting of the US-8 genotype by other equally aggressive and stable genotypes of the pathogen. The proposed project, using field and controlled environment studies on potato foliage and tubers, will document whether the competitive ability of diverse *P. infestans* genotypes, potato cultivars/ABL with variable levels of host resistance, or environmental factors are important criteria for *P. infestans* genotype composition, maintenance and stability. The overall objective of this project is to develop an understanding of the factors (e.g., pathogen temperature tolerance, fitness, and host resistance) which govern pathogen genotype selection and stability.

Specific objectives are to:

1. Breed improved cultivars for the industry that have foliar and tuber resistance to late blight using marker-assisted and transgenic approaches.
2. Using ABL from the MSU potato breeding program (objective 1), evaluate the effects of potato cultivar on the frequency and diversity of *P. infestans* genotype selection and occurrence and of genotype composition (avr phenotype) from a sample of late blight lesions recovered after inoculation in the field.
3. Determine the impact of co-inoculations of potato varieties on the competitive ability (fitness components) of diverse genotypes and genotype composition in growth chamber experiments using parental isolates from objective 2. Compare these results with a sample of isolates recovered from the field experiments in objective 2.
4. Evaluate the fitness of a variety of *P. infestans* genotypes on tubers of ABL (identified in objective 1) at different commonly used storage temperatures (3, 7 and 10°C).
5. Evaluate the potential of a variety of *P. infestans* genotypes to be transmitted from the seed to foliage after storage and planting, in ABL from the MSU potato breeding program.

In 2006, the trials to fulfill objectives 1 through 3 were compromised due to adverse weather conditions and mechanical failure of the water pump at the MSU Muck Soils research Farm (see document in this report "**General Pathology Report for 2006 growing season in Michigan and Meteorological conditions at the Muck Soils Research Farm, Laingsburg, MI; 2006.**" Therefore in this report only objective 4 is addressed as objective 5 will be addressed during 2007.

4. Evaluate the fitness of a variety of *P. infestans* genotypes on tubers of ABL (identified in objective 1) at different commonly used storage temperatures (3, 7 and 10°C).

The portion of the project devoted to tuber response was initiated in 2006 and the results from the first round of experiments carried out in 2005/06 are shown in Tables 1 and 2 however the second round of experiments are pending as of January 16, 2007, (set up during Dec, 2006). The main effects indicated that some varieties were more resistant to *P. infestans* regardless of genotype or storage temperature. The varieties Stirling, Torridon and Jacqueline-Lee were the most resistant followed by other MSU bred lines e.g. MSL757-1. MSJ461-1 was the most susceptible line despite having excellent foliar resistance to *P. infestans.* The most aggressive genotype of *P. infestans* was US-8. No other genotypes were particularly aggressive on the lines tested. Most tuber blight (measured as %RARI) developed at 10C followed by 7 and 3C. These results indicate that the lines Stirling, Torridon and Jacqueline-Lee could contribute to tuber blight resistance breeding efforts in the future. All three lines are partially resistant to US-8 genotype of *P. infestans* which is predominant in MI. The genotype was isolated from all three loci where epidemics established in MI in 2006.

The results were presented as the mean tuber disease response as affected by the components of variety and storage temperature (Table 2). All varieties were partially resistant to the US-1 genotype regardless of storage temperature although some disease developed in certain varieties. Values close to zero (including negative values) indicate no establishment of *P. infestans* within the tubers. In some cases e.g. in Jacqueline-Lee, MSL757-1, MSM182 and Torridon late blight developed to some extent at 3C but not at higher temperatures. This is unusual but it is known that many isolates of *P. infestans* can survive well at temperatures close to 0C.

These results indicate that *P. infestans* can survive well at temperatures close to 3C, the seed tuber storage temperature, which presents a risk for commercial growers even with resistant cultivars. Although varieties with partial resistance to foliar and tuber phases of potato late blight are important in the overall management of the disease these results indicate that varietal resistance is not the only component of disease management, For this reason we are proposing that varieties (close to commercial release) with partial resistance to the US-8 genotype of *P. infestans* are profiled in a variety x fungicide interaction this coming year.

Table 1. Main effects analyses of variety, genotype of *Phytophthora infestans* and temperature on tuber tissue darkening [Mean RARI (%)] in potato tubers.

Variety	Mean RARI (%)[a]	Genotype of *P. infestans*	Mean RARI (%)[a]	Temp-erature (^{o}C)	Mean RARI (%)[a]
MSJ461-1	6.85 a[b]	US-8	15.66 a	10	6.15 a
MSM182	5.81 ab	US-11	1.87 b	7	3.40 b
MSM137-2	5.61 ab	US-14	1.24 b	3	2.78 b
MSM171-A	5.33 ab	US-1	0.90 b		
MSL766-1	4.41 bc	US-10	0.88 b		
MSL757-1	3.31 cd				
Jacqueline-Lee	2.50 de				
Torridon	1.71 e				
Stirling	1.48 e				

[a] Normalized tuber tissue darkening score expressed % RARI = [1- Mean ARI $_{treatment}$ / Mean ARI $_{control}$] *100; % RARI has a minimum value of zero (no darkening, but if the value is negative the tuber tissue was lighter than the control) and maximum value of 100 (cut tuber surface is completely blackened). The numbers are derived from the mean average reflective intensity of three surfaces cut latitudinally 25, 50 and 75% from the apex of n = 10 tubers per treatment combination.

[b] Values followed by the same letter are not significantly different at P = 0.05 for comparisons of mean RARI values within different *P. infestans* genotypes of cultivar/ABL combinations and temperature treatments (Tukey Multiple Comparison)

Table 2. Tuber tissue darkening [Mean RARI (%)] in different varieties and advanced breeding lines of potatoes after inoculation with different genotypes of *Phytophthora infestans*.

Variety	Temper-ature (°C)	US-1		US-8		US-10		US-11		US-14	
		Tuber tissue darkening caused by different genotypes of *P. infestans* [Mean RARI (%)[a]]									
MSJ461-1	3	-1.38	g-i[b]	19.18	d-f	0.39	b-e	1.40	d-g	0.86	b-g
	7	-2.39	hi	26.91	a-d	-1.03	c-e	3.05	b-e	1.52	b-f
	10	-1.12	f-i	35.27	ab	-0.19	b-e	18.14	a	2.12	a-e
Jacqueline-Lee	3	3.40	a-d	5.09	h-k	3.31	a-d	0.89	d-g	1.94	a-e
	7	1.90	a-g	7.07	h-k	1.97	a-e	2.92	b-e	1.10	b-g
	10	0.02	d-i	10.89	f-i	-0.92	c-e	-1.46	fg	-0.59	d-g
MSL757-1	3	3.97	a-c	-0.95	k	2.21	a-e	2.48	b-f	0.10	d-g
	7	-1.71	g-i	6.15	h-k	0.00	b-e	-0.49	d-g	-2.02	fg
	10	1.78	a-g	23.56	c-e	6.79	a	2.36	b-f	5.45	a
MSL766-1	3	0.35	c-i	8.27	h-k	-0.69	c-e	-1.49	fg	0.85	b-g
	7	2.83	a-e	26.21	b-d	1.82	b-e	2.74	b-f	0.58	bg
	10	-2.95	i	27.03	a-d	3.65	a-c	-0.52	d-g	-2.50	g
MSM137-2	3	-0.80	e-i	22.03	c-e	-0.39	b-e	1.92	c-f	-1.35	e-g
	7	-1.38	g-i	23.81	cd	-0.65	c-e	1.67	d-f	-0.95	e-g
	10	1.87	a-g	31.46	a-c	2.02	a-e	0.57	d-g	4.31	ab
MSM171-A	3	5.39	a	9.00	g-j	1.27	b-e	1.66	d-f	3.03	a-d
	7	2.78	a-f	21.44	de	4.32	ab	1.54	d-f	1.54	b-f
	10	-0.24	d-i	26.26	b-d	2.73	a-e	-0.52	d-g	-0.20	d-g
MSM182	3	3.32	a-d	4.95	h-k	1.93	a-e	6.32	b	1.10	b-g
	7	0.96	c-i	10.39	f-j	-0.39	b-e	1.87	d-f	0.30	c-g
	10	4.99	ab	35.95	a	3.57	a-d	6.18	bc	5.64	a
Stirling	3	2.76	a-f	1.13	jk	2.61	a-e	3.58	b-d	1.38	b-f
	7	-2.16	hi	3.51	i-k	-1.28	de	-1.38	fg	-1.51	e-g
	10	1.08	b-h	14.22	e-h	-1.03	c-e	-0.36	d-g	-0.38	d-g
Torridon	3	2.71	a-f	2.28	i-k	2.25	a-e	-1.01	e-g	-2.11	fg
	7	-0.23	d-i	3.19	i-k	1.18	b-e	1.40	d-g	4.08	a-c
	10	-1.33	g-i	18.45	d-g	-1.86	e	-2.86	g	-0.49	d-g

[a] Normalized tuber tissue darkening score expressed % RARI = [1- Mean ARI $_{treatment}$ / Mean ARI $_{control}$] *100; % RARI has a minimum value of zero (no darkening, but if the value is negative the tuber tissue was lighter than the control) and maximum value of 100 (cut tuber surface is completely blackened). The numbers are derived from the mean average reflective intensity of three surfaces cut latitudinally 25, 50 and 75% from the apex of n = 10 tubers per treatment combination.

[b] Values followed by the same letter are not significantly different at P = 0.05 for comparisons of mean RARI values within different *P. infestans* genotypes of cultivar/ABL combinations and temperature treatments (Tukey Multiple Comparison).

1. Kirk, W.W., F. M. Abu-El Samen, J.B. Muhinyuza, R. Hammerschmidt, D.S. Douches, C. A. Thill, H. Groza and A. L. Thompson. 2005. Evaluation of Potato Late blight Management Utilizing Host Plant Resistance and Reduced Rates and Frequencies of Fungicide Applications. Crop Protection 24: 961 - 970.
2. Baker, K.M., W.W. Kirk, J.M. Stein and J.A. Andresen. 2005. Climatic trends and potato late blight risk in the Upper Great Lakes region. HortTechnology 15(3):510-518.
3. Rubio-Covarrubias O.A., D.S. Douches, R. Hammerschmidt, A. daRocha and W.W. Kirk. 2005. Effect of temperature and photoperiod on symptoms associated with resistance to *Phytophthora infestans* after leaf penetration in susceptible and resistant potato cultivars. Amer. J. Potato Res. 82:153 - 160.
4. Young, G.K., L.R. Cooke, W.W. Kirk, and P. Tumbalam. 2004. Competitive selection of

Phytophthora infestans in the US and Northern Ireland. Proceedings of the eighth workshop of an European network for development of an integrated control strategy of potato late blight. European Journal of Plant Pathology Special Report No.10: 271 -275.
5. Douches, D.S., J. Coombs, K. Felcher and W.W. Kirk. 2004. Field evaluation of foliar resistance to *Phytophthora infestans* in potato. Amer. J. Potato Res. 81:443-448.
6. Stein, J.M. and W.W. Kirk. 2004. Development of resistance in *Phytophthora infestans* isolates from several genetic backgrounds to Dimethomorph. Plant Disease 88:930-934.
7. Baker K.M, W.W. Kirk, J. Andresen and J.M. Stein. 2004. A problem case study: Influence of climatic trends on late blight epidemiology in potatoes. Acta Hort (ISHS) 638:37-42.

Evaluation of fungicide programs for potato brown spot and grey mold control, 2006.

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Evaluation of fungicide programs for potato leaf brown spot and grey mold control, 2006.

Potatoes (cut seed, treated with Maxim MZ 0.5D at 0.5 lb/cwt) were planted at the Michigan State University Muck Soils Experimental Station, Bath, MI on 25 May into two-row by 25-ft plots (34-in row spacing), separated by a five-foot unplanted row and replicated four times in a randomized complete block design. Plots were irrigated as needed with sprinklers and were hilled immediately before the foliar fungicide sprays began. All fungicides in this trial were applied on a 7-day interval from 28 Jun to 22 Aug (8 applications) with an ATV rear-mounted R&D spray boom calibrated to deliver 25 gal/A (80 p.s.i.) using three XR11003VS nozzles per row. Foliar late blight was prevented with foliar applications of Previcur Flex (1.2 pt/A) applied on a 7-day interval starting on 11 Jul. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 25 May), Basagran (2 pt/A on 28 Jun and 11 Jul) and Poast (1.5 pt/A on 11 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting and on 28 Jun), Sevin 80S (1.25 lb/A on 11 and 25 Jul), Thiodan 3EC (2.33 pt/A on 1 and 21 Aug) and Pounce 3.2EC (8 oz/A on 11 Jul). Plots were rated visually for percent of foliar area infected with brown leaf spot on 24 and 30 Aug, and 11 and 18 Sep and Botrytis grey mold on 24 Jul, 17 Aug and 18 Sep. Vines were killed with Reglone 2EC (1 pt/A on 13 Sep). Plots (2 x 25-ft row) were harvested on 2 Oct and tubers were weighed and graded. Meteorological variables were measured with a Campbell weather station located at the farm, latitude 42.8269 and longitude -84.365deg. P-values (45^{o}F base) were accumulated for each month from planting to desiccation; the total accumulated were 187.4 from 25 to 31 May; 806.1 to 30 Jun; 1642.3 to 31 Jul; 2381.4 to Aug 31; and 2594.9 to desiccation on 18 Sep. Maximum and minimum soil moisture (% of field capacity) was 116.6 and 66.7 (Jul) and 119.1 and 80.4 (Aug) during which time severe flooding occurred. Precipitation was 2.93 in. (Jun), 6.77 in. (Jul), 3.47 in. (Aug) and 0.68 in. (Sep). Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

Plants emerged quickly during May and early Jun (95% on 18 Jun) and fungicide applications were initiated on 28 Jun when P-values were 244, 10 days after 95% plant emergence. Severe weather during late Jul resulted in flooding for about 4-d and soil temperatures during this period in excess of 90^{o}F caused damage to plant roots and severely reduced the potential of plants to recover. Secondary diseases, brown leaf spot and botrytis grey mold developed shortly after the severe weather. Potato leaves with target-spot lesions (20) were harvested from non-treated and fungicide treated plots and the pathogen was isolated. Morphological characteristics of the conidia were consistent with those of *Alternaria alternata* and no *Alternaria solani* was recovered from any lesions. On 11 Sep, 28 days after the last fungicide application, foliar brown leaf spot infections (severity) were significantly less for all treatments compared to the untreated (42.5%) except Manzate and Headsup (alone). Eight days after the last fungicide application treatments with 0.75 to 2.75% and 6.25 to 7.5% (untreated) foliar brown leaf spot were not significantly different. Fourteen days after the last fungicide application treatments with 2.0 to 9.5%, 4.3 to 11.3%, 5.0 to 12.5% and 9.5 to 17.0% (untreated) foliar brown leaf spot were not significantly different. 26-days after the final fungicide application treatments with 5.0 to 18.3, 7.5 to 21.3, 12.5 to 25.0, 13.3 to 27.5, 15.0 to 28.8 and 28.8 to 42.5% (untreated) foliar brown leaf spot were not significantly different. On 17 Aug all treatments had significantly less Botrytis grey mold infection than the untreated (63.8%) except Headsup applied alone. Botrytis grey mold developed concurrently with brown leaf spot and on 25 Jul, 5 days after the previous fungicide application and treatments with 7.5 to 20.0 and 12.5 to 31.2% (untreated) botrytis grey mold were not significantly different. One-day after the final fungicide application treatments with 22.5 to 35.0 and 63.8% (untreated) botrytis grey mold were not significantly different. By the final assessment the contribution of brown leaf spot and grey leaf mold to defoliation and loss of green leaf area was confounding and therefore an assessment of green leaf area remaining was taken. 33-days after the final fungicide application treatments with 52.5 to 37.5, 50.0 to 28.7, 38.7 to 28.7, 37.5 to 18.7 and 30.0 (untreated) to 16.2% green leaf area remaining were not significantly different. Treatments with marketable yield (US1 grade) 152 to 115, 144 to 101 and 143 to 95 cwt/A (untreated) were not significantly different. No treatments had significantly greater total yield in comparison to the non-treated control (216 cwt/A, respectively) and ranged from 210 to 265 cwt/A. Phytotoxicity was not noted in any of the treatments.

Treatment and rate/A and rate/cwt seed[z]	Brown leaf spot severity (%)[y] 24 Aug 92 DAP[w] 8 DAFA[v]		30 Aug 98 DAP 14 DAFA		11 Sep 110 DAP 26 DAFA		Grey mold severity (%) 24 Jul 61 DAP 5 DAFA		17 Aug 85 DAP 1 DAFA		GLA[x] (%) 18 Sep 117 DAP 33 DAFA		Yield US1		Total	
1 Echo ZN 6SC 2.125 pt (B,H[u]) Echo ZN 6SC 2.125 pt + Scala 60SC 0.44 pt (C,E,G) Echo ZN 6SC 1.5 pt + Scala 60SC 0.25 pt (D,F)................................	1.3	b[t]	4.3	cd	7.5	ef	7.5	a	22.5	a	46.2	ab	152	a	260	a
2 Echo ZN 6SC 1.5 pt + Scala 60SC 0.25 pt (B,D,F,G) Echo ZN 6SC 2.125 pt (C,E,H,I).....................	1.0	b	5.8	bcd	17.5	b-f	13.7	ab	28.7	a	50.0	ab	128	abc	223	a
3 Echo 720SC 1.4 pt (B,C,D,E,F,G,H,I).............	1.8	b	9.5	a-d	25.0	bcd	20.0	ab	25.0	a	43.7	ab	120	abc	219	a
4 Manzate 75DF 2 lb (B,C,D,E,F,G,H,I)............	2.5	b	12.5	ab	28.8	ab	15.0	ab	28.7	a	50.0	ab	128	abc	219	a
5 Scala 60SC 0.44 pt (C,E,G,I) Scala 60SC 0.25 pt (D,F)................................	1.5	b	5.0	bcd	12.5	def	11.2	a	31.2	a	16.2	e	143	abc	240	a
6 Dithane 75DF 2 lb (B,C,D,E,F,G,H,I).............	0.8	b	4.5	cd	13.3	c-f	7.5	a	22.5	a	52.5	a	139	abc	250	a
7 Gavel 75DF 2 lb (B,C,D,E,F,G,H,I)................	0.8	b	5.8	bcd	15.0	b-f	12.5	ab	32.5	a	28.7	b-e	133	abc	252	a
8 Headsup 50WG 0.004 oz/cwt (A[z])..................	6.3	a	11.3	abc	37.5	abc	16.2	ab	53.7	ab	30.0	b-e	141	abc	243	a
9 Headsup 50WG 0.004 oz/cwt (A[z]) Headsup 50WG 0.44 lb (B) Echo ZN 6SC 2.125 pt (B,C,D,E,F,G,H,I)......	2.5	b	9.5	a-d	18.3	b-f	13.7	ab	33.7	a	37.5	a-d	136	abc	223	a
10 Headsup 50WG 0.44 lb (B) Echo ZN 6SC 2.125 pt (B,C,D,E,F,G,H,I)......	2.3	b	7.8	bcd	15.0	b-f	13.7	ab	30.0	a	38.7	a-c	116	abc	216	a
11 Echo ZN 6SC 2.125 pt (B,C,D,E,F,G,H,I) Endura 250WG 5.5 oz (D,F)...........................	1.0	b	2.0	d	5.0	f	13.7	ab	28.7	a	47.5	ab	144	ab	250	a
12 Untreated...	7.5	a	17.0	a	42.5	a	31.2	b	63.8	b	18.7	de	95	c	216	a
LSD p = 0.05	3.50		7.51		14.63		19.17		20.80		21.53		48.9		62.3	

[z] Seed treatment rate where applicable. Applied on day of planting.
[y] Brown leaf spot caused by *Alternaria alternata*.
[x] GLA = green leaf area remaining (%).
[w] DAP = Days after planting.
[v] DAFA = Days after last fungicide application .
[u] Application dates: A[z]= 24 May; B= 28 Jun; C= 5 Jul; D= 11 Jul; E= 19 Jul; F= 26 Jul; G= 2 Aug; H= 9 Aug; I= 16 Aug.
[t] Values followed by the same letter are not significantly different at p = 0.05 (Tukey Multiple Comparison).

Table 10: The combined effect of planting time, seed treatment, fungicide applied, and application timing on both potato plant growth and development as well as disease symptoms caused by *Rhizoctonia solani* for the cultivar Superior.

Seed Treatment	Treatment Application (amount per 1000 ft)	Application Time [z]	Rate of Emergence: RAUEPC [y]		Number of Stems [x]		Percentage of Stems with Rhizoctonia Canker [w]		Number of Stolons [x]		Percentage of Stolons with Rhizoctonia Canker [w]		Black Scurf Severity [v]		Black Scurf Incidence [u]	
Maxim 4FS [t]	Amistar 80WDG 0.25 oz	IF	0.050	abc [s]	3.2	a	28.7	ab	10.9	a	11.7	a	1.9	a	7.5	a
		14 DPE	0.064	a	2.3	a	33.0	ab	10.8	a	18.2	a	5.8	a	20.3	a
	Moncut 70DF 1.18 oz	IF	0.064	a	3.0	a	36.9	ab	10.3	a	14.0	a	2.9	a	9.3	a
		14 DPE	0.060	abc	2.8	a	37.2	ab	9.4	a	17.0	a	1.7	a	4.5	a
	None	N/A	0.061	ab	2.8	a	23.0	b	9.6	a	14.6	a	7.3	a	24.2	a
None	Amistar 80WDG 0.25 oz	IF	0.045	bc	2.7	a	37.2	ab	10.6	a	19.9	a	3.8	a	20.0	a
		14 DPE	0.045	bc	2.0	a	36.5	ab	10.0	a	25.7	a	2.5	a	13.8	a
	Moncut 70DF 1.18 oz	IF	0.043	c	2.5	a	59.3	a	10.5	a	25.7	a	2.5	a	8.0	a
		14 DPE	0.048	abc	2.3	a	38.2	ab	10.1	a	23.8	a	3.0	a	13.0	a
	None	N/A	0.048	abc	2.0	a	42.6	ab	7.8	a	15.2	a	7.9	a	28.0	a

[z] Application timings: In-furrow at-planting (IF); 14 days post-emergence (14 DPE); Emergence was considered the point at which 75% of the plants had broken the soil surface.

[y] RAUEPC: Relative area under the emergence progress curve (max = 100), calculated from the day of planting to 45 (planting time 1) and 28 (planting time 2) days after planting.

[x] Numbers of stems and stolons are the average of 4 plants (per replicate) taken 69 (planting time 1) and 61 (planting time 2) days after planting.

[w] Percentage of diseased stems and stolons had greater than 5% girdling caused by *Rhizoctonia solani* are from an average of 4 plants per replicate.

[v] Severity of black scurf (index calculated by counting the tuber number (n = 20 per replicate) falling into class 0 = 0%; 1 = 1 - 5%; 2 = 6 - 10%; 3 = 11 - 15%; 4 = >16% surface area. Indices of 0 to 25 cover the range 0 - 5%; 25 - 50 cover the range 6 - 10%; 51 - 75 cover the range 11 - 15%; 75 - 100 cover the range >15% surface area of the tuber with sclerotia.

[u] Percent incidence of tubers with black scurf from a sample of 20 tubers per replicate Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[t] Maxim 4FS at Seed treatment at 0.08 fl oz/cwt.

[s] Values followed by the same letter are not significantly different at a = 0.05 (Tukey's HSD Comparison).

Evaluation and comparison of biofungicides and fungicides for the control of post harvest potato tuber diseases.

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Summary
Potatoes are susceptible to a variety of storage pathogens, including late blight (*Phytophthora infestans*), Fusarium dry rot (*Fusarium sambucinum*), Pythium leak (*Pythium ultimum*), tuber soft rot (*Erwinia* spp.), and silver scurf (*Helminthosporium solani*). Current recommendations for potato storage diseases include sanitation and exclusion as the primary controls for these pathogens in storage facilities. No fungicides are registered for direct application to tubers for control of these important pathogens and few compounds are available for potato tuber treatment in storage, including chlorine-based disinfectants such as, sodium hypochlorite, calcium hypochlorite and chlorine dioxide. In recent years several new biofungicides based on the biocontrol bacteria *Bacillus subtilis* Serenade) and *B. pumilis* (Sonata) have been registered or are awaiting EPA approval for use on potato, and have shown promise in the control of seed and soil borne diseases such as late blight, black scurf and pink rot. None of these products has been evaluated for the control of these pathogens under post-harvest potato tuber storage conditions. Thus, studies were initiated to evaluate the efficacy of these biofungicides for the control of potato storage pathogens under post-harvest conditions. For a comparison, several commercial storage products [Phostrol (sodium, potassium and ammonium phosphates), and Oxidate (hydrogen dioxide)] and experimental treatments [Amistar (azoxystrobin) and Zoxium(zoxamide)] were evaluated for their effectiveness under storage conditions. Preliminary results show that in general conventional fungicide Amistar provided the most effective disease control. The biofungicides provided more limited control. However, in all cases results for the biofungicides were not significantly different from those for Amistar. In the case of *Pythium*, the biofungicides were as effective in controlling disease as Amistar and results were not significantly different from the non-inoculated control.

Introduction
Potatoes are susceptible to a variety of storage pathogens, including late blight (*Phytophthora infestans*), Fusarium dry rot (*Fusarium sambucinum*), Pythium leak (*Pythium ultimum*), pink rot (*Phytophthora erythroseptica*) and tuber soft rot (*Erwinia* spp). These pathogens are of major concern to potato producers due to the great losses they cause in stored potatoes. Current recommendations for potato storage diseases include sanitation and exclusion as the primary controls for these pathogens. No fungicides are registered for direct application to tubers for control of these pathogens and few compounds are available for potato tuber treatment in storage. In recent years, several new biofungicides based on the biocontrol bacteria *Bacillus subtilis* (Serenade) and *B. pumilis* (Sonata) have been registered or are awaiting EPA approval for use on potato. These have shown promise in the control of seed and soil borne diseases such as late blight and pink rot. Neither of these products has been evaluated for the control of potato storage pathogens under post-harvest conditions. Thus, studies were initiated to evaluate the efficacy of these biofungicides under post-harvest storage conditions. For a comparison, several commercial storage products [Oxidate (hydrogen dioxide), and Phostrol (sodium, potassium and ammonium phosphates)] and experimental treatments [Amistar (azoxystrobin) and Zoxium (zoxamide)] were evaluated for their effectiveness under storage conditions.

Materials and Methods

Experiments were carried out in November 2005 with potato cultivar "FL1879". Potatoes free from visible diseases were selected for the trials from tubers harvested in October 2005. Tubers were prepared for inoculation by grazing with a single light stroke with a wire brush, sufficient to abrade the skin of the tubers to a depth of 0.01 mm. Solutions (1 x 10^3/ml) of sporangia/zoosporangia of *P. infestans* (late blight), oospores/sporangia of *P. erythroseptica* (pink rot), oospores of *P. ultimum* (Pythium leak), macroconidia of *F. sambucinum* (dry rot) and bacterial cells of *E. carotovora* (soft rot) were prepared from cultures of the pathogens previously isolated from potato tubers in Michigan. All pathogens were grown on PDA for 10 days prior to preparation of inoculum solutions. Two non-treated controls, either inoculated with one of the pathogens or non-inoculated were included in the trial. Damaged tubers, (10/replicate/treatment; total 40 tubers/treatment) were sprayed with 10 ml of pathogen suspension, for a final dosage of about 0.25 ml per tuber. Tubers were stored for 24 h after inoculation at 20°C before treatment. Fungicides were applied as liquid treatments in a water suspension with a single R&D XR11003VS spray nozzle at a rate of 1L/ton at 50 psi onto the tuber surfaces, with an entire seed surface being coated in the seed treater. After inoculation, tubers were incubated in the dark in plastic boxes at 12°C for 60 days. Tubers were cut open and the number of tubers with symptoms or signs of the individual pathogens were counted to determine incidence of disease. Disease severity was assessed using a disease severity index. Disease severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease. The disease severity index was then calculated as the number in each class multiplied by the class number and summed. The sum was then multiplied by a constant to express severity on a 0 – 100 scale. Data were analyzed using analysis of variance and the Tukey's LSD test in JMP (SAS Institute, NC).

Results and Conclusions

In the late blight studies (Table 1) none of the treatments were significantly different from the inoculated check. However, the Amistar and Sonata treatments had the lowest mean severity and disease incidence indices followed by Serenade (Table 1). In the Pythium leak experiment (Table 2), Amistar, followed by Oxidate provided the best disease control and results were not significantly different from the non-inoculated check. The biofungicides Serenade and Sonata provided more limited disease control but results were not significantly different from those obtained with Amistar and Oxidate (Table 2). There were no significant differences among treatments in the Fusarium dry rot (Table 3) or Erwinia soft rot (Table 4) experiments. In the Erwinia experiments, disease incidence in the inoculated check was low indicating a poor rate of infection of tubers. In the Pink rot experiments (Table 5), only Amistar provided effective disease control, with disease incidence in the other treatments being higher than in the inoculated check. Overall in this study, Serenade and Sonata provided limited control of potato storage diseases. However, in all cases these biofungicides were as effective in controlling disease as the conventional fungicide Amistar.

Table 1. Percentage of tubers in each disease severity class, the mean potato late blight severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

		Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
	Treatment (rate/ton)[z]	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	87.5	3.8	0.0	1.3	7.5	0.0	7.5	a[w]	12.5	a
2	Amistar 80WG (70g)	96.3	0.0	0.0	0.0	1.3	2.5	3.5	a	3.8	a
3	Oxidate 27SC (76 ml)	86.3	3.8	0.0	1.3	0.0	8.8	10.3	a	13.8	a
4	Phostrol 53.6SC (190 ml)	86.3	3.8	2.5	3.8	2.5	1.3	7.3	a	13.8	a
5	Serenade ASO (190 ml)	85.0	1.3	0.0	0.0	7.5	6.3	12.5	a	15.0	a
6	Serenade ASO (95 ml)	88.8	3.8	0.0	0.0	3.8	3.8	7.5	a	11.3	a
7	Sonata AS (190 ml)	95.0	2.5	0.0	0.0	1.3	1.3	2.8	a	5.0	a
8	Zoxium 80WG (0.45 kg)	82.5	5.0	0.0	0.0	3.8	8.8	12.8	a	17.5	a
9	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	b	0.0	b
	$LSD_{0.05}$	19.6	10.4	2.4	6.9	10.7	12.5	14.8		19.6	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values of diseased tubers within a column followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

Table 2. Percentage of tubers in each disease severity class, the mean Pythium leak severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

		Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
	Treatment (rate/ton)[z]	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	73.8	0.0	0.0	0.0	6.3	20.0	25.0	bcd[w]	26.3	bcde
2	Amistar 80WG (70g)	95.0	0.0	0.0	0.0	0.0	5.0	5.0	d	5.0	de
3	Oxidate 27SC (76 ml)	87.5	0.0	0.0	1.3	0.0	11.3	12.0	cd	12.5	cde
4	Phostrol 53.6SC (190 ml)	17.5	0.0	0.0	0.0	11.3	71.3	80.3	a	82.5	a
5	Serenade ASO (190 ml)	70.0	2.5	0.0	0.0	5.0	22.5	27.0	bcd	30.0	bcde
6	Serenade ASO (95 ml)	55.0	0.0	0.0	0.0	7.5	37.5	43.5	bc	45.0	bc
7	Sonata AS (190 ml)	66.3	0.0	0.0	0.0	3.8	30.0	33.0	bcd	33.8	bcd
8	Zoxium 80WG (0.45 kg)	46.3	0.0	0.0	0.0	12.5	41.3	51.3	ab	53.8	ab
9	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	d	0.0	e
	$LSD_{0.05}$	35.2	2.4		2.1	16.6	34.0	33.1		35.2	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values of diseased tubers within a column followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

Table 3. Percentage of tubers in each disease severity class, the mean Fusarium dry rot severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

	Treatment (rate/ton)[z]	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Mean Severity Index[x]		Mean disease incidence	
		Percentage of tubers in each disease severity class[y]									
1	Inoculated check	31.3	31.3	26.3	8.8	2.5	0.0	24.0	a[w]	68.8	a
2	Amistar 80WG (70g)	51.3	25.0	20.0	2.5	1.3	0.0	15.5	abc	48.8	ab
3	Oxidate 27SC (76 ml)	47.5	23.8	21.3	7.5	0.0	0.0	17.8	ab	52.5	ab
4	Phostrol 53.6SC (190 ml)	71.3	12.5	10.0	1.3	2.5	2.5	11.8	a	28.8	a
5	Serenade ASO (190 ml)	56.3	21.3	16.3	1.3	2.5	2.5	16.0	abc	43.8	ab
6	Serenade ASO (95 ml)	51.3	36.3	12.5	0.0	0.0	0.0	12.3	bc	48.8	ab
7	Sonata AS (190 ml)	55.0	25.0	17.5	1.3	1.3	0.0	13.8	abc	45.0	ab
8	Zoxium 80WG (0.45 kg)	56.3	28.8	13.8	1.3	0.0	0.0	12.0	bc	43.8	ab
9	Untreated check (non-inoculated)	73.8	0.0	0.0	0.0	6.3	20.0	7.0	c	26.3	b
	LSD$_{0.05}$	35.3	34.7	19.3	8.2	6.1	3.4	14.8		35.3	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values of diseased tubers within a column followed by the same letter are not significantly different at *p* = 0.05 (Tukey test).

Table 4. Percentage of tubers in each disease severity class, the mean Erwinia soft rot severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

	Treatment (rate/ton)[z]	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Mean Severity Index[x]		Mean disease incidence	
		Percentage of tubers in each disease severity class[y]									
1	Inoculated check	92.5	2.5	0.0	0.0	1.3	3.8	8.8	a[w]	7.5	a
2	Amistar 80WG (70g)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	a	0.0	a
3	Oxidate 27SC (76 ml)	97.5	0.0	1.3	0.0	0.0	1.3	2.8	a	2.5	a
4	Phostrol 53.6SC (190 ml)	96.3	1.3	0.0	0.0	0.0	2.5	2.8	a	3.8	a
5	Serenade ASO (190 ml)	96.3	1.3	0.0	0.0	0.0	0.0	0.0	a	3.7	a
6	Serenade ASO (95 ml)	100.0	0.0	0.0	0.0	0.0	2.5	3.5	a	0	a
7	Sonata AS (190 ml)	95.0	1.3	0.0	0.0	2.5	1.3	4.4	a	5	a
8	Zoxium 80WG (0.45 kg)	98.8	0.0	0.0	0.0	0.0	1.3	1.6	a	1.2	a
9	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	a	0	a
	LSD$_{0.05}$	15.5	5.5	2.1		3.2	8.6	10.9		15.5	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values of diseased tubers within a column followed by the same letter are not significantly different at *p* = 0.05 (Tukey test).

Table 5. Percentage mean pink rot disease incidence 120 days after treatment with fungicides/ biofungicides.

Treatment (rate/ton)[z]		Mean disease incidence	
1	Inoculated check	23.3	ab[y]
2	Amistar 80WG (70g)	10.0	ab
3	Oxidate 27SC (76 ml)	38.8	ab
4	Phostrol 53.6SC (190 ml)	75.0	a
5	Serenade ASO (190 ml)	33.8	b
6	Serenade ASO (95 ml)	53.8	ab
7	Sonata AS (190 ml)	75.0	ab
8	Zoxium 80WG (0.45 kg)	42.5	ab
9	Untreated check (non-inoculated)	0.0	b
	$LSD_{0.05}$	69.8	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Mean values of diseased tubers followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

Control of potato tuber diseases with Headsup, Oxidate and Phostrol.

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Tuber preparation

Potato tubers cv. FL1879 (10 ton) were selected during Nov 2005 grown from FS2 seed tubers previously stored at 3°C after harvest in Oct 2005. The tubers were prepared for treatment by two cycles of washing and rinsing in tap water. Potato tubers free from visible diseases were selected for the trials and disinfested by immersion in 750 L baths filled with 3% Clorox (sodium hypochlorite) solution for 30 min. Tubers were dried in a controlled environment with continuous airflow at 15°C in dry air (30% relative humidity) for 24 hours prior to inoculation. After drying, the tubers for inoculations were damaged by passing them over an apple-grader with rollers covered in coarse hair bristles prior to inoculation at a throughput rate of about 35 kg/minute while water was applied at a rate of about 1 L/ metric ton tubers at 50 psi pressure through four single nozzle R&D XR11003VS spray nozzles set about 15 cm apart (Figure 1). The grading table was 0.5 m (wide) x 2 m (long) and passage over the table was sufficient to abrade areas of the skin of the tubers to a depth of 0.01 mm.

Inoculation

Solutions of sporangia/zoosporangia of *Phytophthora infestans* (late blight), oospores of *Pythium ultimum* (Pythium leak), macroconidia of *Fusarium sambucinum* (dry rot) and bacterial cells of *Erwinia caratovora* (Soft rot) were prepared from cultures of the pathogens previously isolated from potato tubers in Michigan. Solutions (1 x 10^3/ml) of sporangia/zoosporangia of *P. infestans* (late blight), oospores of *P. ultimum* (Pythium leak), macroconidia of *F. sambucinum* (dry rot) and bacterial cells of *E. carotovora* (soft rot) were prepared from cultures of the pathogens previously isolated from potato tubers in Michigan. All pathogens were grown on PDA for 10 days prior to preparation of inoculum solutions. Two non-treated controls, either inoculated with one of the pathogens or non-inoculated were included in the trial. The damaged tubers 125 kg/replicate/treatment/pathogen; (total 500 kg tubers/inoculation) were sprayed with 2 L of the pathogen suspension, for a final dosage of about 0.25 ml applied per tuber.

Application of post-harvest fungicides

Twenty-four hours after inoculation, fungicides/bactericides were applied as liquid treatments in water suspension with four single R&D XR11003VS spray nozzle spaced about 15 cm apart at a rate of 1 L/ton at 40 psi onto the exposed tuber surfaces, with the entire tuber surface being coated. The tubers were passed over the washer/damager/inoculation/treatment table a total of four times. Each combination of pathogen x treatments was replicated four times and each of the 125 kg capacity sections of the 500 kg capacity boxes was a single replication of the fungicide treatment. Tubers were incubated in the dark in wooden aerated boxes at 12°C for 90 days after inoculation (Figure 2). Tubers were tipped from the boxes into wooden boxes (35 kg capacity) and a post storage weight obtained. Diseased tubers were then separated from healthy tubers and the weight of tubers with symptoms or signs of the individual pathogens were determined. The proportionate weight of diseased tubers was analyzed by analysis of variance for the individual pathogens. Non-inoculated non-treated controls were included in the study to determine the presence of background diseases.

Figure 1. Treatment table (apple-grader) showing nozzles and CO_2– powered system used to damage, inoculate, and to apply fungicides to potato tubers.

Figure 2. Storage boxes split into sections to hold 125 kg of potato tubers. Each box represented a single replicate for each disease treated with one of three fungicide treatments and the non treated inoculated control.

Results

No disease symptoms developed on the non-inoculated non-treated controls which indicated that the pre-treatment and sterilization of tubers removed all surface pathogens. These treatments were not included in the analyses.

Dry rot (*Fusarium sambucinum*; Table 1).
No treatments significantly reduced the percentage by weight of tubers with symptoms or signs of Fusarium dry rot in comparison with the non-treated inoculated control.

Potato late blight (*Phytophthora infestans*; Table 1).
No treatments significantly reduced the percentage by weight of tubers with symptoms or signs of late blight in comparison with the non-treated inoculated control.

Pythium leak (*Pythium ultimum*); (Table 1).
No treatments significantly reduced the percentage by weight of tubers with symptoms or signs of Pythium leak in comparison with the non-treated inoculated control.

Soft rot (*Erwinia caratovora*;); (Table 1).
No treatments significantly reduced the percentage by weight of tubers with symptoms or signs of Pythium leak in comparison with the non-treated inoculated control.

Table 1. Percentage of tubers with symptoms or signs of Fusarium dry rot, potato tuber late blight, pink rot, Pythium leak and bacterial soft rot on potato tubers treated with fungicides/bactericides.

	Percentage of rotted tubers by weight[y]							
Treatment rate/ton[z]	Fusarium		Late Blight		Pythium		Soft Rot	
Headsup WDG (2 g)	27.2	a[x]	4.6	a	3.0	a	0.9	a
Oxidate 27SC (76 ml)	23.0	a	4.7	a	0.6	a	2.2	a
Phostrol 53.6SC (190 ml)	19.5	a	14.4	a	3.9	a	2.8	a
Untreated	38.2	a	6.6	a	0.7	a	2.4	a
HSD *p*=0.05	3.20		2.97		3.12		2.97	

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.
[y] Percentage of rotted tubers determined by weight of tubers with symptoms or signs of disease/total weight of tubers 90 days after inoculation with macroconidia of *Fusarium sambucinum* (dry rot), sporangia/zoospores of *Phytophthora infestans* (late blight), oospores of *Pythium ultimum* (Pythium leak), and bacterial cells of *Erwinia caratovora* (Soft rot).
[x] Mean values percentage of rotted tubers by weight followed by the same letter are not significantly different at p = 0.05 (Tukey test).

Control of silver scurf with Serenade and Commercial Storage Products. 2005-06

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Tuber preparation

Potato tubers cv. Red Norland were selected during Nov 2004 and 2005 from FS2 seed tubers previously stored at 3^{o}C after harvest in Oct 2004 and 2005. The tubers were prepared for treatment by two cycles of washing and rinsing in tap water. Potato tubers had a background of silver scurf (*Helminthosporium solani*) with an average of 5.9 $\pm$ 2.83% (n = 50 tubers) of the surface area affected at the start of the experiment. Tubers were surface disinfested by immersion in 20 gal baths filled with 3% Clorox (sodium hypochlorite) solution for 30 min. Tubers were dried for 24 h prior to treatment.

Application of post-harvest fungicides

The tubers (20/replicate/treatment; total 80 tubers/treatment) were sprayed with fungicides/biofungicides applied as post-harvest potato tuber liquid treatments in water suspension with a single nozzle R&D XR11003VS spray nozzle at a rate of 0.1 pt/cwt (0.25 gal/ton) at 50 psi onto the exposed tuber surfaces, with the entire seed surface being coated in the seed treater. Tubers were incubated in the dark in plastic boxes at 4^{o}C for 90 days after inoculation. No sprout inhibitors were applied and the boxes remained undisturbed for the duration of the experiment. Tubers were washed and assessed for silver scurf (*H. solani*) severity 90 days after treatment. Severity of silver scurf was measured as an index calculated by counting the number of tubers (n = 80) falling in class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 75; 5 > 75% surface area of each tuber affected by silver scurf. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. The percentage falling into each class and the final mean index values were analyzed by ANOVA.

Results

2005: No tubers fell into class 0 as at the initiation of the experiment all tubers had about 5% surface area affected by silver scurf. Treatments with percentage of tubers in severity class 1 from 17.5 to 36.4 and 31.3 to 60.0% were not significantly different (the higher numbers indicate better control of silver scurf). There were no significant differences among any treatments with respect to percentage of tubers in disease severity classes 2 through 5. The mean index of severity of silver scurf indicated that treatments with indices from 47.5 to 37.5; 41.3 to 25.7; and 25.7 to 14.1 were not significantly different. Lower index values indicate better control of silver scurf.

2006: No tubers fell into class 0 as at the initiation of the experiment all tubers had on average about 10% surface area affected by silver scurf. Treatments with percentage of tubers in severity class 0 from 6.3 to 27.8 and 10.0 to 28.8% were not significantly different (the higher numbers indicate better control of silver scurf). Treatments with percentage of tubers in severity class 3 from 15.0 to 36.3 and 20.0 to 37.5% were not significantly different There were no significant differences among any treatments with respect to percentage of tubers in disease severity classes 2, 4 and 5. The mean index of severity of silver scurf indicated that treatments with indices from 24.1 to 43.8; 31.9 to 25.7; and 25.7 to 48.1 were not significantly different. Lower index values indicate better control of silver scurf. Amistar (active ingredient azoxystrobin) had the lowest index (24.1, Table 2).

Table 1. Percentage of tubers in each silver scurf severity class and the mean silver scurf severity index 90 days after treatment with fungicides/biofungcides; 2005.

Treatment rate/cwt seed tubers[z]	Percentage of tubers in each disease severity class[y]						Mean silver scurf severity index[x]	
	Class 0		Class 1	Class 2	Class 3	Class 4		
Mertect 340F 0.053 fl oz	36.4	ab[w]	41.3	10.0	8.8	3.8	25.7	bc
Oxidate 27SC 0.8 fl oz	28.8	b	22.5	21.25	17.5	10.0	39.4	ab
Phostrol 53.6SC 0.64 fl oz	60.0	a	30.0	3.8	6.3	0	14.1	c
Serenade ASO 0.16 fl oz	17.5	b	22.5	28.8	15.0	16.3	47.5	a
Serenade ASO 0.32 fl oz	31.3	ab	22.5	21.3	15.0	10.0	37.5	ab
Untreated non-inoculated	30.0	b	18.8	22.5	13.8	15.0	41.3	ab

[z] The rate of product per cwt seed tubers applied in mixture with water at 1.6 fl oz/cwt.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% surface area of tuber with silver scurf.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values percentage of rotted tubers by weight followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

Table 2. Percentage of tubers in each silver scurf severity class and the mean silver scurf severity index 90 days after treatment with fungicides/biofungcides; 2006.

Treatment rate/cwt seed tubers[z]	Percentage of tubers in each disease severity class[y]							Mean silver scurf severity index[x]	
	Class 0		Class 1	Class 2		Class 3	Class 4		
Mertect 340F 0.053 fl oz	12.5	ab[w]	31.3	33.8	ab	16.3	6.3	43.1	ab
Oxidate 27SC 0.8 fl oz	23.8	ab	38.8	20.0	ab	11.3	3.8	31.9	ab
Phostrol 53.6SC 0.64 fl oz	16.3	ab	38.8	27.5	ab	15.0	2.5	37.2	ab
Serenade ASO 0.16 fl oz	17.5	ab	22.5	30.0	ab	22.5	6.3	43.8	ab
Serenade ASO 0.32 fl oz	6.3	b	23.8	37.5	a	21.3	7.5	48.1	a
Sonata ASO 0.32 fl oz	11.3	ab	27.5	27.5	ab	26.3	6.3	46.6	a
Headsup 0.11 oz	17.5	ab	27.5	35.0	ab	12.5	5.0	38.8	ab
Amistar 80WDG 0.125 oz	28.8	a	38.8	15.0	b	7.5	1.3	24.1	b
Zoxium 80WDG 0.4 oz	11.3	ab	35.0	26.3	ab	18.8	7.5	43.4	ab
Untreated non-inoculated	10.0	ab	35.0	36.3	ab	13.8	5.0	42.2	ab
LSD p = 0.05	22.4		24.2	22.16		25.63	11.39	20.41	
Untreated non-inoculated start	56.3		30.0	13.8		1.3	0	15.3	

[z] The rate of product per cwt seed tubers applied in mixture with water at 1.6 fl oz/cwt.
[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% surface area of tuber with silver scurf.
[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.
[w] Mean values percentage of rotted tubers by weight followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

Potato Insect Biology and Management

Report to the Michigan Potato Industry Commission
18 January 2007

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Outline.

I. Resistance of Colorado potato beetle populations to imidacloprid and thiamethoxam was evaluated for field populations from Michigan, as well as other locations in the Midwest and locations in the northeastern U.S.

II. Field insecticide evaluations of registered and experimental insecticides.

III. Use of trap crop and alternative insecticides were evaluated for managing resistant Colorado potato beetles.

I. Resistance of Colorado potato beetle populations to imidacloprid and thiamethoxam.

Imidacloprid (Admire Pro®, Provado®) and thiamethoxam (Platinum®, Actara®) remain the most frequently used compounds for Colorado potato beetle control. In 2005, these compounds were applied to greater than 80% of the acreage in Michigan, Wisconsin, and Minnesota (NASS 2006). Such heavy reliance on these compounds significantly increases the likelihood for resistance development. Further, the similarities between these compounds is not fully understood, making it important to continue scrutinizing populations for resistance development and cross-resistance.

Our objectives were to continue gathering data on susceptibility to imidacloprid and thiamethoxam in Colorado potato beetle populations collected from commercial potato fields in Michigan and other regions of the United States. A second objective was to monitor the correlations between imidacloprid and thiamethoxam susceptibility. To accomplish these objectives, 55 Colorado potato beetle populations (32 Michigan populations, 17 populations collected in other states, and six laboratory populations) were selected and/or bioassayed with imidacloprid and/or thiamethoxam.

Methods

During 2006, 32 Colorado potato beetle populations were collected from three different Michigan counties (Isabella, Mecosta, and Montcalm). Cooperators also provided one population from Washington state, two populations each from Massachusetts and Delaware, three populations from Minnesota, four populations from Maine, and five populations from Wisconsin. Six laboratory strains were also tested (Table I.1).

Colorado potato beetle adults were either kept at room temperature (25±1° C) and fed foliage daily or, for longer term storage, kept in controlled environment chambers (11±1° C) and fed weekly. Beetles were treated with 1 µl of acetone/insecticide solution of known concentration applied to the ventral surface of the abdomen using a 50 µl Hamilton® microsyringe. Following treatment, beetles were placed in 100 mm diameter petri dishes lined with Whatman® No. 1 filter paper and provided with fresh potato foliage. They were kept at 25±1° C and the foliage and filter paper were checked daily and changed as needed.

A preliminary screen was conducted on most populations (for populations tested in previous years, screening was sometimes not necessary) to determine relative susceptibility to imidacloprid and thiamethoxam by testing 10 beetles each with two concentrations of insecticide/acetone solution. Based on the results fo these screens, a range of five concentrations was selected for each population to be assayed and each bioassay was replicated up to three times. In each replicate, 15 beetles were treated with each concentration (five beetles per dish and three dishes per concentration). For one population, few beetles were available and only a preliminary screen was run.

Beetle response was assessed 7 days post treatment. A beetle was classified as dead if its abdomen was shrunken, it did not move when its legs or tarsi were pinched, and its elytra were darkened. Beetles that had died due to *Beauvaria* sp. infection were excluded from analysis; these beetles were easily recognized by their pale petrified appearance or presence of white filamentous fungi. A beetle was classified as walking and healthy if it was able to grasp a pencil and walk forward normally. A beetle was classified as poisoned if its legs were extended and shaking, it was unable to right itself or grasp a pencil, and it was unable to walk forward normally at least one body length. Dead and poisoned beetle numbers were pooled for analysis. Data were analyzed using standard log-probit analysis (SAS® System v9.1.3).

Results

The imidacloprid LD_{50} value (dose lethal to 50% of the beetles) for the susceptible laboratory strain (New Jersey) was 0.039 µg/beetle. The LD_{50} values for imidacloprid ranged from 0.019 µg/beetle (Sackett Ranch, fields TO 1-4) to 3.244 µg/beetle (Sackett Potatoes, fields 47 & 48) for Michigan populations (Figure I.1A) and from 0.022 µg/beetle (Rosemount, MN) to 7.152 µg/beetle (Northampton, MA) for out-of-state populations (Figure I.2A, Table I.2).

Significant levels of resistance to imidacloprid were again present in Michigan. Beetles from Sackett Potatoes, field 47&48 were 83-fold resistant to imidacloprid, compared to the susceptible strain. Four other fields on the same farm (field 1, field 3, field 4, and field 31) were also greater than 20-fold resistant to imidacloprid. In total, 12 samples were tested with imidacloprid from the Sackett Potato home farm (Figure I.1B). All but three samples were greater than 10-fold resistant to imidacloprid. There was also an obvious pattern of lower LD_{50} values from fields tested using overwintering adults. Despite certain fields having higher LD_{50} values, it is our belief that the resistance at the Sackett Potatoes home farm is rather homogenous; limited, localized dispersal could help explain some of the field-by-field differences.

Even more troubling for Michigan growers was the detection of three additional sites with high levels of imidacloprid resistance. Paul Main Farm, field R1, located about 12 km to the northwest of Sackett Potatoes home farm, had an LD_{50} value of 1.457 µg/beetle, which is 37-fold resistant to imidacloprid compared to the susceptible strain. Paul Main Farm, Shurlow site, located about 11 km to the southwest of Sackett Potatoes home farm, had an LD_{50} value of 3.142 µg/beetle, which is 81-fold resistant to imidacloprid. Lastly, Sackett Potatoes, fields 102 and 103, located about 12 km to the northeast of Sackett Potatoes home farm, had an LD_{50} values of 0.668 µg/beetle (17-fold resistant to imidacloprid) and 0.447 µg/beetle (11-fold resistant to imidacloprid), respectively. It is not clear what led to the emergence of resistance at these sites (dispersal, transport on equipment, and/or independent origin), but the implications for Michigan's potato production region are immense. Continued monitoring of these sites and those that have not reported problems will be essential in understanding the spread of resistance and how we can maximize the efficacy of available insecticides.

An additional seven Michigan populations had LD_{50} values that were significantly higher than the susceptible New Jersey strain, but less than 10 times higher – a situation also found for three populations from Wisconsin and one each from Minnesota and Washington. On the other hand, beetles from four Michigan sites (Anderson Bros. field 7, Sackett Potatoes fields 140&143-145, Sackett Ranch C6&C21, and Sackett Ranch TO 1-4) appeared to be susceptible, with mortalities equal to or greater than 80% at 0.3 µg/beetle.

The thiamethoxam LD_{50} value for the susceptible laboratory strain (New Jersey) was 0.032 µg/beetle. The LD_{50} values for thiamethoxam ranged from 0.018 µg/beetle (Paul Main field R17) to 0.417 µg/beetle (Sackett Potatoes field 47&48) for Michigan populations (Figure I.3A) and from 0.019 µg/beetle (Rosemount, MN) to 0.578 µg/beetle (Deerfield, MA) for out-of-state populations (Figure I.2B, Table I.3). The Deerfield, MA population was the only out-of-state population expressing greater than 10-fold resistance to thiamethoxam, however, the two populations from Fryeburg, ME did have significantly greater LD_{50} values than the susceptible New Jersey strain.

As in 2005, the only Michigan populations with greater than 10-fold resistant to thiamethoxam were on the Sackett Potatoes home farm; in 2006, three fields eclipsed this mark (Figure 3B). While the state's remaining fields were rather susceptible to thiamethoxam, the number of fields with significantly higher LD_{50} values than the susceptible New Jersey strain was higher than in previous years.

Susceptibility to imidacloprid (as measured by LD_{50}) in field-collected Colorado potato beetle populations was highly correlated with susceptibility to thiamethoxam (Figure I.4). This result was also found in 1998, 1999, 2000, 2002, 2003, 2004, and 2005 (e.g. Grafius et al. 2004, 2005; Byrne 2006). This high correlation and other data on cross resistance (e.g. Mota-Sanchez et al. 2006) indicate that alternation between imidacloprid and thiamethoxam will not be an effective resistance management technique.

The Sloth and Vegas strains were collected from Sackett Potatoes home farm field 3-4 in 2005 and survivors from selections with thiamethoxam and imidacloprid, respectively, were used to start the laboratory strains. Adults from each generation were selected with thiamethoxam

(Sloth) or imidacloprid (Vegas) doses causing 30-90% mortality. Bioassays were conducted after three generations. Thiamethoxam LD_{50} values have not shown noticeable change to date. Although not statistically different from the LD_{50} values obtained from the original field populations last summer, the LD_{50} value for Vegas did nearly double after three generations of selection. We will continue the selections and bioassays on these laboratory strains.

Table I.1. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2005.

Michigan populations
Anderson Bros.-7 Adults were collected on 30 August 2006 from commercial potato field in Montcalm Co., MI
Montcalm Farm Adults were collected on 18 July 2006 from the Michigan State University Montcalm Potato Research Farm in Entrican, MI.
Paul Main Farm Adults were collected by Mark Otto, AgriBusiness Consultants, Inc. from commercial potato fields in Mecosta Co.
Field R1 Overwintering adults were collected on 30 May and 1 & 6 June 2006 and summer adults were collected on 2 and 8 August 2006.
Field R6 Adults were collected on 6 June 2006.
Field R7 Adults were collected on 5 August 2006.
Field R8 Adults were collected on 25 July and 5 August 2006.
Field R17 Adults were collected on 3 & 6 June 2006.
Shurlow field Adults were collected on 14 August 2006.
Sackett Acres *Field 12* Adults were collected on 7 and 13 June 2006 by Mark Otto, AgriBusiness Consultants, Inc., from a commercial potato field in Mecosta Co., MI.
Sackett Potatoes Adults were collected by Mark Otto, AgriBusiness Consultants, Inc., and Michigan State University researchers from commercial potato fields in Mecosta Co., MI.
Field 1 Adults were collected on 2 August 2006.
Field 3 Adults were collected on 3 August 2006.
Field 4 Adults were collected on 19 July and 2 August 2006.
Field 5 Adults were collected on 30 & 31 May 2006.
Fields 8 & 32 Adults were collected on 8 June 2006.
Field 14 Adults were collected on 6 June 2006.
Fields 26-29 Adults were collected on 30 & 31 May 2006.
Field 31 Adults were collected on 30 & 31 May 2006.
Field 42 Adults were collected on 30 & 31 May and 6 June 2006.
Field 43 Adults were collected on 6 June 2006.
Fields 47-48 Overwintering adults were collected on 3 June 2006 and summer adults were collected on 19 July and 3 August 2006.
Field 83 Adults were collected on 5 June 2006.
Fields 88-90 Adults were collected on 6 June 2006.
Field 92 Adults were collected on 6 June 2006.
Field 100 Adults were collected on 6 June 2006.
Field 102 Adults were collected on 17 July and 8 August 2006.
Field 103 Adults were collected on 2 June 2006.

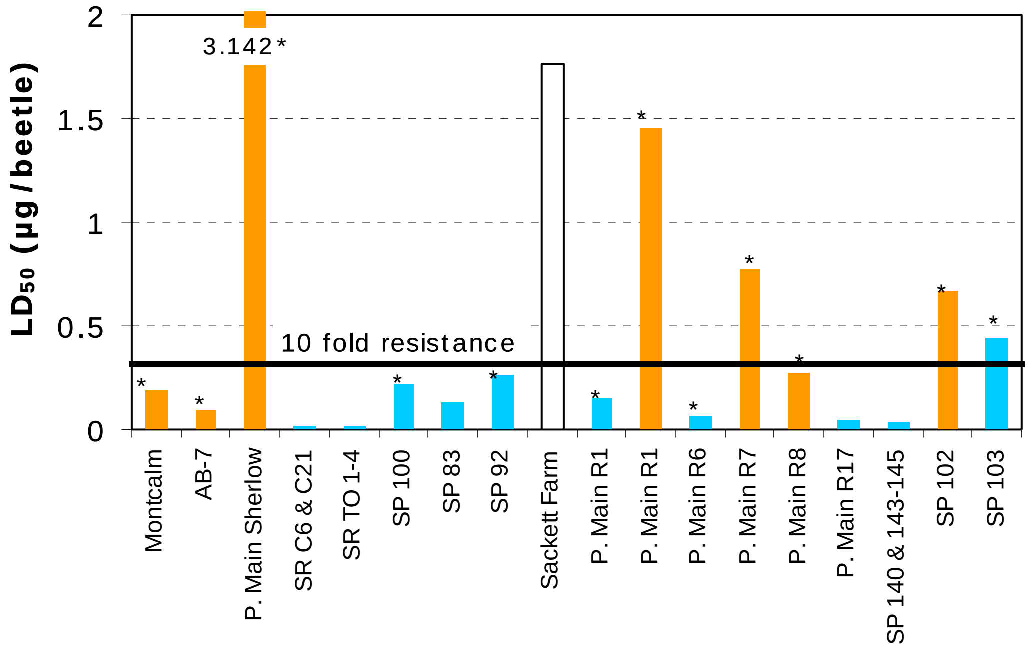
Table I.1 cont'd. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2005.

Fields 140 & 143-145 Adults were collected on 8 June 2006.
Sackett Ranch Adults were collected by Mark Otto, AgriBusiness Consultants, Inc., from a commercial potato field in Mecosta Co., MI.
Fields C6 & C21 Adults were collected on 6 June 2006.
Fields TO 1-4 Adults were collected on 2 June 2006.
Out-of-state populations
Aroostook, Maine Adults were collected on 17 August 2006 by Gary Sewell, University of Maine, from untreated potato research plots near Presque Isle, ME.
Becker, Minnesota Adults were collected on 7 August 2006 by David Ragsdale, University of Minnesota, from a commercial potato field, treated with Admire, dimethoate, Asana, Actara, and Furadan, near Becker, MN.
Bridgewater, Maine Adults were collected on 22 June 2006 by Gary Sewell, University of Maine, from an organic potato field near Bridgewater, ME.
Deerfield, Massachusetts Adults were collected on 4 August 2006 from a commercial potato field, treated with Cruiser and Agrimek, near Deerfield, MA.
Fryeburg-Anne, Maine Adults were collected on 20 June 2006 by Andrei Alyokhin, University of Maine, from untreated potatoes in the Anne Field, near Fryeburg, ME.
Fryeburg-Eastman, Maine Adults were collected on 20 June 2006 by Andrei Alyokhin, University of Maine, from untreated potatoes in the Eastman Field, near Fryeburg, ME.
Hancock, Wisconsin Adults were collected on 7 June 2006 by Scott Chapman, University of Wisconsin-Madison, from untreated potatoes at the Hancock Agricultural Research Station, Waushara Co., WI
Little Creek, Delaware Adults were collected on 5 July 2006 by Joanne Whalon, University of Delaware, from a commercial potato field, treated with Platinum, Kryocide, and Spintor, near Little Creek, DE.
Madison, Wisconsin Adults were collected on 14 June 2006 by Scott Chapman, University of Wisconsin-Madison, from a commercial potato field near Madison, WI.
Northampton, Massachusetts Adults were collected on 4 August 2006 from a commercial potato field, treated with Admire and Rimon, near Northampton, MA.
Okray, Wisconsin Adults were collected on 10 July 2006 by Scott Chapman, University of Wisconsin-Madison, from a commercial potato field in Okray, WI.
Pasco, Washington Adults were collected on 21 August 2006 by Donald Drader, Syngenta Crop Protection, Inc. from a commercial potato field, treated with Asana, Monitor, Furadan, Leverage, and Vydate, in Pasco, WA.
Plainfield, Wisconsin Adults were collected on 25 July 2006 by Scott Chapman, University of Wisconsin-Madison, from a commercial potato field near Plainfield, WI.
Pries, Delaware Adults were collected on 5 July 2006 by Joanne Whalon, University of Delaware, from a commercial potato field, treated with Leverage, Spintor, Kryocide, and Actara, near Magnolia, DE.
Rosemount, Minnesota Adults were collected on 20 June 2006 by David Ragsdale, University of Minnesota, from untreated potatoes near Rosemount, MN.
Sand Plains, Minnesota Adults were collected on 21 June 2006 by Brian McCormick, University of Minnesota, from research plots near Becker, MN

Table I.1 cont'd. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2005.

Spring Green, Wisconsin Adults were collected on 20 July 2006 by Scott Chapman, University of Wisconsin-Madison, from a commercial potato field near Spring Green, WI.
Laboratory strains
Evans Collected from Montcalm Co., MI in summer 1997. Adults from most generation have been selected with imidacloprid doses targeting 60-80% mortality.
Hadley Collected from Hadley, MA in July 2003. Adults from each generation have been selected with thiamethoxam doses targeting 60-80% mortality.
New Jersey Adults obtained from the Phillip Alampi Beneficial Insects Rearing Laboratory, New Jersey Department of Agriculture.
NY-Select Collected from Long Island, NY in 1997. Adults from most generations selected with imidacloprid doses targeting 60-80% mortality.
Sloth Collected from Sackett Potatoes, Mecosta Co., MI in summer 2005. Adults from each generation have been selected with thiamethoxam doses targeting 60-80% mortality.
Vegas Collected from Sackett Potatoes, Mecosta Co., MI in summer 2005. Adults from each generation have been selected with imidacloprid doses targeting 60-80% mortality.

A. Michigan populations



B. Sackett Potatoes

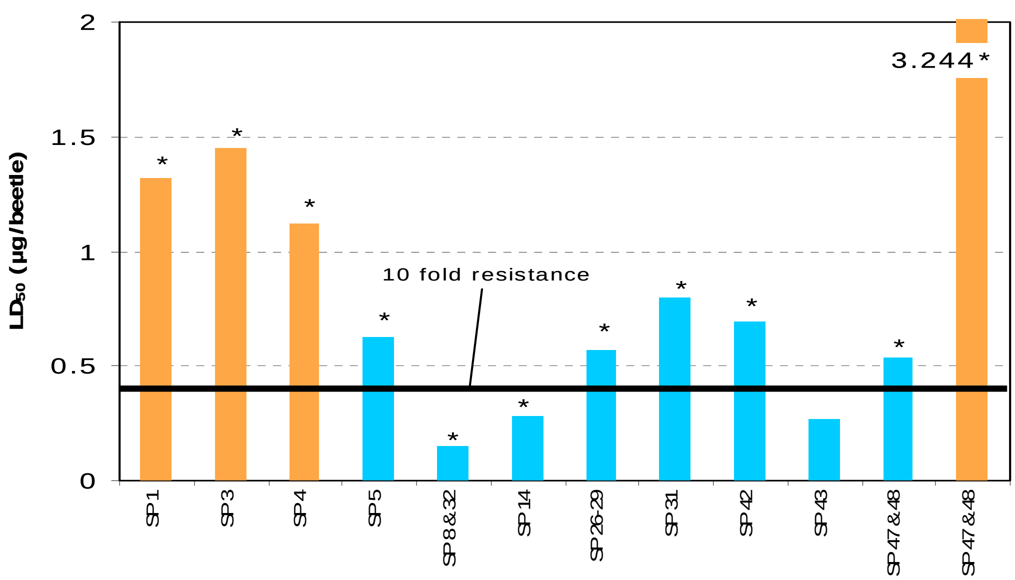
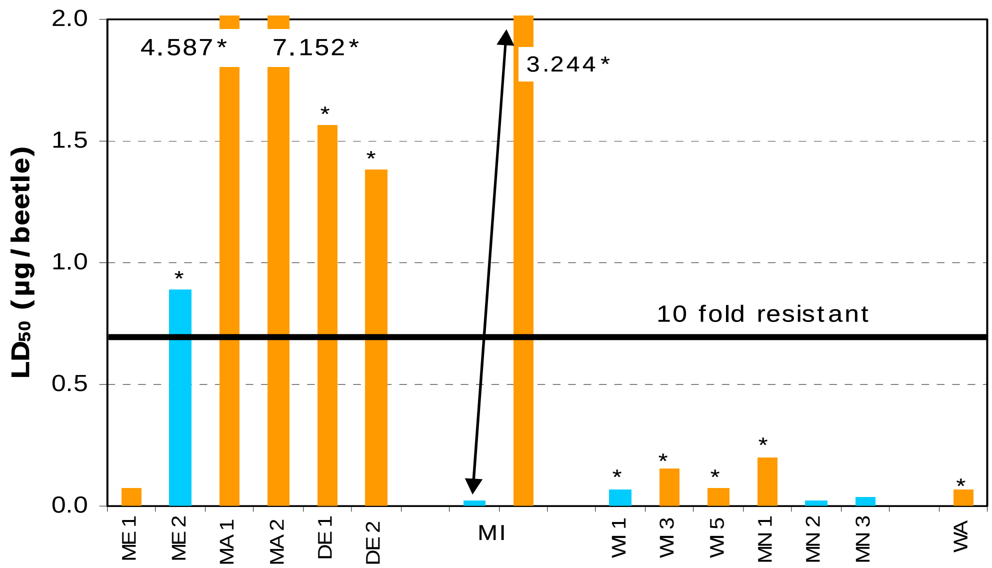


Figure I.1. Susceptibility of Michigan field populations of Colorado potato beetle to imidacloprid. The Sackett Farm value in figure A. is an average of all populations presented in figure B. An asterisk (*) denotes values significantly greater than the susceptible strain.

A. Imidacloprid



B. Thiamethoxam

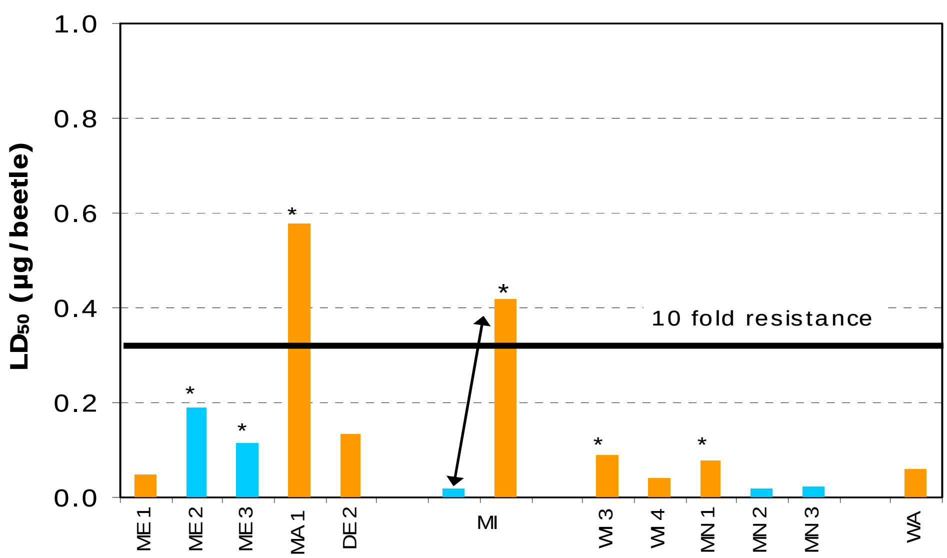


Figure I.2. Susceptibility of field populations of Colorado potato beetle to imidacloprid (A) and thiamethoxam (B). Michigan values presented as a range from lowest to highest value. An asterisk (*) denotes values significantly greater than the susceptible strain.

Table I.2. LD_{50} values (μg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with imidacloprid at 7 days after treatment.

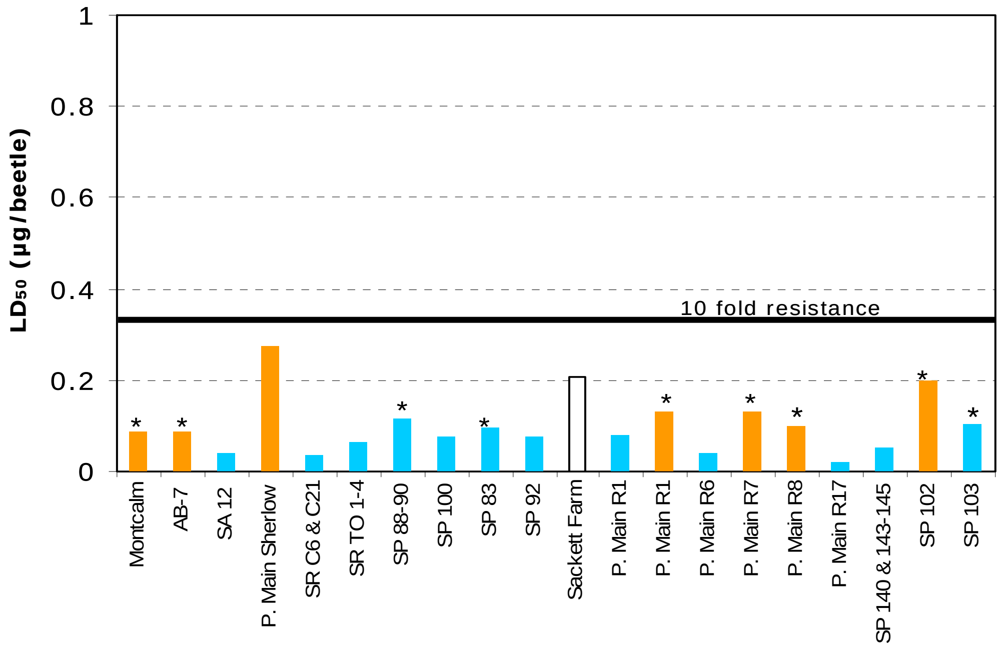
	LD_{50}	95% fiducial limits
Michigan populations		
Anderson Brothers Field7	0.093	0.024-0.146
Montcalm Farm	0.189[1]	0.137-0.345
Paul Main Farm		
Field R1-winter	0.147	0.035-0.236
Field R1-summer	1.457[2]	0.773-12.277
Field R6	0.069[1]	0.051-0.091
Field R7	0.773[2]	0.598-1.054
Field R8	0.275[1]	0.199-0.439
Field R17	0.044	0.0001-0.092
Shurlow site	3.142[2]	1.643-12.229
Sackett Potatoes		
Field 1	1.322[2]	1.058-1.664
Field 3	1.448[2]	1.224-1.802
Field 4	1.122[2]	0.928-1.508
Field 5	0.628[2]	0.538-0.719
Fields 8&32	0.149[1]	0.109-0.232
Field 14	0.285[1]	0.225-0.356
Fields 26-29	0.570[2]	0.158-0.888
Field 31	0.794[2]	0.652-0.952
Field 42	0.696[2]	0.250-1.089
Field 43	0.271	0.039-0.428
Fields 47&48-winter	0.533[2]	0.335-0.673
Field 47&48-summer	3.244[2]	2.426-4.889
Field 83	0.128	0.028-0.208
Field 88-90	0.042	*
Field 92	0.260[1]	0.187-0.321
Field 100	0.214[1]	0.092-0.293
Field 102	0.668[2]	0.529-0.935
Field 103	0.447[2]	0.241-0.791
Fields 140&143-145	0.035	0.002-0.068
Sackett Ranch		
Fields C6&C21	0.020	0.004-0.032
Fields TO1-4	0.019	0.004-0.032

Table I.2 cont'd. LD50 values (µg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with imidacloprid at 7 days after treatment.

	LD_{50}	95% fiducial limits
out-of-state populations		
Aroostook, ME	0.073	0.021-0.122
Becker, MN	0.198[1]	0.122-0.379
Bridgewater, ME	0.022	*
Deerfield, MA	4.587[2]	3.492-6.788
Fryeburg-Anne, ME	0.887[2]	0.686-1.084
Hancock, WI	0.068[1]	0.060-0.077
Little Creek, DE	1.563[2]	0.249-2.553
Madison, WI	0.051	*
Northampton, MA	7.152[2]	4.993-15.514
Okray, WI	0.158[1]	0.130-0.196
Pasco, WA	0.066[1]	0.056-0.078
Plainfield, WI	2.310	*
Pries, DE	1.385[2]	0.534-2.095
Rosemount, MN	0.022	0.019-0.025
Sand Plains, MN	0.035	0.030-0.040
Spring Green, WI	0.070[1]	0.052-0.086
laboratory strains		
Evans	8.215[2]	4.541-80492.000
Hadley	24.590[2]	*
New Jersey	0.039	0.034-0.044
NY-Select	3.371[2]	2.222-4.442
Vegas	1.134[2]	0.609-1.525

[1] significantly greater than LD_{50} value for susceptible New Jersey strain
[2] greater than 10 times the LD_{50} value for susceptible New Jersey strain

A. Michigan populations



B. Sackett Potatoes

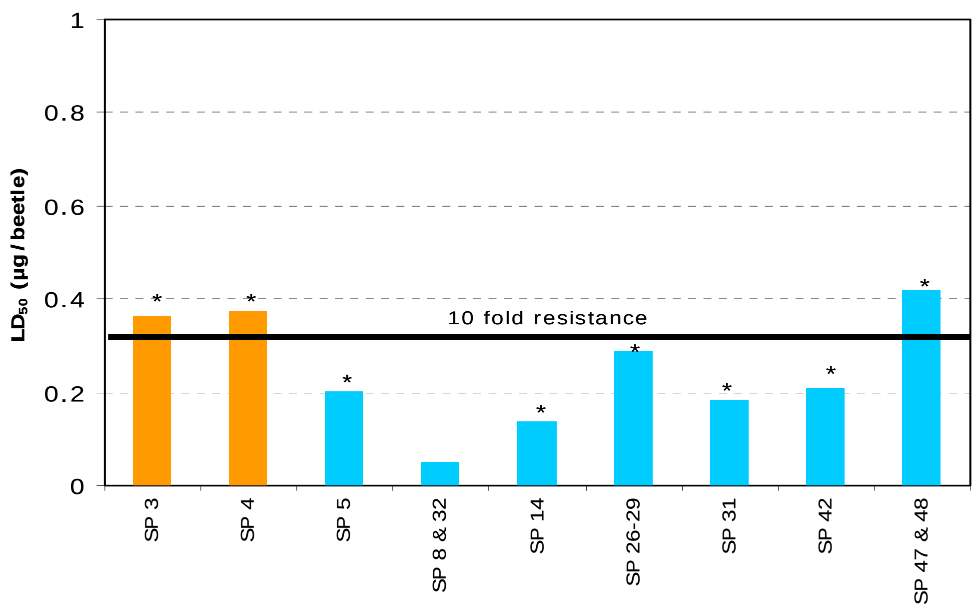


Figure I.3. Susceptibility of Michigan field populations of Colorado potato beetle to imidacloprid. The Sackett Farm value in figure A. is an average of all populations presented in figure B. An asterisk (*) denotes values significantly greater than the susceptible strain.

Table I.3. LD_{50} values (µg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with thiamethoxam at 7 days after treatment.

	LD_{50}	95% fiducial limits
Michigan populations		
Anderson Brothers Field 7	0.088[1]	0.072-0.106
Montcalm Farm	0.086[1]	0.065-0.108
Paul Main Farm		
Field R1-winter	0.080	0.036-0.114
Field R1-summer	0.133[1]	0.099-0.187
Field R6	0.039	0.030-0.048
Field R7	0.132[1]	0.114-0.159
Field R8	0.101[1]	0.080-0.134
Field R17	0.018	0.0002-0.039
Shurlow site	0.276	0.054-0.431
Sackett Acres Field 12	0.038	0.022-0.050
Sackett Potatoes		
Field 3	0.365[2]	0.294-0.437
Field 4	0.374[2]	0.326-0.427
Field 5	0.201[1]	0.173-0.236
Field 8&32	0.052	0.041-0.068
Field 14	0.138[1]	0.088-0.253
Fields 26-29	0.289[1]	0.235-0.339
Field 31	0.183[1]	0.099-0.353
Field 42	0.210[1]	0.174-0.252
Fields 47&48	0.417[2]	0.355-0.483
Field 83	0.096[1]	0.070-0.118
Fields 88-90	0.114[1]	0.087-0.138
Field 92	0.075	0.039-0.104
Field 100	0.074	0.040-0.102
Field 102	0.200[1]	0.162-0.238
Field 103	0.104[1]	0.087-0.123
Fields 140&143-145	0.053	0.004-0.089
Sackett Ranch		
Fields C6&C21	0.036	0.027-0.043
Fields TO 1-4	0.064	0.049-0.084

Table I.3 cont'd. LD50 values (µg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with thiamethoxam at 7 days after treatment.

	LD_{50}	95% fiducial limits
out-of-state populations		
Aroostook, ME	0.050	0.038-0.062
Becker, MN	0.076[1]	0.065-0.092
Bridgewater, ME	0.014	*
Deerfield, MA	0.578[2]	0.467-0.729
Fryeburg-Anne, ME	0.189[1]	0.138-0.233
Fryeburg-Eastman, ME	0.114[1]	0.054-0.168
Hancock, WI	0.071	*
Little Creek, DE	0.294	*
Madison, WI	0.053	*
Okray, WI	0.088[1]	0.068-0.110
Pasco, WA	0.059	0.052-0.066
Plainfield, WI	0.258	*
Pries, DE	0.134	0.011-0.217
Rosemount, MN	0.019	0.014-0.022
Sand Plains, MN	0.021	0.018-0.025
Spring Green, WI	0.042	0.032-0.051
laboratory strains		
Evans	0.747[2]	0.599-0.991
Hadley	1.807[2]	1.518-2.111
New Jersey	0.032	0.003-0.056
NY-Select	0.172[1]	0.149-0.200
Sloth	0.226[1]	0.180-0.290
Vegas	0.193[1]	0.154-0.233

[1] significantly greater than LD_{50} value for susceptible New Jersey strain
[2] greater than 10 times the LD_{50} value for susceptible New Jersey strain

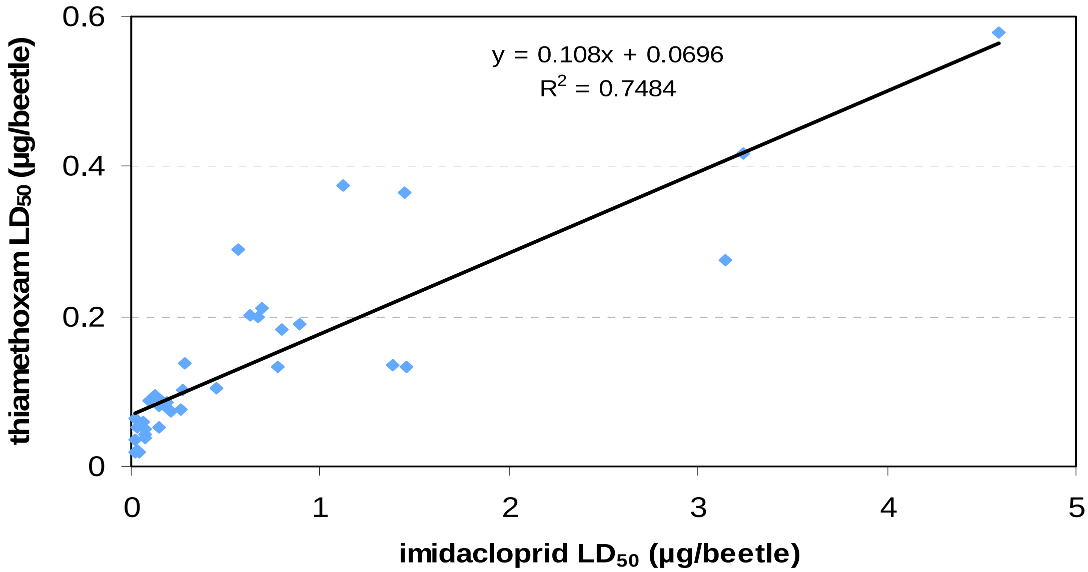


Figure I.4. Correlation between susceptibility to imidacloprid and thiamethoxam for all field populations tested in 2006 (n=36).

II. Field insecticide evaluations of registered and experimental insecticides.

Evaluation of registered and potential insecticides for control of Colorado potato beetle provides data on comparative effectiveness of products and data to support future product registrations.

<u>Methods.</u>

Nineteen insecticide treatments plus an untreated check (Table II.1) were tested at the Michigan State University Montcalm Research Farm, for control of CPB. 'Pike' seed pieces were planted 12 in. apart, with 34 in. row spacing on 10 May 2006. Treatments were replicated four times in a RCB design. Plots were 50 ft long and three rows wide.

Admire Pro, Platium, and Belay treatments were applied in-furrow at planting using a single nozzle hand-held boom (30 gpa, 30 psi). Foliar treatments were first applied at greater than 50% egg hatch on 22 June. Subsequent first-generation sprays for most treatments were applied on 28 June, 5 July, and 12 July depending on treatment (Table II.1).

Post-spray counts of CPB adults, egg masses, small larvae (1st and 2nd instars), and large larvae (3rd and 4th instars) on five randomly selected plants from the middle row of each plot were made 5 to 6 days after each foliar application. On 8 September, the middle row of each plot was harvested mechanically and the tubers were separated by size and weight. Data were analyzed using two-way ANOVA (treatment and block) and significant differences were determined with Fisher's Protected LSD test (p=0.05).

Results.

The seasonal average number of large larvae was significantly lower in treated plots compared to untreated plots (Table II.1). All treatments resulted in significantly fewer large larvae than the untreated plots. The insecticide treatments kept large larvae below the economic threshold of 1 to 2 large larvae per plant compared to 11 large larvae per plant in the untreated plots. The seasonal average number of small larvae included larvae that had recently hatched and were still on the egg mass, resulting in high variability in these results. All treatments resulted in significantly higher yields than the untreated plots (Table II.2). There was high variability in the emergence of the 'Pike' seed pieces in all plots and this may explain the variability in the yield data. Planting occurred on 10 May and was followed by 5 days of rain and then cold temperatures.

The 2006 insecticide evaluations tested several non-neonicotinoid insecticides, and combinations of non-neonicotinoid insecticides, all provided effective control of CPB. Although these chemicals may have cost limitations, restrictions in number of applications, and timing of application, they are valuable chemicals to slow CPB resistance to neonicotinoids.

Table II.1. The seasonal average number of first generation Colorado potato beetle adults, egg masses, small larvae, and large larvae per plant.

Treatment/ formulation	Rate	Adults	Egg Masses	Small Larvae	Large Larvae
A-13623[6]	2.75 oz/A	0.7 cde	0.9 f	4.6 cd	0.4abcd
A-13623[6]	4 oz/A	0.5abcd	0.8 def	4.7 bc	0.9 bcde
A15543A[6]	8.6 oz/A	0.9 def	0.4abc	9.3 de	0.2abc
Actara[6]	3 oz/A	0.7 de	0.5abcde	9.1 cde	0.3abcd
Admire Pro[1]	7 oz/A	1.1 ghi	0.4abcd	1.1ab	0.3abc
BAS 320 or Rimon[5]	4.57 oz/A 9 oz/A	0.5ab	0.7 cdef	7.4 cde	0.4abcd
BAS 320 or Spintor[5]	4.57 oz/A 6 oz/A	1.2 ghi	1.0 f	6.3 cde	1.4 e
Battalion[2]	12 oz/A	0.3 bcd	0.8 def	5.1 cd	0.5abcde
Baythroid[2]	1.5 oz/A	2.4 j	0.9 ef	10.6 de	1.4 e
Belay[1]	12 oz/A	2.3 hij	0.4ab	0.8a	0.6abcd
Belay[1]	18 oz/A	0.6 efg	0.2a	0.9a	0.1ab
Clutch[3]	2 oz/A	1.0 def	0.7 bcdef	6.3 cd	0.7abcde
Clutch[6]	3 oz/A	0.1a	0.7 bcdef	8.1 cde	0.3abcd
Leverage[8]	3.75 oz/A	0.2 de	0.7 bcdef	7.2 cd	1.0 bcde
Platium[1]	8 oz/A	0.2abc	0.2a	2.3ab	0.0a
Rimon[4]	9 oz/A	1.8 fgh	0.8 bcdef	14.1 e	1.1abcde
Rimon[4]	12 oz/A	1.0 j	0.6 cdef	12.8 e	0.5 de
Rimon + Baythroid[4]	9 oz/A 1.5 oz/A	0.2 cde	0.8 def	8.0 cde	0.8 bcde
Warrior[6]	3.42 oz/A	0.2 de	0.8 def	8.7 cde	1.0 cde
Untreated	------	0.8 ij	0.5abcd	11.0 de	13.4 f

Average numbers within a column followed by a different letters are significantly different (P,0.05, Fisher's Protected LSD). Data transformed for analysis with log (x+1), presented in non-transformed units.

[1]Treatments applied in-furrow at planting May 10, 2006
[2]Treatments applied: 22 Jun, 28 Jun, 5 Jul, 12 Jul
[3]Treatments applied: 22 Jun, 28 Jun, 5 Jul
[4]Treatments applied: 22 Jun, 28 Jun
[5]Treatments applied: 22 Jun, 5 Jul
[6]Treatments applied: 22 Jun, 12 Jul

Table II.2. The average yield (lbs/50 row feet) of harvested 'Pike' potatoes.

Treatment/ formulation	Rate	Size A[7]	Size B[7]	Total
A-13623[6]	2.75 oz/A	40.2 bcde	5.2	45.2 cdef
A-13623[6]	4 oz/A	43.5 cde	5.0	48.8 def
A15543A[6]	8.6 oz/A	30.2 bcd	5.0	35.2 bcde
Actara[6]	3 oz/A	44.2 cde	4.0	48.2 def
Admire Pro[1]	7 oz/A	51.0 e	4.8	55.8 f
BAS 320 or Rimon[5]	4.57 oz/A 9 oz/A	38.2 bcde	4.5	42.8 bcdef
BAS 320 or Spintor[5]	4.57 oz/A 6 oz/A	26.8 bc	4.2	31.0 bc
Battalion[2]	12 oz/A	45.3 de	5.2	50.5 def
Baythroid[2]	1.5 oz/A	39.3 bcde	4.5	43.8 cdef
Belay[1]	12 oz/A	50.0 de	5.2	52.2 ef
Belay[1]	18 oz/A	53.7 e	5.8	59.5 f
Clutch[3]	2 oz/A	37.2 bcde	4.8	42.0 bcdef
Clutch[6]	3 oz/A	42.0 cde	4.8	46.8 cdef
Leverage[8]	3.75 oz/A	44.0 cde	4.2	48.2 cdef
Platium[1]	8 oz/A	51.6 e	5.2	56.8 f
Rimon[4]	9 oz/A	31.6 bcd	4.2	35.8 bcd
Rimon[4]	12 oz/A	23.2 b	4.0	27.2 b
Rimon + Baythroid[4]	9 oz/A 1.5 oz/A	39.5 bcde	5.0	44.5 cdef
Warrior[6]	3.42 oz/A	39.0 bcde	5.0	44.0 cdef
Untreated	------	4.2a	3.0	7.2a

Average numbers within a column followed by a different letters are significantly different (P,0.05, Fisher's Protected LSD). Data transformed for analysis with log (x+1), presented in non-transformed units.
[1]Treatments applied in-furrow at planting May 10, 2006
[2]Treatments applied: 22 Jun, 28 Jun, 5 Jul, 12 Jul
[3]Treatments applied: 22 Jun, 28 Jun, 5 Jul
[4]Treatments applied: 22 Jun, 28 Jun
[5]Treatments applied: 22 Jun, 5 Jul
[6]Treatments applied: 22 Jun, 12 Jul
[7]Size A = tubers greater than 2 inches. Size B= tubers less than 2 inches.

III. Managing Neonicitinoid Resistant Colorado Potato Beetles.
Resistance to neonicitinoid insecticides first appeared in CPB field populations in Michigan in 2004. In 2005, CPB populations collected from three nearby locations were 10-fold resistant to imidacloprid. Faced with this reality, it is important to help growers manage resistant CPB without increasing the degree of resistance or encouraging dispersal of resistant individuals (thus spreading the resistance). For the past two seasons we have studied the use of trap crops and alternative (non-neonicitinoid) insecticides in a crop rotation system to manage CPB and limit dispersal. In 2005 approximately 100,000 adult CPB were attracted to the trap crop upon emerging from overwintering. Almost no CPB were found in the main potato crop at this time. The trap crop was disced down on 1 Jul, before the larvae matured and entered the ground to pupate. Alternative insecticides were applied only to the trap crop and cost to the grower was less than $600, compared with a cost of $4,500 for treatment of the entire 75-acre potato field.

In 2006 we again investigated the use of trap crops and alternative insecticides to manage neonicitinoid-resistant Colorado potato beetle at the same general location as the 2005 study. This time we planted trap crops at several locations

Methods.

Trap crops of early potatoes (cv 'Atlantic') were planted on 18 April along the edges of fields that were in potatoes in 2005 and were to be planted in corn in 2006 ("old fields"). Fields to be planted in potatoes in 2006 were directly across from the trap crop ("new fields") (Figure III.1). Depending on the site, either four or eight rows of trap crop potatoes were planted and one or two edges of each field had a trap crop. New fields were planted from 24 April to 3 May 2006 (one to two weeks after the trap crop was planted).

After the trap crop emerged, two sampling areas (each 10 m -wide x 8 rows) on each edge were flagged off for intensive sampling (Figure III.1). A similar-sized area was marked off in the corn adjacent to the sampling area in the trap crop ("old field") and in the potatoes ("new field") directly across from the trap crop.

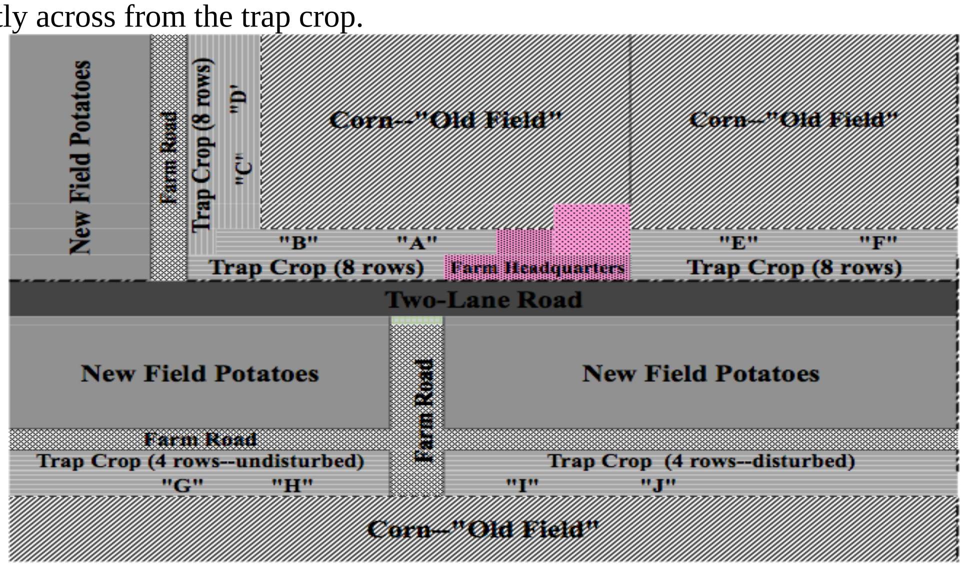


Figure III.1. Map of the 2006 study area.

Potatoes in the trap crop sampling areas were searched for Colorado potato beetles one to two times per week from May 25 to June 29, 2006. Sampling areas in the corn and new field were also searched during this period.

To examine the dispersal of beetles in the trap crop we marked and released adult CPB in each sampling area. Adults were collected and transported back to the lab in ice-filled coolers. They were then marked on the elytra with felt tipped paint pens (DecoColor, Uchida of America Corp). They were then transported back to the field and released at the center of each sampling area (100 beetles per sampling area per date). The color and pattern of each marking denoted the date and location of their release. Beetles were released on 6 June and another group of beetles were released on 13 June.

Each sampling area in the trap crop was searched for marked beetles on 8, 15 and 22 June. When encountered, the color and pattern of each marked beetle found was recorded, dead beetles were collected, but live beetles were left in the plot. The new potato field just opposite each sampling area was also searched for marked beetles on these same dates and all marked beetles encountered were collected.

We sampled individual plants in the trap crop to determine the age-structure CPB on each date. Two-plants per row were examined and the number of egg masses, small and large larvae and adults were counted. When a significant portion of the larvae sampled had matured, the trap crop was disced down (beginning of July). .

Results.
Temperatures were unseasonably cool in early and mid-May, which delayed both crop growth and beetle emergence. On the first sampling date (22 May), the trap crop was still emerging; few beetles were found (less than 1 adult beetle per 30 meters of trap crop row) and no beetles were found in the corn. None of the potatoes in the new field had emerged.

Daily temperatures moderated between 22 and 25 May (highs in the 70's, lows in the 30's) and then rose dramatically between 26 and 30 May (highs in the 80's to 90F, lows in the 50's and 60's F). Soil temperatures rose correspondingly. As a result, a lot of potato growth and CPB emergence took place in a short period of time.

By 25 May beetle numbers in the trap crop had increased to an average of 13 adults per 10 meters of row. The corn had just been planted in the old field, but had not yet germinated. No beetles were found in the corn, although the highest concentration of beetles were found in the trap crop rows nearest the corn field, indicating that they were emerging in the corn and moving to the trap crop (Figure III.2) Only two beetles (total) were found in the potatoes ("new field").

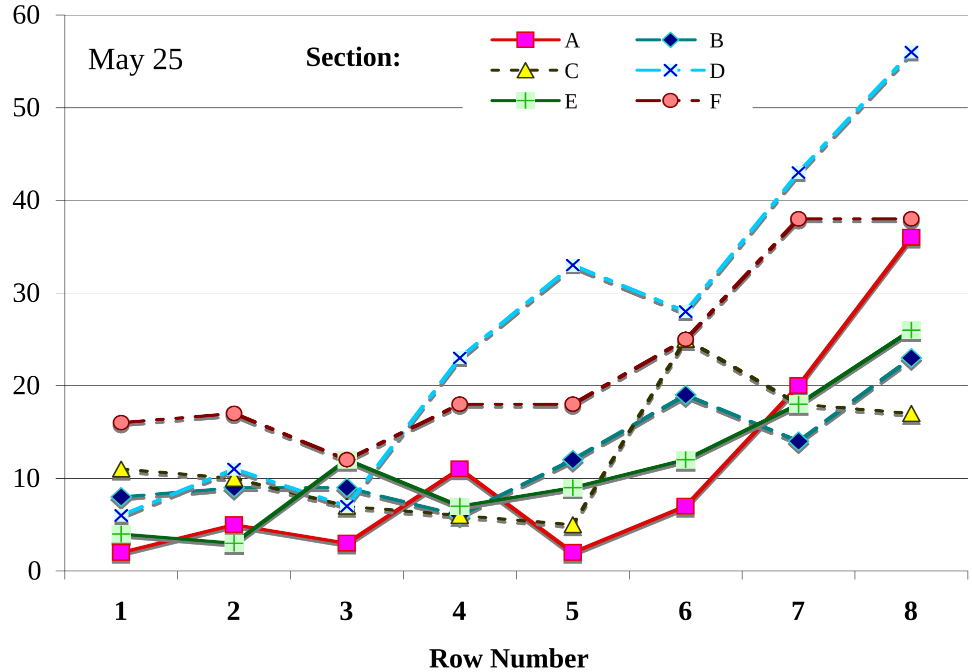


Figure III.2. Number of beetles found in each row of potato trap crop on 25 May. Row 1 is on the edge of the field and row 8 is farthest from the edge (closest to the corn).

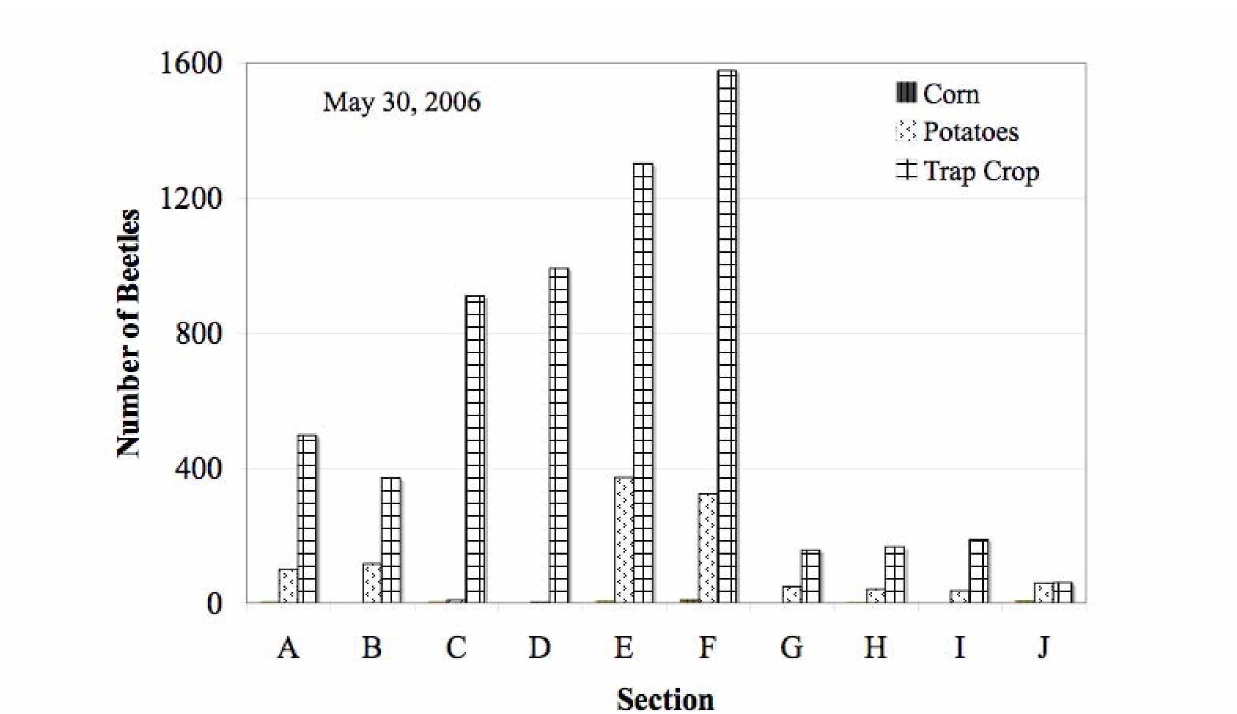


Figure III.3. Number of beetles found in a 10 m by 8 rows section of early-planted potato trap crop and equivalents areas of the corn, and the new potato field on 30 May.

By 30 May, an average of 89 beetles per 10 meters of row were found in the trap crop and egg masses were found. The corn was just starting to germinate and an average of 0.35 beetles were found in an equivalent sampling area in the corn. Many CPB had already migrated to the main crop and were laying eggs. In areas across from "E" and "F" over 40 beetles were found in an equivalent sampling area in the potatoes (Figure III.3). Because of this surge in beetle numbers the grower sprayed the trap crop rows with 8 oz Agri-Mek ® (Syngenta) on 30 May. At this time he also applied Agri-Mek to the first 16 rows of the new potato field directly across from sampling areas "A" & "B" and "E" & "F" the areas with the highest densities of beetles.

This Agri-Mek application reduced the number of CPB on the trap crop and in the potatoes. On 6 June there were between 25 and 50 adult beetles per 10 meters of row in the trap crop (Figure III.4). The number of CPB in the potato field was also reduced. Additional insecticide applications were made to the trap crop on 12 June (4.5 oz SpinTor ® (Dow)) to control larvae.

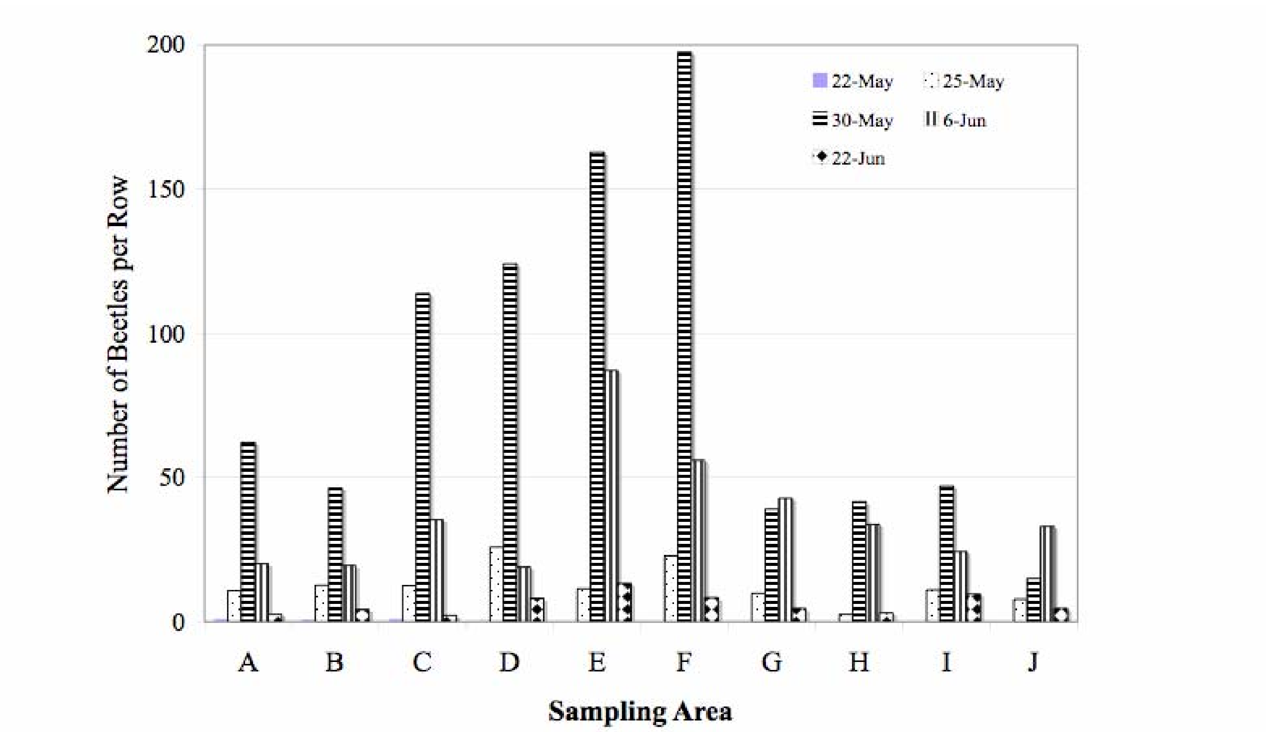


Figure III.4. Mean number of Colorado potato beetles per row in a 10-meter section of trap crop during spring emergence 2006.

Marked CPB (100 per plot per date) were released into the center of each sampling area of the trap crop on 6 June. Most of the marked beetles found on a later date were found in the sampling area (Figure III.5). The percentage of beetles found decreased as time after release increased, but very few marked beetles were found in the potatoes ("new field"). In most sampling areas, no marked beetles were found in the potatoes and the highest percentage of marked beetles found in the potatoes (7%) was In area "G".

Another set of marked beetles was released on 13 June. As with the previous release, the percentage of marked beetles found in the trap crop decreased with time (Figure III.6) and almost no marked beetles were found in the potatoes ("new field").

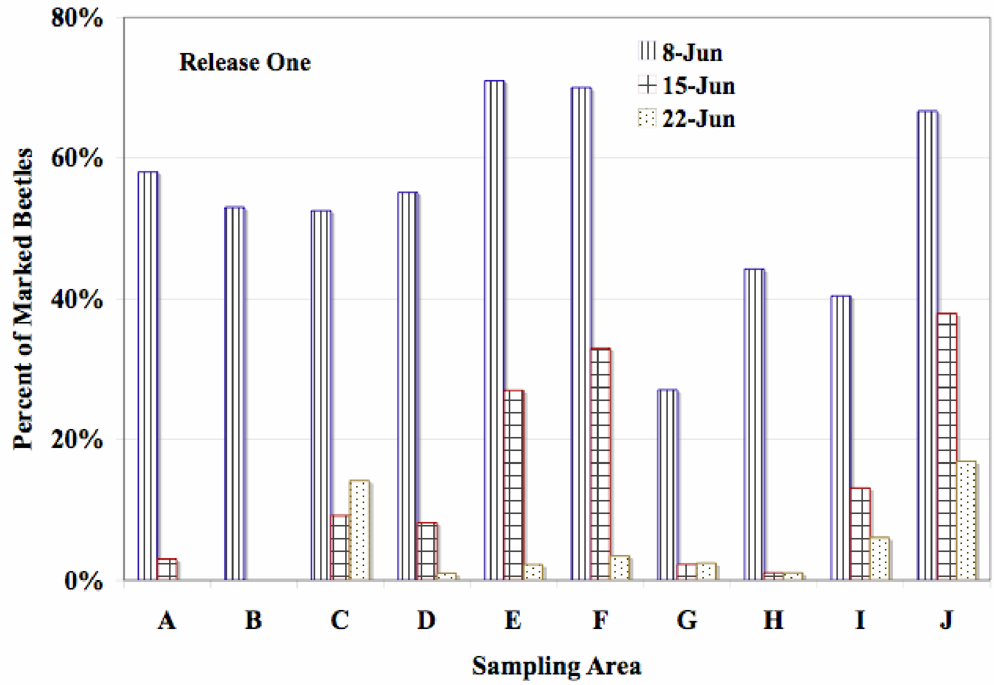


Figure III.5. Percent of marked CPB released in the trap crop sampling area on 6 June that were found in the same area on 8, 15 and 22 June.

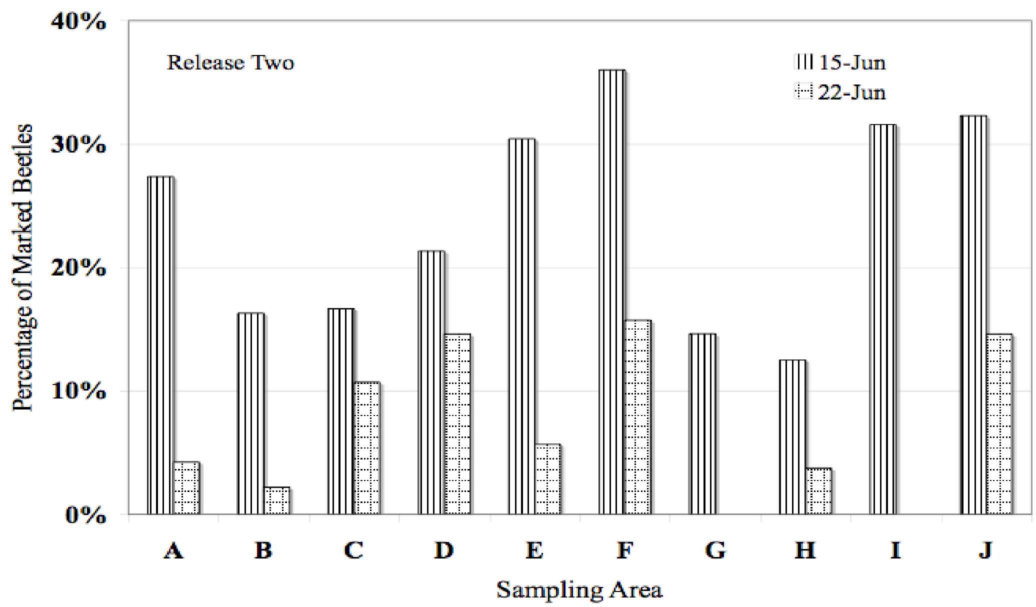


Figure III.6. Percent of marked CPB released in the trap crop sampling area on 13 June that were found in the same area on 15 and 22 June.

Summary: The weather conditions in 2006 were not ideal for using trap crops to control and manage resistant CPB. Cool weather in early May delayed potato growth and Colorado potato beetle emergence. Late in May the weather warmed to above-normal temperatures, and potatoes (both trap crop and main crop) grew quickly; as a result there was minimal difference in size between the trap crop and the main crop by mid-June. CPB emerged from overwintering over a short period of time and in large numbers and many flying beetles were observed. Such conditions are ideal for CPB dispersal. However, the trap crop concentrated most of the beetles during their emergence and the grower was able to spot-treat the trap crop and the potato field edges with alternative insecticides to control CPB. More marked beetles were found in the trap crop that they were released into than were found in the main potato field. Beetles may have dispersed out of the sampling area, but remained in the trap crop, but these areas were not inspected for marked beetles.

The grower was able to control CPB by using a reduce rate of Admire Pro in most of the new potato fields (some fields had no neonicitinoids) at planting. Besides the spot-treatments of the trap crop used described, the grower used treatments of Agri-Mek to sections of the fields where needed in June and July

Literature citations:

Byrne, A., W. Pett, E. Grafius, and B. Bishop. 2006. Potato insect biology and management. Michigan Potato Research Report 37:106-125. Mich. Agric. Exper. Station, East Lansing, Michigan.

Grafius, E., B. Bishop, W. Pett, A. Byrne, and E. Bramble. 2004. Potato insect biology and management. Michigan Potato Research Report 35:96-109. Mich. Agric. Exper. Station, East Lansing, Michigan.

Grafius, E., W. Pett, B. Bishop, A. Byrne, and E. Bramble. 2005. Potato insect biology and management. Michigan Potato Research Reprot 36:42-56. Mich. Agric. Exper. Station, East Lansing, Michigan.

Mota-Sanchez, D., R. Hollingworth, E. Grafius, and D. Moyer. 2006. Resistance and cross-resistance to neonicotinoid insecticides and spinosad in the Colorado potato beetle (Coleoptera: Chrysomelidae). Pest Management Science 62:30-37.

Nat. Agric. Stats. Serv. 2006. p. 45-54 in http://usda.mannlib.cornell.edu/usda/nass/AgriChemUsFC//2000s/2006/AgriChemUsFC-05-17-2006.pdf.

SAS Institute. 2003. SAS/STAT user's guide, version 9.1. SAS Institute, Cary, NC.

Michigan Potato Industry Commission
2006 Bird Nematology Program Annual Report

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The 2006 Bird Nematology Laboratory Potato Research Program consisted of the following six projects:

1. Impact of Alternative Tillage Systems on the Potato Early-Die Disease (PED) Complex (MPIC funded).
2. Bio-Fumigation.
3. Cover-Crop/Root-Lesion Nematode Host Assessment (MPIC funded).
4. Chancellor Development (MPIC and USDA/IR4 funded).

. 5. Soil Management Systems (BOKS Trial) for PED Suppression (MPIC funded).
6. Potato line and variety evaluation for Root-Lesion Nematode Tolerance (USDA MSU Special Potato Grant).

In 2006-2007, two articles were published in *Michigan Potato NewsLine*. The first, *Potato Cyst Nematode:2006* (MPNL Vol. 18, No. 5, pp 4-5) summarized the current status of the Potato Cyst Nematode situation and made specific recommendation for the immediate and long-term future. A significant portion of the 2006 potato nematode research was published in NPNL (Vol. 18, No. 7, pp. 4-5) under the title of *Nematodes - Cover Crops - Biofumigation* . In addition, a document entitled, *Plant-Parasitic Nematodes Associated with Michigan Potato Production* was prepared and submitted to MPIC. The document summarizes the results of the nematode surveys of 1953, 1975, 1982 and 1985, and the observations of both MSU Diagnostic Services and the former MSU Nematode Diagnostic Services.

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1. Impact of Tillage on Potato Tuber Yield and Root-Lesion Nematodes

The project evaluated two tillage systems (chisel plow and mold board plow) in relation to potato yield, PED (Potato Early Die Disease Complex) an the root-lesion nematode (*Pratylenhus penetrans*). A three-year rotation with potato, wheat and corn was used with the chisel plow system, compared to the the Montcalm Potato Research Farm. Clover was frost-seeded into the wheat. 2006 was the last year of this six-year trial of two cycles of this three-year rotation. The research was conducted under high PED risk conditions. Over the six-year experimental period, Tuber yields averaged 16% or 45 cwt/acre more under the chisel system, compared to the mold board plow system

(Table 1).

Table 1. 2001-2006 influence of alternative tillage systems on potato tuber yield (cwt/acre).

Tillage	2001	2002	2003	2004	2005	2006	Mean
Chisel Plow	247	487	180	280	268	255	286
Mold Board Plow	196	382	134	232	259	243	241
T Test P Value	0.33	0.64	0.00	0.09	0.33	0.24	0.42

A-size tuber yields associated with the chisel plow system were 19% or 50 cwt/acre greater (P = 0.01) than those associated with the mold board plow system (Table 2).

Table 2. 2001-2006 influence of alternative tillage systems on A-size potato tuber yield (cwt/acre).

Tillage	2001	2002	2003	2004	2005	2006	Mean
Chisel Plow	220	452	159	256	262	241	265
Mold Board Plow	165	340	103	202	251	226	215
T Test P Value	0.31	0.23	0.00	0.09	0.30	0.33	0.36

The early-season soil population densities of root-lesion nematodes associated with wheat were significantly lower (P = 0.05) for both of the soil tillage systems, compared to the corn and potato. There were no significant differences in early-season root-lesion nematode population densities between the chisel and mold board plow systems (Table 3).

Table 3. Early-season soil population densities of root-lesion nematodes (*Pratylenchus penetrans*)associated with alternative potato production till systems.

System	2001	2002	2003	2004	2005	2006	Mean
Chisel plow	131 b	62 a	107a	97 a	22	11	72
Mold board plow	43 a	124 a	76a	86a	53	11	66

Mid-season root system population densities of the root-lesion nematode were significantly higher (P = 0.05) in the corn and wheat, compared to potato. There were no significant differences between the two tillage systems in relation to the root-lesion nematode population densities (Table 4). While the chisel plot system has a positive impact on potato tuber yields, it did not decrease the risk to the Potato Early-Die Disease Complex.

Table 4. Mid-season (1.0 g root tissue) population densities of root-lesion nematodes (*Pratylenchus penetrans*)associated with alternative potato production till systems.

System	2001	2002	2003	2004	2005	2006	Mean
Chisel plow	169 a	46 a	125 a	134 a	129	24	105
Mold board plow	130 a	54 a	216 a	154 a	179	42	129

2. Bio-fumigation

The chemical composition of various plants is such that when they decompose in soil, the plant organic matter is transformed into chemicals that have both fumigant and nematicidal properties. The specific chemicals and their concentration generation potentials are plant variety specific. In 2005-2006, a biofumigation trial was conducted at the Montcalm Potato Research Farm with Pacific Gold Yellow Mustard. The cover crop was planted early in the fall of 2005, grown to green-pod stage and managed in four different ways: 1) mowed, 2) incorporated into the soil as a green manure, 3) incorporated followed by immediate soil packing and 4) incorporated and immediately tarped . Ruset Norkodah potato seed pieces were planted in the spring of 2006 and the crop grown to maturity. The penetrans root-lesion nematode population density was evaluated throughout the 2006 growing season. The results were compared to those from a nematicide trial in the research range immediate to the east of the biofumigation trial. The nematicide trial was planted late. Seed quality was very poor, but the growing conditions were excellent.

Both Vapam and Vydate resulted in greater tuber yields compared to the non-treated control (Table 5).

Table 5. Influence of Vapam (75 gallons per acre) on potato tuber yields compared to a non-fumigated control.

Tuber grade	U.S. #A	B Grade	Jumbo	Total Yield
Vapam yield increase	+59.4(cwt/a)	+1.5(cwt/a)	+1.5 (cwt/a)	+62.4(cwt/a)
Vydate yield increase		+1.7(cwt/a)		

The biofumigation trial was planted early. Both seed quality and the early part of the growing season were poor, resulting in low tuber yields. Total plant biomass incorporation, incorporation plus soil packing and incorporation plus tarping resulted in greater tuber yields than those associated with the mowed cover crop treatment Table 6). No significant difference was observed between the incorporation plus packing and the incorporation plus tarping treatments. The yield increases, however, were not as great as those associated with Vapam.

Table 6. Influence of management practices (incorporation, packing and tarping on the biofumigation properties of Pacific Gold Yellow Mustard compared to mowing the cover crop.

Tuber grade	U.S. #A	B Grade	Jumbo	Total Yield
Incorporation	+5.0(cwt/a)	-6.8(cwt/a)	-----	-1.8(cwt/a)
Incorporation plus packing	+27.0(cwt/a)	-6.0(cwt/a)	-----	+21.1(cwt/a)
Incorporation plus tarping	+31.7(cwt/a)	-7.1(cwt/a)	-----	+24.6(cwt/a)

Mid-season population densities of penetrans root-lesion nematodes were 157, 96, 48 and 77 per gram of potato root tissue for the mowed, incorporated, packed and tarped treatments, respectively.

There are many different types of glucsinolates. There presence and concentrations vary among different plant species and varieties (Table 7).

Glucosinolate Production for Biofumigation

Moles/gram dry weight	White Mustard	Yellow Mustard	Broccoli
Propenyl	---	14.8	---
Hydroxy-butenyl	0.8	---	---
Benzyl	4.1	---	---
Phenylethyl	---	0.8	---
Hydroxybenzyl	10.9	---	---
Indolyl methyl	---	---	1.7
Total	**15.8**	**15.7**	1.7

Bio-fumigation enhanced potato tuber yield and reduced population densities of root-lesion nematodes (Table 8). Both yield enhancement and nematode control, however, were not as great as with Vapam..

Table 8. Potential of biofumigation for control of potato early die.

Management Practice	Crop Yield	Nematode Control
Soil Fumigation	+31%	94%
Non-fumigant nematicide	+8%	82%
Bio-fumigation incorporation	-1%	39%
Bio-fumigation inc. plus sealing	+11%	69%
Bio-fumigation inc. plus tarping	+12%	51%

3. Cover-Crop/Root-Lesion Nematode Host Assessment

Cover crops can be used in agricultural for many different production system objectives. These include:

- Soil Quality Enhancement (Soil Organic Matter Quality and Quantity)
- Soil Quality Maintenance (SOM Quality and Quantitly)
- Erosion Management
- Crop Nutrition (Nitrogen Fixation, Green Manure)
- Soil Water Enhancement (Decrease in Irrigation Requirements)
- Weed Management (Numerous Mechanisms)
- Non-Hosts (Lowering Plant Pathogen Populations)
- Trap Crops (Trapping and Killing Pathogens)
- Bio-Fumigation (Lowering Plant Pathogen Populations)
- Livestock Grazing
- Hay Crop
- Silage Crop
- Seed Crop

During the past five years it has been learned that selecting the appropriate variety of the cover crop is essential. For example, Michigan sugar beet growers use Adagio or Colonel oil seed radish as a trap crop for management of the sugar beet cyst nematode. These varieties were developed specifically for this purpose. Both are good hosts for the penetrans root-lesion nematode and are not appropriate for use by Michigan potato growers for management of potato early-die.

Because of the diversity of the host range of the penetrans root-lesion nematode, identification of cover crops that are non-hosts for this nematode has been difficult. In 2005, the University of Wisconsin reported that Pearl Millet may have this property. This hypothesis was tested in 2006 at the Montcalm Potato Research Farm in a twelve cover crop trial, with each variety being replicated six times. In this trial, Pearl Millet 444 and Pearl Millet Millex 32 were the poorest hosts for the root-lesion nematode and should have excellent potential for use in Michigan potato production systems (Table 9)..

Table 9. 2006 Root-Lesion Nematode Reproduction Associated with Twelve Cover Crops at the Montcalm Potato Research Farm.

Cover crop	Root –lesion nematodes per 100 gram of root tissue (Aug. 22, 2006)
Millet pearl 444	3
Millet Pearl Millex 32	5
Millet Pearl Leafy 23	14
White Mustard	10
Mustard Mix	34
Yellow Mustard	37
Mustard Bio-Fumigation Blend	26
Oil Seed Radish, Common	21
Oil Seed Radish, Colonel	53
Rape	60
Sudax	16
Wheeler Rye	155

4. Evaluation of a Bio-Nematicide for PED Control

The candidate bio-nematicide, Chancellor (*Bacillus firmus*), was evaluated throughout Michigan in 2006 under ten different crop systems, including potato. It was compared with Vapam, Vydate and two candidate chemical nematicides. Although tuber yields were low because of late planting and poor quality seed, the highest yield was associated with the Vapam treatment (Table 10). Yields associated with Vydate and Chancellor WD were greater than those associated with the non-treated control. Both Vapam and Vydate provided excellent nematode control. No nematode population reductions were observed with Chancellor WD and the candidate chemical nematicide products. It is highly probable that the method of application of Chancellor WD was wrong. Results with the product in the other ten sites has been highly variable, but spectacular in some cases with lettuce and carrots. The best field trials have been with apple and cherry trees.

Table 10. Influence of candidate nematicides on potato tuber yield and root-lesion nematode control.

Treatment	"A" Tuber Yield (cwt/acre)	Root-Lesion Nematodes No./g root (7/25/06)
Non-treated Control	126	32 a
Vapam (75 gal/acre)	190	2 b
Vydate (1.0 + 0.5 + 0.5 lbs/acre)	151	6 b
Chancellor WD (50 + 50 + 50 lbs/acre)	144	38 a
V-10200 (1.0 lb/acre)	114	32 a
V-10200 (0.5 lb/acre)	123	35 a
V-10199 (1.0 lb/acre)	103	22 a
V-10199 (0.5 lb/acre)	112	36 a

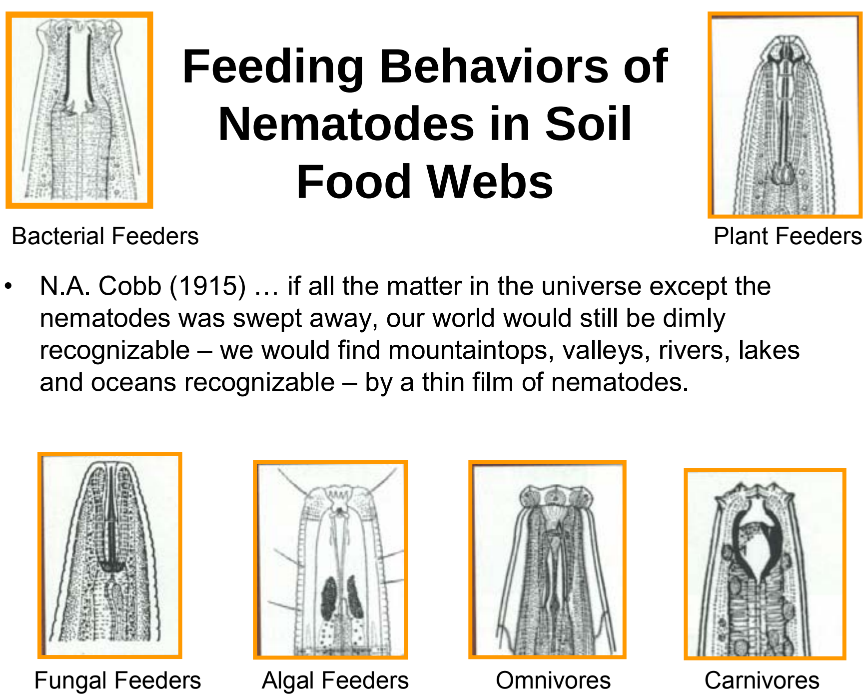
5. Soil Management Systems (BOKS Trial) for Soil Quality Restoration

In 2003, a soil quality restoration research site was established at the Montcalm Potato Research Farm. This is a cooperative projective with George Bird, Sieglinde Snapp, Willie Kirk and Mark Otto serving as co-principal investigators. The trial consists of four soil management systems: 1) Fumigated control (wheat/rye/potato), 2) Biofumigant (mustard and rye/sudax/mustard & rye/potato 3) Wheat and mustard (wheat/mustard and rye/potato), and 4) Legume (hairy vetch and rye/soybean green manure/vetch and rye/potato. At the end of the first growing season, the overall soil quality and nematode community structure was poor. There were, however, significant differences among the four management systems. The fumigated system had the highest relative density of fungivores. The biofumigation system had the highest population density of bacterivores and the highest overall absolute density. The legume system had highest relative and absolute population densities of herbivores, leading to a significant negative impact on tuber yield. Only the cover crops were planted in 2006. The soil fumigation treatment with Vapam will be made in the spring of 2007. The entire range will be planted to potato in 2007. A 2007 research proposal for funding for the final year of this project has been submitted to the Michigan Potato Industry for consideration.

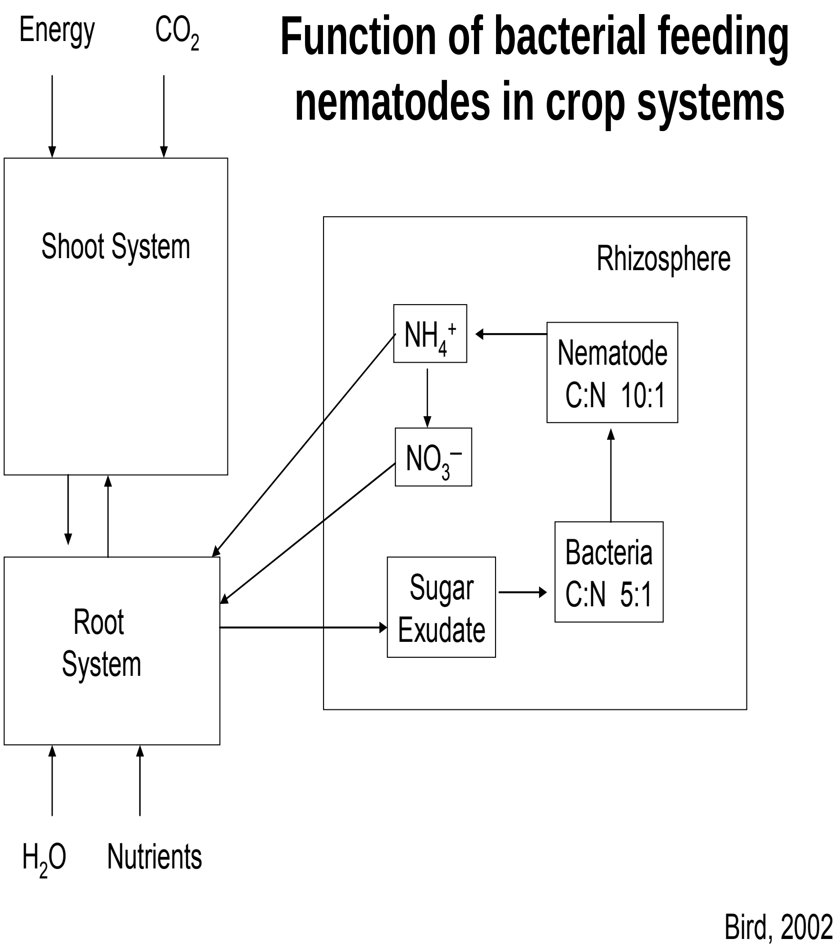
Tuber yields in 2005 were highly correlated with cover-crop root early-season (April) population density of the root-lesion nematode. The highest nematode population densities (200/g root tissue) and lowest tuber yields (<350 cwt/acre) were associated with the legume system. The lowest nematode population densities (very close to 0) and the highest potato tuber yields (438 cwt/acre) were associated with the fumigant system. Yields from the fumigated and bio-fumigated plots, however, were not significantly different from each other.

The bio-fumigation system looks very promising and will be improved on during the second two-year cycle of the project. The post-fumigation recovery of beneficial nematodes (from a potato production point-of-view) appears to be more rapid with the bio-fumigation than following chemical fumigation with metham. The highest yielding plot (>460 cwt/are) was a bio-fumigation plot. Yields associated with all of the fumigation plots were nearly identical. The low yields in three of the four legume plots, one wheat/mustard plot and one failed bio-fumigation plot were all associated with early-season cover-crop root-lesion nematode population densities greater than 50/1.0 gram of root tissue. Although the bio-fumigation associated with this trial looks very promising, the two-year nature of the trial may be inadequate. It is estimated that at least three cycles of the soil enhancement systems will be required to see a significant improvement in overall soil quality.

Today, modern science estimates that four out of every five animals currently alive on our planet are nematodes. Their feeding behaviors are highly diverse as indicated in the following illustration.



The bacterial and fungal feeding nematodes are of major significance in agriculture because of their role in making soil nutrients available for plant growth and development. As illustrated in the following figure, nitrogen mineralization takes place in the immediate root environment (rhizosphere) where it is taken up and used by the plant before having the opportunity to be transformed and transported to other parts of the environment, such as groundwater or the atmosphere.



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Recent research shows that nematode community structure varies greatly among different types of Michigan ecosystems. In 2006, a Nematode Community Structure Standard was developed and is being used for assessment of soil quality. In the following figure, the numbers in the bottom row represent the total nematode population density present (number of nematode) present in a cup of soil, for each of four different ecosystems (wood lot, old field succession, conventional agriculture, organic agriculture). The other numbers in each column represent the % of the population in each of the six different feeding behavior groups for each specific ecosystem. More than 50% of the nematodes associated with the conventional corn-soybean system were plant root feeders and very few bacterial or fungal feeding nematodes detected. This is not a desirable situation.

Nematode Community Structure
2006 Michigan Relative Density Standard

(G.W.Bird, based on the Works of J. Smith and M. Berney)

Feeding Behavior		Woodlot	Old Field Succession	Certified Organic	Conventional Agriculture
	Bacterivore	51	83	73	28
	Fungivore	18	7	26	14
	Herbivore	28	7	0.6	57
	Omnivore	3	2	0.2	0.2
	Carnivore	1	1	0.003	0.05
	Algavore	NA	0.03	NA	NA
Absolute Density		500	1700	3500	200

6. Potato line and variety evaluation for Root-Lesion Nematode Tolerance.
Evaluation of Potato Varieties and Breeding Lines for Tolerance to Early-Die

Since 1998, selected potato varieties and lines have been evaluated annually at the Montcalm Potato Research Farm for tolerance to the Early-Die Disease Complex. This work has been supported by the USDA Potato Grant and done in cooperation with the MSU Potato Breeding Program under the direction of Dr. Dave Douches. Twenty-one lines and varieties were evaluated in 2006. One line, MSK498-1Y exhibited tolerance to PED based on a lack of yield response to soil fumigation (Table 11). The 2006 root-lesion nematode population pressure was relatively low. All three of the PED standards exhibited high levels of susceptibility.

During the past nine years, one variety (Boulder) and one line (MSE228-1) have been classified as tolerant to PED (Table 12.). An additional 18 lines-varieties have exhibited PED tolerance, but require one to three additional years of data before being classified as tolerant. The research project involves six varieties that are known to be highly susceptible. An additional seven varieties-lines have been classified as PED susceptible. Forty-five other lines-varieties are probably susceptible, but one to three more years of observations are required before making a formal classification. Results from seven varieties-lines, including Marcy) have been inconclusive, and MSF349-1RY responded as a PED resistant line.

Table 11. 2006 Potato PED assessment variety trial selected data.

Variety	TotalYield (cwt/A)	*P. penetrans* (1.0 g root)	Total Yield (cwt/A	*P. penetrans* (1.0 g root)	Advantage (%) U.S. # 1
PED Tolerant in 2006					
1. MSK498-1Y	435	0	354	27	14.5
PED Susceptible in 2006					
2. FL1833	335	0	296	101	16.1
3. MSJ036-A	457	0	322	47	21.9
4. MSN106-2	369	0	234	71	26.2
5. MegaChip	410	0	303	36	26.9
6. Silverton Russet	370	0	241	72	32.4
7. MAJ461-1	438	0	314	39	33.2
8. MSJ147-1	364	0	241	67	33.3
9. MSL211-3	336	0	199	47	39.2
10. Beacon Chipper	442	0	289	51	39.4
11. Gold Rush	399	0	229	24	39.4
12. MSJ316-A	476	0	283	52	39.9
13. NY132	437	0	233	61	41.9
14. MSK061-4	341	0	187	61	47.1
15. MI Purple	553	0	270	147	51.8
16. FL1879	430	0	213	36	52.6
17. MSM0513	454	0	210	91	53.8
18. A8254-2BRUS	485	0	273	17	54.1
2005 PED Standards					
19. Atlantic	368	0	240	101	26.2
20. Snowden	416	0	233	119	37.8
21. Russet Norkotah	307	0	125	98	65.1

Table 12. Summary of 1998-2006 Michigan State University Potato Early-Die Nematode Tolerance-Resistance Research conducted at the Montcalm Potato Research Farm.

High yield in presence of potato early-die conditions with normal root-lesion nematode reproduction during four or more growing seasons.

Boulder, MSF 373-3 (98, 00, 03, 04)
PED susceptible in 05 under higher nematode pressure

MSE 228-1, Russet Nuggett x Spartan Pearl (98, 99, 00, 01)

Possible Tolerance Varieties-Lines

Seventeen varieties-lines with one to three years of additional PED evaluation are required to be designated as PED tolerant.

MSK498-1Y (06)
MSJ 461-1 (03, 05)
Beacon Chipper (05)
MSJ147-1 (05)
Gem Star (05)
WI 1201 (02, 04)
MSE 018-1 (99, 00, 03)
MSH 095-4 (03)
MSJ 316-A (03)
Bannock Russet (02)
NY 120 (01, 02)
MSH 094-8 (01, 02)
MSH 333-3 (01
WI 1431 (01)
MSE 028-1 (00)
MSE 273-8 (00)
MSF 060-6 (00)
MSJ 036A (05)

Susceptible Varieties and Lines

Low yields in presence of potato early-die conditions, normal or high root-lesion nematode reproduction, and good response to soil fumigation.

Standards
Atlantic (97, 99, 00, 01, 02, 03, 04, 05, 06)
Snowden (97, 99, 00, 01, 02, 03, 04, 05, 06)
Russet Norkotah (02, 03, 04, 05, 06)
Onaway (01, 02, 03)

Russet Burbank (03, 05)
Superior (01, 02, 03)

Others
A8254-2BRUS (06)
Beacon Chipper (06)
MegaChip (06)
MSM0513 (06)
Jacqueline Lee   MSG 274-3 (99, 00, 01, 02)
MI Purple (00, 02 tolerant, 01, 03, 04, 05, 06 susceptible)
Liberator [MSA 091 (01, 02)]
MSE 202-3 Rus (00, 01, 02, 03)
MSF 099-3 (99, 00, 01, 02)
MSE 149-5Y (98, 99, 00,01)
MSG 227-2 (00, 03, 04 05 susceptible, 01 tolerant, 02 tolerant)
MSK061-4 (06)
MSL211-3 (06)
MSN106-2 (06)
FL 1833 (04, 05, 06)
FL 1867 (04, 05)
FL 1879 (05, 06)
FL 1922 (04, 05)
MSK 061-4 (03, 05)
MSI005-20Y (04, 05)
MSJ126-9Y (05)
MSE018-1 (04, 05)
NY126 (05)
NY132 (05, 06)
MSM051-3
MSH 067-3 (03, 04)
MSH094-8 (03, 04)
MSE 192-8Rus (03, 04)
MSF349-1RY (04)
Spunta (04)
Pike (02)
Goldrush (02, 03, 06)
MSE 221-1 (00, 01, 03)
BO 766-3 (03)
WI 1836-3Rus (03)
NDTX 4271-SR (03)
MS I005-20Y (03)
MSJ036-A (06)
MSJ147-1 (06)
MSJ316-A (06)
MSJ 317-1 (03)
MSJ 167-1 (03)

MSJ461-1 (06)
MSB 076G-3 (01)
MSB 106-7 (00)
MSG 015-C (01)
MSG 124-85 (00)
MSH 026-3 Rus (01)
MSP 81-11-5 (00)
Silverton Russet (06)
WI 1368 (01)
WI 1386 (01)

Inconclusive Results

Variable response to soil fumigation, additional information required.

NY112, Marcy (01 tolerant, 02 tolerant, 04, 05 susceptible)

MSG 004-3 (00 susceptible, 01 tolerant)
MSH 031-5 (00 tolerant, 01 susceptible)
MSB 107-1 (98 inconclusive, 99 susceptible, 00 tolerant)
MSF 313-3 (98 susceptible, 00 tolerant)
MSG 050-2 (99 possible resistance, 00 susceptible)
MSE 048-2Y (98 possible tolerant., 99 susceptible, 00 susceptible)

Highly Unique Response

MSF349-1RY (98, 00, 01, 02 resistant; 03 tolerant; 04 susceptible)
Rose Gold x WI 877, highly susceptible to scab. The resistant reaction most likely was antibiotic mediated through extensive Actinomycetes pressure in 98, 00, 01 and 02, but not in 04.

Potato Scab Ratings (Extra)

The 21 lines-varieties used in the PED tolerance were also rated for potato scab using a 0-5 index (Table 13). The varieties commonly grown in Michigan were susceptible. Two varieties, Gold Rush and Silverton Russet and one line A8254-BRUS did not exhibit scab. MSJ036-A and MSN106-2 also showed promise in relation to scab tolerance/resistance. Unless the impact of soil fumigation with Vapam on scab was variety specific, it did not have an impact on scab incidence.

Table 13. 2006 potato scab ratings (0-5).

Variety-line	Fumigated	Non-Fumigated	Mean
PED Tolerant in 2006			
MSK498-1Y	3	3	3
PED Susceptible in 2006			
FL1833	3.5	3.3	3.4
MSJ036-A	1.5	1	1.3
MSN106-2	1.8	1.5	1.7
MegaChip	2.5	2.8	2.7
Silverton Russet	0.8	0	0.4
MAJ461-1	3.5	3.5	3.5
MSJ147-1	3.0	2.8	2.9
MSL211-3	2.8	3.0	2.9
Beacon Chipper	2.5	2.5	2.5
Gold Rush	0.8	0.0	0.4
MSJ316-A	1.5	2.5	2.0
NY132	2.0	1.8	1.9
MSK061-4	1.8	1.8	1.8
MI Purple	3.0	2.3	2.7
FL1879	3.8	3.8	3.8
MSM0513	2.5	2.0	2.3
A8254-2BRUS	0.8	0.8	0.8
2005 PED Standards			
Atlantic	3.3	4.3	3.8
Snowden	3.3	2.9	3.1
Russet Norkotah	3.8	2.0	2.9

Book (Extra)

A copy of a new book:

Francis, Charles, A., Raymond P. Poincelot and George W. Bird. 2006. *Developing and Extending Sustainable Agriculture: A New Social Contract*. Haworth Press. New York. 367 pp.

is being donated to the Michigan Potato Industry Commission under the custody of Director Ben Kudwa.

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Biological Approaches to Nematode Management in Michigan Agriculture: Use of Biofumigants in Potato Soils

By

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ABSTRACT:
This study was part of a larger project dealing with developing sustainable alternatives to methyl bromide (MBr) use, with particular emphasis on the effects and appropriate use of a mustard type of biofumigants against the northern root-knot nematode (RKN, *Meloidogyne hapla*). This, in turn, requires a clear relationship between nematode biology (life cycle) and the purpose (as a trap crop or as a green manure) for which mustard type biofumigants are to be used. RKN is one of the three economically significant plant-parasitic nematode genera in Michigan agriculture. In the absence of resistant cultivars and impending loss of MBr with few sustainable alternatives, the nursery and vegetable industries face significant challenges in managing RKN. Jointly funded by MDA, MPIC and Celery Research Inc., this study tested the interactions of oil seed radish cv. 'Common' (OSRC), soil types and selected Michigan RKN populations from nursery (PN, WL and SW) and vegetable (ED) soils. Isolated from sandy (PN and WL), loamy sand (SW) and muck (ED) soils, the nematodes had exhibited reproductive potential (pathogenecity) differences in tomato, suitable host for RKN but had never been planted in the fields from where the nematodes came. Thus, raising the question of whether or not the one-option-fits-all management approach applies to these nematodes. When the PN, WL, SW and ED populations were inoculated at 2,000 to 3,000 eggs/300 cm^3 of either sandy (WL), loamy sand and muck soils brought from the same fields as the nematodes and maintained for 500 degree days (DD, base 10 ^oC), generally similar numbers of juveniles and adults were found in OSRC roots. This shows the approximate time when the nematodes complete a life cycle and that OSRC can be a tool against these RKN populations, but as a trap crop by destroying the plants before the end of the nematode life cycle. The infection rate of the nematodes however was significantly higher in sandy soil, showing that the efficacy of OSRC against these RKN populations is dependent on soil type. Thus, challenging the one-option-fits-all management approach. Overall, the study provides the necessary basis for comprehensive field studies to develop a management model for biofumigant use for the prevailing Michigan conditions.

INTRODUCTION

The northern root-knot nematode (RKN, *Meloidogyne hapla*), root-lesion (RLN, *Pratylenchus* spp.), and cyst (*Heterodera* spp.) are the most problematic nematodes in the diversified Michigan agriculture (Bird et al., 2004). Without nematode resistant cultivars and the gradual phase out and/or restrictions of broad-spectrum nematicides, many commodities, the nursery and vegetable industries in particular, face short- and long-term challenges in managing nematodes. Research priorities recognized by MNLA and the vegetable industry stakeholders include mapping of nematode populations, breeding for nematode resistance, developing alternatives to broad-spectrum pesticides and nematicides, identifying effective cultural practices, biosuppression, nematicidal plants, and effective and sustainable soil amendments (http://www.greeen.msu.edu/priorities.htm).

Meeting the stakeholders' multi-dimensional and short-, mid- (most), and long-term (breeding for resistance) priorities hinge on understanding the complexities of the nematodes and the production systems in question. For example, RKN has a high degree of genetic (Chen et al. 2003; Liu and Williamson, 2004) and parasitic variability even in populations that come from about 20 miles apart (Melakeberhan et al. 2007). Although most ideal, developing management practices based on each nematodes' interaction with its hosts will be expensive. A worthwhile strategy, within the umbrella of industry priorities, is to design practices that affect multiple crops and/or nematodes. Using an RKN model, this project was developed to look at the effects of mustard type biofumigants on nematode populations. The objective is to test the efficacy of oilseed radish (OSR) on RKN populations in muck, loamy sand and sandy soils under greenhouse conditions.

MATERIALS AND METHODS

Greenhouse conditions:

Greenhouse studies were conducted to determine the interactions among OSR, soil types and RKN populations from the different soil types. Greenhouse conditions were set at 28 ± 2 ^{o}C with diurnal cycles of 8 hours dark and 16 hours day with photosynthetically active radiation of 450 to 550 µmol.s-^{1}.m-^{2} at canopy level. All studies were conducted using 300 cm^{3} of steam-sterilized soil contained in white Styrofoam cups. Pots were watered to saturation with tap water one hour prior to transplanting and as needed thereafter.

Nematode sources and soil types:

The nematodes used in the study included two populations from sandy (PN and WL) and one each from loamy sand (SW) and muck (ED) soil fields with pHs of 6.56, 7.43, 7.15 and 6.30, respectively (Melakeberhan et al., 2007). The muck soil was a vegetable production system, the rest were nursery fields, and all were within a 20 miles radius. Tested in tomato (*Lycopersicon esculentum* L.) cv 'Rutgers', neutral host and not planted in the fields before, the nematodes showed differences in pathogenicity (Melakeberhan et al., 2007). Consequently, challenging the one-option-fits-all management approach.

The three soil types, sandy, loamy sand, and muck, used in the study were brought from the fields where the WL, SW, and ED nematodes were isolated, respectively. This was necessary to test the nematodes' behavior in relation to OSR response under the soil types where they had been residing before they came to the greenhouse conditions. Barrels of soils from each field were brought to campus during the summer of 2005 and steam-sterilized prior to being used in the study.

Experiments:

In the first study, one-week-old OSR cultivar cv 'Common' (OSRC) and an organically certified stoke (OSRS, Lot # RO4S-PSOSR, R. Stuckey, North Alger Rd., Alma, MI, 48801) seedlings were transplanted from potting soil into 300 cm^3 Styrofoam cups containing the assigned soil type. Three days after transplanting, seedlings of the two OSR cultivars were inoculated with either 0 or 3,000 eggs of the ED, PN and SW populations per pot (Mennan et al., 2006). Inocula were collected from greenhouse cultures following Hussey and Barker's (1973) bleach (5% NaOCl) method. A total of 96 experimental units (4 nems x 3 soils x 2 hosts x 4 reps) were used. The experiment was terminated 28 days after nematode inoculation.

In the second study, delayed about six months due to some difficulties with nematode cultures, only OSRC was used (see results). The four nematodes (PN, WL, SW and ED) and a control were inoculated at 0 or 2,000 eggs to 3-week-old seedlings, and the experiment lasted 30 days after inoculation. A total of 60 experimental units (5 nems x 3 soils x 4 reps) were used.

At the experimental temperature, 504 degree-days (DD, base 10 ^oC) and 540 DD were accumulated by the end of the first and second studies, respectively. These are enough heat units under which all nematodes can complete a life cycle (Insera et al., 1982).

Nematode infection measurements and data analysis:

At the end of the studies, shoots were cut off at the base and fresh weights determined. Roots were very carefully separated from soil, gently washed free of soil, and rated for root-knot galling indices on a 0 (no galling) to 5 (more than 75 % of the root system galled) scale (Kinloch, 1990). In order to minimize experimental errors, whole root systems were stained and nematodes counted (Melakeberhan and Dey, 2003). Stained samples were kept at 4º C until counted, *M. hapla* developmental stages determined as illustrated in Agrios (1997), and categorized as second-stage juveniles (J2), third and fourth-stage males and females (J3/J4) and females (Melakeberhan and Dey, 2003). Nematode population density data were standardized on a per g fresh root weight basis and statistical analyses were performed with SAS System Release 8 (SAS, 2000).

Results and Discussion

Mustard types of crops can be used as trap or cover crops or as biofumigants when incorporated into the soil to suppress weeds, nematodes and other soil borne yield-limiting biological factors (Hafez and Sundararaj, 2001; McSorley et al., 1997; Ngouajio and Mutch, 2004; Tseo et al., 2002). In order to exploit the multipurpose use of biofumigants, we need to understand the intricate relationships among nematode biology, their living environments, and the performance of the biofumigants. Integrating nematode biology and parasitic variability with soil environment, this study provides biological basis towards the appropriate use of OSR for Michigan conditions.

The effect of soil type was most striking. Across nematodes, sandy soil was the most (P = 0.05) favorable for nematode invasion of OSR (Fig. 1, Table 1). Thus, clearly showing that the best use of OSR will be dependent on the soil type. Subsequently, challenging the one-option-fits-all management approach. For example, high RKN infection of OSR in sandy soil can be good if the plants are removed before the nematodes complete a life cycle. Otherwise, it will increase the RKN problem.

The nematodes used in this study came from nursery and vegetable production systems within approximately 20 miles radius. They have been shown to exhibit parasitic variability and reproductive potential differences (Melakeberhan et al. 2007). By definition, a difference in reproductive potential can lead to differences in threshold levels. Consequently, the management decision-making processes with significant economic and/or ecological implications to growers and the environment.

In the first experiment, the SW population was most (P = 0.05) pathogenic while all four nematode populations infected similarly in Experiment 2 (Table 2). Although nematodes in whole root systems were counted, the difference in nematode numbers may have natural experimental errors. Nonetheless, the results show that all four RKN populations do infect OSRC. Moreover, the presence of juveniles and adult stages shows that the nematodes can reproduce in OSRC.

Infection by these nematodes can be good or bad depending on the purpose the OSR use. For example, if the OSRC is to be used as a trap crop for RKN it is good that more nematodes invade the roots. The nematodes however should not be allowed to complete a generation, which means that the OSR in use has to be removed or chopped and incorporated into the soil. This, in turn, requires knowing when to terminate the controlled or field experiment. All other things being similar, temperature is the best indicator for determining when the nematode is likely to complete its life cycle. Based on this study and using eggs as inoculum, approximately 450 to 500 DD from the time of inoculation appears to be the likely time for the nematodes to complete a life cycle. However, comprehensive field studies are needed to determine if the controlled experimental results can be reproduced under field conditions.

The OSR cultivars tested were selected for agronomic and availability reasons. Although galling was more in OSRC than in OSRS, the data show that both hosts carried similar numbers of nematodes (Fig. 1). Hence, which OSR to use may depend on cost and availability. The relationship among suitability to nematodes, soil type and OSR growth (Table, 3) sheds some light to the purpose of OSR use. As discussed here, sandy soil favors nematode infection of OSRC while vegetative mass growth may be more in the muck and loamy sand soils. Thus, the removal of RKN when using OSRC as a trap crop needs to be balanced with the potential use of OSRC as a biofumigant when incorporated into the soil.

Multi-taxa nematode presence in any given environment is likely and presents additional challenges on how OSR (and other tactics) may be used. When considering OSR against RKN in the presence of other nematodes, integrating the purpose (form) OSR use and nematode biology become critical. For example, RKN (sedentary endo-parasite) has only one infective stage (second-stage juvenile), whereas, all four vermiform stages of RLN (migratory endo-parasite) are infective. If OSR is to be used as a trap crop for either RKN or RLN, it needs to be removed or chopped before the nematodes complete their life cycle. When incorporated into the soil, OSR serves as a biofumigant against RKN, RLN and other nematodes present in the soil.

Because RKN has only one infective stage, suppressing its population density with trap cropping may be easier than RLN. Again, field tests are needed to verify these results.

Overall, the study shows the significance of incorporating nematode biology, parasitic variability, and soil conditions to provide valuable information towards making decisions when considering the best use OSR. Most significantly, it is fair to say that the one-option-fits-all management approach needs to be reconsidered. Further laying the groundwork for adopting site-specific management approaches (Melakeberhan, 2002) as well as incorporating new and emerging more efficient trap crops for RKN (Melakeberhan et al., 2006).

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Literature Cited

Anonymous. 2006 a. Project GREEEN Industry Priorities. Web/URL: http://www.greeen.msu.edu/priorities.htm/

Anonymous. 2006 b. North Central Region Crop Profiles. Web/URL: http://www.ncipmc.org/profiles/index.cfm/

Bird, G. W., B. Bishop, E. Grafius, M. Hausbeck, L. J. Jess, W. Kirk, and W. Pett. 2004. Insect, disease and nematode control for commercial vegetables. MSUE Bulletin E-312.

Chen, P., P. A. Roberts, A. E. Metcalf, and B. C. Hyman. 2003. Nucleotide substitution patterning within the *Meloidogyne* rDNA D3 region and its evolutionary implications. Journal of Nematology 35: 404-410.

Hafez, S. L., and P. Sundararaj. 2001. Impact of agronomic and cultural practices of green manure crops for the management of *Heterodera schachtii* in sugarbeet. International Journal of Nematology 10: 177-182.

Hussey, R.S., K. R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. Plant DiseaseReporter 57:1025-1028.

Insera, R. N., G. R. Griffin, and D. V. Sisson. 1982. Effect of temperature and root leachates on embryogenic development and hatching of *Meloidogyne chitwoodi* and *M. hapla*. Journal of Nematology 15: 123-127.

Liu, Q., and V. Williamson. 2004. Genetics of the root-knot nematode, *Meloidogyne hapla*. Journal of Nematology 36: 331

McSorley, R., P. A. Stansly, J. W. Noling, T. A. Obreza, and J. M. Conner. 1997. Impact of organic soil amendments and fumigation on plant-parasitic nematodes in Southwest Florida vegetable fields. Nematropica 27: 181-189.

Melakeberhan, H. 2002. Embracing the emerging precision agriculture technologies for site-specific management of yield–limiting factors. Journal of Nematology 34: 1-4.

Melakeberhan, H., and J. Dey. 2003. Competition between *Heterodera glycines* and *Meloidogyne incognita* or *Pratylenchus penetrans*: Independent infection rate measurements. Journal of Nematology 35: 1-6.

Melakeberhan, H., S. Mennan, S. Chen, B. Darby, and T. Dudek. 2007. Integrated biological approaches to understanding and managing *Meloidogyne hapla* populations' parasitic variability. *Crop Protection*, 25: In press.

Melakeberhan, H., A. Xu, A. Kravchenko, S. Mennan, and E. Riga. 2006. Potential use of arugula (*Eurica sativa* L.) as a trap crop for *Meloidogyne hapla*. *Nematology,* 8: In press.
Mennan, S., S. Chen, and H. Melakeberhan. 2006. Suppression of *Meloidogyne hapla* populations by *Hirsutella minnesotensis*. Biocontrol Science and Technology 16: 181-193.
Ngouajio, M., and D. R. Mutch. 2004. Oilseed radish: A new cover crop for Michigan. MSUE Bulletin E 2907.
SAS Institute 2000. *SAS user's guide: Statistics*. Cary NC: The SAS Institute Inc.
Tsao, R., C. J. Peterson, and J. R Coats. 2002. Glucosinolate breakdown products as insect fumigants and their effect on carbon dioxide emission of insects. *BMC Ecology* 2002, 2 URLhttp://www.biomedcentral.com/1472-6785/2/5.

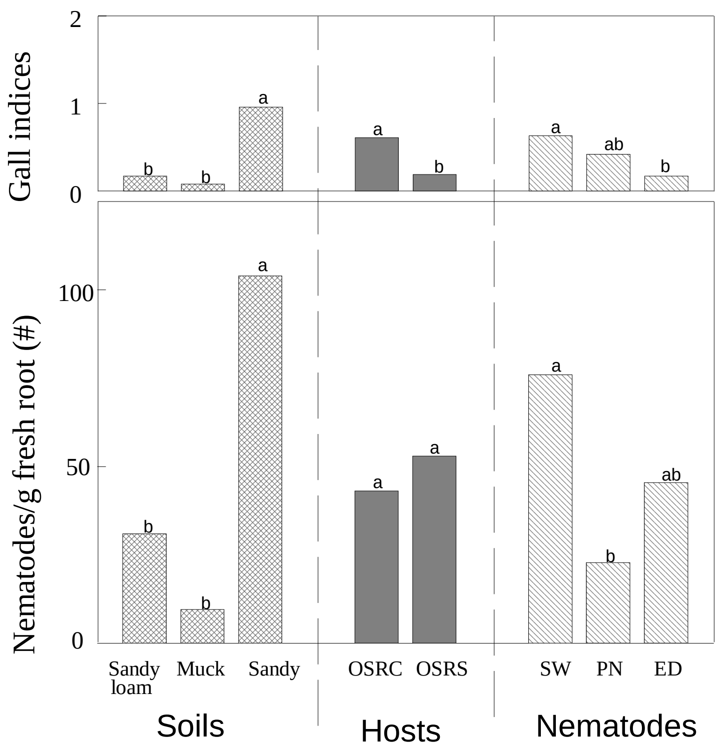

Fig. 1. The effects of soil types, oil seed radish cultivars (OSRC and OSRS), and three Michigan RKN populations (ED, PN and SW) on the numbers of nematodes per g fresh root and galling indices.

Gall indices are based on a 0 (none) to 5 (100%) scale.

Bars with the same letters within a category are not statistically different from one another.

Table 1. Numbers of juveniles (JUVS), adult females and total nematodes per gram of fresh root weight from loamy sand (LS), muck (M) and sandy (S) soils in Experiment 2.

Soil	JUVS	Females	Total
LS	4.1	83.6 b	87.7 b
M	25.4	72.1 b	98.0 b
S	16.4	293.9 a	311.8 a
P	*0.2984*	*0.0001*	*0.0001*

[1] Means followed by different letters with a category are statistically significant at the probability (*P*) levels indicated.

Table 2. Numbers of juveniles (JUVS), adult females and total nematodes per gram of fresh root weight of the *Meloidogyne hapla* populations (Mhp) from loamy sand (SW), Sandy (PN and WL) and muck (ED) soils, and the interactions of Mhp and soil in Experiment 2.

Mhp	JUVS[1]	Females[1]	Total[1]
SW	5.1	131.8	137.4
PN	10.0	149.9	160.4
ED	18.9	148.4	168.2
WL	25.5	182.1	208.5
P	*0.1076*	*0.3414*	*0.1754*
Mhp*soil	*0.2935*	*0.2828*	*0.2742*

[1] Means with a category are statistically significant at the probability (*P*) levels indicated.

Table 3. Effect of loamy sand (LS), muck (M) and sandy (S) soils, *Meloidogyne hapla* populations (Mhp) and their interactions on root and shoot fresh weight (g) in Experiment 2.

Soil	Root[1]	Shoot[1]
LS	2.16 a	10.41 a
M	0.97 c	12.17 a
S	1.51 b	4.93 b
P	*0.0064*	*0.0001*
Mhp	*0.5041*	*0.1444*
Mhp*soil	*0.9637*	*0.6619*

[1] Means with a category are statistically significant at the probability (*P*) levels indicated.

Funding: MPIC

Summary Report for the 2005-2006 Dr. B. F. (Burt) Cargill Potato Demonstration Storage

Brian Sackett, Chris Long, Dick Crawford, Todd Forbush (Techmark, Inc.), Steve Crooks, Dennis Iott, Keith Tinsey, Tim Young, Jason Walther, Troy Sackett, Randy Styma and Ben Kudwa

Introduction

This is a summary report of the 2005-2006 Dr. B.F. (Burt) Cargill Potato Demonstration Storage Annual Report Volume 5. This report is designed to provide a short summary of the 2005-2006 storage committee activities. To obtain a copy of the full 2005-2006 Demonstration Storage Report please contact the Michigan Potato Industry Commission office (517-669-8377) or Chris Long at Michigan State University (517-355-0271 ext.#193). The full report will be provided to you free of charge.

Goals and Objectives

The 2005 growing season resulted in below average specific gravity with average overall yields. The early part of the season was cool and wet. The harvest season was generally dry and warm causing breakdown in some early storage varieties.

The goal of the MPIC Storage and Handling Committee for the 2005-2006 bulk bin storage season was to develop storage profiles on three promising advanced seedlings and evaluate the effectiveness of Reverse Air Flow (RAF) ventilation on preventing pressure bruise in commercial bulk piled potatoes. The first variety tested for storage profiling was MSG227-2, a clone from the potato breeding program at Michigan State University. This clone offers chip quality and common scab resistance. MSG227-2 was tested in a bulk bin in the 2004-2005 storage season. The second variety, Monticello which was developed at Cornell University, has been grown commercially for some time. Monticello was promoted in Maine and later jointly released to the public in the early 1990’s. From our box bin testing in 2003-2005 this variety appeared to have some good long-term storage potential and moderate scab tolerance. A major goal of the Storage and Handling Committee is to discover and develop long-term storage varieties. We were able to evaluate Monticello's long-term chip quality on a larger scale in 2005-2006. W2128-8, the third variety of interest, is a University of Wisconsin developed clone with good agronomic quality. This was the first season W2128-8 has been evaluated on a large scale.

When the MPIC demonstration storage was constructed in 1999 it was designed in such a manner that the reversal of bin pile air could be achieved. The nature of this design would allow the Storage and Handling Committee to conduct experimentation on the effect of directional bin pile air on stored potatoes. When air is introduced to the bottom of a potato pile it tends to be dry (low relative humidity) and causes the potatoes to lose water or dehydrate. The potatoes at the bottom of a pile are experiencing stress from the potatoes above in the form of weighted pressure and an increase in pressure bruising with discoloration under the skin is most generally noted in these potatoes. The committee wanted to demonstrate that if bin pile air flow was reversed (introducing air first into the top of the pile), weight loss at the bottom of a potato pile could be eliminated and thus greatly reduce pressure bruising. This experiment was conducted in 2005-2006 on the variety Snowden.

The committee's objective in testing these varieties was to determine what the optimal storage temperature was for each variety, while maintaining acceptable storage quality. Also of interest was the level of pressure bruise damage that may be incurred by each variety at a given storage temperature. The goal for the MSG227-2 variety (Bulk Bin 2) was to evaluate longevity at a given storage temperature while maintaining chip quality. Based on blackspot bruise numbers, sugar accumulation and stem end defect, this variety was left warm and slated for a November to December shipping window. Monticello (Bulk Bin 3) was evaluated for duration of storability. As the chip quality improved on this variety the pile would be cooled to extend storage life in hopes of reaching a May to June shipping window. Bulk Bin 4, W2128-8 was tested to evaluate the long-term storability of this line. The variety appeared to have a higher amount of external defects at harvest related to greening and black spot bruising. Sugar accumulation was watched closely around the defect areas before cooling the potatoes to a long-term storage profile temperature of

48 ºF.

Bulk Bin 5 served as a control bin for testing the effectiveness of RAF on reducing pressure bruise in a commercial potato storage situation. Bulk Bin 6 was our test bin. In this bin the pile air was forced down through the top of the potato pile. The goal was to establish whether introducing the relatively dry air at the top of the bin pile would reduce shrinkage in potatoes at the bottom of the pile where a significant amount of pressure and stress is experienced.

Results for the Bulk Bins:

MSG227-2 bulk bin 2. For the 2005-2006 storage season, this variety was grown by Sackett Acres, Inc., McBride, MI which is located in Montcalm county. The tuber temperature upon arrival at the storage was 70.1 ºF. The variety was tested and found to be 93 percent black spot bruise free. Weight loss numbers were excellent at 4.37 percent and only 0.9 percent of the tubers with pressure bruise had discoloration under the skin. SFA chip color and color related defects were very good. There was a large amount of total defects present in this bin, including internal and external defects, which were 14.4 percent on November 29th, 2005. Most of the internal defects were stem end defects (SED). We do not have a good understanding as to what was causing the external defects. After a month in the storage at 54-57 ºF it was evident that this bin of potatoes contained such a large amount of stem end and external tuber defects that we would have trouble completing our evaluation. At a warm bin pile temperature we were unable to cause change on the amount of chip defects that were present. The sugar related color associated with these defects was not burning off. That prompted the Storage Committee to cut losses in the storage bin and the variety was shipped as an open market load of chip processing potatoes and that ended our evaluations in Bin 2. Sugar profile data appears to be adequate for short-term storage of this clone into February 2006. Over time, more external tuber defects became apparent in MSG227-2. Growth cracks and misshapen tubers increased in frequency in on-farm variety trials from 2004 to 2005. The variety lost a consistent tuber type. Any available seed of MSG227-2 was flushed out of the seed increase system in the Spring of 2006. MSG227-2 is now a source of common scab resistance in the MSU breeding program.

Monticello Bulk Bin 3. Monticello was grown by Walther Farms, Inc. in Hemlock, MI. Only 35 cwt of seed was available in the Spring of 2005 for planting. Consequently, only 410 cwt was harvested and loaded into the storage during the fall of 2005. The variety has a good set of smaller size tubers that averaged 2.5 to 3 inches in diameter. The storage was filed on October 19th with a pulp temperature of 54.6 ºF. The variety was evaluated to be 89 percent bruise free. Based on the quality of the potatoes and our past history with this variety in the box bins it was decided to aim for a long-term storage profile and go to weekly storage sampling through April of 2006. In November 2005 the variety was cooled to 50-51 ºF and evaluated for sugar accumulation. If Monticello performed well at this temperature the variety would be cooled further. Monticello had a 4.79 percent weight loss and 1.3 percent of the tubers had pressure bruise and discoloration under the skin. The overall sugar profile was excellent for this variety with very stable sucrose and glucose levels into early May. This bulk bin was held as cold as 48 ºF. The chip quality time line for this variety is very exciting. Bin 3 was shipped to Herr Foods Inc. on May 16th, 2006 with excellent results. The Storage and Handling Committee would like to continue further testing of Monticello in the 2006-2007 storage season.

W2128-8 Bulk Bin 4. W2128-8 was grown by Crooks Farms, Inc and was delivered on October 31st with a pulp temperature of 52.5 ºF. The goal for this bin was to establish the long-term storage potential of this variety. W2128-8 arrived at the storage with an 83% bruise free rating. Some of the tuber quality of this line appeared to be compromised by extensive shatter bruise. The variety was slated for long-term storage in November of 2005 and scheduled to go to 50 ºF for holding. At this time, the sugar profile was reevaluated and the variety cooled further if chip quality remained. Percent tuber weight loss was 5.24 percent. No pressure bruise with discoloration was recorded. W2128-8 had nice chip quality, with a uniform bright flesh when processed. Excellent chip color was reported with minimal color related defects. The major factor affecting chip quality of this variety is the shatter bruise. There were periods in our sugar profiling that this clone had 28 percent chip defects mostly as a result of the shatter bruise. This variety appears to be a very long season variety and it may not have been mature at harvest, resulting in the shatter bruising. The generally high specific gravity of this line was also a possible contributor to the high black spot and shatter bruise recorded at harvest. Bulk Bin 4 was processed at Herr Foods Inc. on March 29th 2006. The impact of the shatter bruising was devastating. Due to the willingness of Gene Herr, the load was able to be processed. The general practice would have been to reject a load with such extensive external defects. We were grateful to Gene for his help in evaluating this line. Internal defects were minor with some slight hollow heart. Based on the susceptibility of this variety to shatter bruise this line was dropped. No shatter was reported in Michigan on-farm trials in 2004, however, shatter bruise had been previously reported in Wisconsin.

<u>Snowden (Standard Airflow) Bulk Bin 5.</u> Snowden has become a standard in the Michigan chip processing industry. This variety is well adapted for mid-season storability. It appears that Snowden is susceptible to pressure bruise in prolonged storage. Bin 5 served as a control bin for our reverse air flow experiment. The potatoes in Bulk Bins 5 and 6 were grown by Johnson Farms, Howard City, MI. Both bins were filled with potatoes from the same field, harvested the same day and loaded into the demonstration storage at the same time. The Snowdens in Bulk Bin 5 experienced conventional air flow. The pile air was introduced to the potatoes at the bottom of the pile through in-floor air ducts. This is an industry standard. Upon arrival at 59.1 ºF, the tubers were cooled at 0.4 ºF per day until the potatoes reached a temperature of 50 ºF. At that time the status of the potatoes was reevaluated and then cooled to 48 ºF for holding. The tubers were determined to be 87% bruise free at bin loading. The average percent weight loss for Bulk Bin 5 was 3.83. Also, the amount of pressure bruise with discoloration under the skin was minimal at 3.6 percent. This information showed that given this set of storage parameters this 16 foot bulk pile of potatoes did not experience any adverse effects resulting from pressure bruise. Good chip quality was observed for this bulk bin into early March. Sugar profile information was standard for Snowdens under this storage practice. This bin of potatoes was processed at Herr Food, Inc. on March 28, 2006. A slight amount of white knot and black spot bruise was evident in the internal chip defects, as well as some pressure bruise in the external defect score. The bin processed acceptably.

Snowden (Reverse Airflow) Bulk Bin 6. Bin 6 served as the experimental bin for our reverse air flow demonstration. The potatoes in Bulk Bins 5 and 6 were grown by Johnson Farms, Howard City, MI. Both bins were filled with potatoes from the same field, harvested the same day and loaded into the demonstration storage at the same time. The Snowdens in Bulk Bin 6 experienced reverse air flow (RAF). In this bulk bin the pile air was introduced to the potatoes at the top of the pile. The air was then drawn down through the pile, recirculated through the fan and humidicell and reintroduced to the top of the potato pile. The hypothesis was that introducing dryer air to the top of the pile would reduce pressure bruising at the bottom of the potato pile where there is significant pressure. Reducing the potential for pressure bruise at the bottom of the pile would increase the potential longevity of the Snowden variety in storage. Upon arrival at 59.1 ºF, the tubers were cooled at 0.4 ºF per day until the potatoes reached 50 ºF. At that time the status of the potatoes was reevaluated and then cooled to 48 ºF for holding. These tubers were determined to be 83% bruise free at bin loading. The average percent weight loss for Bulk Bin 6 was 6.58. There was almost 3 percent more weight loss experienced by these potatoes than those in Bulk Bin 5. The amount of pressure bruise with discoloration under the skin was minimal at 2.7 percent. This was one percent less than observed in Bulk Bin 5. Just basing our conclusion on this information, there appears to be no significant benefit of utilizing RAF to reduce pressure bruise in a commercial potato pile. The implementation of RAF would create significant expense to potato growers to convert storages, thus the observed benefit must be substantial. The chip quality observed in Bulk Bin 6 is not significantly different than that of Bulk Bin 5. Both Bulk Bins 5 and 6 displayed a very similar chip quality, indicating RAF had little impact on overall quality in Bulk Bin 6. This load was successfully processed at Herr Foods, Inc. on March 28, 2006. The processor reported no increase in chip quality as a result of RAF.

Promising Varieties In the Box Bin Trial:

Varieties that look promising in the Box Bin trial (Bin 1) in 2005 were MSH228-6, MSJ036-A, MSJ126-9Y, MSJ147-1 and MSK061-4. These varieties will be considered for larger scale evaluations in the 2006-2007 storage season.