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MICHIGAN POTATOES
MICHIGAN POTATO INDUSTRY COMMISSION

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PGMI
Potato Growers of Michigan, Inc.

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To All Michigan Potato Growers & Shippers,

Research is at the core of it all. Through research we are able to test, to study, and to advance. Research is a platform for testing ideas and bringing experiments to life. As crop research expands, we learn more about diseases and storage management. We are able to look at potatoes and their resistance to insects. We can look at the levels of individual elements in a potato and learn more about their relationship with one another, creating a better vegetable in the process. Through research we are able to achieve so many things.

This year our focus included the genetic makeup of the potato along with soil health issues. The research is aimed to raise the efficiency and sustainability in modern potato production in Michigan, as well as a plethora of storage and handling issues. Weather data, insect resistance, and tuber set were also a priority in this year's research season. Our overall goal is always to create a healthy and abundant food source.

The following research report was constructed with the help of the Michigan Potato Industry Commission, Michigan State University's AgBioResearch Station and MSU Extension. On behalf of all parties, we are proud to present to you the 2013 potato research projects and results.

We would like to thank our suppliers, researchers, and everyone involved in this year's research season. As the industry faces new challenges and strives for the perfect potato, we are inspired as we look to the future.

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2013 MICHIGAN POTATO RESEARCH REPORT

C. M. Long, Coordinator

INTRODUCTION AND ACKNOWLEDGMENTS

The 2013 Potato Research Report contains reports of the many potato research projects conducted by Michigan State University (MSU) potato researchers at several locations. The 2013 report is the 45th 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 principle 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 Bruce Sackett for the management of the MSU Montcalm Research Center (MRC) and the many details which are a part of its operation. We also want to recognize Michelle Wieferich at MPIC and Andrew Camp, MSU for helping with the details of this final draft.

WEATHER

The overall 6-month average maximum temperature during the 2013 growing season was four degrees cooler than the 6-month average maximum temperature for the 2012 season and was identical to the 15-year average (Table 1). The 6-month average minimum temperature for 2013 was one degree lower than the 15-year average. There were 3 days with recorded temperature readings of 90 °F or above in 2013. There were 140 hours of 70 °F temperatures between the hours of 10 PM and 8 AM which occurred over 28 different days, April to September (Data not shown). The level of night time temperature stress experienced during the 2013 growing season was below the 5 year average. There was one day in May that the air temperature was below 32 °F. The average maximum temperatures for July through September 2013 were similar to the 15-year average (Table 1). For the period from September 15th to October 20th, there were fourteen days that the air temperature was below 32 °F.

Rainfall for April through September was 21.50 inches, which was 2.69 inches above the 15-year average (Table 2). In October 2013 4.65 inches of rain was recorded. Irrigation at MRC was applied 13 times from June 20th to September 7th, averaging 0.79 inches for each application. The total amount of irrigation water applied during this time period was 10.2 inches.

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

Year	April		May		June		July		August		September		6-Month Average	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
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	51
2007	53	33	73	47	82	54	81	56	80	58	76	50	74	50
2008	61	37	67	40	77	56	80	58	80	54	73	50	73	49
2009	56	34	67	45	76	54	75	53	76	56	74	49	71	49
2010	64	38	70	49	77	57	83	62	82	61	69	50	74	53
2011	53	34	68	48	77	56	85	62	79	58	70	48	72	51
2012	58	34	73	48	84	53	90	62	82	55	74	46	77	50
2013	**51**	**33**	**73**	**48**	**77**	**55**	**81**	**58**	**80**	**54**	**73**	**48**	**73**	**49**
15-Year Average	58	35	68	46	78	55	82	59	79	58	73	49	73	50

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

Year	April	May	June	July	August	September	Total
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
2007	2.64	1.60	1.58	2.43	2.34	1.18	11.77
2008	1.59	1.69	2.95	3.07	3.03	5.03	17.36
2009	3.94	2.15	2.43	2.07	4.74	1.49	16.82
2010	1.59	3.68	3.21	2.14	2.63	1.88	15.13
2011	3.42	3.08	2.38	1.63	2.57	1.84	14.92
2012	2.35	0.98	0.99	3.63	3.31	0.76	12.02
2013	**7.98**	**4.52**	**2.26**	**1.35**	**4.06**	**1.33**	**21.50**
15-Year Average	2.95	3.84	2.87	2.94	3.66	2.55	18.81

GROWING DEGREE DAYS

Tables 3 and 4 summarize the cumulative growing degree days (GDD) for 2013. Growing degree days base 50 for May through September, 2013, are in (Table 3) and growing degree days base 40 for May through September, 2013, are in (Table 4). The total GDD base 50 for 2013 was 2370 (Table 3), which is slightly higher than the 10-year average. The total GDD base 40 for 2013 was 3798, remaining slightly above the eight year average for the same recorded period, May through September 2006-2013 (Table 4).

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

	Cumulative Monthly Totals				
Year	May	June	July	August	September
2004	245	662	1200	1639	2060
2005	195	826	1449	2035	2458
2006	283	765	1444	2016	2271
2007	358	926	1494	2084	2495
2008	205	700	1298	1816	2152
2009	247	700	1133	1622	1963
2010	352	857	1561	2231	2531
2011	299	788	1512	2085	2393
2012	371	702	1495	2062	2415
2013	**373**	**867**	**1474**	**2014**	**2370**
10-Year Average	293	779	1406	1960	2311

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

	Cumulative Monthly Totals				
Year	May	June	July	August	September
2006	532	1310	2298	3180	3707
2007	639	1503	2379	3277	3966
2008	447	1240	2147	2973	3596
2009	519	1264	2004	2800	3420
2010	610	1411	2424	3402	3979
2011	567	1354	2388	3270	3848
2012	652	1177	2280	3153	3762
2013	**637**	**1421**	**2334**	**3179**	**3798**
2014					
2015					
10-Year Average	575	1335	2282	3154	3760

*2004-2013 data from the weather station at MSU Montcalm Research Center "Enviro-weather", Michigan Weather Station Network, Entrican, MI.

PREVIOUS CROPS, SOIL TESTS AND FERTILIZERS

The general potato research area utilized in 2013 was rented from Steve Comden, directly to the West of the Montcalm Research Center. This acreage was planted to a field corn crop in the spring of 2012 and harvested fall 2012 with crop residue disked into the soil. Two tons/A of dried chicken litter was applied in the fall of 2012 and deep chiseled into the remaining corn residue. The chicken litter nutrient analysis was 4-3-2-8%Ca with a carbon to nitrogen ratio of 6.9:1. In the spring of 2013, the recommended rate of potash was applied. The ground was field cultivated and direct planted to potatoes. The area was not fumigated with Vapam prior to potato planting, but Vydate C-LV was applied in-furrow at planting. Early potato vine senescence was not an issue in 2013.

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

	lbs/A			
pH	P_2O_5	K_2O	Ca	Mg
6.2	292 (146 ppm)	290 (145 ppm)	1174 (587 ppm)	144 (72 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 ($N-P_20_5-K_20-Mg$)
Broadcast at plow down	0-0-21-10	200 lbs/A	0-0-42-20
	10%B	6 lbs/A	0.6 lb. B
	0-0-62	100 lbs/A	0-0-62
At planting	28-0-0	24 gpa	72-0-0
	10-34-0	16 gpa	19-65-0
At cultivation	28-0-0	30 gpa	90-0-0
At hilling	46-0-0	100 lbs/A	46-0-0
Late side dress (late varieties)	46-0-0	150 lbs/A	69-0-0

Calcium and Nitrogen were applied July 18^{th} in the form of liquid Calcium Nitrate (with an analysis of 30% Ca and 25% N) for a total application of 5 gpa. The composite nutrient value resulted in 18 lbs actual Ca and 15 lbs of N being applied per acre on the potato production area.

HERBICIDES AND PEST CONTROL

A pre-emergence application of Linex at 1.25 quarts/A and Dual II at 1.0 pints/A was made in late May. A post-emergence application of Matrix at 1.3 oz/A was made in late July.

Admire and Vydate C-LV were applied in-furrow at planting at a rate of 8 fl oz/A and 2 quarts/A, respectively.

Fungicides used were; Bravo, Tanos, Echo and Manzate over 12 applications.
Potato vines were desiccated with Reglone in early September at a rate of 2 pints/A.

2013 POTATO BREEDING AND GENETICS RESEARCH REPORT

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INTRODUCTION

At Michigan State University, we are dedicated to developing improved potato varieties for the chip-processing and tablestock markets. The program is one of four integrated breeding programs in the North Central region supported through the Potato Special Grant. At MSU, we conduct a multi-disciplinary program for potato breeding and variety development that integrates traditional and biotechnological approaches to breed for disease and insect resistance. In Michigan, it requires that we primarily develop high yielding round white potatoes with excellent chip-processing from the field and/or storage. In addition, there is a need for table varieties (russet, red, yellow, and round white). We conduct variety trials of advanced selections and field experiments at MSU research locations (Montcalm Research Center, Lake City Experiment Station, Clarksville Research Center, and MSU Soils Farm), we ship seed to other states and Canadian provinces for variety trials, and we cooperate with Chris Long on 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, beetle resistance, specific gravity). The SolCAP project has developed a new set of genetic markers (8,303) called SNPs that are located in the 39,000 genes of potato. This USDA-funded SolCAP translational genomics project is finally giving us the opportunity to link genetic markers to important traits (reducing sugars, starch,scab resistance, etc.) in the cultivated potato lines and then breed them into elite germplasm. 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 insect resistance, late blight and PVY resistance, lower reducing sugar, nitrogen use efficiency and drought. Furthermore, the USPB is supporting national early generation trials called the National Coordinated Breeder Trial (NCBT) which will feed lines into the SFA trial and also fast track lines into commercial testing. We are also funded through the USDA/SCRI Acrylamide project to link genetic markers with lower acrylamide traits. We also have funding to develop genome editing technologies that may not be classified at genetic engineering through a USDA/BRAG grant. 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 production input costs as well as the 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 Clarksville Research Center 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 Center, new land at the Lake City Experiment Station along with a well for irrigation and expanded land at the Montcalm Research Center and Lake City Experiment Station, the new plot harvester, the development of the grading line at the MSU campus facility, and expansion of the tissue culture operation so that small amounts certified seed of minitubers can be produced. In 2012 we relocated our research lab in the new Molecular Plant Sciences addition on the MSU campus.

PROCEDURE

I. Varietal Development

Breeding, Selection and Variety Evaluation:

The MSU breeding program has been operating for over 20 years and we feel that we have advanced the germplasm so that we can breed scab and late blight resistant varieties for Michigan. We have the genetic variation to combine tuber shape, skin type, scab resistance and low sugars, yield and storability as well as late blight, PVY and golden nematode resistances. Secondly, we have been improved the efficiency of the breeding cycle by defining more precisely the commercial needs of the new varieties and make better decisions more quickly in the first three years of the breeding program cycle. Third, we have raised our standards for what we consider a commercial selection for testing. Fourth, we have been able to increase our efficiency because we are conducting an integrated selection based upon our disease nurseries, post-harvest evaluations for specific gravity and chip quality and DNA tests. Furthermore, we have also revised the selection scheme so that we have reduced a year from the early generation cycle. The MSU Breeding program continues to test MSU-bred lines in replicated trials (over 160 lines) and on grower farms (over 15 lines). We also annually enter 3-4 lines in the North Central regional trials, 2-4 lines in the USPB/SFA trials and send many of the advanced breeding lines to other states, Canada and various international sites for testing. The NCBT in 2013 allowed us to test the over 50 MSU lines at 11 locations around the country. Through a cooperative effort of MPIC, commercial growers, seed growers, Chris

Long, the MSU breeding program and the processors, we are working together to help move the best lines towards larger scale commercial testing and have chip-processing lines evaluated in the Commercial Demonstration Storage facility (500 cwt bins). At this time, we have many advanced selections that have chipping qualities along with scab or late blight resistance, bruise resistance, etc. with commercial potential. Five of these are in the fast track commercial seed production (MSL007-B, McBride (MSJ126-9Y), Manistee (MSL292-A), MSR061-1 and MSK061-4). McBride and Mansitee can store at temperatures below 50F and maintain low sugars until June.

In 2014 the MSU breeding program will cross elite germplasm to generate and evaluate 60,000 new seedlings for adaptation to Michigan. In the subsequent years these selections are then advanced to 12-hill (year 2), 30-hill (year 3), 50-hill, and 100-hill plots, with increasing selection pressure for agronomic, quality and disease and/or insect resistance parameters. We now have in place field sites for early generation selection for late blight, scab and Colorado potato beetle resistant lines. Early generation evaluation of these key traits increases our effectiveness in identifying commercially valuable advanced selections. From this 3-year early generation evaluation and selection phase of the breeding program we generate about 80 MSU-bred advanced selections that are then to be tested and evaluated under more intensive replicated trials at the Montcalm Research Center. We are also producing the FG1 and FG2 level seed of the most promising selections from the MSU breeding program for in-state grower-cooperator trials, out-of-state trials, North Central Regional trials, national USPB/SFA trials and MSU research farm trials.

Elite clones will be tested for at the Montcalm Research Center for agronomic performance, marketable maturity, chip processing at harvest and in storage, resistance to pitted scab, potato early die and late blight. We place the advanced selections into tissue culture and initiate virus eradication procedures so that virus-free tissue culture plantlets or tuber sources can be made available to the industry. Part of our greenhouse is now approved to produce certified greenhouse minitubers. We are moving towards using a commercial NFT mini-tuber production system to produce mini-tubers of our advanced selections. We have developed a new cryotherapy procedure for virus eradication that replaces the chemotherapy and heat therapy methods because it is faster and predictable.

Currently, the breeding program has in tissue culture about 1300 clones in the MSU bank and 80 new candidates that are in process for transfer to tissue culture. We want to continue to work closely with the commercial growers and seed industry to test and provide seed, as well certified seed greenhouse tubers, for more intensive evaluation. Through this linkage we hope to identify the breeding selections that have merit to achieve varietal status in Michigan.

There is a need to find a russet table potato that will be profitable and produce quality russets for the eastern market. Currently, the three most desirable potatoes for production and type in Michigan are GoldRush, Russet Norkotah and Silverton Russet. The latter two potatoes suffer as symptomless carriers of PVY. Norkotah also has a weak vine and susceptibility to potato early die. We need a PVY resistant Silverton Russet potato. We are continuing to make more russet crosses and selections in the breeding program to support this new russet market.

Evaluation of Advanced Selections for Extended Storage

With the Demonstration Storage facility adjacent to the Montcalm Research Center, 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-developed lines.

II. 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 48 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). 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. We are redirecting the diploid breeding by introducing a self compatability (*SLi*) gene. The ability to self pollinate diploid potato lines will allow us to think of diploid potato breeding more like corn breeding. This is a long-range project but may have benefits in the future.

III. 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 now 18 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* and *Bt-cry1Ia1*), late blight resistance via the *RB* gene (from the wild potato species *S. bulbocastanum*) and also a late blight resistance gene we cloned from *S. microdontum*, drought resistance (*CBF1, IPT*), PVY, and lower reducing sugars with acid invertase gene silencing, and nitrogen use efficiency from a barley alanine aminotransferase gene. We will have field trials in 2014 to evaluate, the nitrogen use efficiency, water use efficiency, invertase silencing for the first time.

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 2013 field season, progeny from about 600 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. During the 2013 harvest, over 1,200 selections were made from the 60,000 seedlings produced. In addition, about 95 second year selections from elite chip-processing crosses were made in a commercial field with high scab pressure. All potential chip-processing selections will be tested in January and April 2013 directly out of 45°F (7.2°C) and 50°F (10°C) storages. Atlantic, Pike (50°F chipper) and Snowden (45°F chipper) are chip-processed as check cultivars. Selections have been identified at each stage of the selection cycle that have desirable agronomic characteristics and chip-processing potential. At the 12-hill and 30-hill evaluation state, about 300 and 80 selections were made, respectively, based upon chip quality, specific gravity, scab resistance, late blight resistance and DNA markers. 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. We are pushing our early generation selections from the 30-hill stage into tissue culture to minimize PVY issues in our breeding and seed stock. We are now using a cryotherapy method that was developed in our lab to remove viruses. We feel that this technique predictably as well as quickly remove virus from tissue culture stocks. Our results show that we are able to remove both PVY and PVS from lines. We will test the removal of PLRV in 2014.

Chip-Processing

Over 80% of the single hill selections have a chip-processing parent in their pedigree. Our most promising advanced chip-processing lines are MSR127-2 (scab resistant), McBride (scab resistant), MSL007-B (scab resistance), MSR169-8Y (scab resistant), MSQ086-3, (late blight resistant), Manistee, MSM246-B and MSR061-1 (scab, late blight and PVY resistant). We have some newer lines to consider, but we are removing virus from those lines. We are using the NCPT trials to more effectively identify promising new selections.

Tablestock

Efforts have been made to identify lines with good appearance, low internal defects, good cooking quality, high marketable yield and resistance to scab, late blight and PVY. 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. We have also been spinning off some pigmented skin and tuber flesh lines that may fit some specialty markets. We released three lines for the specialty market: MSN215-2P (Colonial Purple), MSR226-1RR (Raspberry) and MSQ425-4PY (Spartan Splash). There is also interest in some additional specialty for the "Tasteful selections" market. We have interest from some western specialty potato growers to test and commercial these 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 some 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 2013, while others were tested under replicated conditions at the Montcalm Research Center. Promising tablestock lines include MSL211-3, MSQ440-2, MSM288-2Y, MSL268-D, MSS206-2, MSQ483-1, MSQ487-2 and MSQ176-5. We have a number of tablestock selections with late blight resistance (MSQ176-5, MSM182-1, and MSL268-D). MSL211-3 has earliness and a bright skin. We are using russets as parents in the breeding program to combine the late blight and scab resistance. MSM288-2Y is a bright yellow flesh selection similar in type to Yukon Gold. Some new specialty pigmented lines are MSS576-05SPL (red splash) and Michigan Red and Purple Heart. MSQ558-2RR and MSR226-1RR are red-fleshed chippers. We will be increasing seed of Missuakee for international markets due to its late blight resistance and Golden nematode resistance.

Early harvest breeding material screen

In 2013, we continued our early harvest observation trial of our breeding lines to learn about the potential to replace Atlantic as an early harvest variety. We harvested the plots at 89 days and observed the yield, tuber size and tuber shape/ appearance. In addition, we measured specific gravity and made chips out of the field. From this trial of about 100 lines, we were able to identify some promising early breeding lines for the out-of-the-field chipping use (MSW509-5, MSM246-B, QSMSU08-04 and QSMSU10-09) and table use (MST500-1, MSS483-1, MSW125-3, and MSW239-3SPL). **Table 1** summarizes these results of the lines with the highest merit ratings. Some of these lines are also characterized to have some scab resistance and late blight resistance along with the desirable chipping traits. We will continue to test many of these lines and other selections in 2014.

Table 1 Early Observation Trial: Most promising lines.

Table 1 Early Observation Trial: Most promising lines.

Line	Plot Yield (cwt/a)	Specific Gravity	OTF 8/5/13 SFA Chip Score	Merit[1]	Pedigree	
Chip-processing					Female	Male
Atlantic	**360**	**1.098**	**1.0**	**2.0**		
Atlantic	**263**	**1.091**	**1.0**	**2.0**		
FL1879	312	1.084	1.5	2.5		
Manistee (MSL292-A)	302	1.088	1.0	2.0	Snowden	MSH098-2
MSM246-B	330	1.087	1.0	2.0	MSE274-A	NY115
MSN190-2	297	1.093	1.0	2.5	MSI234-6Y	MSG227-2
MSQ086-3	311	1.071	1.0	2.5	Onaway	Missaukee
MSR127-2	241	1.080	1.0	2.0	MSJ167-1	MSG227-2
MSW509-5	381	1.084	1.0	2.0	Kalkaska	Marcy
NY140	361	1.079	1.0	2.5		
QSMSU08-04	376	1.081	1.0	2.5	MSM037-3	MSL211-3
QSMSU10-09	375	1.083	1.0	2.0	MSN106-2	MSL211-3
Snowden	**278**	**1.089**	**1.0**	**2.5**		

Snowden	**266**	**1.082**	**1.0**	**2.5**		
Tablestock						
MI Purple Sport I	344	1.072	-	2.0		
MSM288-2Y	301	1.079	-	2.0	MSG145-1	MSA097-1Y
MSQ176-5	311	1.069	-	2.0	MSI152-A	Missaukee
MSR148-4	399	1.074	-	2.0	MSI152-A	Dakota Pearl
MSS483-1	390	1.074	-	2.0	MSM171-A	Missaukee
MSS576-05Spl	366	1.074	-	2.0	MSI005-20Y	MSL211-3
MSS934-4	361	1.082	-	2.0	ND6095-1	ND7377Cb-1
MST500-1	391	1.070	-	2.0	Stirling	Boulder
MSW125-3	374	1.061	-	2.0	MSM171-A	MSL211-3
MSW239-3SPL	338	1.059	-	2.0	NDTX4271-5R	Picasso
Onaway	**348**	**1.070**	**-**	**3.0**		
Reba	**286**	**1.073**	**-**	**2.0**		
Reba	**269**	**1.078**	**-**	**2.0**		

[1]Merit Rating: 1-Great, 2-Keep, 3-Marginal, 4-Drop

Planted 5/7/13; Harvested 8/5/13. 90 DAP. 10-hill plots planted in 10 ft plots.

Disease and Insect Resistance Breeding

Scab: In 2013 we had two locations to evaluate scab resistance: a commercial field with a history of severe scab infection and a highly infected site at the Montcalm Research Center in the commercial production area. The commercial site and the new site at the Montcalm Research Center both gave us the high infection levels. Some of results are summarized in **Table 2**. The susceptible checks of Snowden and Atlantic were highly infected with pitted scab. Promising resistant selections were MSJ126-9Y, MSL007-B, MSR061-1, MSR169-8Y, MSP270-1, MSR127-2, U383-A and MSQ440-2. The high level of scab infection at the on-farm site with a history of scab infection and MRC has significantly helped with our discrimination of resistance and susceptibility of our lines. In 2014 we are planning to use the commercial site for primary trait selection of our 30-hill (year 3) lines in elite chip-processing crosses. The MRC scab site was used for assessing scab susceptibility in our advanced breeding lines and early generation material and is summarized below. All susceptible checks were scored as susceptible.

Fig. 1. Scab Disease Nursery Ratings in Early Generation Lines

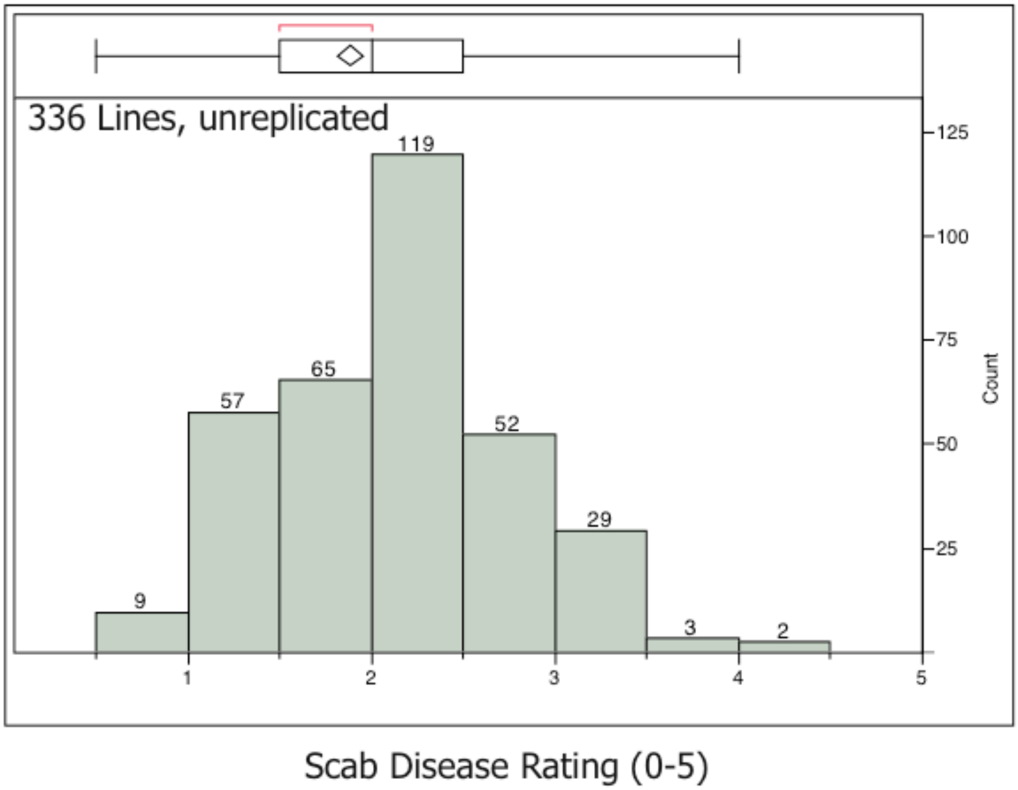
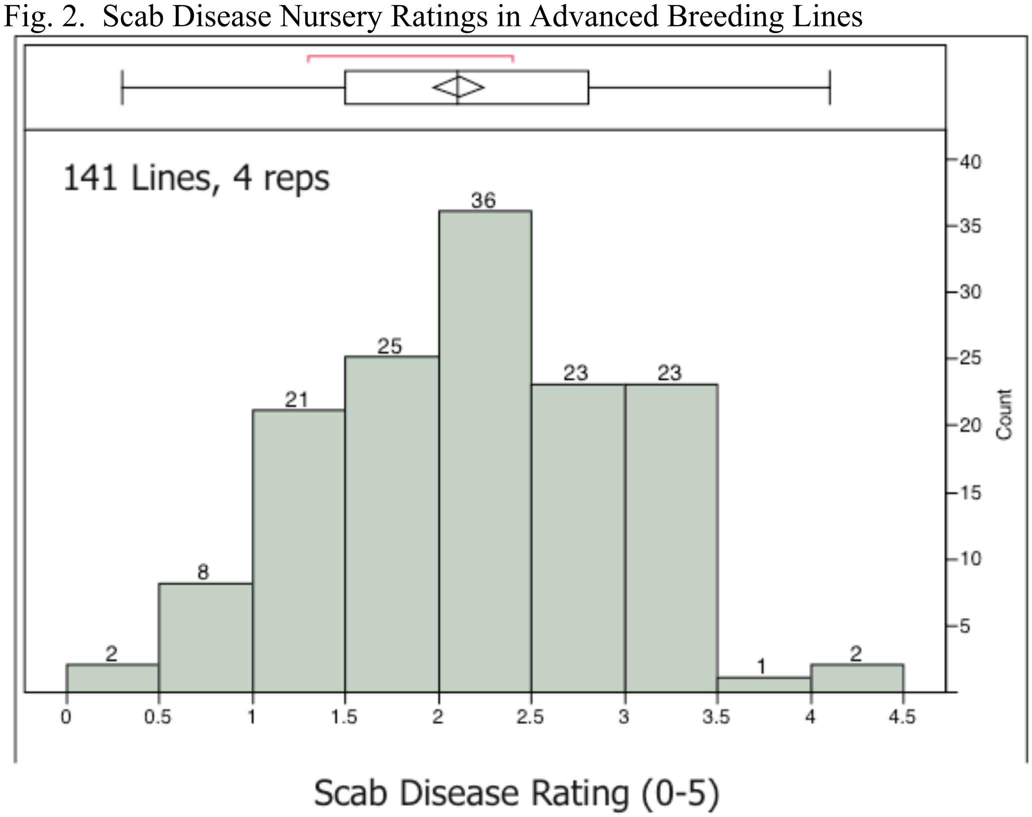


Fig. 2. Scab Disease Nursery Ratings in Advanced Breeding Lines



Based upon this data, scab resistance is increasing in the breeding program. These data were also incorporated into the early generation selection evaluation process at Lake City. We are seeing that this expanded effort is leading to more scab resistant lines advancing through the breeding program. MSU is now being recognized by peer programs for its scab resistant advanced breeding lines.

For two years we collected replicated (4 times) scab infection data from our Montcalm Research Center scab field on 200 progeny from a cross between resistant and susceptible varieties. Of the 200 progeny, about 40% were highly to moderately resistant. Most importantly, we are also using this field data to conduct genome wide QTL analysis with the SolCAP 8300 Potato SNP data in search of genetic markers linked to scab resistance. The data collected from this trial has led us to identify some genetic markers linked to scab resistance that we will test for marker-assisted selection for scab resistance. In 2013 we also made 95 scab-resistant chip-processing selections. The 16 most-promising selections are listed in Table 2.

Table 2. *Streptomyces* Scab Trial Results from On-Farm trial location.

Line	Female	Male	2013 Tuber Appearance	2012 Scab Rating	Field Scab Rating 9/18/13	Washed Scab Rating 9/19/13	2013 SPGR	OTF CHIP 9/19/13	SED 2013
Z052-31	Pike	R127-2	1	1.0	0.5	0.5	1.079	1.0	0.0
Z062-10	R127-2	McBride	2	1.0	0.5	0.5	1.083	1.0	0.0
Z062-15	R127-2	McBride	2	1.0	1.5	1.5	1.078	1.0	1.0
Z062-16	R127-2	McBride	1	1.0	1.0	1.0	1.081	1.5	1.0
Z062-53	R127-2	McBride	2	0.5	0.5	0.5	1.082	1.0	0.0
Z096-3	Boulder	R127-2	2	1.0	1.5	1.0	1.076	1.0	1.0
Z102-5	CO00188-4W	R127-2	1	0.5	1.0	1.0	1.074	1.0	0.0
Z118-8	Kalkaska	Lenape	2	1.0	1.0	1.0	1.084	1.0	0.0
Z118-19	Kalkaska	Lenape	1	0.5	1.0	0.5	1.088	1.0	1.0
Z219-1	R061-1	R127-2	2	0.5	1.5	1.5	1.081	1.5	1.0
Z219-14	R061-1	R127-2	1	0.5	0.5	0.5	1.077	1.5	1.0
Z222-8	R127-2	Tundra	2	1.0	1.0	0.5	1.080	1.0	1.0
Z222-19	R127-2	Tundra	2	1.5	0.5	1.0	1.085	1.0	0.0
Z242-7	R169-8Y	U383-1	1	1.5	1.5	1.5	1.090	1.0	1.0
Z242-9	R169-8Y	U383-1	1	2.0	1.0	0.5	1.090	1.0	0.0
Z242-13	R169-8Y	U383-1	1	1.5	1.5	1.0	1.094	1.0	0.0

Late Blight: Our specific objective is to breed improved cultivars for the industry that have foliar and tuber resistance to late blight using a combination of conventional breeding, marker-assisted strategies and transgenic approaches. Through conventional breeding approaches, the MSU potato breeding and genetics program has developed a series of late blight resistant advanced breeding lines and cultivars that have diverse sources of resistance to late blight. This is a GREEEN-funded project. In 2013 we conducted late blight trials at the Clarksville Research Center. We inoculated with the US22 and US23 genotypes, but the foliar reaction to the *Phytophthora infestans* has been different from all previous years using US8. In some cases lines that were classified as resistant were susceptible. On the other hand, some of the lines with moderate resistance in previous years were highly resistant this past year. In the 2013 trials the infection levels were less than previous year (Figs. 3 and 4). Fourteen sources of resistance can be traced in the pedigrees of these resistant lines. This data infers that we have a broad genetic base to combine resistance genes and also should be able to respond to changes in the pathogen. The distribution of the late blight reaction in the 2013 trials is summarized in Figures 3 and 4. More lines than expected had lower levels of *P. infestans* infection due to the less aggressive strains.

Fig. 3. Foliar Late Blight Reaction in Early Generation Lines

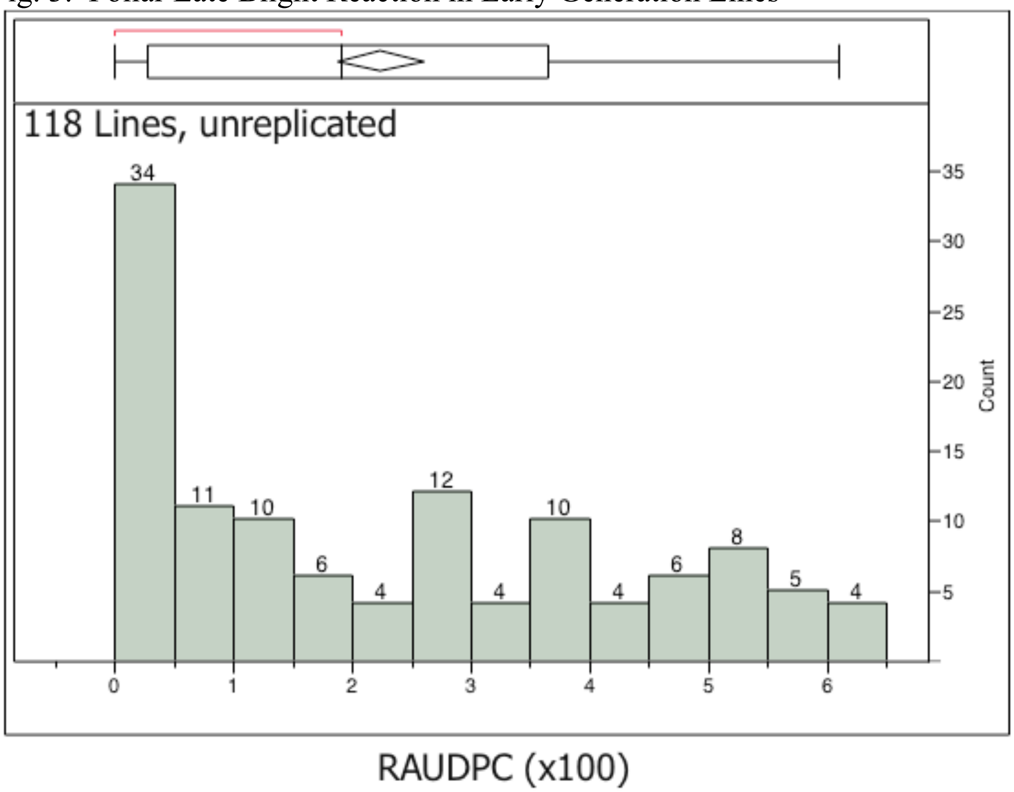
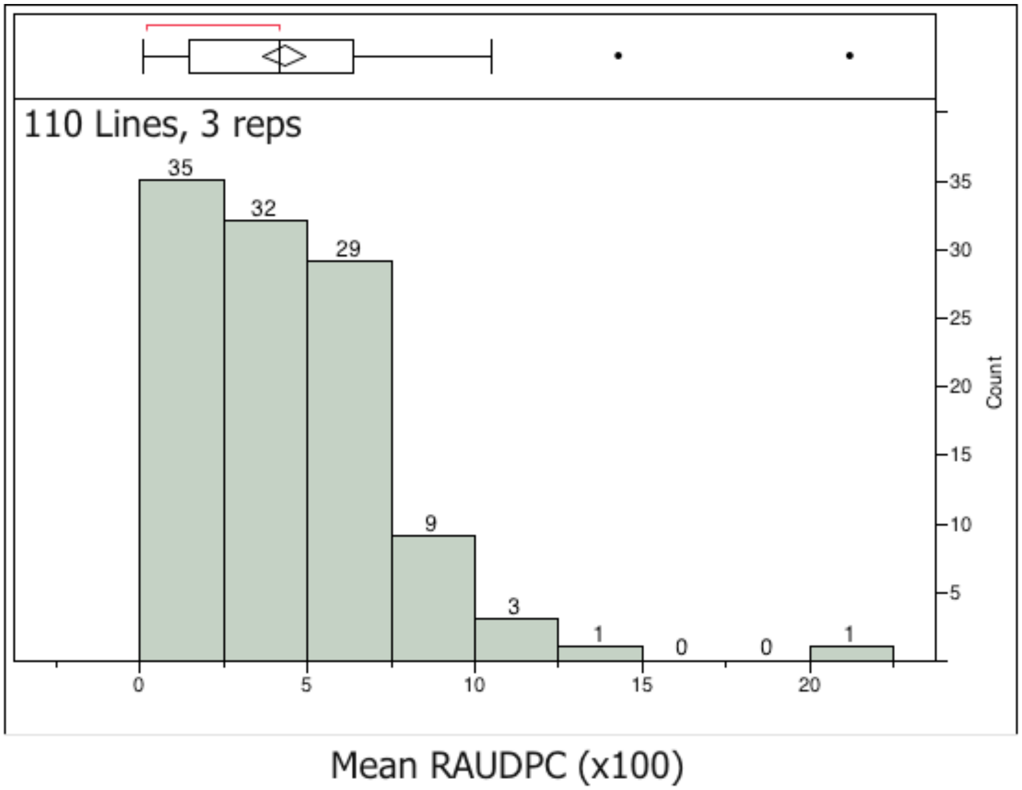


Fig. 4. Foliar Late Blight Reaction in Advanced Breeding Lines



Colorado potato beetle: With support from project GREEEN we evaluated advanced breeding lines from the breeding program for field defoliation by the Colorado potato beetle. Using the Montcalm Research Center beetle nursery, 40 lines with pedigrees of insect resistance germplasm were evaluated in replicated trials. In 2013 the beetle pressure was lower than average. Twenty lines showed significant reduction to defoliation. These lines will be re-evaluated in 2014. We feel after 3 rounds of crossing this tetraploid germplasm we are starting to see some advancement in resistance introgressed from the wild species. However, much value would be gained if we could combine resistance mechanisms. For that reason, we need to identify additional sources of beetle resistance. Combining host plant resistance to insects in a commercially acceptable line is a great challenge. We will be exploring new approaches at the diploid level to select insect resistant germplasm.

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Russet Table Varieties for Michigan

Our breeding strategy has been to make selected crosses that have a high probability of selecting Norkotah types. We grew out large progenies over the past four years to further increase the probability of finding desirable selections. We will continue to use Silverton, Russet Norkotah, MSE192-8RUS, A95109-1RUS, etc. as parents. Single hill selections were made in the past three years. These early generation selections will be evaluated in 2014 as well as a new set of crosses will be evaluated at Lake City.

Sugar Profile Analysis of Early Generation Selections for Extended Storage: Chip-processing Results From the MPIC Demonstration Commercial Storage (October 2012 - June 2013)

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 14 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 MSU breeding program for chip-processing over the whole extended storage season (October-June). Tuber samples of our elite chip-processing selections were placed in the demonstration storage facility in October and were sampled 9 times to determine their ability to chip-process from storage.

In October 2012, tuber samples from 11 MSU lines from the Montcalm Research Center and Lake City Experiment Station trials were placed in the bins along with three check varieties. The first samples were chip-processed in October and then 8 more times until June 2013. Samples were evaluated for chip-processing color and defects. **Table 3** summarizes the chip-processing color and scab rating of 11 lines and three check varieties (FL1879, Pike and Snowden) over the 8-month storage season. Most lines chip-processed well from the storage until April as Snowden color was increasing. Over two thirds of the lines tested chip processed well until June. These lines are highlighted in the last three months of the table. We are also showing that some of the lines with good chip quality also have scab resistance and/or late blight resistance.

Table 3. 2012-2013 Demonstration Storage Chip Results of Elite MSU Breeding Lines

		11/19/12	12/17/12	1/21/13	2/19/13	3/19/13	4/23/13	5/20/13	6/4/13
		SFA Chip Score Rating Scale 1-5							
Line	**Resistance**	52.8F	49.8F	49.6F	49.6F	49.8F	53.8F	52.0F	52.0F
FL1879	**-**	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0
Snowden	**-**	1.0	1.0	1.0	1.0	1.0	2.0	2.5	2.5
Lamoka	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSJ126-9Y	ScabR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSL007-B	ScabR	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5
MSL292-A	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSQ035-3	ScabR	1.5	1.5	2.0	1.0	2.0	2.0	1.5	1.5
MSQ086-3	LBR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSR169-8Y	ScabR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSR061-1	ScabR	1.0	1.0	1.0	1.0	1.0	1.0	1.5	2.5
MSR127-2	ScabMR	1.0	1.0	1.0	1.0	1.0	1.0	ND	2.0
MSS165-2Y	ScabR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
MSR128-4Y	ScabR	1.5	1.0	1.0	1.0	1.0	1.0	2.5	2.0
MSN190-1	ScabR	1.0	1.5	1.0	1.0	1.5	1.5	1.5	1.5

National Coordinated Breeder Trial (NCBT)
2013 was the fourth year of the NCBT. The purpose of the trial is to evaluate early generation breeding lines from the US public breeding programs for their use in chip-processing. The NCBT has 10 sites (North: NY, MI, WI, ND, OR and over 150 lines were tested as 15-hill plots with best performing lines of the previous year being replicated in 2013. The lines were evaluated for tuber type and appearance, yield, specific gravity, chip color and chip defects. Some of the lines are being fast tracked for SFA and commercial trialing. The data is being prepared to be posted on a website database for the public to use. The lines with the best performance will be retested in 2014 and new early generation lines will be added. The MSU lines were more scab resistant than the lines from the programs. Some of the promising lines are MSK061-4, MSM246-B, MSL292-A, MSR061-1, MSL007-B, MSS428-1 and MSR127-2.

NCPT Trial	No. of Entries							
	2010		2011		2012		2013	
	North	South	North	South	North	South	North	South
Tier 1	220	220	167	194	107	139	91	100
Tier 2	N/A	N/A	38	32	60	66	62	66
Total	220	220	205	226	167	205	153	166

MSU Lines with Commercial Tracking

MSJ126-9Y (McBride)

Parentage: Penta x OP
Developers: Michigan State University and the Michigan Agricultural Experiment Station
Plant Variety Protection: To Be Applied For.

Strengths: MSJ126-9Y is a chip-processing potato with an attractive round appearance with shallow eyes. MSJ126-9Y has a medium vine and an early to mid-season maturity. This variety has resistance to *Streptomyces scabies* (common scab) stronger than Pike. MSJ126-9Y also has excellent chip-processing long-term storage characteristics and better tolerance to blackspot bruise than Snowden.

Incentives for production: Excellent chip-processing quality with long-term storage characteristics, common scab resistance superior to Pike, and good tuber type.

MSL292-A (Manistee)

Parentage: Snowden x MSH098-2
Developers: Michigan State University and the Michigan Agricultural Experiment Station
Plant Variety Protection: Will be applied for.

Strengths: MSL292-A is a chip-processing potato with an attractive round appearance with shallow eyes. MSL292-A has a full-sized vine and an early to mid-season maturity. MSL292-A has above average yield potential and specific gravity similar to Snowden. This variety has excellent chip-processing long-term storage characteristics and a similar to better tolerance to blackspot bruise than Snowden.

Incentives for production: Excellent chip-processing quality with long-term storage characteristics, above average yield, specific gravity similar to Snowden, and good tuber type.

MSL007-B

Parentage: MSA105-1 x MSG227-2
Developers: Michigan State University and the Michigan Agricultural Experiment Station
Plant Variety Protection: Will be considered.

Strengths: MSL007-B is a chip-processing potato with an attractive, uniform round appearance with shallow eyes. This variety has resistance to *Streptomyces scabies* (common scab) stronger than Pike, with a strong, netted skin. MSL007-B was the most highly merit rated line in the National Chip Processing Trial across eight locations in 2010.

Incentives for production: **C**hip-processing quality with common scab resistance superior to Pike, and a uniform, round tuber type.

MSR061-1

Parentage: MegaChip x NY121
Developers: Michigan State University and the Michigan Agricultural Experiment Station
Plant Variety Protection: Will be considered.

Strengths: MSR061-1 is a chip-processing potato with resistance to common scab (*Streptomyces scabies*) and moderate foliar late blight (*Phytophthora infestans*) resistance. This variety has medium yield similar to Pike and a 1.079 (average) specific gravity and an attractive, uniform, round appearance. MSR061-1 has a medium vine and an early to mid-season maturity.

Incentives for production: Chip-processing quality with common scab resistance similar to Pike, moderate foliar late blight resistance (US8 genotype), and uniform, round tuber type.

MSR127-2

Parentage: MSJ167-1 x MSG227-2
Developers: Michigan State University and the MSU AgBioResearch.
Plant Variety Protection: To Be Applied For.

Strengths: MSR127-2 is a chip-processing potato with resistance to common scab (*Streptomyces scabies*). This variety yields greater than Atlantic and Snowden, has a 1.086 (average) specific gravity, and an attractive, uniform, round appearance. MSR127-2 has a strong vine and a full-season maturity, and has demonstrated excellent long-term storage chip-processing quality.

Incentives for production: Long-term chip-processing quality with common scab resistance similar to Pike, and uniform, round tuber type.

II. Germplasm Enhancement

In 2010 we developed genetic mapping populations (both at diploid and tetraploid levels) for late blight resistance, beetle resistance, scab resistance and also for tuber quality traits. We have started to characterize these populations in 2011 and conduct the linkage analysis studies using the SNP genotyping. The mapping populations have been a major research focus for us over the previous three years as we try to correlate the field data with the genetic markers. The diploid genetic material 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. We have used lines with Verticillium wilt resistance, PVY resistance, and cold chip-processing. We are monitoring the introgression of this germplasm through marker assisted selection. Through GREEEN funding, we were able to continue a breeding effort to introgress leptine-based insect resistance using new material selected from USDA/ARS material developed in Wisconsin. We will continue conducting extensive field screening for resistance to Colorado potato beetle at the Montcalm Research Farm. We made crosses with late blight resistant diploid lines derived from *Solanum microdontum* to our tetraploid lines. We have conducted lab-based detached leaf bioassays and have identified resistant lines. These lines are being used crosses to further transmit resistance. We are also using some inbred lines of *S. chacoense* that have fertility and vigor to initiate our efforts to develop inbred lines with our own diploid germplasm. We have over 40 populations to make selections and we selected Atlantic haploids to cross to this material so we can develop chip-processing diploid lines.

III. Integration of Genetic Engineering with Potato Breeding

PVY resistance to three PVY strains (O, N and NTN) of the MSE149-5Y, Classic Russet, Silverton Russet and Russet Norkotah lines were evaluated by Jonathan Whitworth over the past three years. A number of lines with PVY resistance were identified. These lines have been increased for seed production so that field studies can be conducted in 2013. In an inoculated field test in Idaho these lines were resistant to PVY. We identified a number of Silverton Russet lines with increased PVY resistance but none with complete resistance to all three PVY strains. Regarding late blight resistance, we have many lines with the RB gene for late blight resistance transformed into MSU lines. In many cases the transformed parent line is a late blight resistance source. The addition of the RB gene allows us to test the effect of multiple resistance genes on the durability of resistance. We have also generated over 70 lines with the gene for nitrogen use efficiency and water use efficiency. Field trials are planned for a subset of these lines in 2014. Lastly, we have some lines with the vacuolar acid invertase silencing that will be field tested in 2014.

Funding: Fed. Grant/MPIC

2013 POTATO VARIETY EVALUATIONS

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INTRODUCTION

Each year, the MSU potato breeding and genetics team conducts a series of variety trials to assess advanced potato selections from the Michigan State University and other potato breeding programs at the Montcalm Research Center (MRC). In 2013, we tested over 100 varieties and breeding lines in the replicated variety trials, plus single observational plots of over 120 lines and 40 replicated lines in the National Chip Processing Trial. The variety evaluation also includes disease testing in the scab nursery (Montcalm Research Center) and foliar and tuber late blight evaluation (Clarksville Research Center). The objectives of the evaluations are to identify superior varieties for fresh or chip-processing markets. The varieties were compared in groups according to market class, tuber type, 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 the field, 45°F (7.2°C) and 50°F (10°C) storage), as well as susceptibilities to common scab, late blight (foliar and tuber), and blackspot bruising are determined.

We would like to acknowledge the collaborative effort of Bruce Sackett, Chris Long and the Potato Breeding Team (especially N. Garrity, A. Harrison, M. Alhashany, S. Mambetova, A. Sardarbekova) for getting the research done.

PROCEDURE

The field variety trials were conducted at the Montcalm Research Center in Entrican, MI. They were planted as randomized complete block designs with two to four replications. The plots were 23 feet (7 m) long and spacing between plants was 10 inches (25.4 cm). Inter-row spacing was 34 inches (86.4 cm). Supplemental irrigation was applied as needed. Nutrient, weed, disease and insect management were similar to recommendations used by the commercial operations. The field experiments were conducted on a sandy loam soil on the Comden ground that was in corn the previous 3 years and in potatoes four years previously.

The most advanced selections were tested in the Advanced trial, representing selections at a stage after the Adaptation Trial. The other field trials were the North

Central, Russet, Adaptation (chip-processors and tablestock), Preliminary (chip-processors and tablestock), the NCPT and the early observational trials. This year, the Advanced and Adaptation chip-processing trials were combined as a single trial. *The early observational trial is discussed in the breeding report.*

2013 was the fourth year of the National Chip Processing Trial (NCPT). The purpose of the trial is to evaluate early generation breeding lines from the US public breeding programs for their use in chip-processing. The NCPT has 10 sites (North: NY, MI, WI, ND, OR and South: NC, FL, MO, CA, TX) in addition to a scab trial in MN.

In each of these trials, the yield was graded into four size classes, incidence of external and internal defects in >3.25 in. (8.25 cm) diameter (or 10 oz. (283.5 g) for Russet types) potatoes were recorded. Samples were taken for specific gravity, chipping, disease tests and bruising tests. Chip quality was assessed on 25-tuber composite sample from four replications, taking two slices from each tuber. Chips were fried at 365°F (185°C). The chip color was measured visually with the SFA 1-5 color chart. Tuber samples were also stored at 45°F (7.2°C) and 50°F (10°C) for chip-processing out of storage in January and March. Advanced selections are also placed in the MPIC B.F. Burt Cargill Commercial Demonstration Storage in Entrican, MI for monthly sampling. The lines in the agronomic trials were assessed for common scab resistance at the nursery at the Montcalm Research Farm. There has been very strong scab disease pressure at the new Montcalm Scab Disease Nursery for four years now. The 2013 late blight trial was again conducted at the Clarksville Research Center. Maturity ratings (1 early - 5 late) were taken for all variety trial plots in late August to differentiate early and late maturing lines. The simulated blackspot bruise results for average spots per tuber have also been incorporated into the summary sheets.

RESULTS

A. Advanced and Chip-Processing Trial (Table 1)

The Advanced Trial and the Adaptation Chip-Processing Trial were combined in 2013. A summary of the 16 entries evaluated in the trial results is given in **Table 1**. Overall, the yields for the Advanced trial (139 days) were above average, however the Snowden and Atlantic yield was below average. The check varieties for this trial were Snowden, Atlantic, and FL1879. The highest yielding lines were MSP497-1, NY140, Lamoka, NY148 and MSR127-2. Vascular discoloration was the predominant internal defect. Specific gravity was high with all lines above 1.080. All chip-processing entries in the trial had excellent chip-processing quality out of the field, with an SFA score of 1.0 or 1.5. Many of the MSU breeding lines have moderate to strong scab resistance, including: MSL007-B, MSR127-2, MSR057-4, MSSS297-1 and Lamoka. MSP497-1 and MSQ494-2 showed resistance to late blight at the CRC trials. The promising chip-processing lines are Manistee (MSL292-A) (chip quality, high yield, good specific gravity, and shows potential as a long-term storage chipper), MSM246-B (good yield, chip quality and shows potential as a long-term storage chipper) and MSR127-2 (strong yield, high specific gravity, scab resistance, and good chip quality).

B. North Central Regional Trial Entries (Table 2)

The North Central Trial is conducted in a wide range of environments (6 regional locations) to provide adaptability data for the release of new varieties from Michigan, Minnesota, North Dakota, Wisconsin, and Canada. Twenty four entries were tested in Michigan in 2013. The results are presented in **Table 2**. The best performing line in the trial was MSS576-5SPL. It is high yielding with round white-fleshed tubers that have a splash of red pigment on the tuber skin. There are some promising red-skinned entries from Wisconsin, Minnesota, and North Dakota. W5955-1 was the only line classified as scab resistant and no lines were late blight resistant. W5015-5 was highly susceptible to blackspot bruising.

C. Russet Trial (Table 3)

We continue to increase our russet breeding efforts to reflect the growing interest in russet types in Michigan. In 2013, 29 lines were evaluated after 127 days. The results are summarized in **Table 3**. Russet Burbank, Russet Norkotah and Silverton Russet were the reference varieties used in the trial. In general, the yields were high for many russet lines while Russet Burbank and Russet Norkotah had low yields. The highest yielding lines were AF3362-1Rus, Silverton Russet, W6234-4Rus which were also high yielding in 2012. There was a moderate incidence of hollow heart with CO05175-1Rus and CO5068-1Rus having the highest incidence and a moderate level of vascular discoloration in the internal quality across most lines. Specific gravity measurements were high to above average to below average with Russet Norkotah at 1.079. In 2012 the reading was 1.065. Quite a difference in the years! Off type and cull tubers were found in nearly all lines tested, with the highest being Russet Burbank (22%) and A02507-2LB (18%). Scab resistance was common among the lines but high susceptibility was in a few lines. No late blight resistance was observed in the lines at the CRC trial.

D. Adaptation Trials (Table 4)

This year the Adaptation Trial for chip-processing lines was combined with the Advanced Trial (Table 1). The Adaptation Trial of the tablestock lines was harvested after 128 days and the results are summarized in **Table 4**. The majority of the lines evaluated in the Adaptation Trial were tested in the Preliminary Trial the previous year. Two reference cultivars (Reba and Red Norland) and 24 advanced breeding lines are reported in the tablestock trial. In general, the yields were above average and internal defects were low, but some lines had below average yields and three lines were noted for IBS (MSS176-1, MSS070-B and MSQ130-4). The highest yielding lines were MSS176-1, MSR216-AP, MSQ086-3, MSS206-2, MSS576-05SPL, MSQ176-5, MSS483-1 and MSS487-2. MSQ086-3 is also verticillium resistant in Wisconsin field experiments. The promising and attractive yellow-fleshed table selection is MSM288-2Y. MSL211-3 is round-oval white with bright skin, early maturity, and excellent internal quality. MSQ176-5 is uniformly round, bright white skinned potato and has demonstrated late blight resistance to both US-8 and US-22. Other late blight resistant lines are MSS176-1, MSS070-B, MSS206-2, MSS483-1, MSL211-3 and MSS487-2. Besides MSQ440-2 there was little scab resistance observed in these lines tested. We continue to evaluate breeding lines with specialty market potential (purple skin such as MSR216-AP; splashes of color such MSS576-05SPL, MP Sport 1 and Spartan Splash).

E. Preliminary Trials (Tables 5 and 6)

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 pedigree assessment for chip-processing and tablestock utilization. The chip-processing Preliminary Trial (**Table 5**) had 14 entries because many lines were tracked to the NCPT. The chip-processing trial was harvested after 132 days. Most lines chip-processed well from the field. Specific gravity values were above average with Atlantic at 1.095 and Snowden at 1.091. All selections had 1.079 or higher specific gravity reading except one line. Internal quality was good across all the lines in the trial. Promising MSU lines are MSV093-1, MST359-3, MST424-6, MSW509-5, QSMSU01-10 and MSS934-4 combining yield, specific gravity, and chip quality. We continue to make progress selecting chip-processing with scab resistance and late blight resistance.

Table 6 summarizes 23 tablestock entries evaluated in the Preliminary Trial (Onaway, Yukon Gold and Reba were the check varieties). This tablestock trial was harvested and evaluated after 127 days. MST500-1, MSV179-2, MSW128-2 QSMSU08-04, QSMSU10-09, MST065-1 and MSQ131-A were the highest yielding lines. This trial also had a low incidence of internal defects. The number of tablestock selections with scab resistance (5) and late blight resistance (5) continue to increase.

F. Potato Common Scab Evaluation (Tables 7 and 8)

Each year, a replicated field trial is conducted to assess resistance to common scab. We have moved the scab testing to two ranges at the Montcalm Research Center where high common scab disease pressure was observed in previous years. This location is being used for the early generation observational scab trial (336 lines), the scab variety trial (141 lines), the scab trial of a tetraploid mapping population (>200 progeny) and the national scab trial sponsored by USDA/ARS.

We use a rating scale of 0-5 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. The 2011-2013 scab ratings are based upon the Montcalm Research Center site. **Table 7** categorizes many of the varieties and advanced selections tested in 2013 over a three-year period. The varieties and breeding lines are placed into six categories based upon scab infection level and lesion severity. A rating of 0 indicates zero scab infection. A score of 1.0 indicates a trace amount of infection. A moderate resistance (1.2 – 1.5) 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, GoldRush, Red Norland, Red Pontiac, Yukon Gold, Onaway, Pike, Atlantic, and Snowden can be used as references (bolded in **Table 7**). The table is sorted in ascending order by 2013 scab rating. This year's results continue to indicate that we have been able to breed numerous lines with resistance to scab. A total of 36 lines, of the 141 tested, had a scab rating of 1.5 or lower in 2013. Most notable scab resistant MSU lines are McBride, MSL007-B,, MSP270-1, MSQ440-2, MSQ279-1, MSR061-1, MSR127-2 and MSR169-8Y; as well as some earlier generation lines MSS297-3, MSV179-1, QSMSU10-09, MST424-6, MST252-1Y, and MSV093-1. 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. There are also an increasing number of scab resistant lines that also have late blight resistance and PVY resistance. We also continue to conduct early generation scab screening on selections in the breeding program beginning after two years of selection. Of the 336 early generation selections that were evaluated, over 131 had scab resistance (scab rating of ≤ 1.5). Scab results from the disease nursery for the advanced selections are also found in the Trial Summaries (**Tables 1-6**).

H. Late Blight Trial (Tables 9, 10 and 11)

In 2013, the late blight trial was planted again at the Clarksville Research Center rather than the Muck Soils Research Farm. The Muck Soils Research Farm is now closed. Over 250 entries were planted in early June for late blight evaluation. These include lines tested in a replicated manner from the agronomic variety trial (118 lines) and entries in the National Late Blight Variety Trial (37 lines) and about 110 entries in the early generation observation plots. The trials were inoculated in early August with a mixture of US-22 and US-23 genotypes of *P. infestans*. Late blight infection was identified in the plots within 2 weeks after inoculation. The plots were evaluated 1-2 times per week over a 50-day period following inoculation. Like 2012, the disease reaction in the plots was not as aggressive as previous years when US-8 was predominant. In 2013, there were 3 lines from the national late blight trial that had strong late blight resistance to the isolates. For the replicated variety trial 23 lines had strong late blight resistance, while 55 lines in the early generation observation plots had strong late blight resistance. These were from various late blight resistance sources in the pedigree of the selections (LBR9, Malinche, Kenya Baraka, Monserrat, Torridon, Stirling, NY121, B0718-3, etc.). **Tables 9, 10 and 11** list the foliar late blight disease ratings for select lines based on percent disease over time (RAUDPC; Relative Area Under the Disease Progress Curve). Please note that because of the lower level of infection, our cutoff for resistance was a very low RAUDPC score so we did not include false positives.

I. Blackspot Bruise Susceptibility (Table 12)

Evaluations of advanced seedlings and new varieties for their susceptibility to blackspot bruising are also important in the variety evaluation program. Based upon the results collected over the past years, the non-bruised check sample has been removed from our bruise assessment. A composite bruise sample of each line in the trials consisted of 25 tubers (a composite of 4 replications) from each line, collected at the time of grading. The 25 tuber sample was held in 50°F (10°C) 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.

In 2013, the bruise levels were comparable to previous years. The most bruise resistant MSU breeding lines this year from the trials were McBride (MSJ126-9Y), Manistee (MSL292-A), MSM288-2Y, MSQ440-2, MSQ089-1, MSS576-05SPL, MSS176-1, MSS927-1, MSQ131-A, MSV111-2, MSW125-3, MSW151-9, MSR061-1 and MSV093-1. The most susceptible lines from the Advanced trial were MSM246-B, W5015-5, Atlantic, MST020-2Y, MSR216-AP.

Table 1

ADVANCED and CHIP-PROCESSING TRIAL
MONTCALM RESEARCH FARM
May 07 to September 23, 2013 (139 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	OTF SED[3]	PERCENT (%) TUBER QUALITY[4] HH	VD	IBS	BC	SCAB[5]	MAT[6]	BRUISE[7]	LB[8]	LB RAUDPC x100	3-YR AVG US#1 CWT/A
MSP497-1	412	448	92	8	89	3	0	1.081	NA	NA	20	5	0	0	3.3	3.0	1.2	LBR	0.3	-
NY148	395	468	85	15	82	3	0	1.103	1.5	1.0	0	0	0	0	2.1	3.5	2.7	LBMR	-	378
NY140	395	464	85	15	85	0	0	1.087	1.5	2.0	0	18	3	0	3.0	3.0	1.6	LBMR	1.5	380
MSR127-2	389	438	89	9	81	8	2	1.095	1.0	1.0	3	8	0	0	1.0	3.3	2.6	LBS	-	349
Lamoka	317	353	90	10	87	3	0	1.093	1.0	1.0	0	8	0	0	1.5	2.5	1.7	LBS	6.4	225
FL1879	**312**	**339**	**92**	**8**	**89**	**3**	**0**	**1.087**	**1.0**	**1.0**	**20**	**28**	**0**	**0**	**-**	**2.0**	**1.5**	**LBS**	**6.7**	**313**
MSM246-B	304	329	92	8	83	10	0	1.097	1.0	1.0	3	8	0	0	3.3	3.0	3.1	LBS	-	-
MSQ492-2	298	399	74	26	74	0	0	1.088	1.5	2.0	0	18	5	0	2.4	3.5	1.8	LBR	0.2	301*
MSL007-B	297	371	80	20	79	1	0	1.093	1.0	2.0	5	3	0	0	1.5	3.0	2.3	LBS	-	292
Atlantic	**289**	**343**	**84**	**16**	**83**	**1**	**0**	**1.101**	**1.0**	**2.0**	**5**	**5**	**3**	**0**	**3.2**	**2.0**	**2.8**	**LBS**	**7.2**	**286**
MSR057-4	288	325	88	11	82	7	1	1.082	1.0	2.0	0	23	0	0	1.3	3.3	1.1	LBS	6.1	-
Manistee (MSL292-A)	260	349	74	26	74	0	0	1.094	1.0	1.0	0	10	0	0	3.3	1.8	1.0	LBS	-	293
Snowden	**254**	**360**	**70**	**30**	**70**	**0**	**0**	**1.094**	**1.0**	**1.0**	**0**	**15**	**0**	**0**	**3.1**	**2.8**	**1.7**	**LBS**	**3.6**	**250**
MSN190-2	253	362	70	30	69	1	0	1.103	1.0	1.0	10	5	3	0	2.0	1.5	1.1	LBS	-	265
MSS297-3	230	300	77	23	77	0	0	1.093	1.0	1.0	0	3	0	0	1.1	2.0	1.6	LBS	10.0	246
MSR061-1	217	351	62	38	62	0	0	1.091	1.0	1.0	0	40	0	0	2.0	2.3	1.4	LBMR	-	211
MEAN	307	375						1.093							2.3	2.6	1.8		4.7	291
$HSD_{0.05}$	91	86						0.004							1.5	1.4	-		9.4	

* Two-Year Average

[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]SED: Stem End Defect, Based on Paul Bethke's (USDA/UWisconsin - Madison) 0 - 5 scale. 0 = no SED; 3 = significant SED; 5 = severe SED
[4]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[5]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[6]MATURITY RATING: August 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).
[7]BRUISE: Simulated blackspot bruise test average number of spots per tuber.
[8]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

Table 2

NORTH CENTRAL REGIONAL TRIAL
MONTCALM RESEARCH FARM
May 7 to September 12, 2013 (128 days)

LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[2]	OTF SED[3]	PERCENT (%) TUBER QUALITY[4] HH	VD	IBS	BC	SCAB[5]	MAT[6]	BRUISE[7]	LB[8]	LB RAUDPC x100	3-YR AVG US#1 CWT/A
Red Pontiac	**490**	**547**	**90**	**6**	**82**	**8**	**5**	**1.067**	**3.0**	**3.0**	**33**	**8**	**0**	**0**	**4.0**	**3.0**	**0.5**	**LBS**	**3.4**	**342**
MSS576-5SPL	433	471	92	8	85	7	0	1.080	1.0	0.0	0	0	0	0	2.2	3.0	1.0	LBMS	2.6	404*
ND7132-1R	411	461	89	10	89	0	0	1.073	1.5	3.0	0	0	0	0	2.8	3.0	1.1	LBS	10.5	-
W8405-1R	406	488	83	16	81	2	0	1.070	2.5	2.0	0	0	0	0	1.9	2.8	1.1	LBS	6.5	369*
MN10020PLWR-08R	404	448	90	7	85	5	3	1.068	2.0	2.0	0	10	0	0	3.3	2.0	0.5	LBS	5.8	-
W6002-1R	382	439	87	13	82	5	0	1.064	3.5	4.0	0	0	0	0	2.1	2.0	0.3	LBS	6.6	273
W5015-5	381	457	83	17	83	0	0	1.095	1.0	0.0	0	0	20	0	1.9	3.3	3.8	LBMS	1.6	-
MSQ089-1	369	419	88	12	87	1	0	1.083	1.0	0.0	0	3	0	0	2.5	3.0	0.8	LBR	0.3	350
W5955-1	357	412	86	13	80	6	0	1.093	1.0	0.0	15	0	0	0	1.5	3.0	0.6	LBS	5.5	-
Atlantic	**355**	**408**	**87**	**13**	**87**	**0**	**0**	**1.095**	**1.5**	**0.0**	**5**	**0**	**0**	**3**	**3.2**	**2.8**	**1.9**	**LBS**	**7.2**	**304**
Snowden	**344**	**398**	**86**	**14**	**82**	**4**	**0**	**1.089**	**1.0**	**0.0**	**8**	**3**	**0**	**0**	**3.1**	**3.3**	**1.6**	**LBS**	**3.6**	**315**
ND6002-1R	338	373	91	9	90	0	0	1.068	2.5	2.0	3	0	0	0	2.1	2.7	0.6	LBS	8.1	-
Elkton	322	371	87	13	81	6	0	1.088	1.0	0.0	18	0	3	0	1.6	3.0	1.7	LBS	4.2	-
MSS165-2Y	299	446	67	33	66	1	0	1.094	1.5	0.0	0	3	0	0	1.9	3.3	2.0	LBMS	3.8	306
NY 153	294	353	83	16	82	1	1	1.095	1.0	0.0	13	0	0	0	2.1	3.3	1.6	LBS	6.7	-
ND7799c-1	287	347	83	17	82	1	0	1.079	1.0	0.0	0	3	0	0	1.9	2.3	0.1	LBS	6.1	-
Red Norland	**281**	**353**	**79**	**20**	**79**	**0**	**0**	**1.064**	**2.5**	**2.0**	**3**	**3**	**0**	**0**	**2.0**	**1.3**	**0.6**	**LBS**	**7.4**	**255**
McBride (MSJ126-9Y)	276	343	80	20	80	0	0	1.086	1.0	0.0	0	0	0	0	0.8	2.8	0.4	LBS	6.5	240
NorValley	**272**	**381**	**71**	**22**	**71**	**0**	**6**	**1.080**	**1.0**	**0.0**	**0**	**0**	**0**	**0**	**3.1**	**2.8**	**1.1**	**LBS**	**6.2**	**288**
MN10001PLWR-01R	222	294	76	23	76	0	1	1.069	2.5	2.0	0	0	0	0	2.8	1.0	0.4	LBS	7.7	-
MN10003PLWR-03R	202	327	60	38	60	0	1	1.057	2.5	3.0	0	0	0	0	3.3	1.0	0.1	-	-	-
ND7982-1R	192	378	50	50	50	0	0	1.076	1.5	2.0	0	0	0	0	2.3	1.7	0.5	LBS	9.7	-
MN10003PLWR-07R	161	286	56	43	56	0	1	1.064	2.0	4.0	0	0	0	0	3.5	1.5	0.4	-	-	-
MN10013PLWR-04	74	219	33	67	33	0	0	1.077	1.5	0.0	13	3	0	0	3.4	1.0	0.6	LBS	14.3	-
MEAN	315	392						1.078	1.7						2.5	2.4	1.0		6.1	297
$HSD_{0.05}$	126	124						0.006							1.5	1.3	-		9.4	

* Two-Year Average

[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]SED: Stem End Defect, Based on Paul Bethke's (USDA/UWisconsin - Madison) 0 - 5 scale. 0 = no SED; 3 = significant SED; 5 = severe SED
[4]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[5]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[6]MATURITY RATING: August 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).
[7]BRUISE: Simulated blackspot bruise test average number of spots per tuber.
[8]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

Table 3

RUSSET TRIAL
MONTCALM RESEARCH FARM
May 7 to September 11, 2013 (127 days)

	CWT/A		PERCENT OF TOTAL[1]						PERCENT (%) TUBER QUALITY[2]								LB RAUDPC	3-YR AVG US#1
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	HH	VD	IBS	BC	SCAB[3]	MAT[4]	BRUISE[5]	LB[6]	x100	CWT/A
AF3362-1Rus	445	479	93	6	72	21	1	1.086	0	35	3	0	-	3.8	1.2	-	-	345
Silverton Russet	**441**	**489**	**90**	**9**	**73**	**17**	**1**	**1.080**	**20**	**5**	**0**	**0**	**1.1**	**3.5**	**1.4**	**LBS**	**4.9**	**328**
W6234-4Rus	415	491	84	11	77	7	5	1.085	3	23	0	0	2.9	3.0	0.4	LBS	3.5	369*
A03158-2TERus	388	476	82	16	71	10	3	1.088	13	5	0	0	0.6	3.3	1.8	LBS	4.2	-
A02062-1TERus	378	458	82	9	64	18	9	1.081	0	17	0	0	0.3	3.0	0.3	LBS	5.8	285
A07103-1T	369	461	80	20	78	2	0	1.099	15	0	0	0	2.1	3.0	0.2	LBS	3.6	-
A01010-1	346	446	77	20	73	4	3	1.089	0	13	0	0	1.8	3.5	0.8	LBS	5.4	-
CO05175-1Rus	342	434	79	11	65	14	10	1.082	40	15	0	0	1.1	3.3	1.8	LBMS	2.6	-
CO05068-1Rus	324	408	79	15	68	12	5	1.097	50	0	0	0	1.3	4.0	2.7	LBMS	2.4	-
A0701012-4BF	303	437	69	31	66	3	0	1.100	30	25	0	0	2.6	4.0	2.2	LBS	4.9	-
W8152-1Rus	286	375	76	21	74	2	2	1.094	23	0	0	0	2.1	3.3	0.8	LBS	3.4	-
A02507-2LB	284	389	73	9	59	14	18	1.090	8	15	0	0	1.0	4.0	1.6	LBMS	2.5	-
CO05110-6Rus	273	347	79	18	74	5	3	1.088	5	3	0	0	2.0	2.5	3.0	LBS	8.6	-
CO05132-2Rus	270	328	82	13	65	17	4	1.081	18	8	23	0	0.5	2.5	0.7	LBS	21.2	-
CO05024-11Rus	265	378	70	29	69	1	1	1.084	0	20	0	0	0.5	2.0	1.6	LBMS	3.2	-
W9133-1Rus	262	328	80	19	71	9	1	1.074	0	3	0	0	2.0	1.5	0.9	LBS	6.2	-
CO05152-5Rus	246	397	61	36	58	3	4	1.086	3	18	0	0	0.4	3.0	1.0	LBS	4.7	-
CO05189-3Rus	242	283	86	14	70	16	0	1.076	0	13	0	0	1.8	1.3	1.9	LBS	5.4	-
CO04233-1Rus	239	298	80	19	73	6	2	1.075	10	15	0	0	0.5	1.0	0.5	LBS	6.5	198*
AF4445-3Rus	222	276	80	14	73	6	6	1.075	0	23	0	0	-	2.0	1.0	-	-	-
CO04220-7Rus	220	310	70	27	64	6	3	1.072	30	25	0	0	1.5	1.0	0.9	LBS	6.5	178*
CO05149-3Rus	218	329	62	34	56	5	4	1.085	18	5	0	0	2.0	2.0	1.0	LBS	8.2	-
A99029-3E	214	307	69	31	65	4	1	1.080	0	15	0	0	1.8	2.5	0.2	LBMS	3.9	-
CO05189-2Rus	201	347	57	40	54	4	2	1.078	0	8	0	0	4.1	1.3	0.3	LBS	8.3	-
AF4532-8Rus	175	235	76	23	71	5	1	1.074	30	20	0	0	-	1.5	1.0	-	-	-
Russet Norkotah	**174**	**303**	**57**	**42**	**57**	**0**	**1**	**1.079**	**5**	**17**	**0**	**0**	**2.5**	**2.0**	**0.1**	**LBS**	**7.0**	**195**
Russet Burbank	**160**	**324**	**49**	**29**	**47**	**2**	**22**	**1.078**	**15**	**8**	**0**	**0**	**1.3**	**3.0**	**0.9**	**LBS**	**4.9**	**121**
A07008-4T	149	310	48	50	48	0	2	1.097	0	20	0	0	2.9	3.0	1.6	LBS	4.3	-
CO05040-1Rus	80	288	28	58	28	0	15	1.075	0	10	0	0	0.6	3.0	1.6	LBS	6.1	-
MEAN	274	370						1.084					1.6	2.6	1.2		5.7	255
$HSD_{0.05}$	166	176						0.012					1.5	2.4	-		9.4	

* Two-Year Average

[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 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).
[5]BRUISE: Simulated blackspot bruise test average number of spots per tuber.
[6]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

ADAPTATION TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH FARM
May 7 to September 12, 2013 (128 days)

	CWT/A		PERCENT OF TOTAL[1]						CHIP	OTF	PERCENT (%) TUBER QUALITY[4]								LB RAUDPC
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[2]	SED[3]	HH	VD	IBS	BC	SCAB[5]	MAT[6]	BRUISE[7]	LB[8]	x100
MSS176-1	597	621	96	4	79	17	0	1.087	1.5	3.0	28	3	25	3	1.8	4.0	0.6	LBR	0.4
CV00088-3	490	528	93	7	88	4	0	1.072	-	-	3	0	0	0	2.9	2.3	0.4	LBS	5.1
MSR216-AP	484	527	92	8	91	1	0	1.080	-	-	0	0	0	0	2.8	3.3	4.0	LBS	3.9
MSQ086-3	482	558	86	14	85	1	0	1.085	1.0	0.0	0	3	0	0	2.4	4.0	1.4	LBS	4.9
MSS070-B	479	506	95	4	84	11	2	1.088	1.0	4.0	0	11	19	0	2.9	3.5	1.2	LBR	0.3
MSS206-2	457	471	97	3	70	27	0	1.075	1.5	2.0	0	8	0	0	2.3	3.8	1.2	LBR	1.1
MSR214-2P	441	482	92	7	88	4	1	1.072	-	-	3	0	0	0	2.3	4.0	1.2	LBS	3.9
MSR186-3P	431	469	92	7	85	6	2	1.076	-	-	0	5	0	0	2.0	3.3	1.9	LBS	2.7
MSS576-5SPL	425	454	93	6	85	8	0	1.081	-	-	5	5	0	0	2.2	3.0	1.1	LBMS	2.6
MSQ176-5	407	441	92	8	81	11	0	1.070	-	-	8	0	0	3	3.0	2.8	1.1	LBR	0.2
MSS483-1	404	483	84	16	83	0	0	1.081	3.0	2.0	5	0	0	0	3.0	2.8	3.2	LBR	0.3
MSS487-2	391	437	89	10	87	2	0	1.086	2.5	3.0	0	0	0	0	2.3	3.5	2.8	LBR	0.2
Michigan Purple Sport I	387	430	89	6	84	6	5	1.075	-	-	0	10	0	0	2.6	1.8	0.9	LBS	-
Michigan Purple	357	402	89	8	85	4	3	1.075	-	-	3	10	0	0	2.8	1.8	1.2	LBS	-
Reba	**352**	**373**	**95**	**5**	**87**	**8**	**0**	**1.078**	**1.5**	**0.0**	**13**	**5**	**0**	**0**	**2.6**	**2.5**	**1.8**	**LBS**	**-**
MSM288-2Y	347	442	78	22	77	1	0	1.083	-	-	0	0	0	0	3.1	1.8	0.2	LBS	-
MSR226-ARR	319	399	80	20	76	3	0	1.076	1.5	3.0	0	0	0	0	1.9	3.0	1.2	-	-
MSS927-1	291	358	81	19	80	1	0	1.086	1.0	0.0	0	0	0	0	2.1	2.3	0.7	LBS	5.4
Red Norland	**289**	**365**	**79**	**20**	**78**	**0**	**1**	**1.063**	**-**	**-**	**0**	**8**	**0**	**0**	**2.0**	**1.0**	**0.5**	**LBS**	**7.4**
MSL211-3	284	339	83	16	78	5	0	1.074	-	-	3	10	3	0	2.3	1.3	1.2	LBR	0.2
MSQ130-4	264	311	85	15	77	8	0	1.082	1.0	0.0	20	0	35	0	2.0	3.0	1.3	LBR	0.7
Spartan Splash	260	370	70	30	70	0	0	1.083	-	-	15	0	8	0	2.4	2.3	1.2	-	-
MSQ440-2	255	284	89	11	86	3	0	1.058	-	-	0	0	0	0	1.0	2.5	0.6	LBR	0.1
MSR128-4Y	246	310	79	20	79	0	1	1.093	1.0	0.0	0	0	0	0	1.4	3.8	1.8	LBS	4.3
MSR157-1Y	234	304	77	23	77	0	0	1.085	1.0	0.0	5	5	0	0	1.3	2.8	1.6	LBS	3.8
CV02321-1	219	289	76	24	76	0	0	1.077	1.0	0.0	3	5	3	0	3.0	2.0	0.9	LBS	7.8
MEAN	369	421						1.078							2.3	2.8	1.4		2.8
$HSD_{0.05}$	133	123						0.009							1.5	1.5	-		9.4

[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]SED: Stem End Defect, Based on Paul Bethke's (USDA/UWisconsin - Madison) 0 - 5 scale. 0 = no SED; 3 = significant SED; 5 = severe SED

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

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

[6]MATURITY RATING: August 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).

[7]BRUISE: Simulated blackspot bruise test average number of spots per tuber.

[8]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

Table 5

PRELIMINARY TRIAL, CHIP-PROCESSING LINES
MONTCALM RESEARCH FARM
May 8 to September 16, 2013 (132 days)

	CWT/A		PERCENT OF TOTAL[1]						CHIP	OTF	PERCENT (%) TUBER QUALITY[4]								LB RAUDPC
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[2]	SED[3]	HH	VD	IBS	BC	SCAB[5]	MAT[6]	BRUISE[7]	LB[8]	x100
MSV093-1	447	490	91	7	84	7	3	1.080	1.0	0.0	0	0	0	0	1.3	4.0	0.4	LBMS	3.5
QSMSU01-10	406	455	89	11	87	3	0	1.089	1.0	1.0	15	0	0	0	2.6	2.5	1.9	-	-
MST359-3	401	416	96	4	87	9	0	1.084	1.0	0.0	0	0	0	0	2.6	3.0	1.6	LBR	0.3
MST424-6	393	432	91	9	91	0	0	1.083	1.0	0.0	0	0	0	0	1.3	1.5	1.4	-	-
MSW509-5	372	428	87	12	83	3	1	1.086	1.0	0.0	10	0	0	0	0.8	3.0	2.7	-	-
MST178-2	327	361	90	10	89	1	0	1.069	2.5	3.0	0	0	0	0	1.5	1.5	1.1	-	-
Snowden	**314**	**398**	**79**	**21**	**78**	**1**	**0**	**1.091**	**1.0**	**0.0**	**5**	**5**	**0**	**0**	**3.1**	**2.5**	**1.6**	**LBS**	**3.6**
MSP516-A	293	350	84	16	78	7	0	1.079	1.5	1.0	15	5	0	0	1.6	3.0	2.6	LBR	0.5
Atlantic	**287**	**327**	**88**	**12**	**85**	**3**	**0**	**1.095**	**1.5**	**1.0**	**15**	**0**	**0**	**0**	**3.2**	**2.5**	**2.9**	**LBS**	**7.2**
MST458-4	278	289	96	4	61	35	0	1.080	1.0	1.0	5	0	0	0	1.9	3.0	1.3	LBS	5.1
Pike	**264**	**315**	**84**	**16**	**84**	**0**	**0**	**1.090**	**1.0**	**0.0**	**0**	**0**	**0**	**0**	**1.4**	**2.0**	**1.6**	**LBS**	**-**
MSS934-4	262	300	86	14	86	0	0	1.083	1.0	1.0	0	5	0	0	-	3.0	1.6	LBMS	3.1
MST184-3	257	284	90	9	90	0	1	1.089	1.0	0.0	0	0	0	0	2.0	3.0	2.6	LBS	-
MSK061-4	246	315	77	23	77	0	0	1.095	1.0	0.0	0	60	0	0	1.9	3.0	2.0	LBS	-
MEAN	325	369						1.085							1.9	2.7	1.8		3.3
$HSD_{0.05}$	NS	NS						0.010							1.5	1.9	-		9.4

[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]SED: Stem End Defect, Based on Paul Bethke's (USDA/UWisconsin - Madison) 0 - 5 scale. 0 = no SED; 3 = significant SED; 5 = severe SED
[4]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[5]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[6]MATURITY RATING: August 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).
[7]BRUISE: Simulated blackspot bruise test average number of spots per tuber.
[8]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

PRELIMINARY TRIAL, TABLESTOCK LINES
MONTCALM RESEARCH FARM
May 7 to September 11, 2013 (127 days)

	CWT/A		PERCENT OF TOTAL[1]						CHIP	OTF	PERCENT (%) TUBER QUALITY[4]								LB RAUDPC
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[2]	SED[3]	HH	VD	IBS	BC	SCAB[5]	MAT[6]	BRUISE[7]	LB[8]	x100
MST500-1	684	726	94	6	83	12	0	1.083	1.5	2.0	10	0	0	0	3.1	4.0	1.4	LBMR	0.8
MSV179-1	503	517	97	3	90	7	0	1.076	1.0	1.0	5	0	0	0	1.1	4.0	1.4	LBS	5.9
MSW128-2	495	513	96	4	67	30	0	1.069	2.5	2.0	25	0	0	0	1.8	3.0	0.7	LBMS	2.1
QSMSU08-04	483	523	92	7	92	1	0	1.085	1.0	2.0	0	0	5	0	2.0	4.0	0.4	LBS	8.3
QSMSU10-09	481	511	94	6	85	9	0	1.096	1.5	2.0	0	0	5	0	1.1	3.0	1.3	LBS	10.3
MST065-1	453	518	87	13	86	2	0	1.094	1.0	2.0	10	10	0	0	2.4	3.5	2.8	LBMR	1.0
MSQ131-A	453	457	99	1	59	40	0	1.073	1.0	0.0	0	0	0	0	1.8	3.0	0.5	LBMS	1.5
Reba	**423**	**444**	**95**	**5**	**87**	**8**	**0**	**1.081**	**1.0**	**1.0**	**0**	**0**	**0**	**0**	**2.6**	**3.0**	**0.8**	**LBS**	**-**
MSW151-9	376	433	87	13	79	7	0	1.080	1.5	2.0	10	0	0	0	2.5	3.5	0.5	LBS	4.2
MSV111-2	376	445	84	16	83	1	0	1.080	1.0	0.0	0	0	10	0	1.9	4.0	0.1	LBR	0.4
MSW182-1Y	363	363	100	0	100	0	0	1.091	1.0	1.0	0	0	20	0	2.6	4.0	1.7		
MSW343-2R	343	396	86	14	86	0	0	1.058	-	-	0	0	0	0	2.1	1.0	0.4	LBR	0.6
MSW125-3	341	392	87	13	84	3	0	1.061	2.0	2.0	0	10	0	0	1.4	1.5	0.2	LBS	4.6
Onaway	**338**	**370**	**91**	**8**	**89**	**2**	**1**	**1.070**	**3.0**	**3.0**	**0**	**5**	**0**	**0**	**2.3**	**1.0**	**2.2**	**LBS**	**-**
MST020-2Y	318	339	94	6	86	8	0	1.075	1.0	1.0	0	0	0	0	2.6	3.0	2.5	LBR	0.2
MST252-1Y	291	386	75	25	74	1	0	1.072	1.0	1.0	0	0	0	0	1.5	1.0	0.8	LBS	3.8
MSV292-1Y	286	311	89	11	80	8	0	1.074	1.0	1.0	0	0	0	0	1.5	3.0	0.4	-	-
Purple Heart	284	341	83	17	83	0	0	1.065	-	-	0	0	0	0	3.2	2.0	0.7	LBS	-
MSV235-2PY	280	280	100	0	100	0	0	1.078	-	-	0	0	0	0	-	1.0	0.7	LBS	6.4
W6703-1Y	254	345	74	26	74	0	0	1.085	1.0	2.0	0	0	0	0	-	2.5	0.4	-	-
CV98173-4	247	314	78	22	78	0	0	1.081	1.0	2.0	5	5	0	15	3.0	1.0	0.4	LBS	4.8
QSMSU10-15	223	300	74	26	73	1	0	1.097	1.0	0.0	0	0	0	0	1.1	3.0	1.1	LBS	4.6
Yukon Gold	**181**	**194**	**94**	**6**	**89**	**5**	**0**	**1.076**	**1.0**	**1.0**	**0**	**5**	**5**	**5**	**-**	**1.0**	**0.04**	**LBS**	
MEAN	368	410						1.078							2.1	2.6	0.9		3.7
$HSD_{0.05}$	310	317						0.008							1.5	1.3	-		9.4

[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]SED: Stem End Defect, Based on Paul Bethke's (USDA/UWisconsin - Madison) 0 - 5 scale. 0 = no SED; 3 = significant SED; 5 = severe SED
[4]QUALITY: HH: Hollow Heart; BC: Brown Center; VD: Vascular Discoloration; IBS: Internal Brown Spot. Percent of 40 Oversize and/or A-size tubers cut.
[5]SCAB DISEASE RATING: MSU Scab Nursery; 0: No Infection; 1: Low Infection <5%; 3: Intermediate; 5: Highly Susceptible.
[6]MATURITY RATING: August 19, 2013; Ratings 1-5; 1: Early (vines completely dead); 5: Late (vigorous vine, some flowering).
[7]BRUISE: Simulated blackspot bruise test average number of spots per tuber.
[8]2013 Late Blight: LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

2011-2013 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2013 RATING	2013 WORST	2013 N	2012 RATING	2012 WORST	2012 N	2011 RATING	2011 WORST	2011 N
Sorted by ascending Average Rating;										
CO05152-5Rus	0.4	0.4	1.5	4	-	-	-	-	-	-
CO05024-11Rus[LBMS]	0.5	0.5	1	4	-	-	-	-	-	-
CO05132-2Rus	0.5	0.5	0.5	4	-	-	-	-	-	-
A02062-1TE	0.6	0.3	1	4	1.0	2	4	0.6	1	4
A03158-2TE	0.6	0.6	1	4	-	-	-	-	-	-
CO05040-1Rus	0.6	0.6	1	4	-	-	-	-	-	-
MSP270-1	0.7	0.6	1	4	0.8	1	4	0.6	1	4
McBride (MSJ126-9Y)	0.8	0.8	1.5	4	0.8	2	4	0.8	2	4
Silverton Russet	0.8	1.1	2	4	0.8	2	4	0.5	1	4
MSR169-8Y	0.9	1.4	2	4	0.8	2	4	0.6	1	4
MSS297-3	0.9	1.1	1.5	4	0.8	1	4	0.9	1	4
A02507-2LB[LBMS]	1.0	1.0	1.5	4	-	-	-	-	-	-
CO05175-1Rus[LBMS]	1.1	1.1	1.5	4	-	-	-	-	-	-
MSV179-1	1.1	1.1	1.5	4	-	-	-	-	-	-
QSMSU10-09	1.1	1.1	1.5	4	-	-	-	-	-	-
QSMSU10-15	1.1	1.1	2	4	-	-	-	-	-	-
CO05068-1Rus[LBMS]	1.3	1.3	1.5	4	-	-	-	-	-	-
MSQ440-2[LBR]	1.3	1.0	1	4	1.5	2	4	1.3	2	8
MSR157-1Y	1.3	1.3	2	4	-	-	-	-	-	-
MST424-6	1.3	1.3	1.5	4	-	-	-	-	-	-
MSV093-1[LBMR]	1.3	1.3	2	4	-	-	-	-	-	-
MSS582-1SPL	1.3	1.3	1.5	4	0.8	1	4	2.0	3	4
Pike	**1.3**	**1.4**	**2**	**4**	**1.1**	**2**	**8**	**1.5**	**3**	**4**
MSL007-B	1.4	1.5	2	4	1.5	2	4	1.1	2	4
Dark Red Norland	**1.4**	**1.6**	**2.5**	**4**	**1.4**	**2**	**4**	**1.3**	**2**	**4**
MSR128-4Y	1.4	1.4	2	4	1.5	2	4	1.4	2	4
Lamoka	1.5	1.5	2	4	1.5	2	4	1.4	2	4
MSR127-2	1.5	1.0	1.5	4	1.5	2	4	2.0	3	4
MST252-1Y	1.5	1.5	2	4	-	-	-	-	-	-
MSV292-1Y	1.5	1.5	2.5	4	-	-	-	-	-	-
W5955-1	1.5	1.5	2	4	-	-	-	-	-	-
MSR061-1[LBMR,PVYR]	1.6	2.0	2	4	1.9	2	4	0.9	2	4
Elkton	1.6	1.6	2	4	-	-	-	-	-	-
A01010-1	1.8	1.8	2.5	4	-	-	-	-	-	-
A99029-3E[LBMS]	1.8	1.8	2.5	4	-	-	-	-	-	-
CO05189-3Rus	1.8	1.8	3	4	-	-	-	-	-	-
MSQ443-1RR	1.8	1.8	2.5	4	-	-	-	-	-	-
MSS176-1[LBR]	1.8	1.8	2	4	-	-	-	-	-	-
NY148[LMBR]	1.8	2.1	2.5	4	1.8	2	4	1.4	2	4
MSN190-2	1.8	2.0	2	4	1.5	2	4	1.9	3	4
MSS165-2Y[LBR]	1.8	1.9	2	4	1.9	2	4	1.6	2	4
MSK061-4	1.9	1.9	2	4	-	-	-	-	-	-
MSS927-1	1.9	2.1	2.5	4	1.9	2	4	1.6	3	4
MST458-4	1.9	1.9	2	4	-	-	-	-	-	-
MSV111-2[LBR]	1.9	1.9	2	4	-	-	-	-	-	-
ND7799c-1	1.9	1.9	2.5	4	-	-	-	-	-	-
W5015-5[LBMS]	1.9	1.9	2.5	4	-	-	-	-	-	-
MSQ131-A[LBMS]	1.9	1.8	2.5	3	1.9	3	4	2.0	2	4
MSR214-2P	1.9	2.3	3	4	1.9	2	4	1.6	3	4
Russet Burbank	**1.9**	**1.3**	**2**	**4**	**2.1**	**3**	**4**	**2.4**	**3**	**4**
MSL211-3[LBR]	2.0	2.3	2.5	4	1.9	2	4	1.8	2	4
CO05110-6Rus	2.0	2.0	2.5	4	-	-	-	-	-	-
CO05149-3Rus	2.0	2.0	2.5	4	-	-	-	-	-	-
MSQ130-4[LBR]	2.0	2.0	2	4	-	-	-	-	-	-
MSR186-3P[LBMS]	2.0	2.0	2.5	4	-	-	-	-	-	-
MSS108-1[LBMR]	2.0	2.0	2.5	4	-	-	-	-	-	-

Table 7

2011-2013 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2013 RATING	2013 WORST	2013 N	2012 RATING	2012 WORST	2012 N	2011 RATING	2011 WORST	2011 N
Sorted by ascending Average Rating;										
QSMSU08-04	2.0	2.0	2.5	4	-	-	-	-	-	-
Red Norland	**2.0**	**2.0**	**2.5**	**4**	**-**	**-**	**-**	**-**	**-**	**-**
W9133-1Rus	2.0	2.0	2.5	4	-	-	-	-	-	-
MSR148-4^{LBMR}	2.0	2.1	2.5	4	2.3	3	4	1.8	2	4
Onaway	**2.0**	**2.3**	**2.5**	**4**	**1.9**	**2**	**8**	**2.0**	**3**	**8**
MSQ086-3	2.1	2.4	3	4	1.9	2	4	2.0	3	4
W6002-1R	2.1	2.1	2.5	4	2.3	3	4	1.9	3	4
A07103-IT	2.1	2.1	2.5	4	-	-	-	-	-	-
ND6002-1R	2.1	2.1	2.5	4	-	-	-	-	-	-
NY 153	2.1	2.1	2.5	4	-	-	-	-	-	-
Spartan Splash	2.1	2.4	3	4	1.8	2	4	2.3	3	4
W8152-1Rus	2.1	2.1	2.5	4	-	-	-	-	-	-
Reba	**2.1**	**2.6**	**3**	**4**	**2.2**	**3**	**8**	**1.6**	**2**	**4**
MSQ089-1^{LBR}	2.2	2.5	3	4	1.9	2	4	2.1	3	4
MSN109-6RR^{LBMR}	2.3	2.3	2.5	4	-	-	-	-	-	-
MSQ558-2RR	2.3	2.3	2.5	4	-	-	-	-	-	-
Russet Norkotah	**2.3**	**2.5**	**3**	**4**	**1.9**	**3**	**4**	**2.5**	**3**	**4**
ND7982-1R	2.3	2.3	2.5	3	-	-	-	-	-	-
MSR161-2^{LBMS}	2.5	2.5	3	4	-	-	-	-	-	-
Michigan Purple	2.5	2.8	3.5	4	2.1	3	4	2.8	3	4
MSQ176-5^{LBR}	2.5	3.0	3.5	4	2.3	3	4	2.4	3	4
A071012-4BF	2.6	2.6	3.5	4	-	-	-	-	-	-
Michigan Purple Sport I	2.6	2.6	3	4	-	-	-	-	-	-
MSM182-1^{LBR}	2.6	2.6	3	4	-	-	-	-	-	-
MST148-3	2.6	2.6	4	4	-	-	-	-	-	-
MST359-3^{LBR}	2.6	2.6	3.5	4	-	-	-	-	-	-
QSMSU01-10	2.6	2.6	3	4	-	-	-	-	-	-
Purple Heart	2.6	3.2	3.5	3	2.6	3	4	2.1	3	4
Snowden	**2.7**	**3.1**	**3.5**	**12**	**2.6**	**3**	**8**	**2.4**	**3**	**4**
MNC0001PLWR-01R	2.8	2.8	3.5	4	-	-	-	-	-	-
ND7132-1R	2.8	2.8	3.5	4	-	-	-	-	-	-
NY140^{LMBR}	2.8	3.0	3.5	4	2.8	3	4	2.5	3	4
NorValley	2.8	3.1	3.5	4	3.0	4	4	2.3	3	4
Manistee (MSL292-A)	2.8	3.3	3.5	4	2.5	3	4	2.8	4	4
A07008-4T	2.9	2.9	3.5	4	-	-	-	-	-	-
CV00088-3	2.9	2.9	3	4	-	-	-	-	-	-
MSS070-B^{LBR}	2.9	2.9	3.5	4	-	-	-	-	-	-
MSS483-1^{LBR}	2.9	3.0	4	4	2.5	3	4	3.1	4	4
MSM288-2Y	3.0	3.1	3.5	4	2.8	3	4	3.0	3	4
Atlantic	**3.0**	**3.2**	**3.5**	**12**	**2.8**	**4**	**12**	**3.0**	**4**	**11**
CV02321-1	3.0	3.0	3.5	3	-	-	-	-	-	-
CV98173-4	3.0	3.0	3.5	4	-	-	-	-	-	-
MSM180-3	3.0	3.0	3	4	-	-	-	-	-	-
Yukon Gold	**3.0**	**3.0**	**3.5**	**4**	**3.0**	**3**	**4**	**3.0**	**4**	**4**
MST123-1RY	3.1	3.1	3.5	4	-	-	-	-	-	-
MST500-1^{LBMR}	3.1	3.1	3.5	4	-	-	-	-	-	-
MSU616	3.1	3.1	3.5	4	-	-	-	-	-	-
MSV235-2PY	3.1	3.1	3.5	4	-	-	-	-	-	-
MN10003PLWR-03R	3.3	3.3	3.5	4	-	-	-	-	-	-
MN10020PLWR-08R	3.3	3.3	3.5	4	-	-	-	-	-	-
MSM246-B	3.3	3.3	3.5	4	-	-	-	-	-	-
MSP497-1^{LBR}	3.3	3.3	3.5	4	-	-	-	-	-	-
MN10013PLWR-04	3.4	3.4	4	4	-	-	-	-	-	-
MN10003PLWR-07B	3.5	3.5	4	4	-	-	-	-	-	-
Red Pontiac	**3.6**	**4.0**	**4**	**2**	**3.4**	**4**	**4**	**3.4**	**4**	**4**
CO05189-2Rus	4.1	4.1	4.5	4	-	-	-	-	-	-
CO04233-1Rus	0.6*	0.5	0.5	4	0.8	2	4	-	-	-

Table 7

2011-2013 SCAB DISEASE TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	3-YR* AVG.	2013 RATING	2013 WORST	2013 N	2012 RATING	2012 WORST	2012 N	2011 RATING	2011 WORST	2011 N
Sorted by ascending Average Rating;										
MSW509-5	0.8*	0.8	1.5	4	0.9	2	4	-	-	-
W6703-1Y	1.1*	1.0	1.5	4	1.1	2	4	-	-	-
CO04220-7Rus	1.2*	1.5	2.5	4	0.9	2	4	-	-	-
MSW125-3	1.2*	1.4	1.5	4	1.0	1	4	-	-	-
MSR057-4	1.3*	1.3	1.5	4	1.4	2	4	-	-	-
MST178-2	1.3*	1.5	2	4	1.1	2	4	-	-	-
MSP516-A^{LBR}	1.5*	1.6	2	4	1.4	2	4	-	-	-
MSR226-ARR	1.6*	1.9	2.5	4	1.4	2	4	-	-	-
MST184-3	1.8*	2.0	2.5	4	1.6	2	4	-	-	-
MSW128-2^{LBMS}	1.8*	1.8	2	4	1.9	3	4	-	-	-
MSS206-2^{LBR}	1.9*	2.3	3	4	1.6	2	4	-	-	-
MSW343-2R^{LBR}	1.9*	2.1	2.5	4	1.6	2	4	-	-	-
MSQ492-2^{LBR}	2.0*	2.4	2.5	4	1.6	2	4	-	-	-
MSS576-05SPL^{LBMS}	2.0*	2.2	2.5	8	1.9	2	4	-	-	-
MST117-3Y	2.1*	2.0	2.5	4	2.3	3	4	-	-	-
W8405-1R	2.2*	1.9	2.5	4	2.5	3	4	-	-	-
MSS434-2	2.3*	2.3	2.5	4	2.3	3	4	-	-	-
MSW122-9^{LBR}	2.4*	2.4	3	4	2.4	3	4	-	-	-
MSW239-3SPL	2.4*	2.3	3	4	2.5	3	4	-	-	-
MSW437-9	2.4*	2.8	3	4	2.1	3	4	-	-	-
MST065-1^{LBMR}	2.5*	2.4	3	4	2.6	3	4	-	-	-
MSW151-9	2.5*	2.5	3	4	2.5	3	4	-	-	-
MSS487-2^{LBR}	2.7*	3.3	3.5	4	2.1	3	4	-	-	-
MST020-2Y^{LBR}	2.7*	2.6	3	4	2.8	4	4	-	-	-
W6234-4Rus	2.7*	2.9	3.5	4	2.5	3	4	-	-	-
MSR216-AP	2.8*	2.8	3.5	4	2.9	3	4	-	-	-
MSW182-1Y	2.8*	2.6	3	4	2.9	4	4	-	-	-
MSS934-4^{LBMS}	2.9*	2.9	3	4	2.9	4	4	-	-	-
$HSD_{0.05}$ =		**1.5**			**1.4**			**1.5**		

SCAB DISEASE RATING: MSU Scab Nursery plot rating of 0-5; 0: No Infection; 1: Low Infection <5%, no pitted leisions; 3: Intermediate >20%, some pitted leisions (Susceptible, as commonly seen on Atlantic); 5: Highly Susceptible, >75% coverage and severe pitted leisions.

N = Number of replications.

*2-Year Average.

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSV383-1	0.5	1	Pike	MSN238-A
MSV498-1	0.5	1	Snowden	MSQ283-2
MSW474-1	0.5	1	MSN190-2	MSP516-A
MSW536-2P	0.5	1	MI Purple Red Sport	MSN105-1
MSX345-4	0.5	1	MSN191-2Y	McBride
MSY046-3	0.5	1	Manistee	MSS026-2Y
MSY485-1R	0.5	1	MSL211-3	MSS544-1R
MSY558-1Rus	0.5	1	Silverton Russet	Russet Norkotah
MSY573-3Rus	0.5	1	Canela	Goldrush Russet
MST202-5	1.0	1	MSJ147-1	McBride
MST386-1P	1.0	1	Michigan Purple	Liberator
MSU616-2PP	1.0	1	MSQ016-3PP	MSQ016-3PP
MSV310-2	1.0	1	MSN238-A	Marcy
MSV313-2	1.0	1	MSN238-A	OP
MSV397-2	1.0	1	MSQ070-1	MSJ147-1
MSV434-4	1.0	1	MSQ283-2	McBride
MSW044-1	1.0	1	Kalkaska	NY139
MSW069-5	1.0	1	MSK061-4	Marcy
MSW119-2	1.0	1	MSM171-A	MSR036-5
MSW123-3	1.0	1	MSM171-A	Dakota Diamond
MSW502-4	1.0	1	CO9505051-7W	Kalkaska
MSW509-5	1.0	1	Kalkaska	Marcy
MSX035-1WP	1.0	1	Beacon Chipper	ARS10091WP
MSX225-2	1.0	1	MSK061-4	W2133-1
MSX245-2Y	1.0	1	Manistee	McBride
MSX345-6Y	1.0	1	MSN191-2Y	McBride
MSX351-3P	1.0	1	Colonial Purple	MSL211-3
MSX389-2	1.0	1	NY139	MSL268-D
MSX472-2	1.0	1	MSQ070-1	MSP292-7
MSX495-2	1.0	1	Q131-A	Kalkaska
MSX501-5	1.0	1	MSQ176-5	McBride
MSX503-5	1.0	1	MSQ176-5	MSL268-D
MSX526-2	1.0	1	MSR036-5	NY139
MSX920-3	1.0	1	MSK061-4	Atlantic Newleaf
MSY007-10Y	1.0	1	MSP515-2	McBride
MSY007-11	1.0	1	MSP515-2	McBride
MSY022-2	1.0	1	MSS176-1	MST096-2Y
MSY027-2	1.0	1	MST096-2Y	Pike
MSY041-1	1.0	1	Dakota Diamond	MSP368-1
MSY042-1	1.0	1	MSJ147-1	W2133-1
MSY044-1	1.0	1	MSK061-4	MST096-2Y
MSY049-3	1.0	1	MSP270-1	MSQ089-1
MSY077-5	1.0	1	MST220-08	MSR169-8Y
MSY111-1	1.0	1	MSQ086-3	McBride
MSY118-1	1.0	1	MSQ070-1	MSH228-6
MSY136-5	1.0	1	NYL235-4	Snowden
MSY156-2	1.0	1	MSK061-4	Kalkaska
MSY157-1	1.0	1	Kalkaska	MSN191-2Y
MSY167-6	1.0	1	CO95051-7W	MSR102-3
MSY168-4	1.0	1	Boulder	MSS165-2Y
MSY169-4	1.0	1	Boulder	MSR102-3
MSY190-1	1.0	1	MSR058-1	Dakota Diamond
MSY256-B	1.0	1	Kalkaska	Manistee
MSY410-2	1.0	1	MSQ086-3	MSL211-3

Table 8

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSY436-1	1.0	1	Stirling	MSS544-1R
MSY445-3R	1.0	1	MSS544-1R	Colonial Purple
MSY462-1	1.0	1	MSN230-1RY	MSQ440-2
MSY468-16	1.0	1	NYL235-4	MSL211-3
MSY489-1	1.0	1	MSL211-3	MSQ279-1
MSY517-8YSPL	1.0	1	Spartan Splash	Bison
MSY520-1	1.0	1	MSQ440-2	MSN105-1
MSY527-1R	1.0	1	Colonial Purple	Bison
MSY534-1	1.0	1	MSM171-A	Sherriff
MSY555-1	1.0	1	Silverton Russet	Goldrush Russet
NDU044-1	1.0	1	Ebt 6-5-5	ND 8331Cb-2
QSMSU10-05	1.0	1	MSN106-2	MSL211-3
MSM269-1Y	1.5	1	84SD22	USDA8380-1
MSU379-1	1.5	1	MSP238-1	Missaukee
MSV092-2	1.5	1	McBride	MSP239-1
MSV266-3P	1.5	1	MSQ426-2RR	MSM148-A
MSV307-2	1.5	1	MSN238-A	McBride
MSV393-1	1.5	1	MSQ070-1	MSG227-2
MSW075-7	1.5	1	MSK061-4	W2133-1
MSW100-1	1.5	1	LBR9	MSP292-7
MSW122-3	1.5	1	MSM185-1	MSP085-2
MSW128-2	1.5	1	MSM171-A	MSQ176-5
MSW134-1	1.5	1	Marcy	Dakota Diamond
MSW158-1	1.5	1	Atlantic	MSH228-6
MSW163-3	1.5	1	Atlantic	MSR036-5
MSW206-2P	1.5	1	LBR9	Colonial Purple
MSW450-1	1.5	1	MSK061-4	MSH228-6
MSW509-1	1.5	1	Kalkaska	Marcy
MSW537-6	1.5	1	MSM070-1	MSP516-A
MSX018-2	1.5	1	ARS10342-4	Pike
MSX042-3	1.5	1	Beacon Chipper	NY121
MSX105-1	1.5	1	Dakota Crisp	McBride
MSX142-2	1.5	1	Eva	MSQ176-5
MSX172-7	1.5	1	McBride	W2133-1
MSX199-3	1.5	1	Missaukee	W2133-1
MSX241-2	1.5	1	Kalkaska	W2310-3
MSX255-1	1.5	1	MSM171-A	ARS10342-4
MSX324-1P	1.5	1	MSN105-1	Colonial Purple
MSX324-2R	1.5	1	MSN105-1	Colonial Purple
MSX417-1	1.5	1	MSJ147-1	OP
MSX426-1RR	1.5	1	OPRRC	Q558-2RR
MSX506-3	1.5	1	MSQ176-5	MSR169-8Y
MSX526-1	1.5	1	MSR036-5	NY139
MSX569-1R	1.5	1	MSS002-2R	MSS544-1R
MSY006-2	1.5	1	MSM037-3	MSN191-2Y
MSY007-4Y	1.5	1	MSP515-2	McBride
MSY008-3	1.5	1	MSP515-2	Manistee
MSY026-2	1.5	1	MST096-2Y	MSN191-2Y
MSY032-6	1.5	1	W5015-12	MSN191-2Y
MSY078-1	1.5	1	MST220-08	MSP368-1
MSY087-4	1.5	1	MSS176-1	MSR161-2
MSY117-A	1.5	1	MSQ070-1	MSH228-6
MSY136-4	1.5	1	NYL235-4	Snowden
MSY137-7	1.5	1	MSP270-1	MSR102-3

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSY145-1	1.5	1	Manistee	MSN191-2Y
MSY157-11Y	1.5	1	Kalkaska	MSN191-2Y
MSY160-3	1.5	1	Dakota Diamond	CO97065-7W
MSY192-2PP	1.5	1	Q405-1PP	MSQ461-2PP
MSY193-1	1.5	1	MSQ279-1	B2731-2
MSY225-1Y	1.5	1	ND01496S1-B	McBride
MSY240-1	1.5	1	MSL505-3	P459-5
MSY408-1RY	1.5	1	MSN230-1RY	MN96013-1RY
MSY431-2PY	1.5	1	Spartan Splash	MSN230-1RY
MSY432-1	1.5	1	MSR157-1Y	MSN105-1
MSY452-1	1.5	1	MSQ176-5	MSL211-3
MSY452-5	1.5	1	MSQ176-5	MSL211-3
MSY474-11	1.5	1	MSM182-1	Haig Ind 98
MSY480-3RY	1.5	1	MN96013-1RY	MSS544-1R
MSY487-2	1.5	1	MSL211-3	MSQ440-2
MSY515-1	1.5	1	Reba	Haig Ind 98
MSY532-1	1.5	1	MSM182-1	MSQ086-3
MSY536-2RY	1.5	1	MN96013-1RY	MSN230-1RY
MSY557-2Y	1.5	1	Torridon	Silverton Russet
ND4044-2	1.5	1		
QSMSU10-15	1.5	1	MSN106-2	MSL211-3
MSW153-1	1.6	1	1989-86061	MSI152-A
MSW263-5	1.6	1	MSN105-1	Picasso
MSL505-3	2.0	1	B3692-4	8380-1 chc, 4x
MSL512-6	2.0	1	B9335-3	8380-1 chc, 4x
MSM269-HORG	2.0	1	84SD22	USDA8380-1
MSM270-BY	2.0	1	84SD22	W5337.3
MSU016-2	2.0	1	Boulder	MSN105-1
MSU200-5PP	2.0	1	MSN111-4PP	NDTX4271-5R
MSU202-1P	2.0	1	Colonial Purple	MSL211-3
MSV146-1	2.0	1	Keuka Gold	Malinche
MSV179-6	2.0	1	LBR8	MSL211-3
MSV283-2P	2.0	1	Monserrat	Colonial Purple
MSV284-1	2.0	1	Monserrat	MSP239-1
MSV289-2P	2.0	1	Montanosa	Colonial Purple
MSV305-1PP	2.0	1	Colonial Purple	MSQ480-7RR
MSV434-1Y	2.0	1	MSQ283-2	McBride
MSW068-4	2.0	1	MSK061-4	MSM246-B
MSW111-1	2.0	1	MSL505-3	MSR061-1
MSW125-3	2.0	1	MSM171-A	MSL211-3
MSW138-2	2.0	1	MegaChip	Eva
MSW151-5	2.0	1	Montanosa	MSL211-3
MSW151-9	2.0	1	Montanosa	MSL211-3
MSW154-4	2.0	1	1989-86061	MSL211-3
MSW159-3	2.0	1	Atlantic	Kalkaska
MSW239-3	2.0	1	NDTX4271-5R	Picasso
MSW252-2	2.0	1	MSP516-A	OP
MSW299-2	2.0	1	MSP516-A	MSR061-1
MSW343-2R	2.0	1	MSQ440-2	NDTX4271-5R
MSW394-1	2.0	1	W2133-1	MSJ319-1
MSW410-12Y	2.0	1	E69-6	MSN105-1
MSW418-1	2.0	1	RB G227-2	MSJ319-1
MSW418-2	2.0	1	RB G227-2	MSJ319-1
MSW476-4R	2.0	1	N230-6RY	NDTX4271-5R

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSW485-2	2.0	1	MSQ070-1	MSR156-7
MSW501-5	2.0	1	Boulder	White Pearl
MSX001-4WP	2.0	1	ARS10091WP	MSL211-3
MSX001-9WP	2.0	1	ARS10091WP	MSL211-3
MSX007-4RR	2.0	1	ARS10117RR	Raspberry
MSX009-2	2.0	1	ARS10241-2	Missaukee
MSX010-3	2.0	1	ARS10241-2	MSL211-3
MSX011-4	2.0	1	ARS10241-2	MSN105-1
MSX050-1	2.0	1	Beacon Chipper	W2133-1
MSX120-5Y	2.0	1	Dakota Diamond	McBride
MSX129-1	2.0	1	Dakota Diamond	MSN191-2Y
MSX137-6	2.0	1	Eva	MSL211-3
MSX150-1	2.0	1	MSH228-6	MSM246-B
MSX196-1	2.0	1	Missaukee	Manistee
MSX198-5	2.0	1	Missaukee	OP
MSX221-1	2.0	1	MSK061-4	MSR036-5
MSX239-8	2.0	1	Kalkaska	MSS026-2Y
MSX293-1Y	2.0	1	MSM288-2Y	MSQ176-5
MSX295-1Y	2.0	1	MSM288-2Y	MSR160-2Y
MSX304-2	2.0	1	MegaChip	Manistee
MSX411-4	2.0	1	MSP292-7	OP
MSX420-2Y	2.0	1	MSN191-2Y	OP
MSX469-2	2.0	1	MSQ070-1	OP
MSX496-2	2.0	1	Q131-A	MSL211-3
MSX517-3SPL	2.0	1	Spartan Splash	MSQ176-5
MSX540-4	2.0	1	MSR061-1	NY139
MSX542-2	2.0	1	MSR102-3	Megachip
MSX618-1P	2.0	1	MSS544-1R	Colonial Purple
MSX654-2	2.0	1	Torridon	MSL211-3
MSXUNK-3P	2.0	1	Unknown Purple	
MSY001-3	2.0	1	Boulder	Manistee
MSY001-4	2.0	1	Boulder	Manistee
MSY001-8	2.0	1	Boulder	Manistee
MSY012-2	2.0	1	MSQ070-1	ND8304-2
MSY015-1	2.0	1	MSQ070-1	MSS934-4
MSY017-3	2.0	1	MSQ086-3	Pike
MSY018-3PP	2.0	1	MSQ461-2PP	MSN191-2Y
MSY028-4Y	2.0	1	MST096-2Y	MSR169-8Y
MSY038-1	2.0	1	Boulder	Atlantic
MSY059-1Y	2.0	1	MSQ089-1	MSS165-2Y
MSY061-1	2.0	1	MSQ134-5	MSR102-3
MSY079-2	2.0	1	MST220-08	MSK476-1
MSY089-2	2.0	1	MSS176-1	B2731-2
MSY090-1	2.0	1	MSS165-2Y	MSS026-2Y
MSY091-2	2.0	1	MSS165-2Y	ND7519-1
MSY093-4	2.0	1	MSS026-2Y	MSR102-3
MSY095-2	2.0	1	Superior	MSN191-2Y
MSY100-2	2.0	1	MSR157-1Y	MSR102-3
MSY108-4	2.0	1	MSR058-1	Pike
MSY135-2	2.0	1	MSN148-A	MSR102-3
MSY137-2	2.0	1	MSP270-1	MSR102-3
MSY157-5	2.0	1	Kalkaska	MSN191-2Y
MSY159-1	2.0	1	MSH228-6	CO97065-7W
MSY164-1	2.0	1	CO97065-7W	Manistee

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSY164-4	2.0	1	CO97065-7W	Manistee
MSY168-1	2.0	1	Boulder	MSS165-2Y
MSY168-2Y	2.0	1	Boulder	MSS165-2Y
MSY175-1	2.0	1	Atlantic	MSQ089-1
MSY188-1	2.0	1	MSR169-8Y	MegaChip
MSY188-2	2.0	1	MSR169-8Y	MegaChip
MSY193-2	2.0	1	MSQ279-1	B2731-2
MSY225-7	2.0	1	ND01496S1-B	McBride
MSY229-1	2.0	1	M137-2	Sherriff
MSY237-3	2.0	1	MegaChip	McBride
MSY269-1Y	2.0	1	McBride	ND7519-1
MSY271-13	2.0	1	McBride	CO97065-7W
MSY271-15	2.0	1	McBride	CO97065-7W
MSY413-4	2.0	1	Reba	MSL211-3
MSY413-5	2.0	1	Reba	MSL211-3
MSY414-3Y	2.0	1	Reba	Penta
MSY426-4	2.0	1	NDTX4271-5R	Colonial Purple
MSY437-1	2.0	1	Torridon	MSQ440-2
MSY450-1	2.0	1	Spartan Splash	MSS544-1R
MSY456-1	2.0	1	MSQ070-1	MSL211-3
MSY466-3	2.0	1	MSN105-1	MSQ440-2
MSY468-13	2.0	1	NYL235-4	MSL211-3
MSY474-08	2.0	1	MSM182-1	Haig Ind 98
MSY483-11	2.0	1	MSL505-3	MSN105-1
MSY491-2Y	2.0	1	MSL183-AY	MSL211-3
MSY498-1	2.0	1	MST033-2	MSN105-1
MSY507-2	2.0	1	Superior	MSL211-3
MSY511-9	2.0	1	MSR157-1Y	MSQ440-2
MSY517-6SPL	2.0	1	Spartan Splash	Bison
MSY520-3	2.0	1	MSQ440-2	MSN105-1
MSY529-1SPL	2.0	1	NDTX4271-5R	Picasso
MSY544-5R	2.0	1	Bison	MSS544-1R
MSY617-2	2.0	1	RBE69.6	Sb-Rpi 2122
MSY628-1	2.0	1	RB G227-2	MSQ440-2
MSV158-2	2.5	1	King Harry	Missaukee
MSV234-1	2.5	1	Malinche	MSN105-1
MSW027-1	2.5	1	Eva	MSQ176-5
MSW042-1	2.5	1	MSMSI152-A	MSL211-3
MSW097-5Y	2.5	1	LBR9	MSM288-2Y
MSW122-9	2.5	1	MSM185-1	MSP085-2
MSW164-2	2.5	1	Atlantic	MSR061-1
MSW182-1Y	2.5	1	MSI005-20Y	POR02PG7-5
MSW198-1Y	2.5	1	MSK498-1	Malinche
MSW259-6	2.5	1	N073-2	MSR159-2
MSW294-1	2.5	1	MSP292-7	MSH228-6
MSW298-4Y	2.5	1	MSP408-10Y	MSL211-3
MSW432-13	2.5	1	Boulder	MSI152-A
MSW437-9	2.5	1	Boulder	MSR036-5
MSW443-3	2.5	1	Kalkaska	OP
MSW500-4	2.5	1	Boulder	MSP516-A
MSW501-2	2.5	1	Boulder	White Pearl
MSW556-1	2.5	1	MSP102-5	MSL505-3
MSX021-1	2.5	1	Atlantic	MSH228-6
MSX104-2Rus	2.5	1	Canela Rus.	Goldrush Russet

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSX111-3	2.5	1	Dakota Crisp	MSN191-2Y
MSX156-1Y	2.5	1	MSI005-20Y	Boulder
MSX240-3	2.5	1	Kalkaska	W2133-1
MSX245-1	2.5	1	Manistee	McBride
MSX277-1	2.5	1	MSM246-B	MSJ147-1
MSX292-4Y	2.5	1	MSM288-2Y	MSQ134-5
MSX497-6	2.5	1	Q131-A	MSL268-D
MSX517-5Y	2.5	1	Spartan Splash	MSQ176-5
MSX921-1	2.5	1	MSK409-1	Atlantic Newleaf
MSX929-2	2.5	1	MegaChip	Atlantic Newleaf
MSY012-1	2.5	1	MSQ070-1	ND8304-2
MSY047-1	2.5	1	MSN170-A	Manistee
MSY055-4	2.5	1	MSQ035-3	MegaChip
MSY058-2	2.5	1	MSQ089-1	MSR102-3
MSY071-1	2.5	1	MST220-08	MSR102-3
MSY084-1	2.5	1	MSS927-1	MSR102-3
MSY149-1	2.5	1	MSK061-4	MSR102-3
MSY155-4	2.5	1	MSK061-4	MSL211-3
MSY159-8	2.5	1	MSH228-6	CO97065-7W
MSY192-4PP	2.5	1	Q405-1PP	MSQ461-2PP
MSY235-5	2.5	1	MSM037-3	CO97065-7W
MSY237-A	2.5	1	MegaChip	McBride
MSY239-1	2.5	1	MSL505-3	Reba
MSY256-A	2.5	1	Kalkaska	Manistee
MSY269-3	2.5	1	McBride	ND7519-1
MSY435-2R	2.5	1	MSS544-1R	Bison
MSY468-07	2.5	1	NYL235-4	MSL211-3
MSY468-09	2.5	1	NYL235-4	MSL211-3
MSY487-1	2.5	1	MSL211-3	MSQ440-2
MSY487-10	2.5	1	MSL211-3	MSQ440-2
NY121	2.5	1		
QSND5407-1R	2.5	1		
MSV165-1	3.0	1	Kufri Jeevan	MSL211-3
MSW122-12	3.0	1	MSM185-1	MSP085-2
MSW148-1P	3.0	1	Michigan Purple	MSP516-A
MSW273-3R	3.0	1	NDTX4271-5R	MSN105-1
MSW326-6	3.0	1	MSQ070-1	MSN190-2
MSW360-18	3.0	1	MSR061-1	MSN238-A
MSW360-18	3.0	1	MSR061-1	MSN238-A
MSW424-5Y	3.0	1	RH	MSS187-02
MSX157-4Y	3.0	1	MSI005-20Y	MSMSM288-2Y
MSX208-2	3.0	1	MSK061-4	MSM246-B
MSX269-4Y	3.0	1	MSM182-1	MSL268-D
MSX271-6R	3.0	1	MSM182-1	NDTX4271-5R scab
MSX292-1	3.0	1	MSM288-2Y	MSQ134-5
MSX432-1	3.0	1	MSP292-7	MSM246-B
MSX467-1	3.0	1	MSQ070-1	NY139
MSX507-1R	3.0	1	MSQ176-5	MSR219-2R
MSX520-1PP	3.0	1	MSQ461-2PP	Colonial Purple
MSY034-5	3.0	1	Atlantic	NY121
MSY096-1	3.0	1	Snowden	MSN191-2Y
MSY104-1	3.0	1	MSR061-1	Boulder
MSY158-6	3.0	1	Kalkaska	MSM246-B
MSY160-2	3.0	1	Dakota Diamond	CO97065-7W

2013 SCAB DISEASE EARLY GENERATION TRIAL SUMMARY
SCAB NURSERY, MONTCALM RESEARCH CENTER , MI

LINE	2013 RATING	2013 N	FEMALE	MALE
Sorted by ascending 2013 Rating;				
MSY164-2	3.0	1	CO97065-7W	Manistee
MSY431-3RY	3.0	1	Spartan Splash	MSN230-1RY
MSY494-6	3.0	1	Dakota Diamond	MSL211-3
MSY505-1	3.0	1	MSS483-1	MSQ440-2
MSY535-1	3.0	1	MSM137-2	Stirling
MSY536-5RY	3.0	1	MN96013-1RY	MSN230-1RY
MSY569-1RUSY	3.0	1	Torridon	CO99053-3RUS
MSY174-3	3.5	1	Atlantic	MSS026-2Y
MSY242-2	3.5	1	Manistee	CO97065-7W
MSY483-02	3.5	1	MSL505-3	MSN105-1
MSW276-2	4.0	1	MSP084-3	MSL505-3
MSY438-2	4.0	1	Torridon	MSN105-1

SCAB DISEASE RATING: MSU Scab Nursery plot rating of 0-5; 0: No Infection; 1: Low Infection <5%, no pitted leisions;
3: Intermediate >20%, some pitted leisions (Susceptible, as commonly seen on Atlantic); 5: Highly Susceptible, >75% coverage and severe pitted leisions.
N = Number of replications.

Table 9

MICHIGAN STATE UNIVERSITY
POTATO BREEDING and GENETICS

2013 MSU LATE BLIGHT VARIETY TRIAL
CLARKSVILLE RESEARCH CENTER, MI

Line Sort:

LINE	N	RAUDPC[1] MEAN	*
A01010-1	3	5.4	LBS
A02062-ITE	3	5.8	LBS
A02507-2LB	3	2.5	LBMS
A03158-2TE	3	4.2	LBS
A07008-4T	3	4.3	LBS
A071012-4BF	3	4.9	LBS
A07103-IT	3	3.6	LBS
A99029-3E (RVS)	3	3.9	LBMS
Atlantic	3	7.2	LBS
C004220-7RUS	3	6.5	LBS
C004233-1RUS	3	6.5	LBS
C005024-11RUS	3	3.2	LBMS
C005040-1RUS	3	6.1	LBS
C005068-1RUS	3	2.4	LBMS
C005110-6RUS	3	8.6	LBS
C005132-2RUS	3	21.2	LBS
C005149-1RUS	3	8.2	LBS
C005152-5RUS	3	4.7	LBS
C005175-1RU	3	2.6	LBMS
C005189-2RUS	3	8.3	LBS
C005189-3RUS	3	5.4	LBS
CV00088-3	3	5.1	LBS
CV02321-1	3	7.8	LBS
CV98173-4	3	4.8	LBS
Elkton	3	4.2	LBS
FL1879	3	6.7	LBS
Lamoka	3	6.4	LBS
LBR8	3	0.6	LBR
McBride	3	6.5	LBS
MN100013PLWR-04	3	7.4	LBS
MN10001PLWR-01R	3	7.7	LBS
MN10003PLWR-04	6	14.3	LBS
MN10020PLWR-08R	3	5.8	LBS
MSL211-3	3	0.2	LBR
MSM182-1	3	0.6	LBR
MSN109-6RR	3	1.2	LBMR
MSP497-1	3	0.3	LBR
MSP516-A	3	0.5	LBR
MSQ086-3	3	4.9	LBS
MSQ089-1	3	0.3	LBR
MSQ130-4	3	0.7	LBR
MSQ131-A	3	1.5	LBMS
MSQ176-5	3	0.2	LBR
MSQ440-2	3	0.1	LBR
MSQ492-2	3	0.2	LBR
MSR057-4	3	6.1	LBS
MSR128-4Y	3	4.3	LBS
MSR148-4	3	1.0	LBMR
MSR157-1Y	3	3.8	LBS
MSR161-2	3	3.2	LBMS
MSR186-3P	3	2.7	LBMS
MSR214-2P	3	3.9	LBS
MSR216-AP	6	3.9	LBS
MSS070-B	3	0.3	LBR
MSS108-1	3	1.9	LBMR
MSS165-2Y	3	3.8	LBMS
MSS176-1	3	0.4	LBR
MSS206-2	3	1.1	LBR
MSS297-3	3	10.0	LBS

RAUDPC Sort:

LINE	N	RAUDPC[1] MEAN		Female	Male
MSQ440-2	3	0.1	LBR	K214-1R	Missaukee
MSL211-3	3	0.2	LBR	G301-9	G274-3
MSQ176-5	3	0.2	LBR	I152-A	Missaukee
MST020-2Y	2	0.2	LBR	ARS4070-16Y	G004-3
MSW324-1	3	0.2	LBR	Q070-1	Marcy
MSQ492-2	3	0.2	LBR	Pike	Missaukee
MSS487-2	3	0.2	LBR	Stirling	Missaukee
MSS070-B	3	0.3	LBR	MN-E65	L211-3
MSS483-1	3	0.3	LBR	M171-A	Missaukee
MSW122-9	3	0.3	LBR	M185-1	P085-2
MSP497-1	3	0.3	LBR	J456-4	NY120
MSQ089-1	3	0.3	LBR	A91790-13	Missaukee
MST359-3	3	0.3	LBR	M185-1	Missaukee
MSS176-1	3	0.4	LBR	ND5822C-7	L211-3
MSV111-2	3	0.4	LBR	J316-A	N105-1
MSP516-A	3	0.5	LBR	Pike	Missaukee
LBR8	3	0.6	LBR		
MSM182-1	3	0.6	LBR	Stirling	NY121
MSW343-2R	3	0.6	LBR	Q440-2	NDTX4271-5R
MSQ130-4	3	0.7	LBR	Boulder	J456-4Y
MSW078-1	1	0.8	LBR	K409-1	Malinche
MST500-1	3	0.8	LBMR	Stirling	Boulder
MSR148-4	3	1.0	LBMR	I152-A	Dakota Pearl
MST065-1	3	1.0	LBMR	Boulder	L211-3
MSS206-2	3	1.1	LBR	Beacon Chipper	Missaukee
MSN109-6RR	3	1.2	LBMR	G147-3P	I201-2PY
NY140	6	1.5	LBMR		
MSQ131-A	3	1.5	LBMS	F373-8	Missaukee
MSW100-1	3	1.5	LBR	LBR9	P292-7
MSW153-1	3	1.6	LBMS	1989-86061	I152-A
W5015-5	3	1.6	LBMS		
MSS108-1	3	1.9	LBMR	McBride	Stirling
MSW128-2	6	2.1	LBMS	M171-A	Q176-5
C005068-1RUS	3	2.4	LBMS		
MSW360-18	3	2.4	LBMS	R061-1	N238-A
A02507-2LB	3	2.5	LBMS		
MSS576-05SPL	3	2.6	LBMS	I005-20Y	L211-3
C005175-1RU	3	2.6	LBMS		
MSR186-3P	3	2.7	LBMS	MN19525R	K034-1
MSS934-4	3	3.1	LBMS	ND6095-1	ND7377Cb-1
MSR161-2	3	3.2	LBMS	Stirling	McBride
C005024-11RUS	3	3.2	LBMS		
W8152-1RUS	3	3.4	LBS		
Red Pontiac	3	3.4	LBS		
MSV093-1	3	3.5	LBMS	McBride	P408-14Y
W6234-4RUS	3	3.5	LBS		
A07103-IT	3	3.6	LBS		
Snowden	6	3.6	LBS		
MSS165-2Y	3	3.8	LBMS	M188-1	L159-AY
MST252-1Y	3	3.8	LBS	L024-AY	L211-3
MSR157-1Y	3	3.8	LBS	Jacqueline Lee	J316-A
A99029-3E (RVS)	3	3.9	LBMS		
MSR214-2P	3	3.9	LBS	ND5084-3R	J317-1
MSR216-AP	6	3.9	LBS	NDC5281-2R	J317-1
Elkton	3	4.2	LBS		
MSW151-9	3	4.2	LBS		
A03158-2TE	3	4.2	LBS		
A07008-4T	3	4.3	LBS		
MSR128-4Y	3	4.3	LBS	J167-1	McBride

2013 MSU LATE BLIGHT VARIETY TRIAL
CLARKSVILLE RESEARCH CENTER, MI

Line Sort:				*RAUDPC Sort:*					
		RAUDPC[1]				RAUDPC[1]			
LINE	N	MEAN	*	LINE	N	MEAN		Female	Male
MSS434-2	3	9.0	LBS	MSW125-3	3	4.6	LBS	M171-A	L211-3
MSS483-1	3	0.3	LBR	QSMSU10-15	3	4.6	LBS		
MSS487-2	3	0.2	LBR	C005152-5RUS	3	4.7	LBS		
MSS576-05SPL	3	2.6	LBMS	CV98173-4	3	4.8	LBS		
MSS582-2SPL	6	7.0	LBS	Russet Burbank	3	4.9	LBS		
MSS927-1	3	5.4	LBS	A071012-4BF	3	4.9	LBS		
MSS934-4	3	3.1	LBMS	MSQ086-3	3	4.9	LBS	Onaway	Missaukee
MST020-2Y	2	0.2	LBR	Silverton Russet	3	4.9	LBS		
MST065-1	3	1.0	LBMR	MST458-4	3	5.1	LBS	Pike	Missaukee
MST148-3	3	5.3	LBS	CV00088-3	3	5.1	LBS		
MST252-1Y	3	3.8	LBS	MST148-3	3	5.3	LBS	I152-A	Yukon Gold
MST359-3	3	0.3	LBR	A01010-1	3	5.4	LBS		
MST458-4	3	5.1	LBS	C005189-3RUS	3	5.4	LBS		
MST500-1	3	0.8	LBMR	MSS927-1	3	5.4	LBS	ND4350-3	ND7799C-1
MSV093-1	3	3.5	LBMS	W5955-1	3	5.5	LBS		
MSV111-2	3	0.4	LBR	A02062-ITE	3	5.8	LBS		
MSV179-1	3	5.9	LBS	MN10020PLWR-08R	3	5.8	LBS		
MSV235-2PY	3	6.4	LBS	MSV179-1	3	5.9	LBS	LBR8	L211-3
MSW078-1	1	0.8	LBR	ND7799C-1	2	6.1	LBS		
MSW100-1	3	1.5	LBR	MSR057-4	3	6.1	LBS	Stirling	Liberator (A091-1)
MSW122-9	3	0.3	LBR	C005040-1RUS	3	6.1	LBS		
MSW125-3	3	4.6	LBS	W9133-1RUS	3	6.2	LBS		
MSW128-2	6	2.1	LBMS	Norvalley	3	6.2	LBS		
MSW151-9	3	4.2	LBS	MSV235-2PY	3	6.4	LBS	Malinche	Colonial Purple
MSW153-1	3	1.6	LBMS	Lamoka	3	6.4	LBS		
MSW324-1	3	0.2	LBR	C004233-1RUS	3	6.5	LBS		
MSW343-2R	3	0.6	LBR	C004220-7RU	3	6.5	LBS		
MSW360-18	3	2.4	LBMS	McBride	3	6.5	LBS	Penta	OP
ND6002-1R	3	8.1	LBS	W8405-1R	3	6.5	LBS		
ND7132-1R	3	10.5	LBS	W6002-1R	3	6.6	LBS		
ND7799C-1	2	6.1	LBS	FL1879	3	6.7	LBS		
ND7982-1R	3	9.7	LBS	NY153	3	6.7	LBS		
Norvalley	3	6.2	LBS	MSS582-2SPL	6	7.0	LBS	Purple Haze	L211-3
NY140	6	1.5	LBMR	Russet Norkotah	3	7.0	LBS		
NY153	3	6.7	LBS	Atlantic	3	7.2	LBS		
QSMSU08-04	3	8.3	LBS	Red Norland	3	7.4	LBS		
QSMSU10-09	3	10.3	LBS	MN100013PLWR-04	3	7.4	LBS		
QSMSU10-15	3	4.6	LBS	MN10001PLWR-01R	3	7.7	LBS		
Red Norland	3	7.4	LBS	CV02321-1	3	7.8	LBS		
Red Pontiac	3	3.4	LBS	ND6002-1R	3	8.1	LBS		
Russet Burbank	3	4.9	LBS	C005149-1RUS	3	8.2	LBS		
Russet Norkotah	3	7.0	LBS	QSMSU08-04	3	8.3	LBS		
Silverton Russet	3	4.9	LBS	C005189-2RUS	3	8.3	LBS		
Snowden	6	3.6	LBS	C005110-6RUS	3	8.6	LBS		
W5015-5	3	1.6	LBMS	MSS434-2	3	9.0	LBS	MS716-15	NY123
W5955-1	3	5.5	LBS	ND7982-1R	3	9.7	LBS		
W6002-1R	3	6.6	LBS	MSS297-3	3	10.0	LBS	J147-1	M066-4
W6234-4RUS	3	3.5	LBS	QSMSU10-09	3	10.3	LBS		
W8152-1RUS	3	3.4	LBS	ND7132-1R	3	10.5	LBS		
W8405-1R	3	6.5	LBS	MN10003PLWR-04	6	14.3	LBS		
W9133-1RUS	3	6.2	LBS	C005132-2RUS	3	21.2	LBS		
$HSD_{0.05}$		9.4				9.4			

[1]Ratings indicate the average plot RAUDPC (Relative Area Under the Disease Progress Curve).
*LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible
LB Isolates used: US-22 & US-23

2013 NATIONAL LATE BLIGHT VARIETY TRIAL
CLARKSVILLE RESEARCH CENTER, MI

Line Sort: LINE	N	RAUDPC[1] MEAN	*	*RAUDPC Sort:* LINE	N	RAUDPC[1] MEAN		Female	Male
A02138-2	3	6.4	LBS	MSS487-2	3	0.0	LBR	Stirling	Missaukee
A02424-83LB	3	1.8	LBMS	B0692-4	3	0.3	LBR		
A02507-2LB	3	2.9	LBMS	AF4696-1	3	0.4	LBR		
A03158-2TE	3	5.2	LBS	B0718-3	2	1.1	LBMR		
A07426-8LB	3	4.6	LBS	AF4692-1	3	1.6	LBMR		
AC01151-5W	3	5.6	LBS	A02424-83LB	3	1.8	LBMS		
AC03433-1W	3	2.8	LBMS	AF4573-2	3	1.8	LBMR		
AF4573-2	3	1.8	LBMR	AF4615-5	3	2.1	LBMS		
AF4615-5	3	2.1	LBMS	MSS934-4	3	2.3	LBMS	ND6095-1	ND7377Cb-1
AF4677-1	3	3.3	LBS	MSS165-2Y	2	2.3	LBMS	MSM188-1	MSL159-AY
AF4692-1	3	1.6	LBMR	MSR058-1	3	2.3	LBMS	W1201	MSJ319-1
AF4696-1	3	0.4	LBR	AC03433-1W	3	2.8	LBMS		
ATX91137-1RU	3	4.8	LBS	A02507-2LB	3	2.9	LBMS		
B0692-4	3	0.3	LBR	AF4677-1	3	3.3	LBS		
B0718-3	2	1.1	LBMR	A07426-8LB	3	4.6	LBS		
B2827-13	3	5.3	LBS	MSQ086-3	3	4.7	LBS	Onaway	Missaukee
B2834-8	3	5.7	LBS	CO03276-5RU	3	4.8	LBS		
BNC182-5	3	4.9	LBS	ATX91137-1RU	3	4.8	LBS		
CO03276-5RU	3	4.8	LBS	BNC182-5	3	4.9	LBS		
CO04067-8R/Y	3	5.3	LBS	A03158-2TE	3	5.2	LBS		
MSQ086-3	3	4.7	LBS	B2827-13	3	5.3	LBS		
MSR058-1	3	2.3	LBMS	CO04067-8R/Y	3	5.3	LBS		
MSS165-2Y	2	2.3	LBMS	AC01151-5W	3	5.6	LBS		
MSS487-2	3	0.0	LBR	B2834-8	3	5.7	LBS		
MSS934-4	3	2.3	LBMS	Sierra Rose	3	6.0	LBS		
Sierra Rose	3	6.0	LBS	A02138-2	3	6.4	LBS		
$HSD_{0.05}$		3.1				3.1			

[1] Ratings indicate the average plot RAUDPC (Relative Area Under the Disease Progress Curve).

*LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible

LB Isolates used: US-22 & US-23

2013 LATE BLIGHT EARLY GENERATION TRIALS
CLARKSVILLE RESEARCH CENTER, MI

Line Sort:				***RAUDPC Sort:***					
LINE	N	RAUDPC[1] MEAN	*	LINE	N	RAUDPC[1] MEAN		Female	Male
NY121	EG	0.1	LBR	MSV146-1	EG	0.0	LBR	Keuka Gold (NY 101)	Malinche
MSU379-1	EG	1.4	LBMR	MSV283-2P	EG	0.0	LBR	Monserrat	Colonial Purple
MSV146-1	EG	0.0	LBR	MSW151-5	EG	0.0	LBR	Montanosa	MSL211-3
MSV158-2	EG	1.9	LBMS	MSW418-1	EG	0.0	LBR	RB G227-2	MSJ319-1
MSV165-1	EG	1.3	LBMR	MSX142-2	EG	0.0	LBR	Eva	MSQ176-5
MSV179-6	EG	0.6	LBMR	MSX198-5	EG	0.0	LBR	Missaukee	OP
MSV283-2P	EG	0.0	LBR	MSX269-4Y	EG	0.0	LBR	MSM182-1	MSN105-1
MSV284-1	EG	0.1	LBR	MSX293-1Y	EG	0.0	LBR	MSM288-2Y	MSQ176-5
MSV289-2P	EG	3.4	LBS	MSX324-2R	EG	0.0	LBR	MSN105-1	Colonial Purple
MSW042-1	EG	0.9	LBMR	MSX389-2	EG	0.0	LBR	Lamoka	MSL268-D
MSW097-5Y	EG	0.2	LBR	MSX495-2	EG	0.0	LBR	MSQ131-A	Kalkaska
MSW100-1	EG	0.5	LBR	MSX497-6	EG	0.0	LBR	MSQ131-A	MSL268-D
MSW111-1	EG	1.1	LBMR	MSX507-1R	EG	0.0	LBR	MSQ176-5	MSR219-2R
MSW119-2	EG	0.4	LBR	MSX517-3SPL	EG	0.0	LBR	Spartan Splash	MSQ176-5
MSW123-3	EG	3.6	LBS	MSY491-2Y	EG	0.0	LBR	MSL183-AY	MSL211-3
MSW125-3	EG	2.8	LBMS	MSY501-1Y	EG	0.0	LBR	Torridon	MSL268-D
MSW151-5	EG	0.0	LBR	MSY535-1	EG	0.0	LBR	MSM137-2	Stirling
MSW151-9	EG	1.6	LBMR	MSY543-2	EG	0.0	LBR	Dakota Diamond	MSL211-3
MSW154-4	EG	0.1	LBR	MSY628-1	EG	0.0	LBR	RB G227-2	MSQ440-2
MSW182-1Y	EG	1.4	LBMR	MSV284-1	EG	0.1	LBR	Monserrat	MSP239-1
MSW198-1Y	EG	2.7	LBMS	MSX496-2	EG	0.1	LBR	MSQ131-A	MSL211-3
MSW206-2P	EG	1.3	LBR	MSY118-1	EG	0.1	LBR	MSQ070-1	MSH228-6
MSW252-2	EG	1.9	LBMS	NY121	EG	0.1	LBR		
MSW343-2R	EG	1.0	LBR	MSW154-4	EG	0.1	LBR	1989-86061	MSL211-3
MSW418-1	EG	0.0	LBR	MSX542-2	EG	0.1	LBR	MSR102-3	Megachip
MSW418-2	EG	0.6	LVMR	MSY534-1	EG	0.2	LBR	MSM171-A	Sherriff
MSW443-3	EG	4.4	LBS	MSW097-5Y	EG	0.2	LBR	LBR9	MSM288-2Y
MSX001-4WP	EG	2.0	LBMS	MSY474-11	EG	0.2	LBR	MSM182-1	Haig Ind 98
MSX009-2	EG	1.3	LBMR	MSY507-2	EG	0.2	LBR	Superior	MSL211-3
MSX010-3	EG	2.8	LBMS	MSX324-1P	EG	0.3	LBR	MSN105-1	Colonial Purple
MSX137-6	EG	4.7	LBS	MSY527-1R	EG	0.3	LBR	Colonial Purple	Bison
MSX142-2	EG	0.0	LBR	MSY452-1	EG	0.3	LBR	MSQ176-5	MSL211-3
MSX196-1	EG	1.3	LBMR	MSY515-1	EG	0.3	LBR	Reba	Haig Ind 98
MSX198-5	EG	0.0	LBR	MSW119-2	EG	0.4	LBR	MSM171-A	MSR036-5
MSX199-3	EG	1.3	LBMR	MSW100-1	EG	0.5	LBR	LBR9	MSP292-7
MSX221-1	EG	1.3	LBMR	MSV179-6	EG	0.6	LBMR	LBR8	MSL211-3
MSX255-1	EG	1.6	LBMR	MSW418-2	EG	0.6	LBMR	RB G227-2	MSJ319-1
MSX269-4Y	EG	0.0	LBR	MSX271-6R	EG	0.6	LBMR	MSM182-1	NDTX4271-5R
MSX271-6R	EG	0.6	LBMR	MSY436-1	EG	0.6	LBMR	Stirling	MSS544-1R
MSX292-1	EG	2.7	LBMS	MSY437-1	EG	0.6	LBMR	Torridon	MSQ440-2
MSX293-1Y	EG	0.0	LBR	MSY489-1	EG	0.6	LBMR	MSL211-3	MSQ279-1
MSX295-1Y	EG	2.2	LBMS	MSX540-4	EG	0.8	LBMR	MSR061-1	Lamoka
MSX324-1P	EG	0.3	LBR	MSW042-1	EG	0.9	LBMR	MSI152-A	MSL211-3
MSX324-2R	EG	0.0	LBR	MSX501-5	EG	0.9	LBMR	MSQ176-5	McBride
MSX351-3P	EG	2.8	LBMS	MSY474-08	EG	0.9	LBMR	MSM182-1	Haig Ind 98
MSX389-2	EG	0.0	LBR	MSW343-2R	EG	1.0	LBMR	MSQ440-2	NDTX4271-5R
MSX467-1	EG	3.5	LBS	MSW111-1	EG	1.1	LBMR	MSL505-3	MSR061-1
MSX469-2	EG	3.1	LBS	MSV165-1	EG	1.3	LBMR	Kufri Jeevan	MSL211-3
MSX472-2	EG	3.5	LBS	MSW206-2P	EG	1.3	LBMR	LBR9	Colonial Purple
MSX495-2	EG	0.0	LBR	MSX009-2	EG	1.3	LBMR	ARS10241-2	Missaukee
MSX496-2	EG	0.1	LBR	MSX196-1	EG	1.3	LBMR	Missaukee	Manistee
MSX497-6	EG	0.0	LBR	MSX199-3	EG	1.3	LBMR	Missaukee	W2133-1
MSX501-5	EG	0.9	LBMR	MSX221-1	EG	1.3	LBMR	MSK061-4	MSR036-5
MSX503-5	EG	4.1	LBS	MSU379-1	EG	1.4	LBMR	MSP238-1	Missaukee
MSX506-3	EG	3.1	LBS	MSW182-1Y	EG	1.4	LBMR	MSI005-20Y	POR02PG7-5
MSX507-1R	EG	0.0	LBR	MSX255-1	EG	1.6	LBMR	MSM171-A	ARS10342-4
MSX517-3SPL	EG	0.0	LBR	MSW151-9	EG	1.6	LBMR	Montanosa	MSL211-3
MSX517-5Y	EG	2.7	LBMS	MSV158-2	EG	1.9	LBMS	King Harry (NY131)	Missaukee
MSX526-1	EG	3.6	LBS	MSW252-2	EG	1.9	LBMS	MSP516-A	OP
MSX526-2	EG	2.5	LBMS	MSY569-1RUSY	EG	1.9	LBMS	Torridon	CO99053-3RUS

2013 LATE BLIGHT EARLY GENERATION TRIALS
CLARKSVILLE RESEARCH CENTER, MI

Line Sort:

LINE	N	RAUDPC[1] MEAN	*
MSX540-4	EG	0.8	LBMR
MSX542-2	EG	0.1	LBR
MSX654-2	EG	2.7	LBMS
MSY012-1	EG	5.2	LBS
MSY012-2	EG	2.1	LBMS
MSY015-1	EG	4.2	LBS
MSY022-2	EG	3.8	LBS
MSY034-5	EG	5.3	LBS
MSY058-2	EG	4.7	LBS
MSY059-1Y	EG	5.3	LBS
MSY061-1	EG	3.3	LBS
MSY071-1	EG	1.9	LBMS
MSY084-1	EG	6.1	LBS
MSY087-4	EG	4.6	LBS
MSY089-2	EG	5.4	LBS
MSY090-1	EG	3.5	LBS
MSY091-2	EG	5.5	LBS
MSY093-4	EG	2.8	LBMS
MSY100-2	EG	5.7	LBS
MSY104-1	EG	2.8	LBMS
MSY108-4	EG	5.8	LBS
MSY118-1	EG	0.1	LBR
MSY135-2	EG	5.6	LBS
MSY137-2	EG	6.0	LBS
MSY137-7	EG	3.9	LBS
MSY149-1	EG	6.1	LBS
MSY167-6	EG	6.0	LBS
MSY168-1	EG	5.0	LBS
MSY168-2Y	EG	4.7	LBS
MSY168-4	EG	5.7	LBS
MSY169-4	EG	3.5	LBS
MSY190-1	EG	4.7	LBS
MSY229-1	EG	3.5	LBS
MSY436-1	EG	0.6	LBMR
MSY437-1	EG	0.6	LBMR
MSY438-2	EG	5.0	LBS
MSY452-1	EG	0.3	LBR
MSY452-5	EG	5.3	LBS
MSY474-08	EG	0.9	LBMR
MSY474-11	EG	0.2	LBR
MSY485-1R	EG	2.5	LBMS
MSY489-1	EG	0.6	LBMR
MSY491-2Y	EG	0.0	LBR
MSY494-6	EG	4.2	LBS
MSY501-1Y	EG	0.0	LBR
MSY507-2	EG	0.2	LBR
MSY511-9	EG	4.9	LBS
MSY515-1	EG	0.3	LBR
MSY517-8YSPL	EG	3.5	LBS
MSY527-1R	EG	0.3	LBR
MSY532-1	EG	2.1	LBMS
MSY534-1	EG	0.2	LBR
MSY535-1	EG	0.0	LBR
MSY543-2	EG	0.0	LBR
MSY544-5R	EG	5.3	LBS
MSY557-2Y	EG	2.7	LBMS
MSY569-1RUSY	EG	1.9	LBMS
MSY628-1	EG	0.0	LBR

RAUDPC Sort:

LINE	N	RAUDPC[1] MEAN		Female	Male
MSY071-1	EG	1.9	LBMS	MST220-08	MSR102-3
MSX001-4WP	EG	2.0	LBMS	ARS10091WP	MSL211-3
MSY012-2	EG	2.1	LBMS	MSQ070-1	ND8304-2
MSY532-1	EG	2.1	LBMS	MSM182-1	MSQ086-3
MSX295-1Y	EG	2.2	LBMS	MSM288-2Y	MSR160-2Y
MSX526-2	EG	2.5	LBMS	MSR036-5	Lamoka
MSY485-1R	EG	2.5	LBMS	MSL211-3	MSS544-1R
MSW198-1Y	EG	2.7	LBMS	MSK498-1	Malinche
MSX292-1	EG	2.7	LBMS	MSM288-2Y	MSQ134-5
MSX517-5Y	EG	2.7	LBMS	Spartan Splash	MSQ176-5
MSX654-2	EG	2.7	LBMS	Torridon	MSL211-3
MSY557-2Y	EG	2.7	LBMS	Torridon	Silverton Russet
MSY093-4	EG	2.8	LBMS	MSS026-2Y	MSR102-3
MSW125-3	EG	2.8	LBMS	MSM171-A	MSL211-3
MSX010-3	EG	2.8	LBMS	ARS10241-2	MSL211-3
MSX351-3P	EG	2.8	LBMS	Colonial Purple	MSL211-3
MSY104-1	EG	2.8	LBMS	MSR061-1	Boulder
MSX469-2	EG	3.1	LBS	MSQ070-1	OP
MSX506-3	EG	3.1	LBS	MSQ176-5	MSR169-8Y
MSY061-1	EG	3.3	LBS	MSQ134-5	MSR102-3
MSV289-2P	EG	3.4	LBS	Montanosa	Colonial Purple
MSX467-1	EG	3.5	LBS	MSQ070-1	Lamoka
MSX472-2	EG	3.5	LBS	MSQ070-1	MSP292-7
MSY090-1	EG	3.5	LBS	MSS165-2Y	MSS026-2Y
MSY229-1	EG	3.5	LBS	MSM137-2	Sherriff
MSY517-8YSPL	EG	3.5	LBS	Spartan Splash	Bison
MSY169-4	EG	3.5	LBS	Boulder	MSR102-3
MSW123-3	EG	3.6	LBS	MSM171-A	Dakota Diamond
MSX526-1	EG	3.6	LBS	MSR036-5	Lamoka
MSY022-2	EG	3.8	LBS	MSS176-1	MST096-2Y
MSY137-7	EG	3.9	LBS	MSP270-1	MSR102-3
MSX503-5	EG	4.1	LBS	MSQ176-5	MSL268-D
MSY015-1	EG	4.2	LBS	MSQ070-1	MSS934-4
MSY494-6	EG	4.2	LBS	Dakota Diamond	MSL211-3
MSW443-3	EG	4.4	LBS	Kalkaska	OP
MSY087-4	EG	4.6	LBS	MSS176-1	MSR161-2
MSX137-6	EG	4.7	LBS	Eva	MSL211-3
MSY058-2	EG	4.7	LBS	MSQ089-1	MSR102-3
MSY168-2Y	EG	4.7	LBS	Boulder	MSS165-2Y
MSY190-1	EG	4.7	LBS	MSR058-1	Dakota Diamond
MSY511-9	EG	4.9	LBS	MSR157-1Y	MSQ440-2
MSY438-2	EG	5.0	LBS	Torridon	MSN105-1
MSY168-1	EG	5.0	LBS	Boulder	MSS165-2Y
MSY012-1	EG	5.2	LBS	MSQ070-1	ND8304-2
MSY544-5R	EG	5.3	LBS	Bison	MSS544-1R
MSY034-5	EG	5.3	LBS	Atlantic	NY121
MSY059-1Y	EG	5.3	LBS	MSQ089-1	MSS165-2Y
MSY452-5	EG	5.3	LBS	MSQ176-5	MSL211-3
MSY089-2	EG	5.4	LBS	MSS176-1	B2731-2
MSY091-2	EG	5.5	LBS	MSS165-2Y	ND7519-1
MSY135-2	EG	5.6	LBS	MSN148-A	MSR102-3
MSY100-2	EG	5.7	LBS	MSR157-1Y	MSR102-3
MSY168-4	EG	5.7	LBS	Boulder	MSS165-2Y
MSY108-4	EG	5.8	LBS	MSR058-1	Pike
MSY137-2	EG	6.0	LBS	MSP270-1	MSR102-3
MSY167-6	EG	6.0	LBS	CO95051-7W	MSR102-3
MSY084-1	EG	6.1	LBS	MSS927-1	MSR102-3
MSY149-1	EG	6.1	LBS	MSK061-4	MSR102-3

[1] Ratings indicate the average plot RAUDPC (Relative Area Under the Disease Progress Curve).
*LBR = Late Blight Resistant; LBMR = Late Blight Moderately Resistant; LBMS = Late Blight Moderately Susceptible; LBS = Late Blight Susceptible
LB Isolates used: US-22 & US-23

2013 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

		NUMBER OF SPOTS PER TUBER						PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
ENTRY	SP GR	0	1	2	3	4	5+		
ADVANCED and CHIP-PROCESSING TRIAL									
Manistee (MSL292-A)	1.094	8	9	7	1			32	1.0
MSN190-2	1.103	5	14	5	1			20	1.1
MSR057-4	1.082	9	8	5	3			36	1.1
MSP497-1	1.081	6	9	10				24	1.2
MSR061-1	1.083	1	15	8	1			4	1.4
FL1879	**1.087**	**4**	**8**	**10**	**2**	**1**		**16**	**1.5**
MSS297-3	1.093	3	10	7	4	1		12	1.6
NY140	1.087	4	6	10	5			16	1.6
Snowden	**1.094**	**4**	**5**	**11**	**5**			**16**	**1.7**
Lamoka	1.093	1	9	11	4			4	1.7
MSQ492-2	1.088	2	8	10	4	1		8	1.8
MSL007-B	1.093		7	9	5	3	1	0	2.3
MSR127-2	1.095	1	2	11	5	4	2	4	2.6
NY148	1.103	1	5	5	6	6	2	4	2.7
Atlantic	**1.101**		**4**	**7**	**6**	**5**	**3**	**0**	**2.8**
MSM246-B	1.097			8	9	5	3	0	3.1
RUSSET TRIAL									
Russet Norkotah	**1.079**	**22**	**3**					**88**	**0.1**
A07103-1T (2 Rep)	1.099	24	3		1			86	0.2
A99029-3E (2 Rep)	1.080	20	4	1				80	0.2
A02062-1TERus	1.081	18	7					72	0.3
CO05189-2Rus	1.078	18	7					72	0.3
W6234-4rus	1.085	16	9					64	0.4
CO04233-1Rus (2 Rep)	1.075	15	8	2				60	0.5
CO05132-2Rus	1.081	9	15	1				36	0.7
A01010-1	1.089	12	9	2	2			48	0.8
W8152-1Rus	1.094	10	12	2		1		40	0.8
CO04220-7Rus (2 Rep)	1.072	16	2	4	1	1	1	64	0.9
W9133-1rus	1.074	8	12	5				32	0.9
Russet Burbank	**1.078**	**11**	**7**	**5**	**2**			**44**	**0.92**
CO05149-3Rus	1.085	10	7	7	1			40	1.0
CO05152-5Rus	1.086	9	10	4	2			36	1.0
AF4532-8Rus	1.074	10	8	6			1	40	1.0
AF4445-3Rus	1.075	8	10	5	2			32	1.0
AF3362-1Rus	1.086	7	8	7	3			28	1.2
Silverton Russet	**1.080**	**7**	**6**	**7**	**4**	**1**		**28**	**1.44**
CO05040-1Rus (2 Rep)	1.075	5	7	8	4	1		20	1.6
CO05024-11Rus (2 Rep)	1.084	4	7	10	3	1		16	1.6
A02507-2LB (2 Rep)	1.090	7	5	6	4	3		28	1.6
A07008-4T (2 Rep)	1.097	1	13	6	4	1		4	1.6
A03158-2TERus	1.088	5	4	10	5		1	20	1.8
CO05175-1Rus	1.082	6	3	9	4	3		24	1.8
CO05189-3Rus	1.076	3	5	8	9			12	1.9
A0701012-4BF (2 Rep)	1.100	1	3	12	8	1		4	2.2
CO05068-1Rus (2 Rep)	1.097		4	9	5	4	3	0	2.7
CO05110-6Rus	1.088	2	2	5	5	6	5	8	3.0
NORTH CENTRAL REGIONAL TRIAL									
ND7799c-1	1.079	23	2					92	0.1
MN10003PLWR-03R	1.057	22	3					88	0.1
W6002-1R	1.064	18	6	1				72	0.3
MN10001PLWR-01R	1.069	16	9					64	0.4
MN10003PLWR-07R	1.064	16	8	1				64	0.4
McBride (MSJ126-9Y)	1.086	17	6	1	1			68	0.4

2013 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	SP GR	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MN10020PLWR-08R	1.068	15	7	3				60	0.5
ND7982-1R	1.076	14	10		1			56	0.5
Red Pontiac	**1.067**	**14**	**9**	**2**				**56**	**0.5**
MN10013PLWR-04	1.077	12	12	1				48	0.6
ND6002-1R	1.068	15	6	3	1			60	0.6
Red Norland	**1.064**	**12**	**10**	**3**				**48**	**0.6**
W5955-1	1.093	13	8	4				52	0.6
MSQ089-1	1.083	11	11	1	2			44	0.8
MSS576-5SPL	1.080	10	8	4	3			40	1.0
NorValley	**1.080**	**7**	**11**	**5**	**2**			**28**	**1.1**
ND7132-1R	1.073	6	11	7	1			24	1.1
W8405-1R	1.070	8	9	5	3			32	1.1
Snowden	**1.089**	**6**	**6**	**8**	**4**		**1**	**24**	**1.6**
NY 153	1.095	4	7	9	4	1		16	1.6
Elkton	1.088	4	8	7	4	2		16	1.7
Atlantic	**1.095**		**10**	**8**	**6**	**1**		**0**	**1.9**
MSS165-2Y	1.094	4	6	6	5	3	1	16	2.0
W5015-5	1.095		1	3	6	4	11	0	3.8

ADAPTATION TRIAL, TABLESTOCK LINES

ENTRY	SP GR	0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSM288-2Y	1.083	19	6					76	0.2
CV00088-3	1.072	16	8	1				64	0.4
Red Norland	**1.063**	**15**	**7**	**3**				**60**	**0.5**
MSQ440-2	1.058	13	10	2				52	0.6
MSS176-1	1.087	14	8	2	1			56	0.6
MSS927-1	1.086	12	10	2	1			48	0.7
MP Sport I	1.075	8	13	3	1			32	0.9
CV02321-1	1.077	8	12	4	1			32	0.9
MSQ176-5	1.070	8	10	4	3			32	1.1
MSS576-5SPL	1.081	9	8	5	2	1		36	1.1
MSL211-3	1.074	8	8	6	3			32	1.2
MSS206-2	1.075	8	8	6	3			32	1.2
Spartan Splash	1.083	8	9	6	1		1	32	1.2
MSR214-2P	1.072	7	11	3	3	1		28	1.2
MSS070-B	1.088	9	7	5	3	1		36	1.2
Michigan Purple	1.075	7	8	8	1	1		28	1.2
MSR226-ARR	1.076	4	11	10				16	1.2
MSQ130-4	1.082	6	9	7	3			24	1.3
MSQ086-3	1.085	3	12	7	3			12	1.4
MSR157-1Y	1.085	4	9	8	1	3		16	1.6
MSR128-4Y (significant shatter bruise)	1.093	4	6	9	4	2		16	1.8
Reba	**1.078**	**3**	**9**	**8**	**1**	**3**	**1**	**12**	**1.8**
MSR186-3P	1.076	4	7	6	5	2	1	16	1.9
MSS487-2	1.086	3	4	5	3	4	6	12	2.8
MSS483-1	1.081		2	6	8	4	5	0	3.2
MSR216-AP	1.080		1		7	7	10	0	4.0

PRELIMINARY TRIAL, CHIP-PROCESSING LINES

ENTRY	SP GR	0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
MSV093-1	1.080	17	6	2				68	0.4
MST178-2	1.069	11	9		3	1	1	44	1.1
MSW437-9	1.071	7	6	11	1			28	1.2
MST458-4	1.080	5	11	6	2	1		20	1.3
MSM180-3	na	3	12	8	2			12	1.4
MST424-6	na	13		4	5	3		52	1.4
MST359-3	1.084	5	7	9	2	2		20	1.6
MSW122-9	1.073	2	13	5	4	1		8	1.6

2013 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

ENTRY	SP GR	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	PERCENT (%) BRUISE FREE	AVERAGE SPOTS/TUBER
Pike	**1.090**	**6**	**8**	**5**	**4**	**1**	**1**	**24**	**1.6**
MSS934-4	1.083	5	7	8	3	2		20	1.6
Snowden	**1.091**	**3**	**8**	**9**	**5**			**12**	**1.6**
MSR161-2	1.087	3	7	9	4	1	1	12	1.8
QSMSU01-10	1.089	3	7	7	5	3		12	1.9
MSK061-4	1.095	1	6	11	7			4	2.0
MST117-3Y	1.079	1	3	11	7	3		4	2.3
MST184-3	1.089	2	4	6	6	5	2	8	2.6
MSP516-A	1.079		5	8	7	2	3	0	2.6
MSW509-5	1.086	1	4	8	5	2	5	4	2.7
Atlantic	**1.095**		**4**	**5**	**7**	**7**	**2**	**0**	**2.9**
PRELIMINARY TRIAL, TABLESTOCK LINES									
Yukon Gold	**1.076**	**24**	**1**					**96**	**0.04**
MSV111-2	1.080	23	2					92	0.1
MSU616	1.080	19	6					76	0.2
MSW125-3	1.061	19	6					76	0.2
CV98173-4	1.081	18	5	2				72	0.4
MSV292-1Y	1.074	18	5	2				72	0.4
MSW343-2R	1.058	18	5	2				72	0.4
W6703-1Y	1.085	17	6	2				68	0.4
QSMSU08-04	1.085	14	11					56	0.4
MSQ131-A	1.073	14	10		1			56	0.5
MSW151-9	1.080	13	11	1				52	0.5
MSW128-2	1.069	10	12	3				40	0.7
Purple Heart (significant shatter bruise)	1.065	10	12	3				40	0.7
MSV235-2PY (2 PP mix)	1.078	13	5	3	2			57	0.7
MST252-1Y	1.072	12	8	3	2			48	0.8
Reba	**1.081**	**12**	**7**	**5**	**1**			**48**	**0.8**
QSMSU10-15	1.096	9	7	7	2			36	1.1
QSMSU10-9	1.097	4	11	9	1			16	1.3
MST500-1	1.083	6	9	6	3	1		24	1.4
MSV179-1	1.076	5	9	8	2	1		20	1.4
MSW182-1Y	1.091	4	9	6	2	4		16	1.7
Onaway	**1.070**	**1**	**6**	**8**	**7**	**2**	**1**	**4**	**2.2**
MST020-2Y	1.075	2	6	6	5	1	5	8	2.5
MST065-1 (13 tubers)	1.094	1	1	1	6	4		8	2.8
USPB/SFA TRIAL CHECK SAMPLES (Not bruised)									
W5955-1	1.080	25						100	0.0
W6483-5	1.064	25						100	0.0
CO02321-4W	1.081	23	2					92	0.1
A00188-3C	1.079	22	3					88	0.1
AF4157-6	1.074	21	4					84	0.2
MSL292-A	1.075	22	2	1				88	0.2
Snowden	**1.078**	**21**	**4**					**84**	**0.2**
W6609-3	1.080	20	5					80	0.2
A01143-3C	1.076	20	4	1				80	0.2
Atlantic	**1.084**	**18**	**5**	**2**				**72**	**0.4**
MSL007-B	1.081	15	10					60	0.4
MSR061-1	1.076	17	6	2				68	0.4
NY140	1.076	13	11	1				52	0.5
NY148	1.082	13	11	1				52	0.5
W4980-1	1.077	15	7	3				60	0.5
CO03243-3W	1.078	14	7	3	1			56	0.6
AC01151-5W	1.067	11	10	4				44	0.7

2013 BLACKSPOT BRUISE SUSCEPTIBILITY TEST
SIMULATED BRUISE SAMPLES*

		NUMBER OF SPOTS PER TUBER						PERCENT (%) BRUISE	AVERAGE
ENTRY	SP GR	0	1	2	3	4	5+	FREE	SPOTS/TUBER
CO00197-3W	1.073	8	6	7	3	1		32	1.3
USPB/SFA TRIAL BRUISE SAMPLES									
W6483-5	1.064	20	5					80	0.2
CO02321-4W	1.081	17	7	1				68	0.4
MSR061-1	1.076	16	9					64	0.4
W6609-3	1.080	16	8	1				64	0.4
AC01151-5W	1.067	13	12					52	0.5
A00188-3C	1.079	14	10		1			56	0.5
W5955-1	1.080	16	6	2	1			64	0.5
Atlantic	**1.084**	**12**	**8**	**5**				**48**	**0.7**
Snowden	**1.078**	**8**	**14**	**2**	**1**			**32**	**0.8**
NY140	1.076	9	9	7				36	0.9
CO03243-3W	1.078	8	6	7	4			32	1.3
AF4157-6	1.074	6	9	7	2	1		24	1.3
A01143-3C	1.076	2	8	13	2			8	1.6
MSL292-A	1.075	6	5	8	5	1		24	1.6
NY148	1.082	3	5	11	3	1	2	12	2.0
MSL007-B	1.081	4	4	8	3	5	1	16	2.2
CO00197-3W	1.073		6	9	7	2	1	0	2.3
W4980-1	1.077			6	4	6	9	0	3.7

* Twenty to 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 10/25/2013. The table is presented in ascending order of average number of spots per tuber.

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2013 On-Farm Potato Variety Trials

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Introduction

On-farm potato variety trials were conducted with 16 growers in 2013 at a total of 21 locations. Ten of the locations evaluated processing entries and eleven evaluated fresh market entries. The processing cooperators were Crooks Farms, Inc. (Montcalm), Walther Farms, Inc. (St. Joseph), Lennard Ag. Co. (St. Joseph), County Line Potato Farms, Inc. (Allegan), Main Farms (Montcalm), Sackett Potatoes (Mecosta), Michigan State University (MSU) Montcalm Research Center (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), Eisenga Potato Farms (Osceola), Elmaple Farms (Kalkaska), Kitchen Farms, Inc. (Antrim), Horkey Bros. (Monroe), T.J.J. VanDamme Farms (Delta), Walther Farms, Inc. (St. Joseph) and Brian Williams Farms (Sanilac).

Procedure

There were six types of processing trials conducted this year. The first type contained 15 entries which were compared with the check varieties Snowden, Pike and FL1879. This trial type was conducted at Main Farms, Lennard Ag. Co. and County Line Farms. Varieties in these trials were planted in 100’ strip plots. In-row seed spacing in each trial was 10 inches. The second type of processing trial, referred to as a “Select” trial, contained seven 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 were 10” and 34”, respectively. These trials were conducted on Crooks Farms, Inc. (Gratiot and Montcalm Counties). The third type was a processing variety trial where each plot consisted of three, 34” wide rows which were 15’ long. Only the center row was harvested for the yield evaluation from each of four replications. This trial was conducted at Walther Farms, Inc. (St. Joseph). At Walther’s, 17 varieties were compared to the check varieties Snowden, Pike and FL1879. The plots were planted at 10” in-row seed spacing. The fourth type was the Box Bin trial at the Montcalm Research Center in Montcalm County, MI. This trial contained 16 varieties compared against the check variety Snowden. Each of the 16 varieties was planted in a single 34” wide row, 600’ long with 10” in-row seed spacing. A single 23’ yield check was taken to evaluate each clone. The fifth type of chip trial consisted of large multiple acreage blocks of three newly commercialized or soon to be commercialized varieties. Agronomic and production practices for these varieties were based on each individual grower’s production system. The growers and varieties were: Sandyland Farms (Montcalm), MSL007-B and Manistee (MSL292-A); Sackett Potatoes (Mecosta), Lamoka (NY139).

The USPB / SFA chip trial was the sixth chip processing trial type. For procedural details on this trial, reference the 2013 annual report published by the United States Potato Board.

Within the fresh market trials, there were 62 entries evaluated. There were 3 to 34 lines planted in each of the following counties: Antrim, Delta, Ingham, Kalkaska, Monroe, Montcalm, Osceola, Presque Isle, Sanilac, St. Joseph and Washtenaw counties. The varieties in each trial ranged from mostly round white varieties to mostly russet varieties. These varieties were generally planted in 100' strip plots. A single 23' yield check was taken to evaluate each clone in these strip trials. Seed spacing varied from 8 to 12 inches depending upon grower production practices and variety. The second fresh pack trial type was the Russet Select Trial. The select russet trials were planted at three locations Elmaple Farm (Kalkaska), Montcalm Research Center (Montcalm) and Walther Farms (St. Joseph). At Elmaple Farms, each russet variety was planted in one, three row plot, that was thirty feet long with 34" wide rows and 11-12" in-row spacing. A yield determination was made on 23 feet of the center row. At Walther Farms, Inc. (St. Joseph), three row plots, replicated four times were evaluated. The plots were 15' long by 34" wide and seed spacing was 12". Only the center row was harvested and evaluated. Each select trial varied in the number of varieties tested.

Results

A. Processing Variety Trial Results

A description of the processing varieties, their pedigree and scab ratings are listed in Table 1. The overall averages from ten locations across Allegan, Branch, Gratiot, Montcalm and St. Joseph counties are shown in Table 2. The varieties listed below in the highlights section are listed in yield and trial performance order, highest to lowest. Not all varieties are listed.

Processing Variety Highlights

MSS934-4; this is an MSU clone with excellent yield potential. In the 2013 on-farm trials, this variety yielded 550 cwt./A US#1 with a 1.083 specific gravity, which is five points above the overall trial average of 1.078. A large precent of oversize tubers was observed in this clone. No tubers were observed to have hollow heart (Table 2). This variety had a vine maturity that was slightly later than Snowden. Tuber type was uniform and round and chip quality was good from out-of-the-field.

A01143-3C; this clone was developed in Aberdeen, ID. In 2013, it yielded 505 cwt./A US#1 with 7 percent oversize tubers (Table 2). No hollow heart was observed in the 30 cut tubers. The specific gravity was below the trial average at 1.076. A trace of SED was reported in the out-of-the-field chip sample.

Manistee (MSL292-A); this is a Michigan State University developed variety. In 2013, Manistee had an average yield at 426 cwt./A US#1(Table 2). This variety had 91 percent marketable yield and a slightly above average specific gravity at 1.077. Raw internal tuber quality was good and tuber type was very uniform and round. Four hollow heart in 130 cut tubers were reported. This variety is common scab susceptible. MSL292-A exhibited excellent chip quality out-of-the-field and from storage in 2012, 2013 and early 2014. This variety has chipped well from storage at 48 °F.

NY148 (NYE106-4); this Cornell University developed clone exhibited a strong yield, good size profile and common scab tolerance. In 2013, NY148 yielded 413 cwt./A US#1 over ten locations with an 87% marketable yield average (Table 2). The specific gravity of this clone was seven points above the trial average at 1.083. Two hollow heart were noted in 150 cut tubers. Vine maturity for this variety appeared to be 120 to 130 days. NY148 chipped well in our Michigan trials in 2012 and 2013.

MSL007-B; this is an MSU selection with a heavy netted skin, uniform tuber type and common scab tolerance (Table 1). In 2013, it yielded above average at 407 cwt./A US#1 (Table 2). Chip quality appears to be good from early storage, but some stem end defect has been observed in finished chips from various regions of the state.

BNC182-5; this clone was crossed in North Carolina and selected in Beltsville, MD. In 2013, it yielded 406 cwt./A US#1 with 4 percent oversize tubers (Table 2). None of the oversize tubers were reported to be hollow. The specific gravity was above the trial average at 1.084. The variety had a full season maturity at 120 days. The apical eyes were moderately deep on the larger tubers. Some SED was reported in the out-of-the-field chip sample. The variety had a generally round to flattened appearance and expressed moderate common scab tolerance. The SED remains a concern.

Lamoka (NY139); this is a Cornell University developed clone. This variety continues to exhibit a strong yield and good size profile. In the 2012 processing potato variety trials, Lamoka yielded 404 cwt./A US#1 over eight locations with a 93% marketable yield average (Table 2). The specific gravity of this clone was just above the trial average at 1.079. Three hollow heart were noted in 90 cut tubers. Vine maturity for this variety appeared to be medium-late (120 days). Lamoka continues to chip process well out of mid to late season storage and in some tests is chipping well at 48 ºF. The concern of tuber wet breakdown in storage continues to be raised with Lamoka. Blackleg, Pink Rot, Pythium Leak and Dry Rot are all suggested as causal agents. Lamoka appears to have a storage rot susceptibility similar to Pike.

W5955-1; this selection has been developed at the University of Wisconsin. This variety appears to chip process well from out-of-the-field and early to mid-season storage. It’s yield potential was good, producing 397 cwt./A US#1 in 2013 (Table 2). The average specific gravity of this line was 1.080 across nine locations.

Twenty-one tubers with hollow heart were observed in 120 cut tubers. This line has some common scab tolerance and appears to exhibit a full-season maturity. The internal quality of this variety poses some concern and will be evaluated closely in the future.

MSR127-2; this is an MSU clone with common scab tolerance. In the 2013 on-farm trials, this variety yielded 361 cwt./A US#1 with a 1.079 specific gravity, which is just above the trial average of 1.078. There were two tubers with hollow heart observed in 90 cut tubers (Table 2). This variety had a vine maturity that was similar to Snowden. Tuber type was uniform and round and chip quality was good from mid-season storage.

B. USPB / SFA Chip Trial Results

The Michigan location of the USPB / SFA chip trial was on Sandyland Farms, LLC in Montcalm County in 2013. Table 3 shows the yield, size distribution and specific gravity of the entries when compared with Atlantic and Snowden. Table 4 shows the at-harvest raw tuber quality results. Table 5 shows the out-of-the-field chip quality evaluations from samples processed and scored by Herr Foods, Inc., Nottingham, PA. Table 6 provides the blackspot bruise susceptibility of each entry. Table 7 provides a pre-harvest panel for each of the 18 varieties in the trial.

USPB / SFA Chip Trial Highlights

NY148 and A01143-3C topped the yield table in 2013, followed by a group of lines that yielded above average. These lines were: NY140, CO03243-3W, MSL292-A, and Atlantic (Table 3). W5955-1 had the largest percentage of recorded oversize tubers followed closely by Atlantic (Table 3). AC01151-5W and W6483-5 recorded very low specific gravities. Additional lines with marginal specific gravities reported were MSL292-A, AF4157-6 and CO00197-3W (Table 3). Internal quality across the trial was generally acceptable, but the evidence of in-season environmental stress was observed in some lines. Hollow heart was present in Atlantic and to a lesser extent in W5955-1 and AC01151-5W. CO00197-3W displayed a moderate level of internal brown spots. A00188-3C, MSL007-B and AC01151-5W each recorded above average amounts of vascular discoloration (Table 4). Table 5 shows the post-harvest chip quality based on samples collected on October 3rd, 2013 and processed at Herr Foods, Inc. on October 8th. Chip color was generally acceptable across the trial, with CO02321-4W having the highest Agtron score of the trial at 69.1. The varieties, listed in ranked order based on quality observations from Herr Foods, Inc. are as follows: MSL292-A, MSL007-B, W6609-3, MSR061-1, W6483-5, Snowden, NY148, CO02321-4W, Atlantic, W4980-1, W5955-1, CO03243-3W, A00188-3C, CO00197-3W, AF4157-6, NY140, AC01151-5W and lastly A01143-3C. W4980-1, CO00197-3W, MSL007-B and NY148 showed the greatest susceptibility to blackspot bruise (Table 6).

C. Fresh Market and Variety Trial Results

A description of the freshpack varieties, their pedigree and scab ratings are listed in Table 8. Table 9 shows the overall yield averages for the eight freshpack locations: Antrim, Delta, Kalkaska, Monroe, Montcalm, St. Joseph, and Washtenaw Counties.

Fresh Market Variety Highlights

Two red skin, two yellow flesh, two round white and six russet lines are worthy of mention from the 2013 freshpack on-farm variety trials. They are W6002-1R and W8893-1R (the reds); MSM288-2Y and W6703-1Y (the yellow flesh varieties); MSQ086-3 and NY151 (the white flesh varieties); and the russets are AF3362-1Rus, CO05189-3Rus, W8516-1Rus, W8722-1Rus, W9161-3Rus, W9433-1Rus.

W6002-1R; this University of Wisconsin variety has a smooth bright dark red skin appearance with an oval tuber shape (Table 8). In the 2013 freshpack variety trials, this clone had a 394 cwt./A US#1 yield with a 1.070 specific gravity (Table 9). No hollow heart was observed in 30 cut tubers. Tuber size distribution was good with 84 percent of the tubers being marketable. Thirteen percent oversize tubers were reported. The vine maturity of this clone is medium.

W8893-1R; this University of Wisconsin variety has an early maturity with a good yield of oval tuber type tubers (Table 8). In the 2013 freshpack variety trials, this clone had a 416 cwt./A US#1 yield with a 1.060 specific gravity (Table 9). No hollow heart was noted in 10 cut tubers. Tuber size distribution was good with 84 percent of the tubers being marketable. The skin type of this variety is smooth and bright and the tubers are uniform in shape. The vine maturity is medium-early.

MSM288-2Y; this Michigan State University variety has uniform tuber type with a nice yellow flesh. The tubers have pink eye color similar to Yukon Gold. In 2013, MSM288-2Y yielded 427 cwt./A US#1 with a medium vine maturity (Table 9). The total yield of this variety was reported as 496 cwt./A. The percentage of the total tuber yield that was “B” sized was 11 and the specific gravity was 1.075. This variety expresses common scab susceptibility.

W6703-1Y; this University of Wisconsin variety has a uniform tuber type with a nice yellow flesh and common scab tolerance (Table 8). In 2013, W6703-1Y yielded 327 cwt./A US#1, exhibiting a medium vine maturity (Table 9). The total yield of this variety was reported as 371 cwt./A. The percentage of the total tuber yield that was “B” sized was 11 percent and the specific gravity was 1.072.

MSQ086-3; this Michigan State University variety has uniform tuber type with a bright tuber appearance. In 2013, MSQ086-3 yielded 343 cwt./A US#1 expressing a medium vine maturity (Table 9). The total yield of this variety was reported as 424 cwt./A. The percentage of the total tuber yield that was "B" sized was 20 and the specific gravity was 1.072. This variety expresses common scab tolerance.

NY151; this variety was developed at Cornell University. The tubers have a medium maturity, a large set of medium tubers and a bright skin appearance with shallow eyes (Table 8). In 2013, NY151 yielded 503 cwt./A US#1 (Table 9). The total yield of this variety was reported as 585 cwt./A. The percentage of the total tuber yield that was "B" sized was 11 and the specific gravity was 1.063. This variety expresses common scab tolerance. Overall tuber appearance is uniform in size, smooth and bright.

AF3362-1Rus; this University of Maine selection had a 399 cwt./A US#1 yield, an average specific gravity of 1.075 and three out of 60 tubers exhibited hollow heart (Table 9). Twenty-two percent of the marketable yield was oversized, warranting a closer in-row seed spacing than 12 inches. The tuber appearance was long and blocky with a nice netted russet skin. Vine maturity was medium. This variety appears very promising for the early russet market. AF3362-1Rus performed well across all geographic latitudes and it also has common scab tolerance.

CO05189-3Rus; this is a variety developed at Colorado State University. CO05189-3Rus was only evaluated at one location in 2013 due to the lack of available seed. This variety yielded 418 cwt./A US#1. Fifty percent of the marketable yield was oversize. The specific gravity was 1.065. No cut tubers were reported to have hollow heart. Tuber type was nice and blocky. Common scab tolerance was observed in this clone.

W8516-1Rus; this University of Wisconsin selection had a 395 cwt./A US#1 yield, a specific gravity of 1.071 and 19 of 80 tubers exhibited hollow heart (Table 9). The variety was tested over five locations and the majority of the hollow heart was observed in southern Michigan. Thirteen percent of the total yield were undersize tubers. The tuber's appearance was oblong to blocky with a nice russeted skin. Vine maturity was medium.

W8722-1Rus; this University of Wisconsin selection had a 370 cwt./A US#1 yield and a specific gravity of 1.071 when averaged over six locations (Table 9). No hollow heart was reported in 80 cut tubers. Overall tuber size profile was medium, recording 13 percent oversize tubers. The tuber's appearance was round to oval and somewhat blocky. This clone expresses a very dark russet skin. Vine maturity was medium-late.

W9161-3Rus; this University of Wisconsin selection had a 440 cwt./A US#1 yield, a specific gravity of 1.069 and 2 of 80 tubers exhibited hollow heart (Table 9). Averaged over five locations, 21 percent of the total tuber yield were reported to be oversize and 14 percent were reported as pickouts. The pickouts were recorded as misshapen tubers. The tuber appearance was oblong to blocky with a nice russeted skin. Vine maturity was medium.

W9433-1Rus; this University of Wisconsin selection had a 560 cwt./A US#1 yield with an average specific gravity of 1.075. This clone was the top yielding russet line in the 2013 trials, averaging 36 percent oversize and 4 percent undersize tubers across five locations. No hollow heart was noted in 50 cut tubers (Table 9). The tuber appearance was oblong to blocky with a light russet skin. Vine maturity was medium. This line appears to have good potential for commercialization.

Table 1

2013 MSU Processing Potato Variety Trials

Entry	Pedigree	2013 Scab Rating*	Characteristics
Atlantic	Wauseon X B5141-6 (Lenape)	3.2	High yield, early maturing, high incidence of internal defects, high specific gravity
Elkton (B1992-106)	B1255-5 X B0564-9	-	Medium to medium-late maturity, average yield potential, round to oval tuber type, light netted skin
FL1879	Snowden X FL1207	3.0	High yield, late maturity, large tuber type, late season storage, medium specific gravity
Lamoka (NY139)	NY120 X NY115	1.5	High yield, mid-late season maturity, medium specific gravity, oval to oblong tuber type, low internal defects, long term chip quality
MSL292-A (Manistee)	Snowden X MSH098-2	3.3	Above average yield, scab susceptible, late blight susceptible, medium specific gravity, long storage potential, uniform tuber type, heavy netted skin
MegaChip (W1201)	WISCHIP X FYF85	-	High specific gravity, round oval tubers, medium-large size, scab resistant
Nicolet (W2133-1)	Snowden X S440	-	Medium to high yield, similar to Snowden, high specific gravity, mid-season chip quality
Pike (NYE55-35)	Allegany X Atlantic	1.4	Average yield, early to mid-season maturity, small tuber size profile, early storage, some internal defects, medium specific gravity
Snowden (W855)	B5141-6 X Wischip	3.1	High yield, late maturity, mid-season storage, reconditions well in storage, medium to high specific gravity
A00188-3C	A91790-13 X Dakota Pearl	0.5	High U.S. No. 1 yield, scaly buff skin, high specific gravity, mid-season chip quality, common scab tolerance
A01143-3C	COA95070-8 X Chipeta	1.8**	Average yielding, scaly buff chipper, smaller tuber size, late maturity
AC01151-5W	COA96142-7 X NDA2031-2	1.2	Medium maturity, medium vine size, oblong shape with white flesh
AF0338-17	AF303-5 X SA8211-6	0.5	High yielding, round white, early bulking, moderately susceptible to common scab, resistant to verticillium wilt
AF4157-6	Yankee Chipper X Dakota Pearl	4.0	Medium-early maturity, round to oblong netted tubers, good specific gravity, good chip color from the field and storage, common scab susceptible

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 1 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
AF4386-16	NY120 X CF77154-10	-	
BNC182-5	Tacna X B0766-3	0.5	Short dormancy, above average yield potential, moderate common scab resistance, average chip quality, late blight susceptible, large round flat to oval tuber type
CO00197-3W	A91790-13W X NDTX4930-5W	3.5**	Medium yield potential, small size profile, minimal grade defects, early maturity, medium-high specific gravity, ability to recondition out of 40º F
CO02321-4W	NY115 X BC0894-2W	2.5	Average yield potential, average specific gravity, medium maturity, common scab susceptibility
CO03243-3W	BC894-2W X A91790-13W	3.0	Large vine size with medium maturity, large yield potential
MSL007-B	MSA105-1 X MSG227-2	1.5	Average yield potential , early to mid-season maturity, uniform tuber type, medium specific gravity, scab tolerant, heavy netted skin
MSM246-B	MSE274-A X NY115	3.3	Round-white with a good sugar profile, good specific gravity, excellent chip quality, common scab susceptible
MSN190-2	MSI234-6Y X MSG227-2	2.0	High specific gravity, early maturity, blackspot bruise resistant, average yield
MSR061-1	Mega Chip (W1201) X NY121	2.0	Average yield, round tuber type with netted skin, low reducing sugars, PVY resistant, moderate late blight resistance
MSR127-2	MSJ167-1 X MSG227-2	1.0	Scab resistant, high specific gravity, good chip quality from storage, above average yield potential, medium-late maturity
MSR169-8Y	Pike X MSJ126-9Y	1.4	Below average yield, medium maturity, yellow flesh, average specific gravity, common scab resistant
MSS165-2Y	MSM188-1 X MSL159-AY	1.9	High yield, above average specific gravity, late maturity, uniform round tuber type, heavy netted skin, yellow flesh, good internal tuber quality
MSS934-4	ND6095-1 X ND7377Cb-1	2.9	High yield, oval to oblong tuber type, common scab susceptible

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 1 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
NY140	NY121 X NY115	3.0	Late season chip quality, dual purpose chip and table stock, high yields of large tubers, buff textured skin
NY148	NY128 X Marcy	2.1	Full season maturity, high gravity, scab-resistant chip stock, good yield potential, medium to late season storage quality, black spot bruise susceptible
NY153	Waneta X Pike	2.1	Full season maturity, medium tuber size profile, good chip quality
W2324-1	Snowden X S438	-	Very high yielding potential, high gravity, more susceptible to common scab than Snowden, tolerant of early blight, good early chip quality
W2978-3	Monticello X Dakota Pearl	-	Average yield potential, early bulking, medium-early vine maturity, scab susceptible
W4980-1	B0692-4 X W1355-1	2.5	Medium-early maturity for out-of-the-field chipping, moderate yield potential, low set
W5015-12	Brodick X W1355-1	2.6**	High tuber set and yield, medium-late vine maturity, uniform size tubers, tubers tend toward flat shape, very flat in some environments
W5955-1	Pike X C31-5-120	1.5	High yield, high specific gravity, size profile similar to Atlantic, long storage potential
W6483-5	-	3.0	Above average yield, early maturity, common scab susceptible, below average specific gravity
W6609-3	Pike X Dakota Pearl	0.5	Long term storage potential, common scab resistance, good specific gravity

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 2

2013 Processing Potato Variety Trial
Overall Averages - Ten Locations
Allegan, Branch, Gratiot, Montcalm, & St. Joseph Counties

NUMBER OF		CWT/A		PERCENT OF TOTAL[1]						CHIP	TUBER QUALITY[2]				TOTAL	VINE	VINE		CHIP
LOCATIONS	LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[3]	HH	VD	IBS	BC	CUT	VIGOR[4]	MATURITY[5]	COMMENTS	COMMENTS
4	**FL1879**	**571**	**596**	**95**	**4**	**82**	**13**	**1**	**1.073**	**1.5**	**8**	**21**	**0**	**1**	**60**	**2.6**	**2.7**	**oval to oblong flattened tuber shape, sl Pinkeye, sl alligator hide**	
1	MSS934-4	550	583	94	6	74	20	0	1.083	1.0	0	1	0	0	10	3.0	3.5	common scab susceptible, rhizoctonia	tr SED
1	A01143-3C	505	553	91	5	84	7	4	1.076	1.0	0	4	0	0	30	4.5	1.5	common scab reisistant	tr SED
1	FL1833	479	501	96	4	84	12	0	1.076	1.5	0	3	0	0	10	4.0	3.5	common scab susceptible, large tuber type, light yellow flesh	
5	MSS165-2Y	442	547	79	18	77	2	3	1.082	1.4	3	6	0	0	60	2.6	3.2	sticky stolons, heavy netted skin, knobs and gc in pickouts	tr SED
1	NY140	426	486	88	11	84	4	1	1.076	1.0	0	1	0	0	30	3.5	1.5	common scab susceptible	
9	MSL292-A	426	460	91	7	82	9	2	1.077	1.2	4	16	1	0	130	2.4	2.7	heavy netted skin, flattened apical to stem end, common scab susceptible	
5	MSM246-B	419	454	92	7	87	5	1	1.081	1.0	0	9	0	0	60	2.4	2.9	flat round tuber type, light netted skin, common scab tolerant	
1	CO03243-3W	417	474	88	11	83	5	1	1.078	1.0	0	1	0	0	30	3.0	1.5	common scab susceptible	
10	NY148	413	472	87	12	84	3	1	1.083	1.0	2	21	1	0	150	2.4	2.8	sl common scab, medium netted skin, nice uniform size, tr sticky stolons, common scab tolerant	sl SED
6	MSL007-B	407	457	88	11	85	3	1	1.074	1.1	3	18	2	0	90	2.0	2.8	heavy netted skin, uniform tuber type, common scab tolerant	sl SED
2	BNC182-5	406	479	85	13	81	4	2	1.084	1.8	0	3	0	0	30	1.8	2.6	common scab tolerant, nice size profile	severe SED
8	Lamoka	404	432	93	5	79	14	2	1.079	1.4	3	26	0	1	90	2.7	2.5	oval tuber shape, points and knobs in pickouts, common scab tolerant	
9	W5955-1	397	448	88	9	75	13	3	1.080	1.0	21	27	3	2	120	3.0	2.4	uniform tuber type, misshapen and points in pickouts, tr Pinkeye, common scab tolerant	
2	**Atlantic**	**394**	**440**	**89**	**10**	**84**	**5**	**1**	**1.091**	**1.3**	**5**	**4**	**0**	**0**	**40**	**3.3**	**1.5**	common scab susceptible	**sl SED**
2	AF0338-17	386	447	87	10	79	8	3	1.072	1.0	0	3	0	0	40	1.3	1.8	common scab suscptible	severe scab
6	**Snowden**	**372**	**425**	**86**	**13**	**80**	**6**	**1**	**1.080**	**1.1**	**5**	**16**	**2**	**2**	**100**	**2.9**	**2.6**	uniform round tuber type, common scab susceptible	

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Table 2 continued

NUMBER OF LOCATIONS	LINE	CWT/A US#1	CWT/A TOTAL	PERCENT OF TOTAL[1] US#1	Bs	As	OV	PO	SP GR	CHIP SCORE[3]	TUBER QUALITY[2] HH	VD	IBS	BC	TOTAL CUT	VINE VIGOR[4]	VINE MATURITY[5]	COMMENTS	CHIP COMMENTS
6	**Pike**	**368**	**401**	**92**	**7**	**85**	**7**	**1**	**1.078**	**1.0**	**5**	**5**	**0**	**2**	**70**	**2.2**	**2.3**	**knobs in pickouts, tr growth cracks, common scab resistant**	**sl SED**
8	MSR127-2	361	412	87	10	81	6	3	1.079	1.1	2	10	0	0	90	2.8	2.8	flat oval tuber type, gc in pickouts, common scab resistant	tr SED
4	MSN190-2	337	410	81	19	79	2	0	1.087	1.0	3	2	0	0	40	2.4	3.0	heavy netted skin type, uniform tuber size, common scab resistant	
8	NY153	329	404	80	16	78	2	4	1.080	1.3	18	14	0	0	90	2.8	2.9	tr deep apical eye, misshapen in pickouts, common scab resistant	SED
2	**Elkton**	**320**	**374**	**85**	**15**	**84**	**1**	**0**	**1.087**	**1.5**	**0**	**7**	**0**	**0**	**40**	**1.3**	**2.6**	**common scab tolerant**	**tr VD**
1	CO00197-3W	313	440	72	22	71	1	6	1.073	1.5	0	5	3	1	30	3.5	1.5	common scab susceptible	sl SED
9	A00188-3C	279	391	71	23	70	1	6	1.078	1.2	3	22	0	0	120	3.9	2.3	small tuber size, pointed and knobby in pickouts, sl Pinkeye, common scab resistant	SED
6	W6609-3	278	390	69	29	69	0	2	1.079	1.0	0	9	1	3	90	2.8	2.6	gc and misshapen in pickouts, bright skin appearance, comon scab resistant	tr VD
6	CO02321-4W	274	364	75	25	74	1	0	1.079	1.3	0	14	1	0	90	2.8	2.5	small uniform round tuber type, tr sticky stolons, common scab susceptible	tr SED, tr VD
6	AC01151-5W	273	378	72	25	72	0	3	1.070	1.4	2	19	3	0	90	2.6	2.6	heavy tuber set, moderate Pinkeye, alligator hide, common scab susceptible	tr VD, tr SED
2	AF4157-6	270	378	71	29	71	0	0	1.070	1.0	0	5	0	0	40	2.3	1.5	common scab susceptible	severe scab
1	MSR061-1	270	360	75	24	75	0	1	1.076	1.0	0	2	0	0	30	3.5	1.5	common scab tolerant, tr of pitting	
4	MSR169-8Y	269	343	76	22	73	3	2	1.076	1.3	1	14	0	0	50	1.8	3.3	bright yellow flesh, netted skin, uniform tuber shape, common scab resistant	sl SED
1	W6483-5	232	306	72	23	68	4	5	1.064	1.0	0	3	0	0	30	4.0	1.5	common scab susceptible	
2	W4980-1	214	295	73	27	71	2	0	1.075	1.0	0	5	3	0	40	3.0	1.8	common scab susceptible	tr SED
1	W2978-3	41	173	24	76	24	0	0	1.066	1.0	0	1	0	0	10	2.0	1.5	common scab susceptible, small tuber size	
	MEAN	**359**	**426**						**1.078**										

tr = trace, sl = slight, NA = not available
SED = stem end defect, gc = growth crack

[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 Association
(Out of the field)
Ratings: 1 - 5
1: Excellent
5: Poor

[4]VINE VIGOR RATING
Ratings: 1 - 5
1: Slow Emergence
5: Early Emergence (vigorous vine, some flowering)

[5]VINE MATURITY RATING
Ratings: 1 - 5
1: Early (vines completely dead)
5: Late (vigorous vine, some flowering)

Table 3. Yield , Size Distribution*, Specific Gravity								
	Yield (cwt/A)		Percent Size Distribution					
Entry	US#1	TOTAL	US#1	Small	Mid-Size	Large	Culls	Specific Gravity
NY148	542	614	89	10	83	6	1	1.082
A01143-3C	505	553	91	5	84	7	4	1.076
NY140	426	486	88	11	84	4	1	1.076
CO03243-3W	417	474	88	11	83	5	1	1.078
MSL292-A	395	439	90	10	85	5	0	1.075
Atlantic	**395**	**432**	**92**	**7**	**84**	**8**	**1**	**1.084**
W5955-1	331	389	85	12	76	9	3	1.080
A00188-3C	328	402	81	13	78	3	6	1.079
AF4157-6	324	415	78	21	78	0	1	1.074
MSL007-B	320	376	85	15	84	1	0	1.081
CO00197-3W	313	440	72	22	71	1	6	1.073
Snowden	**291**	**380**	**77**	**23**	**76**	**1**	**0**	**1.078**
MSR061-1	270	360	75	24	75	0	1	1.076
CO02321-4W	260	359	72	28	72	0	0	1.081
AC01151-5W	246	383	64	34	64	0	2	1.067
W6483-5	232	306	72	23	68	4	5	1.064
W4980-1	231	293	79	20	75	4	1	1.077
W6609-3	214	302	70	28	70	0	2	1.080
MEAN	**336**	**411**	**80**	**18**	**77**	**3**	**2**	**1.077**

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

Table 4. At-Harvest Tuber Quality. Sandyland Farms, Howard City, Michigan.					
	Internal Defects[1]				
Entry	HH	VD	IBS	BC	Total Cut
NY148	0	0	0	0	30
A01143-3C	0	4	0	0	30
NY140	0	1	0	0	30
CO03243-3W	0	1	0	0	30
MSL292-A	0	1	0	0	30
Atlantic	**5**	**3**	**0**	**0**	**30**
W5955-1	1	6	0	0	30
A00188-3C	0	10	0	0	30
AF4157-6	0	3	0	0	30
MSL007-B	0	10	0	0	30
CO00197-3W	0	5	3	1	30
Snowden	**0**	**4**	**0**	**0**	**30**
MSR061-1	0	2	0	0	30
CO02321-4W	0	3	0	0	30
AC01151-5W	1	10	0	0	30
W6483-5	0	3	0	0	30
W4980-1	0	3	0	0	30
W6609-3	0	0	0	0	30

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

Table 5. 2013 Post-Harvest Chip Quality[1]						
	Agtron	SFA[2]	Specific	Percent Chip Defects[3]		
Entry	Color	Color	Gravity	Internal	External	Total
NY148	65.2	3.0	1.076	21.8	0.9	22.7
A01143-3C	62.0	3.5	1.071	0.0	6.3	6.3
NY140	63.8	3.0	1.070	25.8	20.5	46.3
CO03243-3W	62.6	2.0	1.074	6.8	22.5	29.3
MSL292-A	62.6	2.0	1.074	3.6	7.8	11.4
Atlantic	**65.8**	**3.0**	**1.083**	**20.2**	**9.6**	**29.8**
W5955-1	63.6	3.0	1.078	12.0	3.8	15.8
A00188-3C	67.1	2.5	1.077	12.9	2.9	15.8
AF4157-6	65.9	3.0	1.076	9.8	15.0	24.8
MSL007-B	64.2	3.0	1.075	4.9	2.0	6.9
CO00197-3W	63.7	3.0	1.077	17.3	13.1	30.4
Snowden	**63.2**	**2.0**	**1.074**	**4.5**	**11.3**	**15.8**
MSR061-1	61.9	2.5	1.070	3.0	4.1	7.1
CO02321-4W	69.1	2.0	1.078	4.5	13.0	17.5
AC01151-5W	59.0	3.0	1.072	16.0	11.6	27.6
W6483-5	67.0	2.0	1.062	0.0	0.0	0.0
W4980-1	64.1	2.5	1.075	22.9	4.1	27.0
W6609-3	66.8	2.5	1.077	9.1	0.0	9.1

[1]Samples collected October 3rd and processed by Herr Foods, Inc., Nottingham, PA on October 8, 2013.

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 6. Black Spot Bruise Test																				
	A. Check Samples[1]										B. Simulated Bruise Samples[2]									
								Percent	Average									Percent	Average
	# of Bruises Per Tuber						Total	Bruise	Bruises Per	# of Bruises Per Tuber							Total	Bruise	Bruises Per
Entry	0	1	2	3	4	5	Tubers	Free	Tuber	0	1	2	3	4	5		Tubers	Free	Tuber
NY148	13	11	1				25	52	0.5	3	5	11	3	1	2		25	12	2.0
A01143-3C	20	4	1				25	80	0.2	2	8	13	2				25	8	1.6
NY140	13	11	1				25	52	0.5	9	9	7					25	36	0.9
CO03243-3W	14	7	3	1			25	56	0.6	8	6	7	4				25	32	1.3
MSL292-A	22	2	1				25	88	0.2	6	5	8	5	1			25	24	1.6
Atlantic	**18**	**5**	**2**				**25**	**72**	**0.4**	**12**	**8**	**5**					**25**	**48**	**0.7**
W5955-1	25						25	100	0.0	16	6	2	1				25	64	0.5
A00188-3C	22	3					25	88	0.1	14	10		1				25	56	0.5
AF4157-6	21	4					25	84	0.2	6	9	7	2	1			25	24	1.3
MSL007-B	15	10					25	60	0.4	4	4	8	3	5	1		25	16	2.2
CO00197-3W	8	6	7	3	1		25	32	1.3		6	9	7	2	1		25	0	2.3
Snowden	**21**	**4**					**25**	**84**	**0.2**	**8**	**14**	**2**	**1**				**25**	**32**	**0.8**
MSR061-1	17	6	2				25	68	0.4	16	9						25	64	0.4
CO02321-4W	23	2					25	92	0.1	17	7	1					25	68	0.4
AC01151-5W	11	10	4				25	44	0.7	13	12						25	52	0.5
W6483-5	25						25	100	0.0	20	5						25	80	0.2
W4980-1	15	7	3				25	60	0.5			6	4	6	9		25	0	3.7
W6609-3	20	5					25	80	0.2	16	8	1					25	64	0.4

[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 7. Pre-Harvest Panel, 8/21/13								
	Specific	Glucose[1]	Sucrose[2]	Canopy		Number of		Average[5] Tuber
Entry	Gravity	%	Rating	Rating[3]	Uniform.[4]	Hills	Stems	Weight
NY148	1.087	0.002	0.548	75	95	3	21	3.16
A01143-3C	1.084	0.006	1.150	80	95	4	16	4.99
NY140	1.076	0.002	0.596	75	90	4	19	3.74
CO03243-3W	1.082	0.003	0.645	40	90	4	25	3.37
MSL292-A	1.076	0.002	1.094	25	85	4	11	4.03
Atlantic	**1.082**	**0.002**	**0.593**	**80**	**95**	**4**	**14**	**3.91**
W5955-1	1.080	0.003	0.636	85	90	6	16	5.10
A00188-3C	1.079	0.013	1.505	85	95	-	-	4.39
AF4157-6	1.073	0.006	1.021	10	95	3	14	2.82
MSL007-B	1.084	0.002	0.570	70	90	4	13	3.36
CO00197-3W	1.079	0.006	1.931	75	95	3	12	2.82
Snowden	**1.080**	**0.002**	**1.023**	**75**	**95**	**4**	**17**	**2.78**
MSR061-1	1.079	0.002	0.632	45	90	4	22	3.20
CO02321-4W	1.085	0.002	0.765	35	90	3	16	2.76
AC01151-5W	1.082	0.007	1.144	80	90	3	14	2.35
W6483-5	1.067	0.002	0.862	10	90	3	12	3.79
W4980-1	1.079	0.002	0.847	75	95	4	15	3.45
W6609-3	1.081	0.002	0.970	75	95	5	19	2.26

1 Percent Glucose is the percent of glucose by weight in a given amount of fresh tuber tissue.

2 Sucrose Rating is the percent of sucrose by weight in a given amount of fresh tuber tissue X10.

3 The Canopy Rating is a percent rating of green foliage (0 is all brown, dead foliage; 100 is green, vigorous foliage).

4 The Canopy Uniformity is a percentage of how uniform the foliage health is at the date of observation.

5 The Average Tuber Weight is the total tuber weight collected, divided by the number of tubers, reported in ounces.

Table 8

2013 MSU Tablestock Potato Variety Trials

Entry	Pedigree	2013 Scab Rating*	Characteristics
Goldrush Russet (ND1538-1Rus)	ND450-3Rus X Lemhi Russet	0.8**	Medium maturity, oblong-blocky to long tubers, bright white flesh, common scab resistance, average yield potential
Katahdin	USDA 40568 X USDA 24642	1.0	Medium to high yield, medium specific gravity, shallow eyes and uniform round to oblong shape, smooth white skin, common scab susceptible
Onaway	USDA X96-56 X Katahdin	2.3	High yield, early maturity, round tuber type, low specific gravity, smooth skin, white flesh, medium deep eyes, few internal defects
Reba (NY 87)	Monona X Allegany	2.6	High yield, bright tuber appearance, low incidence of internal defects, mid to late season maturity, medium-low specific gravity
Red Norland	ND 626 X Red Kote	2.0	Early maturity, medium yield, low specific gravity, smooth round to oblong tubers, medium red skin color
Russet Norkotah (ND534-4Rus)	ND9526-4Rus X ND9687-5Rus	2.5	Average yield, mid-season maturity, long to oblong tubers, heavy russet skin, low specific gravity
Russet Norkotah LT	Russet Norkotah Line Selection	2.2**	Above average yield, medium to medium-late maturity, long to oblong tubers, heavy russet skin, low specific gravity, better vigor than standard Russet Norkotah
Silverton Russet (AC83064-6)	A76147-2 X A 7875-5	1.1	High yield, oblong to long blocky tuber type, medium netted russet skin, masks PVY, medium specific gravity, possible Sencor & Linuron susceptibility
A02062-1TERus	A97201-4 X A97299-1	0.3	Long tuber type, medium-heavy russeting, higher U.S. No. 1 yields and larger tuber size than Russet Norkotah, early to mid-season maturity
A03158-2TERus	A98292-2 x A98104-4	0.6	

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 8 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
AF3362-1Rus	Reeves Kingpin X Silverton Russet	1.3**	Long to oblong, blocky russet tuber type with good yield, processing potential and generally good appearance, common scab tolerance, early bulking potential, medium netted russet skin, similar to Silverton Russet
CO04220-7Rus	CO96109-7Rus X Summit Russet	1.5	
CO04233-1Rus	CO97138-3Rus X Summit Russet	0.5	
CO05024-11Rus	Rio Grande Russet x Sage Russet	0.5	
CO05040-1Rus	Sage Russet x A96095-3	0.6	
CO05068-1Rus	AWN86514-2 x CO98009-3RU	1.3	
CO05110-6Rus	COA96054-3 x CO98009-3RU	2.0	
CO05132-2Rus	Blazer Russet x CO99100-1RU	0.5	
CO05149-3Rus	AC96052-1RU x CO99100-1RU	2.0	
CO05152-5Rus	AC99375-1RU x Blazer Russet	0.4	
CO05175-1Rus	CO94035-15RU x AC96052-1RU	1.1	

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 8 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
CO05189-2Rus	CO97138-7RU x AC92009-4RU	4.1	
CO05189-3Rus	CO97138-7RU x AC92009-4RU	1.8	
CO05211-4R	CO98012-5R x CO00278-4R	1.0	
CO05228-4R	CO99256-2R x CO00292-9R	2.0	
MSJ126-9Y (McBride)	Penta X Op	1.1**	Medium yield, uniform A-size tubers, attractive appearance, good internal quality, mid-season storage potential, low-medium specific gravity, light yellow flesh, netted skin type
MSM288-2Y	MSG145-1 X MSA097-1Y	3.1	A deep yellow flesh selection similar in type to Yukon Gold, common scab susceptible, uniform tuber type, pink eyes on tubers
MSQ086-3	Onaway X Missaukee (MSJ461-1)	2.4	Good yield potential, nice round white tuber type, medium maturity, late blight resistance, good internal quality
MSQ440-2	MSK214-1R X Missaukee (MSJ461-1)	1.0	Average yield potential, uniform round tubers, very bright white skin, common scab tolerance
MSR214-2P	MI Purple X MSK247-9Y	2.3	Medium yield potential, common scab tolerant purple skin with white flesh
MSS576-05SPL	MSI005-20Y X MSL211-3	2.2	

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 8 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
NY140	NY121 X NY115	3.0	Late season maturity, dual purpose chip and table stock, high yields of large tubers, lightly textured skin, resistant to race Ro1 of the golden nematode and moderately resistant to race Ro2
NY141	R6-4 X NY115	1.0	Early to mid-season, common scab resistant, low frequency of internal defects
NY151	NY 121 X Jacqueline Lee (MSG274-3)	0.5	Early season tablestock variety, large tuber set, small tuber size, bright appearance, smooth skin, shallow eyes, bright white flesh, intermediate common scab resistance
W6002-1R	B1491-5 X W1100R	2.1	Nice red color, very uniform tuber type with good market appeal, good skin set, medium-high yield
W6703-1Y	Satina X W2275-2Y	1.0	Good yield, medium maturity, slightly better shape than W6703-5Y, common scab tolerant, medium yellow flesh, buff to slightly netted skin type
W6703-5Y	Satina X W2275-2Y	1.0	Medium yield, medium to medium-late maturity, common scab tolerant, dark yellow flesh, buff to slightly netted skin type
W8152-1Rus	A93004-3Rus X CO94035-15Rus	2.1	High yield potential, blocky shape, high specific gravity, long storage potential
W8405-1R	Kankan X W2303-9R	1.9	Very high yield potential, later maturity than Red Norland, shallow eyes, good internal quality, attractive round oval tuber type, maintains red skin color in storage
W8516-1Rus	Silverton X Ranger Rus	-	High yield, medium-early; mature as early as Russet Norkotah, common scab resistant
W8722-1Rus	A9014-2Rus X W2683-2Rus	-	Yield similar to Russet Norkotah medium-late maturity, common scab resistance, dark russeting, many 6-8 oz. tubers

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data. Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 8 continued

Entry	Pedigree	2013 Scab Rating*	Characteristics
W8886-3R	W2303-8R X B1491-5R	-	Early bulking, as early as Red Norland, nice red skin color and smooth tuber type
W8893-1R	W1101R X Dakota Rose	-	Early maturity, good yield, oval tuber type, nice uniform red skin color
W9161-3Rus		0.5	
W9433-1Rus	Calwhite X A96023-6	0.5	Light russet skin type, less internal defects than Russet Norkotah, tolerance to Verticillium Wilt and Early Blight, medium-late maturity, oblong to long blocky tuber type
W9739-2Rus		0.5	
W9746-4R		1.5	
W9765-3R		1.0	

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible. **2012 Data.
Common Scab data provided by MSU Potato Breeding and Genetics Program.

Table 9

2013 Freshpack Potato Variety Trial
Overall Averages - Eight Locations
St. Joseph, Delta, Antrim, Kalkaska, Montcalm, Washtenaw, and Monroe 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	VINE VIGOR[3]	VINE MATURITY[4]	COMMENTS
1	**Onaway**	**569**	**664**	**86**	**4**	**75**	**11**	**10**	**1.072**	**0**	**3**	**0**	**2**	**10**	**3.5**	**4.0**	sheep nose, deep eyes, misshpen in pickouts
5	W9433-1Rus	560	650	87	4	51	36	9	1.075	0	7	6	0	50	2.6	2.5	light russet skin, points and misshapen in pickouts, nice large blocky tuber type, tr alligator hide, common scab resistant
2	**Russet Norkotah LT**	**555**	**737**	**69**	**9**	**59**	**10**	**22**	**1.079**	**6**	**9**	**0**	**0**	**50**	**2.0**	**NA**	misshapen in pickouts, tr alligator hide
1	W9765-3R	552	700	79	8	78	1	13	1.070	0	0	0	1	10	1.5	3.0	common scab tolerant, medium red color, sl rhizoctonia, severe gc in pickouts, 7 tubers with anthocianin
1	**Katahdin**	**552**	**660**	**84**	**9**	**77**	**7**	**7**	**1.070**	**1**	**1**	**0**	**1**	**10**	**5.0**	**2.0**	common scab resistant, deep eyes and misshapen in pickouts
1	**Nadine**	**532**	**671**	**79**	**16**	**79**	**0**	**5**	**1.059**	**0**	**2**	**3**	**0**	**10**	**2.5**	**3.0**	oval oblong tuber type, gc in pickouts
5	NY151	503	585	85	11	81	4	4	1.063	0	0	4	4	50	3.2	2.7	uniform round tuber type, points in pickouts, common scab tolerant
5	**Russet Norkotah**	**482**	**595**	**82**	**8**	**59**	**23**	**10**	**1.071**	**13**	**9**	**0**	**0**	**80**	**2.9**	**2.3**	misshapen pickouts, common scab tolerant, sl alligator hide
5	**Reba**	**479**	**529**	**87**	**6**	**68**	**19**	**7**	**1.069**	**12**	**3**	**0**	**2**	**50**	**3.2**	**2.5**	deep eyes, large oval tuber type, tr netted skin, common scab tolerant
6	NY140	471	532	84	14	72	12	2	1.075	9	14	3	0	60	3.2	3.5	bright skin appearance, oval tuber type, misshapen in pickouts, common scab tolerant
5	W9161-3Rus	440	563	77	9	56	21	14	1.069	2	4	0	0	80	2.5	3.0	large tubular tuber type, netted russeting, misshapen in pickouts, sl alligator hide, common scab resistant
6	NY141	439	528	82	6	67	15	12	1.073	0	9	0	1	60	3.5	2.8	misshapen in pickouts, flat oval tuber type,tr deep apical eyes, common scab tolerant
5	MSM288-2Y	427	496	84	11	78	6	5	1.075	6	4	0	0	50	3.6	2.5	pink eyes, medium yellow flesh, gc and knots in pickouts, common scab tolerant
6	A02062-TERus	425	579	72	8	49	23	20	1.073	1	22	0	0	90	1.8	2.0	heavy russet skin, long tubular tuber type, misshapen in pickouts
1	W8886-3R	418	469	89	8	81	8	3	1.064	0	1	0	0	10	2.0	2.0	oval to oblong tuber type, tr netted skin, good red skin color
1	CO05189-3Rus	418	541	77	8	27	50	15	1.065	0	0	0	0	10	NA	NA	nice blocky type
5	W9739-2Rus	417	556	75	20	66	9	5	1.076	0	6	1	0	80	2.4	2.7	light russet skin, sl alligator hide, common scab resistant
1	W8893-1R	416	496	84	15	84	0	1	1.060	0	2	0	0	10	2.5	1.5	common scab resistant, smooth oval tuber appearance, good red skin color
1	CO05189-2Rus	413	621	67	17	62	5	16	1.071	0	0	0	0	40	NA	NA	tr alligator hide
2	MSS576-05SPL	412	508	75	24	69	6	1	1.071	0	5	0	0	20	2.0	3.3	pink eye splash, common scab resistant
5	W8152-1Rus	408	480	85	10	75	10	5	1.079	33	5	0	0	90	3.1	2.8	heavy russet skin, gc and misshapen in pickouts, severe alligator hide, common scab tolerant
1	A03158-2TERus	400	577	69	10	62	7	21	1.077	1	0	0	0	30	NA	NA	sl alligator hide
6	AF3362-1Rus	399	479	79	13	57	22	8	1.075	3	24	1	0	60	2.4	2.5	sl alligator hide, heavy netted skin, misshapen and knots in pickouts
5	W8516-1Rus	395	499	79	13	66	13	8	1.071	19	18	0	0	80	2.3	2.8	large blocky tuber type, enlarged lenticels, sl alligator hide
1	CO05132-2Rus	394	486	82	9	65	17	9	1.072	4	15	0	0	40	NA	NA	severe alligator hide
2	**GoldRush Russet**	**394**	**499**	**80**	**13**	**71**	**9**	**7**	**1.074**	**4**	**1**	**0**	**0**	**20**	**2.5**	**2.0**	heavy russet skin

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Table 9 continued

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	VINE VIGOR[3]	VINE MATURITY[4]	COMMENTS
3	W6002-1R	394	467	84	11	71	13	5	1.070	0	0	0	0	30	3.5	3.0	oval tuber type, medium red skin color
1	CO05110-6Rus	380	518	74	11	62	12	15	1.075	3	6	0	0	40	NA	NA	tr alligator hide
4	CO04233-1Rus	377	487	76	17	70	6	7	1.073	8	13	0	0	80	2.0	2.5	medium russet skin, points and misshapen in pickouts, sl Pinkeye, sl alligator hide
1	CO05228-4R	372	478	78	20	78	0	2	1.070	0	0	0	0	10	1.5	2.0	common scab tolerant, small uniform tuber size
5	W8722-1Rus	370	457	81	11	68	13	8	1.071	0	12	0	0	80	1.6	3.2	gc in pickouts, dark heavy russet skin, medium uniform tuber type, tr alligator hide
1	W9746-4R	368	466	79	21	79	0	0	1.064	0	4	0	0	10	2.0	2.5	common scab tolerant, medium red skin color
6	MSJ126-9Y	367	431	84	12	77	7	4	1.075	2	17	2	0	60	2.9	3.0	light yellow flesh, deep eyes, average uniform tuber size, common scab resistant , misshapen in pickouts
7	**Silverton Russet**	**358**	**463**	**75**	**19**	**58**	**17**	**6**	**1.070**	**14**	**11**	**0**	**4**	**100**	**2.8**	**2.9**	sl alligator hide, common scab resistant
1	CO05024-11Rus	355	482	74	12	64	10	14	1.074	5	0	0	0	40	NA	NA	
1	Lamoka	352	368	95	5	89	6	0	1.074	0	3	0	0	10	4.5	2.0	common scab resistant, oval blocky tuber type, netted skin
2	MSR214-2P	344	442	70	22	67	3	8	1.067	1	3	0	2	20	1.5	2.8	deep purple skin color,gc in pickouts, common scab tolerant
6	MSQ086-3	343	424	75	20	74	1	5	1.072	0	6	3	0	60	2.6	3.2	unifrom round tuber type, gc and points in pickouts, bright skin appearance, common scab resistant
5	MSQ440-2	336	386	86	11	78	8	3	1.065	0	13	0	0	50	2.4	2.5	bright skin appearance, medium uniform tuber type, common scab tolerant
1	**Snowden**	**335**	**483**	**69**	**13**	**61**	**8**	**18**	**1.067**	**0**	**3**	**0**	**0**	**10**	**5.0**	**2.5**	common scab resistant, deep eyes and misshapen in pickouts
4	W6703-1Y	327	371	88	11	87	1	1	1.072	1	2	1	0	40	2.6	2.5	medium yellow flesh, uniform tuber type, knobs and points in pickouts, common scab resistant
5	W6703-5Y	326	377	85	11	79	6	4	1.067	0	7	3	0	50	2.1	3.2	gc and misshapen in pickouts, sticky stolens, oblong tuber type, tr alligator hide, common scab tolerant
3	W8405-1R	321	431	74	14	71	3	12	1.070	3	1	6	0	30	2.8	3.2	light red skin color, oblong to long tuber type, misshapen in pickouts
1	**Superior**	**317**	**339**	**93**	**4**	**91**	**2**	**3**	**1.076**	**1**	**1**	**0**	**0**	**10**	**2.0**	**3.0**	**points in pickouts**
1	CO05175-1Rus	304	458	66	11	63	3	23	1.078	2	3	0	0	40	NA	NA	
3	**Red Norland**	**300**	**383**	**79**	**11**	**69**	**10**	**10**	**1.064**	**2**	**2**	**1**	**0**	**30**	**3.0**	**3.0**	**oval tuber type, medium to light red skin color, scab resistant**
1	CO05068-1Rus	288	424	68	14	67	1	18	1.089	5	1	2	0	40	NA	NA	tr alligator hide
4	CO04220-7Rus	279	420	67	25	62	5	8	1.071	18	23	5	0	80	2.1	2.8	misshapen in pickouts, sl alligator hide, medium russeting
1	CO05040-1Rus	263	474	55	22	55	0	23	1.065	0	4	0	0	40	NA	NA	severe alligator hide, small tubular tuber type, misshapen tuber type, not uniform
1	CO05149-3Rus	220	444	49	25	46	3	26	1.074	4	1	0	0	40	NA	NA	tr Pinkeye, tr alligator hide
1	CO05211-4R	204	328	62	35	62	0	3	1.067	0	9	0	0	10	1.5	3.0	common scab resistant, small tuber size, dark red skin color, oblong tuber type
1	CO05152-5Rus	134	550	24	30	24	0	46	1.073	0	9	0	0	40	NA	NA	tr alligator hide, gc and points in pickouts
	MEAN	**389**	**501**						**1.071**								

tr = trace, sl = slight, NA = not available
SED = stem end defect, gc = growth crack

[1]SIZE
Bs: < 1 7/8" or <4oz.
As: 1 7/8" - 3.25" or 4-10oz.
OV: > 3.25" or >10oz.
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]VINE VIGOR RATING
Ratings: 1 - 5
1: Slow Emergence
5: Early Emergence (vigorous vine, some flowering)

[4]VINE MATURITY RATING
Ratings: 1 - 5
1: Early (vines completely dead)
5: Late (vigorous vine, some flowering)

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ENTOMOLOGY RESEARCH REPORT - 2013

Field evaluations of registered and experimental insecticides for managing Colorado potato beetle on potatoes

The Colorado potato beetle (*Leptinotarsa decemlineata*, Say, Coleoptera: Chrysomelidae) is the most widespread and destructive insect pest of potato crops in the eastern United States and Canada. Its ability to develop resistance to insecticides makes it very important to continue testing the efficacy of both new insecticide chemistries and existing compounds. Such tests provide data on comparative effectiveness of products and data to help support future registrations and use recommendations.

METHODS

Fifteen insecticide treatments and an untreated check (Table 1) were tested at the MSU Montcalm Research Farm, Entrican, MI for control of Colorado potato beetle. 'Atlantic' potato seed pieces were planted 12 in. apart, with 34 in. row spacing on 3 June 2012. Treatments were replicated four times in a randomized complete block design. Plots were 50 ft. long and three rows wide with untreated guard rows bordering each plot.

Brigadier 2SC, Verimark 20SC, Admire Pro 4.6SC, and Platinum 75SG treatments were applied as in-furrow sprays at planting on 3 June 2013. Post-plant directed sprays were applied when potatoes first started emerging from the soil, on 10 June 2013. Foliar treatments were first applied at greater than 50% Colorado potato beetle egg hatch on 28 June 2013. Based on the economic threshold of more than one large larva per plant, additional first generation sprays were needed for Gladiator (11 and 18 July), Athena (11 July), Blackhawk (11 July), the low rate of Torac 15 EC (11 July), and Admire Pro (11 and 18 July); no subsequent applications were necessary for any of the Dupont treatments. All applications were made using a single-nozzle hand-held boom (30 gallons/acre and 30 psi).

Post-spray counts of first generation Colorado potato beetle adults, small larvae (1st and 2nd instars), and large larvae (3rd and 4th instars) from five randomly selected plants from the middle row of each plot were made weekly, starting on 2 July. Plots were visually rated for defoliation weekly by estimating total defoliation per plot.

The numbers of small larvae, large larvae, and adults, as well as the defoliation ratings, were transformed log (x + 1) prior to analysis. Analysis of variance was used for data analysis and ad-hoc Tukey means separation was used to compare treatment means ($P < 0.05$).

RESULTS

Except for Admire Pro and Athena, all treatments resulted in significantly fewer small larvae than the untreated control, while all treatments significantly reduced the number of large larvae per plant, compared to the untreated (Table 2). There were also significant differences in numbers of large larvae among the insecticide treatments. All three systemic products (Admire Pro, A16901, and Platinum 75 SG) performed well, with A16901 having significantly fewer large larvae than six of the foliar products. Among the foliar products, Admire Pro required weekly sprays, while F9318 and the low rate of Torac 15 EC were applied three of the four weeks. Athena, Blackhawk, and the high rate of Torac 15 EC required one subsequent application, all two weeks after the initial application. Of these, however, only Blackhawk provided reduction in average large larvae below the threshold of one per plant. Despite one fewer application for the high rate of Torac 15 EC, no significant differences in beetle life stages or defoliation were noted between the high and low rates for this product. All three Benevia 10 OD treatments required only the initial foliar application to provide first generation beetle control.

The untreated plots had significantly greater defoliation compared to all other treatments. The seasonal defoliation average was 36.6% in the untreated plots, compared to less than 6% for all other treatments. Differences in defoliation among insecticide treated plots ranged from 1.1 to 5.9%. Neonicotinoid insecticides are still providing sufficient Colorado potato beetle control for Michigan farmers, but new chemistries like Benevia 10 OD are also proving to be effective.

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Table 1. Insecticide treatments for Colorado potato beetle management in a field trial conducted by MSU vegetable entomology in 2013.

Trt #	Commercial Name	Manufacturer	Formulation	Active Ingredient	Chemical Class	Rate	Type	Application Dates in 2013*
1	Untreated							
2	Brigadier 2SC	FMC	2 SC	bifenthrin	pyrethroid	25.6 oz/A	at planting	6/3
	Gladiator	FMC	0.25 EW	abamectin, z-cypernethrin	avermectin, pyrethroid	14 oz/A	foliar	6/28, 7/18
3	Capture LFR	FMC	1.5 SC	bifenthrin	pyrethroid	25.6 oz/A	at planting	6/3
	Admire PRO	FMC	4.6 SC	imidacloprid	neonicotinoid	5.22 oz/A	post-plant, directed	6/19
	Athena	FMC	0.87 EW	abamectin, bifenthrin	avermectin, pyrethroid	16 oz/A	foliar	6/28, 7/11
4	Brigadier 2 SC	FMC	2 EC	bifenthrin, imidacloprid	pyrethroid, neonicotinoid	25.6 oz/A	post-plant, directed	6/19
	Gladiator	FMC	0.25 EW	abamectin, z-cypernethrin	avermectin, pyrethroid	14 oz/A	foliar	6/28, 7/11
5	Verimark	Dupont	20SC	cyazypyr	diamide	13.5 oz /A	at planting	6/3
	Asana XL	Dupont	0.66 EC	esfenvalerate	pyrethroid	9.6 oz/A	foliar	6/28
6	Exirel	Dupont	10 SE	cyazypyr	diamide	5 oz/A	foliar	6/28
7	Platinum	Syngenta	2 SL	thiamethoxam	neonicotinoids	8 oz/A	at planting	6/3
	Benevia	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
8	Platinum	Syngenta	2 SL	thiamethoxam	neonicotinoids	8 oz/A	at planting	6/3
9	Benevia +	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
	MSO			methylated seed oil	surfactant	0.5% v/v		
10	Benevia +	Dupont	10 OD	cyazypyr	diamide	5 oz/A	foliar	6/28
	MSO			methylated seed oil	surfactant	0.5% v/v		
11	Exirel	Dupont	10 SE	cyazypyr (cyatraniliprole)	diamide	6.75 oz/A	foliar	6/28
12	Admire PRO	Bayer	4.6 SC	imidacloprid	neonicotinoid	1.3 oz/A	foliar	6/28, 7/11, 7/18
13	Blackhawk	Dow	36	spinosad	spinosyns	3.2fl oz/A	foliar	6/28, 7/11
14	Torac	Nichino	15 EC	tolfenpyrad	pyrazoles	14 oz/A	foliar	6/28, 7/11
15	Torac	Nichino	15 EC	tolfenpyrad	pyrazoles	21 oz/A	foliar	6/28
16	Admire PRO	Bayer	4.6 SC	imidacloprid	neonicotinoid	7 oz/A	at planting	6/3

* First foliar application was made at 50% egg-hatch, all subsequent foliar applications are based on 1 large larva per plant threshold.

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Table 2. Mean Colorado potato beetle (CPB) per plant by date in the 2013 MSU vegetable entomology field trial. The bold numbers in the top row correspond to the treatment numbers in Table 1. Bold letters in the green colored 'small and large larvae' rows at the bottom of the table indicate significant differences among the treatments, Tukey HSD (α = 0.05).

date	**Mean CPB**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**TOTAL**
2-Jul	intact egg masses	0.7	0.7	0.25	0.5	0.5	0.3	0	0.15	0.5	0.7	0.25	0.9	0.8	0.6	0.45	0.6	0.52
	hatched egg masses	0	0	3.2	0.55	0	2.45	0	0	0.2	0.3	3.55	2.4	0	0.8	0	0.7	0.92
	small larvae	7.1	0	0.05	0.5	0	0.7	0	0	1.15	0.25	0.75	0.45	0.65	0.9	1	0	0.79
	large larvae	1.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.09
	adults	0.3	0.1	0.1	0.15	0.1	0.25	0.15	0.55	0.15	0.05	0.15	0.4	0.2	0.05	0.05	0.25	0.19
5-Jul	intact egg masses	0.85	0.55	0.4	0.95	0.6	0.3	0	0	0.2	0.25	0.65	1	0.3	0.7	0.2	1.1	0.49
	hatched egg masses	1.05	2.2	3.9	0.1	1.3	2.75	0	0	2.45	2.05	1.95	3.05	0	0.25	0.45	0.05	1.52
	small larvae	2.5	0.25	1.25	5.35	0.35	0.15	0	0	0.25	0.05	0	3.65	0.4	1.25	0.3	0.1	0.94
	large larvae	2.95	0	0	0	0	0	0	0	0	0	0	0.3	0.05	0.15	0	0.15	0.21
	adults	0.55	0.35	0.35	0.35	0.75	0.3	0.25	0.1	0.15	0.2	0.1	0.2	0.25	0.1	0.05	0.1	0.26
10-Jul	intact egg masses	0.65	0.35	0.15	0.5	0.15	0.15	0.05	0	0.15	0.5	0.15	0.1	0.25	0.25	0.4	0.4	0.25
	hatched egg masses	2.05	0	1.05	0.2	0.55	0.1	0	0	0.8	0	0	1.9	0	1.25	0.6	0	0.61
	small larvae	7.85	0.7	1.9	3.15	0.35	0.3	0	0	0.8	1.35	0.5	4.7	1.9	1.25	1.55	3.45	2.09
	large larvae	10.7	0.3	1.1	3.15	0	0.05	0	0	0	0	0.05	6.95	1.45	2	0.1	0.9	1.66
	adults	0	0.25	0.35	0.25	0.25	0.3	0.3	0.1	0.15	0.25	0.25	1.25	0.3	0.1	0.1	0.2	0.26
17-Jul	intact egg masses	0	0	0	0	0.05	0.05	0	0	0.15	0	0.05	0	0.05	0	0.2	0.15	0.04
	hatched egg masses	0	0	0	0	0.25	0	0	0	0.7	0	0.4	0	0	0.25	0.55	0	0.13
	small larvae	2.05	0.65	0.15	0.65	0.05	0.45	0	0.1	0.5	0.6	0.6	0.45	0.05	0.1	0.45	1.35	0.54
	large larvae	4.05	1.65	0.3	1.25	0.25	0.6	0	0	0.25	0.8	0.55	1.35	0	0.75	0.3	1.1	0.93
	adults	0	0	0	0.05	0.05	0.1	0	0.15	0	0	0	0.05	0.05	0	0	0	0.03
24-Jul	intact egg masses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	hatched egg masses	0	0	0	0	0	0.2	0.15	0	0	0	0	0	0.25	0.65	0	0	0.07
	small larvae	0.35	0.4	0.1	0.3	0.45	0.25	0	0.1	0.5	0.55	0.5	0	0.05	0	0.2	0	0.22
	large larvae	0.8	0.45	0.65	0.65	0.05	0.1	0	0	0.55	0.6	0.45	0	0.15	0.2	0.6	0	0.31
	adults	1.35	0.15	0.1	0.25	0.1	0.15	0.1	0.15	0	0.1	0.2	0.25	0.2	0.25	0.2	0.1	0.23
TOTAL	intact egg masses	0.44	0.32	0.16	0.39	0.26	0.16	0.01	0.03	0.2	0.29	0.22	0.4	0.28	0.31	0.25	0.45	0.26
	hatched egg masses	0.62	0.44	1.63	0.17	0.42	1.1	0.03	0	0.83	0.47	1.18	1.47	0.05	0.64	0.32	0.15	0.65
	small larvae	**3.97a**	**0.4bc**	**0.69bc**	**1.99b**	**0.24bc**	**0.37bc**	**0c**	**0.04c**	**0.64bc**	**0.56bc**	**0.47bc**	**1.85b**	**0.61bc**	**0.7bc**	**0.7bc**	**0.98bc**	**0.92**
	large larvae	**3.97a**	**0.48bc**	**0.41bc**	**1.01bc**	**0.06c**	**0.15c**	**0c**	**0c**	**0.16c**	**0.28bc**	**0.21c**	**1.72b**	**0.33bc**	**0.62bc**	**0.22c**	**0.43bc**	**0.64**
	adults	0.44	0.17	0.18	0.21	0.25	0.22	0.16	0.21	0.09	0.12	0.14	0.43	0.2	0.1	0.08	0.13	0.19

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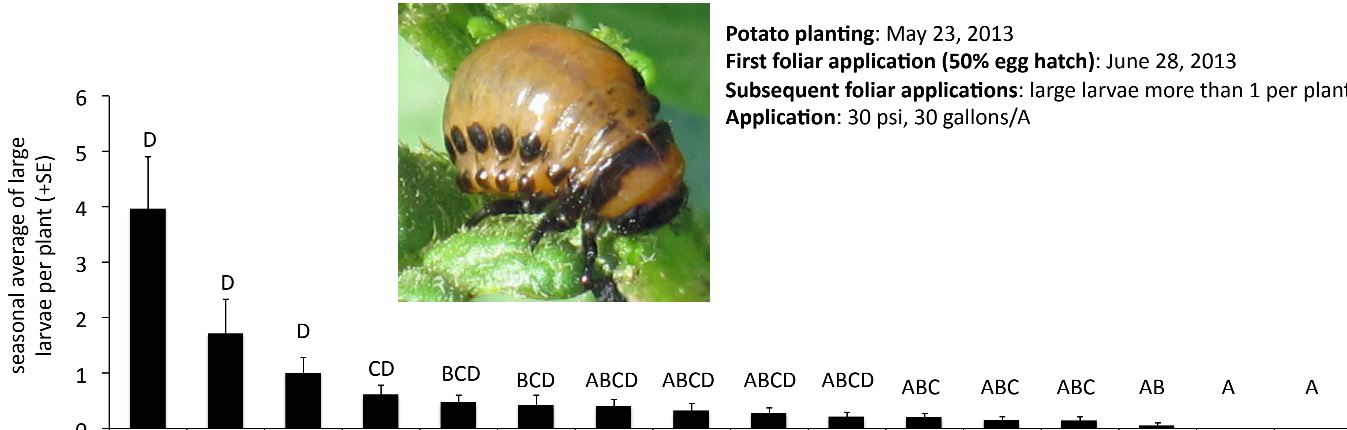
Overwintering generation Colorado potato beetle insecticide trial

Potato planting: May 23, 2013
First foliar application (50% egg hatch): June 28, 2013
Subsequent foliar applications: large larvae more than 1 per plant
Application: 30 psi, 30 gallons/A



treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
at-planting	-	-	-	-	Brigadier 25.6 oz/A	Admire Pro 7 oz/A	Capture 25.6 oz/A	-	-	-	-	-	-	Verimark 13.5 oz/A	Platinum 8 oz/A	Platinum 8 oz/A
at-cracking	-	-	Brigadier 25.6 oz/A	-	-	-	Admire Pro 5 oz/A	-	-	-	-	-	-	-	-	-
foliar	-	Admire Pro 1.3 oz/A (3)	Gladiator 14 oz/A (2)	Torac 14 oz/A (2)	Gladiator 14 oz/A (2)	-	Athena 16 oz/A (2)	Black-hawk 3.2 oz/A (2)	Benevia 5 oz/A (1) *	Torac 21 oz/A (1)	Exirel 6.7 oz/A (1)	Benevia 5 oz/A (1) *	Exirel 5 oz/A (1)	-	Benevia 5 oz/A (1)	-

*two different formulations

Note: Numbers in parentheses are the number of foliar applications needed to keep first generation CPB below threshold.
Bars with the same letters are not statistically different from each other.

Benevia, Exirel, Verimark, Torac – not currently registered

Summary of 2013 CPB insecticide trial results, Moncalm Potato Research Farm.

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Susceptibility of Colorado potato beetle populations to imidacloprid and thiamethoxam

Imidacloprid (i.e.: Admire Pro) and thiamethoxam (i.e.: Platinum, Actara) continue to be the most common means of Colorado potato beetle management. Today, greater than 75% of the commercial potato acres in the northeastern and midwestern United States are protected by these compounds (NASS 2006). Such consistent and heavy dependency on any compound sets the stage for resistance development. Further complicating the issue is the availability of generic imidacloprid formulations; these formulations drive down product cost, which will likely lead to even greater field exposure to these compounds. All of these reasons strongly support the need to continue monitoring resistance development and to encourage growers to adopt resistance management strategies.

Our objective was 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. To accomplish this objective, Colorado potato beetle populations were bioassayed with imidacloprid and/or thiamethoxam.

METHODS

During 2013, 11 Colorado potato beetle populations were collected from Michigan. Cooperators also provided populations from New York (1), Maine (1), and Virginia (3). One susceptible laboratory strain was also tested (Table 3). To assure only healthy beetles were tested, newly received beetles were maintained at room temperature and 16:8 L:D photoperiod and fed pesticide-free, greenhouse-grown potato foliage for 3-7 days before they were used in the bioassay.

Adult Colorado potato 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. Two populations with known resistance issues (Jamesport, NY and Tuscola, MI) required two applications of 1 µl of acetone/insecticide solution per beetle to achieve the desired dose (ie., 1 µl of 20.0 µg/µl plus 1 µl of 10.0 µg/µl to get a dose of 30.0 µg/µl). A range of four to 11 concentrations, plus an acetone-only control, was selected for each population, depending on the number of available beetles and known resistance history for each population. In each bioassay, 27-40 adults were treated with each concentration (nine to 10 beetles per dish and three to four dishes per concentration). Following treatment, beetles were placed in 100 mm diam. 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.

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. 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. Beetles that had died due to *Beauvaria* spp. infection were excluded from analysis; these beetles were easily recognized by their pale, petrified appearance and/or presence of white filamentous fungi. Dead and poisoned beetle numbers were pooled for analysis. Data were analyzed using standard log-probit analysis (SAS Institute, 2009).

RESULTS

The LD_{50} value (dose lethal to 50% of the beetles) for the susceptible laboratory strain was 0.042 µg/beetle for imidaclorid and 0.054 µg/beetle for thiamthoxam (Table 4).

The LD_{50} values from the field for imidacloprid ranged from 0.215 µg/beetle (Sackett Potatoes Field 2) to 4.435 µg/beetle (Sackett Ranch LJ7) for Michigan populations. The imidacloprid LD_{50} values for the out-of-state populations ranged from 0.088 µg/beetle (Aroostook, Maine) to 0.496 (Jamesport, NY). LD_{50} values for imidacloprid for all populations were significantly higher than the susceptible laboratory strain. In 2013, 60% of the Michigan samples were greater than 10-fold resistant to imidacloprid, compared to 75% in 2012, 57% in 2011, 60% in 2010, and 85% in 2009.

The LD_{50} values for thiamethoxam in Michigan ranged from 0.044 µg/beetle (Main Farms H6) to 0.478 µg/beetle (Kalkaska), and from 0.002 µg/beetle (Montgomery, VA) to 0.496 µg/beetle (Jamesport, NY) for out-of-state populations. None of the populations were greater than 10-fold resistant to thiamethoxam.

Table 3. Colorado potato beetle populations tested for susceptibility to imidacloprid and thiamethoxam in 2013.

Michigan populations

Anderson Brothers Field 23 Summer adults were collected on 12 Aug 2013 by Mark Otto, Agri-Business Consultants, Inc., from commercial potato fields in Montcalm County.

Kalkaska Summer adults were collected on 31 July 2013 from a commercial potato field near Kalkaska MI.

Main Farms Summer adults were collected by Mark Otto, Argi-Business Consultants, Inc. from commercial potato fields in Mecosta and Montcalm Counties.

Field C10 Adults were collected on Aug 7 2013.
Field H6 Adults were collected on June 28 2013.
Field R6 Adults were collected on July 30 2013.

Sackett Potatoes

Sackett Potatoes Field 2 Adults were collected on June 14 2013.
Sackett Potatoes Field 19 Adults were collected on June 14 2013.
Sackett Potatoes Field 26 Adults were collected on Aug 19 2013.
Sackett Potatoes Field 150-1 Adults were collected on June 24 2013.

Sackett Ranch

Sackett Ranch LJ7 Adults were collected on June 25 2013.
Sackett Ranch LJ7 Adults were collected on July 23 2013.
Sackett Potatoes Field 26 Adults were collected on Aug 19 2013.
Sackett Potatoes Field 150-1 Adults were collected on June 24 2013.

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Table 4. LD_{50} values (µg/beetle) and 95% fiducial limits for Colorado potato beetle populations treated with imidacloprid and thiamethoxam, 7 days post treatment.

IMIDACLOPRID

Michigan Populations	**LD_{50} (ug/beetle)**	**95 % confidence intervals**
Anderson Brothers Field 23*	0.370	0.184 - 0.593
Kalkaska*	4.119	1.879 - 16.505
Main Farms C10*	1.088	0.076 – 4.344
Main Farms H6^	0.536	0.386 – 0.697
Main Farms R6*	1.843	1.039 - 2.791
Sackett Potatoes Field 2^	0.215	0.104 – 0.353
Sackett Potatoes Field 19^	0.469	0.140 – 0.926
Sackett Potatoes Field 26*	0.301	0.118 – 0.570
Sackett Potatoes Field 150-1^	0.493	0.274 – 0.693
Sackett Ranch LJ7 ^	0.665	0.309 – 1.102
Sackett Ranch LJ7 *	4.435	3.283 – 6.103
Out of State Populations		
Aroostook, Maine*	0.088	0.051 – 0.129
Jamesport, New York^	5.577	3.829 – 6.971
Modestown, VA^	0.655	0.507 – 0.857
Painter, VA^	0.081	0.057 – 0.110
Montgomery, VA(Whitehorne)*	0.089	n/a
Laboratory strain		
New Jersey	0.042	0.037 – 0.055

THIAMETHOXAM

Michigan Populations	**LD_{50} (ug/beetle)**	**95 % confidence intervals**
Anderson Brothers Field 23*	0.122	0.085 – 0.168
Kalkaska*	0.478	0.291 – 0.816
Main Farms C10*	0.207	0.094 – 0.455
Main Farms H6^	0.044	0.020 – 0.080
Main Farms R6*	0.177	0.051 – 0.327
Sackett Potatoes Field 2^	0.182	0.132 – 0.236
Sackett Potatoes Field 19^	0.206	n/a
Sackett Potatoes Field 26*	0.111	0.054 – 0.199
Sackett Potatoes Field 150-1^	0.071	0.041 – 0.101
Sackett Ranch LJ7 ^	0.177	0.133 – 0.225
Sackett Ranch LJ7 *	0.377	n/a
Out of State Populations		
Aroostook, Maine*	0.021	0.014 – 0.03
Jamesport, New York^	0.496	0.376 – 0.620
Modestown, VA^	0.294	0.244 – 0.334
Painter, VA^	0.050	0.289 – 0.070
Montgomery, VA(Whitehorne)*	0.002	n/a
Laboratory strain		
New Jersey	0.054	0.0357 – 0.0947

^ Overwintered generation
* Summer generation

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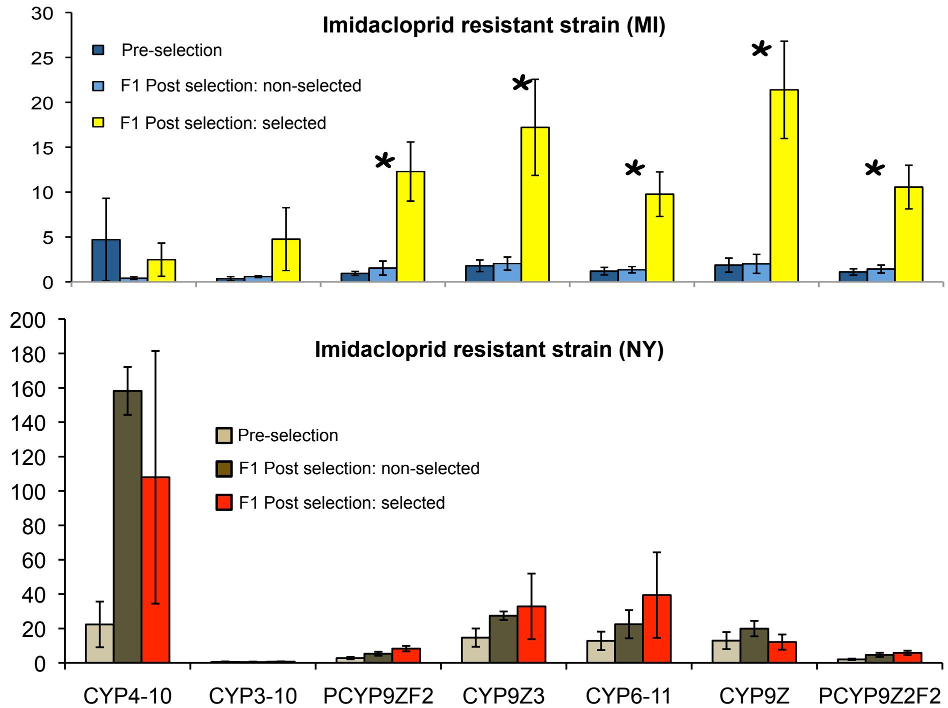
Molecular genetic mechanisms of CPB insecticide resistance

In 2013 we identified numerous genes that play a role in CPB insecticide resistance using our laboratory CPB populations and RNA sequencing. We developed primers for some of the genes of interest and investigated the level of gene expression using real-time PCR method (MSU Research and Technology Support Facility). We determined that a selection event with an insecticide causes over-expression of these genes, which confirmed that these genes are truly involved in the insecticide resistance mechanism, and we also compared these genes in different populations. These results showed that in geographically different populations (MI vs. NY, both imidacloprid resistant) different genes have evolved to play a role in insecticide resistance (see figure below).



Nitrogen Source Response for Potato Production

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Soil Fertility and Nutrient Management
Dept. of Plant, Soil, and Microbial Sciences, Michigan State University

Location: Montcalm Research Farm	**Tillage**: Conventional
Planting Date: May 15, 2013 (Vinekill 9/6/13)	**Trt's**: See below
Soil Type: Loamy sand; 1.5 OM; 6.2 pH; 144 ppm P; 168 ppm K	**Population**: 34 in rows, 11 in. spacing
Variety: EXP. 1 (~ 110-120 day maturity)	**Replicated**: 4 replications

N Source	Total N Rate (lb. N/A)	Timing	Petiole Nitrate (%) 34 DAE	Petiole S (%) 34 DAE	Petiole S (%) 64 DAE	Total Yield cwt/A
ESN	200	Banded, at-plant	1.81	0.18	0.17	391
ESN	250	Banded, at-plant	2.15	0.23	0.16	357
ASN	200	1/3 N Emergence 2/3 N Hilling	1.93	0.28	0.21	443
ASN	250	1/3 N Emergence 2/3 N Hilling	1.82	0.29	0.23	420
Urea	200	1/3 N Emergence 2/3 N Hilling	1.75	0.23	0.17	365
Urea	250	1/3 N Emergence 2/3 N Hilling	1.18	0.17	0.18	362
$LSD_{(0.10)}$[a]			**0.52**	**NS**	**0.02**	**NS**

[a] LSD, least significant difference between means within a column at ($\alpha = 0.10$).

Summary: Trial was conducted to more accurately determine potato response to 3 N sources at 2 N rates including polymer coated urea, ammonium sulfate nitrate (ASN), and urea at 200 and 250 lbs N/A. All treatments received starter fertilizer in the form of 25, 120, and 150 lbs/A of N, P2O5, and K2O, respectfully. Starter N and P were banded at planting, while 100 lbs K2O was band-applied at planting with the remaining 50 lbs K2O pre-plant incorporated. N applications were split with 25 lbs applied as starter, 1/3 of the remaining N applied at emergence (5/31/13), and 2/3 of the remaining N applied at hilling (6/24/13) with the specific N source listed in the table above. However, the polymer coated urea N source was Environmentally Smart Nitrogen (ESN), and this product was applied with a one-time application over the row at planting.

Although a form of slow-release N, ESN applications maintained similar early-season petiole nitrate levels as compared to other soluble N sources. Petiole S concentrations were above the recommended 0.25% S threshold at 34 DAE for ASN. ASN treatments maintained significantly greater petiole S concentrations at 64 DAE. Nitrogen source was not statistically

significant for total yield. However, mean total yields occurred in the following order ASN > ESN > Urea. Ammonium sulfate-nitrate averaged 58 and 68 cwt/A greater than either ESN or urea, respectfully. These results are likely due to the additional 107 and 135 lbs sulfate S/A applied with the 200 and 250 lb N/A rates, respectfully, for ASN. Results suggest producers not utilizing sulfate-S may want to consider about 100 lb S/A to improve potato production without increasing N rates.

Potato Nitrogen Rate Response

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Dept. of Plant, Soil, and Microbial Sciences, Michigan State University

Location: Montcalm Research Farm	**Tillage**: Conventional
Planting Date: May 15, 2013 (Vinekill 9/6/13)	**Trt's**: See below
Soil Type: Loamy sand; 1.5 OM; 6.2 pH; 144 ppm P; 168 ppm K	**Population**: 34 in rows, 11 in. spacing
Variety: EXP. 1 (~ 110-120 day maturity)	**Replicated**: 4 replications

Total N Rate (lb. N/A)	Petiole Nitrate (%) 34 DAE	Petiole Phosphate (%) 34 DAE	Petiole Nitrate (%) 64 DAE	Petiole Phosphate (%) 64 DAE	Petiole S (%) 64 DAE
0	0.62	0.50	0.07	0.27	0.19
80	1.57	0.52	0.06	0.20	0.23
120	1.46	0.52	0.15	0.17	0.24
150	1.82	0.44	0.07	0.17	0.23
200	1.79	0.52	0.27	0.17	0.22
250	2.78	0.37	0.65	0.19	0.23
300	2.05	0.54	0.89	0.20	0.23
350	2.38	0.52	1.60	0.22	0.26
$LSD_{(0.10)}$[a]	**0.73**	**NS**	**0.27**	**0.03**	**0.03**

[a] LSD, least significant difference between means within a column at ($\alpha = 0.10$).

Total N Rate (lb. N/A)	Total Yield (cwt/A)	Yield A's (cwt/A)	Yield B's (cwt/A)	Yield Oversize (cwt/A)	Specific Gravity
0	281	233	48	0	1.20
80	380	346	33	1	1.21
120	388	354	31	3	1.27
150	398	370	18	10	1.21
200	373	329	18	26	1.20
250	401	353	14	34	1.23
300	428	387	20	21	1.22
350	414	369	21	24	1.19
$LSD_{(0.10)}$[a]	**40**	**38**	**11**	**10**	**NS**

[a] LSD, least significant difference between means within a column at ($\alpha = 0.10$).

Summary: Trial was conducted to study the N response of potato across a range of N rates ranging from 0 – 350 lbs N/A. All treatments received starter fertilizer in the form of 25, 120, and 150 lbs/A of N, P2O5, and K2O, respectfully. Starter N and P were banded at planting, while 100 lbs K2O was band-applied at planting with the remaining 50 lbs K2O pre-plant incorporated. N applications were split with 25 lbs applied as starter, 1/3 of the remaining N applied as ammonium sulfate at emergence (5/31/13), and 2/3 of the remaining N applied as urea at hilling (6/24/13).

Petiole nitrate analyses at 34 DAE indicated some significant differences with regards to N rate. Treatments at the 250 lb or greater N rate tested in the optimum range (2-2.3%) while lower N amounts were lacking. Petiole phosphate analyses at 34 DAE were not significant across the gradient of N treatments. At 64 DAE, both petiole nitrate and phosphate values were significantly affected by overall N application rate. Treatments receiving 300 lbs N or more tested optimum while all of the petiole phosphate values tested below target values. Overall N application rate did affect petiole phosphate measurements as expected.

Total yield was significantly impacted by total N application rate. Results from the first year of this trial under 2013 environmental conditions for this maturity length indicate that although total yield was maximized at 300 lbs. N/A, few statistical differences occurred between N rates of 150 – 300 lbs N/A. This response to N was achieved under 2013 precipitation and temperature patterns both of which greatly affect potato N response. Choosing the most economical N rate will depend upon several factors including potato contract price, fertilizer price paid, and nutrient management regime for individual operations. Growers need to remember that as individual operations decide on optimum N application rates, other nutrients may also have to be adjusted (increased or decreased) depending on the actual amount of N applied in addition to the individual N source, N placement, and N timing.

2013 MPIC Research Report
George W. Bird, Professor
Michigan State University

Cover Crop-Soil Health Trial.- A two-year cover crop-soil rotation was started at the Montcalm Research center in 2012. The following four rotations are being evaluated in regards to potato productivity and soil health: 1) potato/rye/corn, 2) wheat/mustard biofumigation, 3) field peas/oil seed radish and 4) clover. The entire site will be planted to potato in 2014 for evaluation of the impacts of the cropping systems on potato yield and quality, potato early-die pathogens and soil health parameters. In a similar MPIC funded research project published in 1995 (Journal of Nematology 27(4S):654-660), two years of sweet clover or alfalfa followed by potato resulted in significantly (P=0.05) increased potato tuber yields compared with three years of potato. The two-year legume and grain rotations followed by potato resulted in significantly (P=0.01) lower root-lesion nematode population densities compared with three years of continuous potato. The sudax/sudax/potato rotation resulted in the lowest potato yields, followed by a corn/corn/potato resulting in the second lowest potato tuber yields. Selected soil health parameters from the Cornell University Soil Health Protocol will be used in evaluating the 2014 research trial. It is anticipated, however that these analyses will be done as part of a new service at a private sector facility in Michigan. As a direct result of the MPIC Soil Health White Paper, I have been invited to give 16 soil health presentations between December 1, 2013 and April 1, 2014.

2012-2014 MRC Potato Cover

Crop/Soil Health Trial

Rotation Systems	2012	2013	2014
1	Potato-Rye	Rye-Corn	**Potato**
2	Potato-Wheat	Wheat-mustard biofumigation	**Potato**
3	Peas-OSR	Wheat-oilseed radish	**Potato**
4	Corn-Clover	Clover	**Potato**

Nine Potato-Row Plot Size

Soil Health Survey.- The 2012 Soil Health Survey of 96 commercial potato sites, conducted as part of the MPIC White Paper on Soil Health, indicated that that soil nutrient levels were optimal; whereas, soil physical and biological parameters needed improvement. Using the Cornell University Soil Health Protocol, the following two aspects of soil health were document: 1) the longer the crop rotation, the higher the soil health score and 2) the greater the diversity of the crops in the potato rotation, the higher the soil health score. In a 2012-2013 trial designed to decrease soil surface and subsurface hardness, using oats/oil seed radish/corn and oats/oil seed radish/soybeans, compared to the same rotations without the oil seed radish, both corn and soybean yields were significantly increased when the cover crop was included in the rotation.

2012-2013 Oil seed radish trial for reduction of soil surface and subsurface hardness.

Crop	Oats/Fallow	Oats/Oil Seed Radish
Corn	126 bu/acre	144 bu/acre
Soybeans	32 bu/acre	39 bu/acre

Mocap/Nematec Evaluation.- Mocap and Nematac were evaluated on a field-scale at Sackett Potatoes in cooperation with Morgan Compost and Michigan AgriBusiness Consultants for control of potato early-die disease complex. Neither of the products had a significant impact on tuber yield at this location in 2013.

Messenger Gold Evaluation.- Messenger Gold was evaluated as a foliar spray on a field-scale basis at SandyLand Farm in 2013. Messenger Gold is a plant health regulator. It is also marketed as ProAct for corn and soybeans and as N-Hibit as a soybean seed treatment. Messenger Gold did not have an impact on potato yields in this trial.

Vydate Evaluation.- Vydate was evaluated at the Montcalm Research Center as part of a larger experimental nematicide trial. Vydate significantly increased potato tuber yield and resulted in significantly lower at-harvest population densities of the root-lesion nematode.

2013 impact of Vydate on potato yield (G. W. Bird Nematology Laboratory, Michigan State University).

Treatment	Total Yield (cwt/A)	A Size (cwt/A)	Jumbo Size (cwt/A)	B Size (cwt/A)
Control	306	247	29	30
Vydate In-Furrow	363	291	42	30
Vydate IF + Foliar	432	320	77	35
P (statistic)	0.06	0.05	<0.01	0.97

2013 impact of Vydate on *Pratylenchus penetran/*100 cm^3 soil (G. W. Bird Nematology Laboratory, Michigan State University).

Treatment	At-planting	Mid-Season	At-Harvest
Control	12.5	0	7
Vydate In-furrow	12	0	2
Vydate In-Furrow + Foliar	15	0	0
P (statistic)	0.71	1.00	0.05

1974-2013 Nematicide Trial Summary.- Between 1974 and 2013, the MSU Bird-Nematology Laboratory conducted 76 nematicide trials. A summary of the results are included in the following table. The average tuber yield increase associated these trials was more than 80 cwt/acre.

1974-2014 Michigan Potato Early-Die Research Summary
Tuber Yield (cwt/A)

Year	Control	Metam	Temik	Vydate	Mocap
1974	388				
1975	278		314		
1976	176		209		
1977	119		172		
1978	267		371		
1979	160		209		
1980	117		216		
1981	330		370		
1982	185		231	285	272
1983	328		408		
1984	306		405		
1985	300	485	349		
1986	300	418	493		
1987	291	418			
1989	151		175	228	
1990	203		337		
1991	209			452	
1992	313	459			
1993	273			403	
1994	298	407		347	450
1996	331		420	390	380
1997	219		257		259
1998	217	370		261	259
1999	266	436	267		
2000	121	348			
2001	252	352			
2006	126	190		151	
2009	404	484		474	
2011	316	350			
2012	382	429			
2013	269	360		432	242
Mean	254	388	306	324	324

Crop rotations for enhancing soil health, plant health, and disease management in potato production

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A long-term potato crop management experimental research trial was established at MSU's Montcalm Research Center (Figures 1 and 2). A randomized complete split-block design with four replications (4-row 50 ft plots) was used and treatment plots consist of the following crop rotations: 1) Potato (2013-16); 2) Corn (2013), Potato (2014), Corn (2015) and Potato (2016); 3) Corn (2013-14) and Potato (2015) and Corn (2016); and 4) Corn (2013-2015) and Potato (2016). The split-block included organic and inorganic fertilizer treatments (Table 1). All management practices (irrigation, fertilization, insects, weeds, nematodes, and disease control) were according to conventional grower practices. Agronomic metrics of crop health such as plant stand, final yield quantity, quality and tuber health were measured. Potato crops were harvested and individual treatments were weighed and graded. Tubers were assessed for scab. Potato petiole where sampled twice during the growing season. Bulk and rhizosphere soil was sampled pre-planting and two times during the growing season from the potato and corn plots for each treatment, and transported immediately to the laboratory on ice.

Experimental field trials

The study was conducted on a sandy loam soil at the Michigan State University Montcalm Potato Research Farm, Entrican at 10-inch spacing and 34-inch rows (Figures 1 and 2). The experiment was arranged as a randomized complete block design with four replications. Individual plots were 12 ft. wide by 50 ft. in length and planted with the potato (*Solanum tuberosum*) and corn (*Zea mays*) cultivar "Snowden" and variety "DKC 48-12" respectively. The organic amendments were a stand-alone nutrient source to provide up to 250 lbs N (Table 1). The inorganic fertility program used a combination of urea, ammonium sulfate and ammonium sulfate-nitrate to provide up to 250 lbs N at 3 application timings of pre-plant incorporated, emergence, and hilling. Plot harvest was from 50 feet from one plot row. The inorganic fertilizer treatments receive starter fertilizer banded on both sides of the seed piece and two inches away from seed pieces. Foliar applications of Bravo WS 6SC 1.5 pt/A was applied on a seven-day interval, total of eight applications, for foliar disease control with a R&D spray boom delivering 25 gal/A (80 psi) and using three XR11003VS nozzles per row. Weeds were controlled by cultivation and with Dual 8E at 2 pt/A 10 DAP, Basagran at 2 pt/A 20 and 40 days after planting (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 6 Sep). Plots (1 x 50-ft row) were harvested on 23 Sept and individual treatments were weighed and graded. Soil samples were taken on 5 Jun (20 DAP), 2 Jul (47 DAP) and 14 Aug (90 DAP). Potato petiole samples were taken on Jul 1 (50 DAP) and Aug 2 (80 DAP). Potato tubers were harvested, graded, culled and internal defects were noted. Tuber numbers for each group and weights (CWT) were recorded. Severity of common scab was measured as surface area affected (1=1 lesion to 1%; 2= 1.1-10%; 3=10.1-20%; 4= 20.1-30%; 5= > 50% surface area). Data was analyzed using ANOVA and treatments separated using mean separation with Fisher's Protected LSD. Meteorological variables were measured with a Campbell weather station located at the farm from 1 May to the end of Sept. Average daily air temperature (^{o}F) from 16 May was 62.0, 66.1, 69.5, 67.3, and 60.47 and the number of days with maximum temperature >90^{o}F was 0, 0, 3, 0 and 0 (May, Jun, Jul, Aug, Sep, respectively). Average daily relative humidity (%) over the same period was 71.4, 70.7, 72.6, 72.0 and 74.1%. Average daily soil temperature at 4" depth (^{o}F) over the same period was 64.7, 72.6, 80.0, 75.8, and 67.6. Precipitation (in.) over the same period was 3.84, 2.26, 1.35, 4.06, and 1.33. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

Based on petiole sampling at 50 DAP percent NO_3N, P, K, Mg and S was significantly different between organic and inorganic treatments. Percent NO_3N, P, K and S was significantly higher for inorganic fertility programs and Mg was significantly higher for organic fertility programs. Similarly at 50 DAP Mn and B ppm was significantly higher in inorganic fertility programs compared to the organic. Based on petiole sampling at 80 DAP leaf fresh weight, percent P, K, Mg, S and Na was significantly different between organic and inorganic treatments. Leaf fresh weight, percent P, K and Mg was significantly higher in organic, and percent S and Na were significantly higher in inorganic fertility programs. Similarly at 80 DAP Zn was significantly higher in organic fertility programs compared to the inorganic, and Mn was significantly higher in inorganic fertility programs. For all other measurable there was no significant differences between fertility programs

Laboratory experiments

Soil was sampled from the plots for each treatment described above three times during the season (pre-planting, emergence and prior to vine kill), and transported immediately to the laboratory on ice. 0.5 grams of soil from each sample will be used for DNA extraction, using the Mo Bio 101 DNA extraction kit (Mo Bio Laboratories Inc., Carlsbad, CA). Three soil samples per plot, consisting of three soil cores (240 DNAs in total) were used for DNA sequence analyses. Subsequent to DNA extraction quantity and quality was assessed using a NanoDrop ND-2000c spectrophotometer (NanoDrop Wilmington, DE). Soil genomic DNA was used for PCR amplification of the 16S variable regions and samples were sequenced by the Illumina paired-end technique using the previously described protocol (1) with slight modifications for total bacterial community analysis. PCR products were separated on 1% (w/v) agarose gel in 0.5×TBE stained with GelRed Nucleic Acid Stain (Phenix Research Products, Chandler, NC) by electrophoresis and visualized by UV exposure using the Gel Doc 2000 apparatus (Bio-Rad, Hercules, CA) (Figure 3). Currently DNA isolated from field experiments are in the queue awaiting sequencing and microbial community analysis.

Literature cited

1. Kozich, J. J., Westcott, S. L., Baxter, N. T., Highlander, S. K., and Schloss, P. D. 2013. Development of a dual-index sequencing strategy and curation pipeline for analyzing amplicon sequence data on the MiSeq Illumina sequencing platform. Applied and Environmental Microbiology.

Figure 1. Aerial image of rotational potato crop management experimental research trial at MSU Montcalm Potato Research Center

Figure 2. Long-term rotational potato crop management experimental research trial at MSU Montcalm Potato Research Center

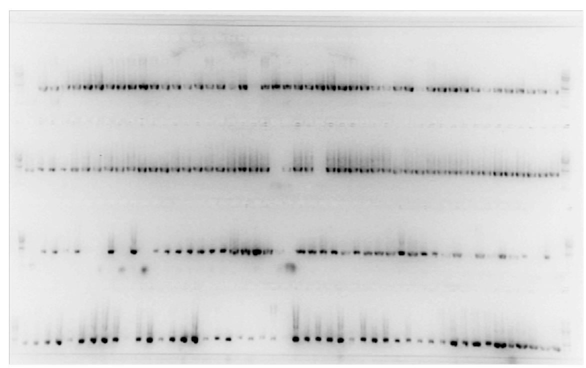

Figure 3. PCR amplification of soil genomic DNA from field trials. Resulting products are used for soil microbial community DNA sequence analyses.

Table 1. Summary of results from long-term rotational potato crop management experimental research trial at Michigan State University Montcalm Potato Research Center

Treatment[a]	Rate	50 DAP[b]									
		SPAD[c,d]	Fresh Weight (g)	NO_3N %	P %	K %	Ca %	Mg %	S %	Zn ppm	Mn ppm
Potatoes, PPPP Inorganic MAP 11-52-0 K2O 0-0-62 AS 21-0-0-24 Urea 46-0-0	 120 lb ai/A 150 lb ai/A 66 lb ai/A 134 lb ai/A	46.95 a	20.15 a	2.3988 a	0.5145 a	11.2323 a	0.6528 a	0.2485 b	0.2418 a	37.175 a	69.720 a
Potatoes, PPPP Organic Herbrucks AS 21-0-0-24 Urea 46-0-0	 2 ton/A 40 lb ai/A 80 lb ai/A	46.95 a	19.75 a	2.2095 b	0.4478 b	10.8093 b	0.6708 a	0.2753 a	0.2255 b	35.993 a	49.013 b
Corn, CPCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	-
Corn, CPCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	-
Corn, CCPC Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	-
Corn, CCPC Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	-
Corn, CCCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	-
Corn, CCCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	-
Fisher's $LSD_{0.10}$		0.531	1.192	0.13849	0.02239	0.14325	0.02685	0.00231	0.00934	3.5141	6.4535
ANOVA p-value		1.0000	0.5608	0.0314	0.0002	0.0002	0.2553	0.0001	0.0092	0.5599	0.0001

[a]Rotation treatments included: 1) Potato (2013-16); 2) Corn (2013), Potato (2014), Corn (2015) and Potato (2016); 3) Corn (2013-14) and Potato (2015) and Corn (2016); and 4) Corn (2013-2015) and Potato (2016).
[b]DAP=days after planting.
[c]SPAD=soil plant analysis development measured by chlorophyll meter indicating leaf color
[d]Means followed by same letter do not significantly differ (P=0.10, LSD)

Table 1. Continued

Treatment[a]	Rate	50 DAP[b]				Total Yield CWT	Specific Gravity
		Cu ppm[c]	B ppm	Al ppm	Na %		
Potatoes, PPPP Inorganic MAP 11-52-0 K2O 0-0-62 AS 21-0-0-24 Urea 46-0-0	 120 lb ai/A 150 lb ai/A 66 lb ai/A 134 lb ai/A	8.2365 a	24.965 a	62.0 a	0.010 a	299.1 a	1.16 a
Potatoes, PPPP Organic Herbrucks AS 21-0-0-24 Urea 46-0-0	 2 ton/A 40 lb ai/A 80 lb ai/A	8.1550 a	24.515 b	61.3 a	0.010 a	297.6 a	1.16 a
Corn, CPCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-
Corn, CPCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-
Corn, CCPC Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-
Corn, CCPC Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-
Corn, CCCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-
Corn, CCCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-
Fisher's $LSD_{0.10}$		0.65087	0.4172	11.81	0.0000	36.36	0.008
ANOVA p-value		0.8272	0.0787	0.9118	1.0000	0.9429	0.9486

[a]Rotation treatments included: 1) Potato (2013-16); 2) Corn (2013), Potato (2014), Corn (2015) and Potato (2016); 3) Corn (2013-14) and Potato (2015) and Corn (2016); and 4) Corn (2013-2015) and Potato (2016).
[b]DAP=days after planting.
[c]Means followed by same letter do not significantly differ (*P*=0.10, LSD)

Table 1. Continued

Treatment[a]	Rate	80 DAP[b] Fresh Weight (g)[c]	Dry Weight (g)	SPAD[d]	NO_3N %	P %	K %	Ca %	Mg %	S %	Zn ppm
Potatoes, PPPP Inorganic		26.65 b	2.10 a	37.60 a	1.6068 b	0.2568 b	8.2025 b	1.2438 a	0.9215 b	0.2633 a	18.668 b
MAP 11-52-0	120 lb ai/A										
K2O 0-0-62	150 lb ai/A										
AS 21-0-0-24	66 lb ai/A										
Urea 46-0-0	134 lb ai/A										
Potatoes, PPPP Organic		32.30 a	2.38 a	37.73 a	3.0573 a	0.3085 a	8.6243 a	1.2713 a	0.9650 a	0.2553 b	21.448 a
Herbrucks	2 ton/A										
AS 21-0-0-24	40 lb ai/A										
Urea 46-0-0	80 lb ai/A										
Corn, CPCP Inorganic		-	-	-	-	-	-	-	-	-	-
Urea 46-0-0	75 lb ai/A										
Urea 46-0-0	120 lb ai/A										
Corn, CPCP Organic		-	-	-	-	-	-	-	-	-	-
Herbrucks	2 ton/A										
Urea 46-0-0	85 lb ai/A										
Corn, CCPC Inorganic		-	-	-	-	-	-	-	-	-	-
Urea 46-0-0	75 lb ai/A										
Urea 46-0-0	120 lb ai/A										
Corn, CCPC Organic		-	-	-	-	-	-	-	-	-	-
Herbrucks	2 ton/A										
Urea 46-0-0	85 lb ai/A										
Corn, CCCP Inorganic		-	-	-	-	-	-	-	-	-	-
Urea 46-0-0	75 lb ai/A										
Urea 46-0-0	120 lb ai/A										
Corn, CCCP Organic		-	-	-	-	-	-	-	-	-	-
Herbrucks	2 ton/A										
Urea 46-0-0	85 lb ai/A										
Fisher's $LSD_{0.10}$		4.717	0.372	0.556	0.23965	0.01515	0.31927	0.05402	0.02710	0.00685	0.4697
ANOVA p-value		0.0541	0.2119	0.6956	0.0001	0.0001	0.0364	0.3822	0.0143	0.0596	0.0001

[a]Rotation treatments included in trial were: 1) Potato (2013-16); 2) Corn (2013), Potato (2014), Corn (2015) and Potato (2016); 3) Corn (2013-14) and Potato (2015) and Corn (2016); and 4) Corn (2013-2015) and Potato (2016).
[b]DAP=days after planting.
[c]Means followed by same letter do not significantly differ (*P*=0.10, LSD)
[d]SPAD=soil plant analysis development measured by chlorophyll meter indicating leaf color

Table 1. Continued

Treatment[a]	Rate	80 DAP[b] Mn ppm[c]	Fe ppm	Cu ppm	B ppm	Al ppm	Na %	122 DAP Scab Incidence	Scab Severity[d]	% Emergence	Yield (BU/A)
Potatoes, PPPP Inorganic MAP 11-52-0 K2O 0-0-62 AS 21-0-0-24 Urea 46-0-0	 120 lb ai/A 150 lb ai/A 66 lb ai/A 134 lb ai/A	275.95 a	307.23 a	7.6078 a	29.703 a	64.3 a	0.0100 b	96.1 a	58.6 a	76.5 a	-
Potatoes, PPPP Organic Herbrucks AS 21-0-0-24 Urea 46-0-0	 2 ton/A 40 lb ai/A 80 lb ai/A	147.55 b	858.85 a	9.7913 a	28.935 a	55.5 a	0.0103 a	94.3 a	51.4 a	72.5 a	-
Corn, CPCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	236.6 a
Corn, CPCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	251.6 a
Corn, CCPC Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	240.7 a
Corn, CCPC Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	258.0 a
Corn, CCCP Inorganic Urea 46-0-0 Urea 46-0-0	 75 lb ai/A 120 lb ai/A	-	-	-	-	-	-	-	-	-	246.3 a
Corn, CCCP Organic Herbrucks Urea 46-0-0	 2 ton/A 85 lb ai/A	-	-	-	-	-	-	-	-	-	242.4 a
Fisher's $LSD_{0.10}$		24.532	552.102	2.60071	1.0524	19.69	0.00022	1.8478	17.062	0.03958	20.40
ANOVA p-value		0.0001	0.1003	0.1604	0.2182	0.4437	0.0687	0.5966	0.4378	0.4457	0.4962

[a]Rotation treatments included in trial were: 1) Potato (2013-16); 2) Corn (2013), Potato (2014), Corn (2015) and Potato (2016); 3) Corn (2013-14) and Potato (2015) and Corn (2016); and 4) Corn (2013-2015) and Potato (2016).

[b]DAP=days after planting.

[c]Means followed by same letter do not significantly differ (P=0.10, LSD)

[d]Severity of common scab was measured as surface area affected (1=1 lesion to 1%; 2= 1.1-10%; 3=10.1-20%; 4= 20.1-30%; 5= > 50% surface area).

Potato diseases update for Michigan State University

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Several disease issues impacted Michigan potato production during 2013. In this short update the highlights of the season will be covered. There were early challenges and some growers experienced severe cases of potato dry rot reported mainly on cv. Pike resulting in very poor stands. Some fields were so badly affected that the fields were replanted. The seed pieces were generally rotted but in some case where there is even mild rot the stems did not develop. Dry rot is one of the most important establishment and postharvest diseases and can be caused by several *Fusarium* species. In the United States (US), yield losses attributed to dry rot in storage is estimated at $69 million to $228 million (unpublished data from USDA, Schisler). Currently there are at least 13 known *Fusarium* species responsible for potato dry rot in the US, and 11 of these species have been recently reported in MI. Seed treatments are effective but in situations where seed is extensively infected efficacy could be impaired. There is no curative action for Fusarium seed piece decay. The bulletins E-2995 (Seed Piece Health Management) and E-2992 (Fusarium Dry Rot) cover these issues extensively. The report on Fusarium dry management with fungicides in this volume covers some options for control.

Potato Late Blight was confirmed in a potato crop in Allegan County in mid-July. The genotype of the *Phytophthora infestans* isolate was the US-23 genotype confirmed by GPI allozyme analysis and DNA fingerprinting. Although this genotype was Ridomil sensitive the recommendations for treatment remain the same as those developed over several years of trials and include treating with one of the translaminar fungicides listed on http://www.lateblight.org/fungrate.html. Although not reported for the past two years, the weather conditions and moderately mild winter favored the re-appearance of this destructive pathogen in MI particularly in the region south of Lansing. Late blight is caused by the water mold *Phytophthora infestans*. The pathogen favors wet weather with moderate temperatures (60 – 80 °F), high humidity and frequent rainfall. Under such conditions, the disease can spread extremely rapidly and has the potential to completely defoliate fields within three weeks of the first visible infections if no control measures are taken. In addition to attacking foliage, *P. infestans* can infect tubers at any stage of development before or after harvest and soft rot of tubers often occurs in storage following tuber infections. Over the growing season there were several more reports of late blight in potatoes and tomatoes all south of Lansing. The genotype in all cases was US-23. The reports on late blight management with fungicides applied as traditional foliar applications and as seed treatments in this volume cover some options for control.

Other diseases were extensively reported in MI such as common scab and potato early die and some of the research trials on theses diseases are reported on in this volume.

Funding: MPIC and Industry

Seed treatments and seed plus in furrow treatments for control of seed-borne *Fusarium sambucinum*, 2013.

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Potato seed (Snowden) was prepared for planting by cutting and treating with fungicidal seed treatments two days prior to planting. The seed were first inoculated by spraying about 7 fl oz of conidial suspension (30 conidia/fl oz) of a mixture of 10 virulent single spore isolates of *Fusarium sambucinum* over the entire cut surface to give a final dosage of about 0.03 fl oz per seed piece. Seed were planted at the Michigan State University Horticultural Experimental Station, Clarksville, MI (Capac loam soil), 42.8733, -85.2604 deg; elevation 895 ft. on 30 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. A 5-ft not-planted alley separated the two-row beds. Dust formulations were measured and added to cut seed pieces in a miniature cement mixer (seed-treater) and mixed for 2 min to ensure even spread of the fungicide. Potato seed liquid treatments were applied in water suspension at a rate of 0.2 pt/cwt onto the exposed seed tuber surfaces in the seed treater. In-furrow at-planting applications were delivered in 8 pt water/A in a 7 in. band using a single XR11003VS nozzle at 30 psi. Foliar applications were applied with a R&D spray boom delivering 25 gal/A (80 psi) 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 N 6SC was applied at 0.7 pt/A on a seven-day interval, total of four applications, starting one day after inoculation of adjacent plots with *Phytophthora infestans* to prevent spread of potato late blight. Weeds were controlled by hilling and with Dual 8E at 2 pt/A 10 DAP and Poast 1.5EC at 1.5 pt/A 58 DAP. Insects were controlled with Admire 2F at 1.25 pt/A at planting or if a formulation included an insecticide the Admire was not applied, 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 15 Sep). Plant stand was rated 21, 25 and 33 days after planting (DAP) and relative rate of emergence was calculated as the Relative Area Under the Emergence Progress Curve [RAUEPC from 0 – 33 DAP, maximum value = 100]. Plots were harvested on 27 Sep and individual treatments were weighed and graded. Four plants per plot were harvested 36 days after planting (20 Jun) and the percentage of stems and stolons with greater than 5% of the total surface area affected were counted. Samples of 20 tubers per plot were stored for 22 days after harvest in the dark at 50^{o}F 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 into each 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 from 1 Jun to harvest (7 Oct). Average daily air temperature (^{o}F) from 1 Jun was 65.8, 69.5, 67.1, 59.7 and 62.0 and the number of days with maximum temperature >90^{o}F was 0, 4, 0 and 0 (Jun, Jul, Aug, Sep, Oct, respectively). Average daily relative humidity (%) over the same period was 71.4, 72.1, 72.7 and 74.7%. Average daily soil temperature at 4” depth (^{o}F) over the same period was 70.3, 75.8, 69.7, 64.0 and 63.6. Average daily soil moisture at 4” depth (% of field capacity) over the same period was 37.4, 39.2, 37.8, 36.6 and 36.3. Precipitation (in.) over the same period was 3.11, 3.31, 3.18, 1.77 and 1.71. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

Treatments with final plant stand greater than 91.5% were significantly higher in comparison to the untreated control (83.0%). No other treatment affected final plant stand in comparison to the untreated control. Treatments with relative rate of emergence (RAUEPC) greater than 48.8 were significantly higher in comparison to the untreated control (42.9). No other treatment affected RAUEPC in comparison to the untreated control. Treatments with total yield greater than 242 cwt/A had significantly higher yield than the untreated control. Treatments with final stem number greater than 5.0 were significantly higher in comparison to the untreated control (3.6 stems/plant). No other treatment affected stem number/plant in comparison to the untreated control. Treatments with less than 77.2% incidence of stems with stem canker with greater than 5% of the total surface area affected had significantly less stem canker than the untreated check (96.9%). No treatments had significantly different number of stolons per plant from the untreated control (10.1 stolons/plant). Treatments with less than 27.7% incidence of stolons with stem canker with greater than 5% of the total surface area affected had significantly less stolon canker than the untreated check (56.7%). Treatments with less than 58.8% incidence of tuber black scurf had significantly less black scurf than the untreated check (78.8%). Treatments with less than 23.8 severity index of tuber black scurf less than in comparison to the untreated check (35.8%). Seed treatments were not phytotoxic.

Funding: MPIC and Industry

Treatment and rate/cwt potato seed (A); rate/1000 row feet (B); foliar rate/A	Emergence (%) 20 DAP		27 DAP		32 DAP		RAUEPC[c] Max = 100 (0 – 32 DAP)		Yield (cwt/A) US-1		Total	
Nubark mancozeb DS 16 oz (A)……….	52.2	ab	59.5	c-f	68.0	bcd	37.8	ab	268	def	328	bcd
Nubark mancozeb DS 16 oz/cwt (A); SP26966 SC 1.31 fl oz (B)……………..	59.5	a	74.1	abc	69.5	bc	43.8	a	359	a	424	a
Nubark mancozeb DS 16 oz (A); SP26966 SC 1.31 fl oz + Serenade Soil SC 4.4 fl oz (B)…………	62.1	a	77.2	ab	70.5	bc	46.3	a	279	b-e	342	bc
Nubark mancozeb DS 16 oz (A); SP26966 SC 1.31 fl oz + Serenade Soil SC 8.8 fl oz (B)…………	51.3	abc	71.4	a-d	70.0	bc	39.3	ab	267	def	330	bc
Nubark mancozeb DS 16 oz/cwt (A); BCS-AR83685 SC 0.59 fl oz + Serenade Soil SC 4.4 fl oz (B)…………	53.5	ab	63.1	b-e	67.0	b-e	39.4	ab	273	cde	334	bc
Nubark mancozeb DS 16 oz A); Quadris FL 0.6 fl oz (B)………………..	60.2	a	72.3	abc	66.0	b-e	44.0	a	317	abc	382	ab
Nubark mancozeb DS 16 oz (A); Inspire SC 0.48 fl oz (B)……………….	55.1	a	68.1	a-d	63.5	cde	40.7	ab	263	def	320	cd
Nubark mancozeb DS 16 oz (A); Medallion WP 0.48 oz (B)……………..	55.8	a	68.7	a-d	71.5	bc	41.9	a	292	bcd	350	bc
Nubark mancozeb DS 16 oz/cwt (A); Luna Tranquility SC 0.55 fl oz (B)…….	57.4	a	62.3	b-e	67.5	bcd	40.6	ab	213	gh	263	ef
Serenade Soil SC 8.8 fl oz (B)…………	17.4	f	24.5	i	34.5	i	14.7	f	127	jk	164	hi
Maxim 4FS FS 0.08 fl oz (A)…………	17.9	f	29.4	hi	39.5	hi	16.2	ef	94	k	132	i
Tenet WP 1.5 oz (B)……………………	34.1	cde	42.0	gh	56.0	ef	26.4	cd	245	efg	300	cde
Tenet WP 2.25 oz (B)…………………..	36.3	b-e	56.5	d-g	68.5	bcd	31.2	bc	265	def	310	cde
Tenet WP 3 oz (B)……………………...	23.4	ef	45.4	fg	46.5	fgh	22.2	c-f	210	gh	261	ef
Maxim 4FS FS 0.08 fl oz (A); Tenet WP 3 oz (B)……………………...	28.9	def	49.0	efg	57.5	def	25.7	cd	244	efg	305	cde
Vertisan EC 1.1 fl oz (B)……………….	24.4	ef	41.0	gh	44.0	ghi	21.5	def	187	hi	229	fg
Maxim 4FS FS 0.08 fl oz (A); Quadris FL 0.6 fl oz (B)………………..	28.4	def	43.5	fgh	49.5	fgh	24.2	cde	143	ij	179	ghi
Inspire SC 0.3 fl oz (B)………………...	25.6	ef	41.9	gh	46.5	fgh	22.1	c-f	223	fgh	274	def
Check (inoculated)………….…………	26.4	ef	44.4	fgh	51.5	fg	23.4	cde	150	ij	199	gh
Check (not-inoculated)…………………	47.5	abc	80.8	a	90.0	a	42.5	a	293	bcd	353	bc

[a] RAUEPC = Relative area under the emergence progress curve measured from planting to 31 days after planting.
[b] Application dates: A= 15 May (liquid formulations for seed piece application at 0.2 pt/cwt); B= 17 May (in-furrow); C= 8 Jun (foliar); D= 23 Aug (foliar).
[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Fishers LSD).

Funding: MPIC and Industry

Seed treatments and seed plus in furrow treatments for control of seed-borne *Rhizoctonia solani*, 2013.

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Potatoes with *Rhizoctonia solani* (black scurf), 2- 5% tuber surface area infected, were selected for the trials. Potato seed (Russet Norkotah) 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 Horticultural Experimental Station, Clarksville, MI (Capac loam soil); 42.8733, -85.2604 deg; elevation 895 ft. on 27 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. A 5-ft not-planted alley separated the two-row beds. Dust formulations were measured and added to cut seed pieces in a miniature cement mixer (seed-treater) and mixed for 2 min to ensure even spread of the fungicide. Potato seed liquid treatments were applied in water suspension at a rate of 0.2 pt/cwt onto the exposed seed tuber surfaces in the seed treater. In-furrow at-planting applications were delivered in 8 pt water/A in a 7 in. band using a single XR11003VS nozzle at 30 psi. Foliar applications were applied with a R&D spray boom delivering 25 gal/A (80 psi) 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 N 6SC was applied at 0.7 pt/A on a seven-day interval, total of four applications, starting one day after inoculation of adjacent plots with *Phytophthora infestans* to prevent spread of potato late blight. Weeds were controlled by hilling and with Dual 8E at 2 pt/A 10 DAP and Poast 1.5EC 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 15 Sep). Plant stand was rated 17, 23 and 35 days after planting (DAP) and relative rate of emergence was calculated as the Relative Area Under the Emergence Progress Curve [RAUEPC from 0 – 35 DAP, maximum value = 100]. Plots were harvested on 7 Oct and individual treatments were weighed and graded. Four plants per plot were harvested 49 days after planting (15 Jul) and the percentage of stems and stolons with greater than 5% of the total surface area affected were counted. Samples of 20 tubers per plot were stored for 58 days after harvest in the dark at 50^{o}F 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 into each 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 from 1 Jun to harvest (7 Oct). Average daily air temperature (^{o}F) from 1 Jun was 65.8, 69.5, 67.1, 59.7 and 62.0 and the number of days with maximum temperature >90^{o}F was 0, 4, 0 and 0 (Jun, Jul, Aug, Sep, Oct, respectively). Average daily relative humidity (%) over the same period was 71.4, 72.1, 72.7 and 74.7%. Average daily soil temperature at 4" depth (^{o}F) over the same period was 70.3, 75.8, 69.7, 64.0 and 63.6. Average daily soil moisture at 4" depth (% of field capacity) over the same period was 37.4, 39.2, 37.8, 36.6 and 36.3. Precipitation (in.) over the same period was 3.11, 3.31, 3.18, 1.77 and 1.71. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

No treatments affected final plant stand in comparison to the not-treated control. Treatments with relative rate of emergence (RAUEPC) greater than 46.6 were significantly higher in comparison to the not-treated control (39.4). No other treatment affected RAUEPC in comparison to the not-treated control. Treatments with US1 and total yield greater than 286 and 365 cwt/A, respectively had significantly higher yield than the not-treated control. No treatments had final stem number greater than the not-treated control (4.8 stems/plant). Treatments with less than 3.9 stems/plant had significantly fewer stems than the not-treated control. Treatments with less than 67.8% incidence of stems with stem canker with greater than 5% of the total surface area affected had significantly less stem canker than the not-treated control (87.3%). No treatments had significantly different number of stolons per plant from the not-treated control (8.8 stolons/plant). Treatments with less than 33.8% incidence of stolons with stem canker with greater than 5% of the total surface area affected had significantly less stolon canker than the not-treated control (58.8%). Tuber black scurf incidence and severity was less severe in 2013 in comparison with 2012 at the same site. Treatments with less than 27.5% incidence of tuber black scurf had significantly less black scurf than the not-treated control (47.5%). Treatments with less than 9.3 severity index of tuber black scurf less than in comparison to the not-treated control (17.0). Seed treatments were not phytotoxic.

Funding: MPIC and Industry

Treatment and rate potato seed (A); In-furrow rate/1000 row feet (B); Foliar rate/A (C,D)	Emergence (%) 35 DAP[a]		RAUEPC[b] Max = 100 (0 – 35 DAP)		Yield (cwt/A) US-1		Total	
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A)….	89.0	a[e]	48.9	b-f	321	a-e	365	a-f
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 4.4 fl oz (B)……	88.5	a	56.4	a	343	ab	394	ab
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 4.4 fl oz + Emesto Prime FS 0.4 fl oz (B)……	90.5	a	56.6	a	328	a-d	375	a-d
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 8.8 fl oz (B)……	89.0	a	53.6	ab	321	a-e	362	a-f
Blocker F 10 fl oz (B)…………….	88.5	a	41.7	f-j	221	g-j	269	g-j
Blocker F 10 fl oz + Quadris FL 0.6 fl oz (B)…………..	86.5	a	42.3	f-j	234	f-j	274	g-j
Quadris FL 0.8 fl oz (B)…………..	85.5	a	45.9	c-h	286	b-f	327	c-h
Vertisan EC 1.1 fl oz (B)………….	85.5	a	47.7	b-g	238	f-j	289	g-j
Regalia SC 2 fl oz (A)…………….	90.5	a	48.2	b-g	250	f-j	286	g-j
Regalia SC 2 fl oz (A); Regalia SC 4 pt (B)……………….	83.5	a	52.3	a-d	325	a-e	375	a-d
Regalia SC 2 fl oz (A); Quadris FL 0.6 fl oz (C)…………..	85.5	a	52.2	a-d	334	abc	380	abc
Regalia SC 4.4 fl oz (B); Quadris FL 0.6 fl oz (B)…………..	91.5	a	47.9	b-g	232	f-j	285	g-j
Regalia SC 4.4 fl oz + Quadris FL 0.6 fl oz (B); Regalia SC 2 pt + Quadris FL 0.6 fl oz (C,D)………..	88.0	a	39.5	hij	200	j	250	j
Quadris FL 0.6 fl oz (B)…………..	83.5	a	46.6	b-h	263	e-j	311	e-j
WE1042-2 DS 1 lb (A)……………	91.5	a	53.4	ab	319	a-e	365	a-f
WE1043-1 DS 1 lb (A)……………	88.5	a	50.4	a-e	282	b-g	324	c-h
Maxim 4FS FS 0.08 fl oz + WE1042-2 DS 1 lb (A)……………	86.5	a	50.0	a-e	279	c-h	331	b-g
Topguard SC 0.96 fl oz (B)……….	87.5	a	45.1	d-h	237	f-j	277	g-j
Serenade Soil SC 8.8 fl oz (B)……	85.5	a	41.1	g-j	216	hij	259	ij
Maxim 4FS FS 0.08 fl oz (A)……..	84.0	a	47.4	b-g	285	b-f	328	c-g
Tenet WP 1.5 oz (B)………………	79.5	a	37.2	ij	225	f-j	269	g-j
Tenet WP 2.25 oz (B)……………..	79.0	a	39.4	hij	225	f-j	264	hij
Tenet WP 3 oz (B)………………...	83.5	a	35.5	j	245	f-j	286	g-j
Maxim 4FS FS 0.08 fl oz (A); Tenet WP 3 oz (B)………………...	87.0	a	53.2	abc	328	a-d	367	a-e
Maxim 4FS FS 0.08 fl oz (A); Quadris FL 0.6 fl oz (B)…………..	89.0	a	56.7	a	357	a	395	a
Inspire SC 0.3 fl oz (B)…………...	90.0	a	47.2	b-g	269	d-i	315	d-i
Non-treated Check………………...	82.5	a	39.4	hij	243	f-j	304	f-j

[a] DAP = Days After Planting.
[b] RAUEPC = Relative area under the emergence progress curve measured from planting to 31 days after planting.
[c] Application dates: A= 24 May (liquid formulations for seed piece application at 0.2 pt/cwt); B= 27 May (in-furrow); C= 6 Jun (foliar); D= 7 Jul (foliar).
[d] Values followed by the same letter are not significantly different at $p = 0.05$ (Fishers LSD).

Funding: MPIC and Industry

Treatment and rate potato seed (A); In-furrow rate/1000 row feet (B); Foliar rate/A (C,D)	Stems (49 DAP)				Stolons (49 DAP)				Tuber black scurf			
	Number		Percent infected[c]		No./ plant		Girdling[d] > 5%		Incidence (%)		Severity (0 – 100 Index)	
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A)….	5.6	ab	40.1	i	7.6	a	34.9	b-g	18.8	ghi	5.8	fgh
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 4.4 fl oz (B)……	4.6	b-f	52.8	f-i	7.7	a	61.5	a	28.8	c-i	7.5	e-h
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 4.4 fl oz + Emesto Prime FS 0.4 fl oz (B)……	5.1	abc	48.3	hi	7.4	a	42.1	a-e	26.3	d-i	7.8	d-h
Emesto Silver FS 0.31 fl oz + Nubark Mancozeb DS 16 oz (A); Serenade Soil SC 8.8 fl oz (B)……	4.3	c-f	50.9	ghi	9.1	a	24.3	efg	21.3	e-i	5.5	gh
Blocker F 10 fl oz (B)…………….	4.8	a-e	52.9	f-i	7.3	a	27.5	d-g	20.0	f-i	5.3	gh
Blocker F 10 fl oz + Quadris FL 0.6 fl oz (B)…………..	4.1	c-g	52.3	ghi	8.8	a	12.9	g	18.8	ghi	5.8	fgh
Quadris FL 0.8 fl oz (B)…………..	3.9	d-g	61.6	d-h	8.2	a	24.3	efg	22.5	e-i	5.8	fgh
Vertisan EC 1.1 fl oz (B)…………	4.9	a-d	61.7	d-h	9.3	a	23.3	efg	52.5	ab	19.8	a
Regalia SC 2 fl oz (A)…………….	4.2	c-f	50.1	ghi	7.9	a	14.2	fg	20.0	f-i	5.5	gh
Regalia SC 2 fl oz (A); Regalia SC 4 pt (B)……………….	5.8	a	64.9	c-h	8.6	a	39.3	a-g	55.0	a	15.5	a-d
Regalia SC 2 fl oz (A); Quadris FL 0.6 fl oz (C)…………..	4.6	b-f	75.0	a-e	6.8	a	57.6	ab	31.3	c-i	9.3	b-h
Regalia SC 4.4 fl oz (B); Quadris FL 0.6 fl oz (B)…………..	3.9	d-g	72.4	a-f	7.0	a	30.7	c-g	26.3	d-i	8.5	c-h
Regalia SC 4.4 fl oz + Quadris FL 0.6 fl oz (B); Regalia SC 2 pt + Quadris FL 0.6 fl oz (C,D)………..	4.6	c-f	61.2	d-h	7.3	a	33.8	b-g	27.5	c-i	8.5	c-h
Quadris FL 0.6 fl oz (B)…………..	3.7	fg	85.4	ab	7.4	a	54.2	abc	38.8	a-g	13.5	a-f
WE1042-2 DS 1 lb (A)……………	4.2	c-f	58.5	e-i	6.9	a	39.5	a-f	27.5	c-i	7.5	e-h
WE1043-1 DS 1 lb (A)……………	4.7	b-f	48.3	hi	6.2	a	13.9	fg	41.3	a-e	12.3	a-g
Maxim 4FS FS 0.08 fl oz + WE1042-2 DS 1 lb (A)……………	3.1	g	74.7	a-e	5.8	a	24.5	efg	28.8	c-i	8.5	c-h
Topguard SC 0.96 fl oz (B)……….	4.3	c-f	69.1	a-g	7.1	a	46.7	a-e	40.0	a-f	11.8	b-h
Serenade Soil SC 8.8 fl oz (B)……	4.1	c-g	86.4	ab	6.5	a	58.5	ab	41.3	a-e	16.0	abc
Maxim 4FS FS 0.08 fl oz (A)……..	4.7	b-f	67.0	b-h	7.3	a	41.2	a-e	30.0	c-i	8.8	c-h
Tenet WP 1.5 oz (B)………………	4.3	c-f	67.8	a-h	8.2	a	34.4	b-g	28.8	c-i	8.8	c-h
Tenet WP 2.25 oz (B)……………..	4.3	c-f	79.9	a-d	8.8	a	43.7	a-e	26.3	d-i	8.3	c-h
Tenet WP 3 oz (B)………………...	3.9	d-g	78.9	a-d	7.6	a	42.4	a-e	43.8	a-d	14.8	a-e
Maxim 4FS FS 0.08 fl oz (A); Tenet WP 3 oz (B)………………...	5.0	abc	86.3	ab	8.6	a	30.3	c-g	38.8	a-g	10.5	b-h
Maxim 4FS FS 0.08 fl oz (A); Quadris FL 0.6 fl oz (B)…………..	4.7	b-f	79.5	a-d	7.6	a	53.1	a-d	15.0	hi	4.0	h
Inspire SC 0.3 fl oz (B)…………...	4.3	c-f	72.3	a-f	7.6	a	44.0	a-e	33.8	b-h	10.3	b-h
Non-treated Check………………...	4.8	a-e	87.3	a	8.8	a	58.8	ab	47.5	abc	17.0	ab

[a] DAP = Days After Planting.
[c] Application dates: A= 24 May (liquid formulations for seed piece application at 0.2 pt/cwt); B= 27 May (in-furrow); C= 6 Jun (foliar); D= 7 Jul (foliar).
[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Fishers LSD).
[d] Stems with greater than 5% of area with stem canker due to *Rhizoctonia solani.*
[e] Stolons with greater than 5% of area with stolon canker due to *Rhizoctonia solani.*

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Seed treatments, in furrow and early foliar treatments for control of seed-borne *Phytophthora infestans* (US-22), 2013.

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INTRODUCTION:

Potato (*Solanum tuberosum* L.) late blight caused by the oomycete *Phytophthora infestans* (Mont. de Bary), is a major constraint in potato production worldwide (Fry *et al*., 1997). The disease can cause significant losses in the field and storage. Economic losses due to late blight from yield loss and cost of disease management is estimated to exceed $6.7 billion annually (USAblight.org). Infected seed tubers, tubers in cull piles, volunteer tubers and rarely oospores (located in the soil); have been reported as primary sources of inoculum for initiation of epidemics (Zwankhuizen et al., 1998; Kirk et al., 2003; Fernandez-Pavia et al., 2004). Infected tubers may rot in field or later in storage, affecting both tubers intended for seed and consumption (Johnson and Cummings, 2009; Kirk et al., 2009; Olanya et al., 2009) or after planting, but can initiate a late blight epidemic if the pathogen survives in seed tubers and is transmitted to the developing shoot and then to foliage (Kirk et al., 1999; Johnson, 2010). However, the rotting of tuber in storage is dependent on the aggressiveness of the *P.infestans* genotype and storage temperature. Storage temperatures of potato tubers vary depending on the intention of use. Potato tubers intended for seed stored at 3^{O}C have been reported to have no or minimal tuber tissue infection even in the tubers infected with aggressive US-8 genotype (Kirk et al., 2001b). Potato seed tubers in long-term cold storage can latently be infected by *P.infestans* (Johnson and Cummings, 2009). Although tubers can be infected in field during the growing season, transmission of pathogen can occur during harvest, seed cutting and seed handling operations (Lambert et al. 1998). Therefore, it is important to treat seed tubers with effective fungicides prior to or at planting. The advent of more aggressive, A2 mating type and mefenoxam (Ridomil^{TM}) insensitive genotypes of *P. infestans* such as US-8 (Lambert and Currier, 1997; Fry, 2008, Kirk et al., 2001) increased the potential for the risk of late blight epidemics. However, genotypes of *P. infestans* that have recently appeared in North America are more sensitive to the phenylamide fungicide mefenoxam (Ridomil^{TM}), than the insensitive biotypes common up to 2009 (Hu et al., 2012). Despites the huge effort by plant breeders, the advent of different new fungicides and technologies to monitor and control the disease, numerous challenges still remain for the management of tuber blight (Olanya *et al*., 2009). Although integrated disease management is most reliable method for controlling late blight, growers heavily rely on fungicides to combat the disease. The right timing and rate of application of fungicides is of great importance to control the late blight. The performance of fungicides against *P. infestans* during handling operations of potato seed piece may be more beneficial than used curative applications (Inglis et al., 1999). The objectives of this study therefore were to evaluate the different fungicides available in the market for the successful management of seed-borne late blight. The specific objectives of this study were to determine (i) effectiveness of different fungicides to control seed borne *P. infestans* applied as seed treatments or in furrow during planting and after emergence and ii) to determine the impact of fungicides applied alone or as combinations.

MATERIALS AND METHODS:

Inoculum Preparation: Multiple isolates of *P infestans* US-22 genotype (A2 mating type, sensitive to mefenoxam) from potato and tomato were used in this study. Isolates were sub-cultured on Rye B media amended with rifampicin, ampicillin and nystatin; incubated at 18°C in dark for two weeks and exposed to light for two days to encourage sporulation. Culture plates (9 cm diameter x 15 mm depth Petri plates) were flooded with 50 ml sterile distilled water and dislodged the mycelia using L-shaped glass rod to release sporangia. The final concentration of inoculum was adjusted to 10^6 sporangia ml^{-1} using a Makler counting chamber. The suspension was placed at 4°C for 2 hours to release the zoospores.

Inoculation and Seed Treatment: Potato tubers [cv. Snowden; susceptible to *P. infestans* (Kirk et al., 2009)] were used in the experiment. Tubers free from disease symptoms were selected for the experiment. Potato tubers were first cut into two or three sections longitudinally (depending on the size of tuber) ensuring the presence of viable sprouts on each seed-piece. The cut seed pieces were immersed in the mixture of mycelium and zoospores of *P. infestans* for 30 minutes then dried at 18^{o}C for 1 h prior to treating with fungicidal seed treatments on the same day of planting. Eight different fungicides with different concentrations (some treated alone and some in combination) were used in the study (Tables 1 - 2). Treatment applied to seed pieces were (i) non-inoculated, (ii) inoculated, (iii) inoculated and treated with fungicides either right after inoculation or left not-treated for in-furrow application. The samples for each treatment consisted of 320 seed pieces that were split into groups of 50 for 6 replications for the field experiment and 20 tubers were sampled for determination of inoculation efficiency in controlled environment chambers. Dust formulations were measured and added to inoculated seed pieces in paper bags and shaken for 2 min to ensure uniform spread of the fungicide until the fungicides were coated on the seed. Fungicides applied as pre-planting potato seed liquid treatments were applied in water suspension at a rate of 0.2 pt H_2O/cwt onto the exposed seed tuber surfaces, with the entire seed surface being coated. In-furrow at-planting applications were delivered at 8 pt water/A in a 7 in. band using a single XR11003VS nozzle at 30 p.s.i.

Experimental set up:

Laboratory experiment: A total of 20 potato seed pieces from each treatment were harvested and placed in 5lb mesh bags and replicated four times consisting 5 tubers in each replication. The tubers were incubated in plastic boxes lined with wet paper towels at 15°C in environmental control chamber for 30 days. After 30 days of incubation, disease incidence was evaluated by counting the number of seed pieces with symptoms of late blight.

Field experiment: To evaluate the effects on emergence and plant stand, treated seed tubers were planted at the Michigan State University Horticultural Experimental Station, Clarksville, MI (Capac loam soil); 42.8733, -85.2604 deg; elevation 895 ft. on 6 June 2013 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 six times in a randomized complete block design. The two-row beds were separated by a 5-ft unplanted 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). Weeds were controlled by hilling and with Dual 8E at 2 pt/A 10 DAP and Poast at 1.5 pt/A 58 DAP. Insects were controlled with Admire Pro 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.

Data Collection and Analysis: The number of emerged plants was recorded over a 37-day period after planting and final plant stand (%) and the relative area under the emergence progress curve (RAUEPC) was calculated. The RAUEPC was calculated by dividing the AUEPC by the maximum AUEPC (100 X duration of emergence period) from planting to full emergence. Data were analyzed using the statistical analysis software package JMP (SAS Institute, Cary, NC) by analysis of variance, and mean separation tests conducted with Least Square Means Tukey HSD at $p \leq 0.05$. Meteorological variables were measured with a Campbell weather station located at the farm from 1 June to 31 September. Average daily air temperature (^oF) from 1 June was 65.9, 69.4, 67.1 and 60.7 and the number of days with maximum temperature >90^oF was 0, 4, 0 and 1 (Jun, Jul, Aug and Sep, respectively). Average daily relative humidity (%) over the same period was 71.4, 72.1, 72.8 and 72.8 (Jun, Jul, Aug and Sep, respectively). Average daily soil temperature at 4" depth (^oF) over the same period was 70.4, 75.8, 69.7 and 65.0 and the number of days with maximum soil temperature >90^oF was 0 from June to Sept. Average daily soil moisture at 4" depth (% of field capacity) over the same period was 37.5, 39.1, 37.8 and 36.6 (Jun, Jul, Aug and Sep, respectively). Precipitation was 3.11, 3.31, 3.18 and 1.77 in (Jun, Jul, Aug and Sep, respectively). Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

RESULT AND DISCUSSION

Lab experiment: Late blight developed successfully in all the replications of the inoculated check seed pieces. Late blight and other diseases did not develop in non-inoculated non-treated check seed pieces. Seed pieces treated with different fungicides developed late blight in some tubers in all treatments (Table 1). Treatment with disease incidence greater than 45% were not significantly different from inoculated check (95%). This study was done to check the efficacy of the inoculation.

Field experiment: Late blight developed in the seed pieces and affected plant stands in all treatments. None of the treatments achieved 100% plant stand including the non-inoculated non-treated check. Non-inoculated non-treated check had significantly greater plant stand (79.7%) in comparison to all the treatments. Although responses of some treatments enhanced the emergence rate, most of the treatments did not perform well.

At the final plant stand evaluation, treatments non-inoculated non-treated check, Nubark mancozeb, both single and double rate of Revus + Nubark mancozeb and Maxim MZ had significantly greater plant stand in comparison to the inoculated check treatment. Treatments with greater than 25.7 to 39.7% plant stand were not significantly different from each other. Emergence taken over a 37 d period (RAUEPC) indicated that treatments with RAUEPC values ≤14.6 were not significantly different from the inoculated check (RAUEPC = 2.5). Treatments with RAUEPC values from 21.9 to 32.0 were not significantly different. Late blight symptoms appeared on stems in some treatments including on plants located in the inoculated check plots. Yield was not harvested due to the extremely low plant stand. At, the time of harvesting all the plants were uprooted and any late blight symptoms on stem or foliage were evaluated in all the treatments. Most of the tubers were rotted before emergence and those plants that emerged from the inoculated check and Tenet (1.5 oz) treatments had developed late blight lesions on stems. Seed treatments and in-furrow applications of fungicides were not phytotoxic.

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Table 1. Effect of seed treatments, in furrow and early foliar treatments for control of seed-borne *Phytophthora infestans* (US-22) on disease incidence in inoculated tubers (%).

Treatment and rate/1000 row feet; Rate/cwt potato seed; and rate/A	Disease Incidence %[a]	
Non-inoculated Check	0	c[c]
Nubark Mancozeb 6DS 1 lb (A[b])....……….…………	30	bc
Revus 250SC 0.307 fl (A) ………..…………………	45	abc
Revus 250SC 0.614 fl oz (A) ………..………………	45	abc
Revus 250SC 0.307 fl oz (A) + Nubark Mancozeb 6DS 1 lb (A) ………..……………	60	ab
Revus 250SC 0.614 fl oz (A) + Nubark Mancozeb 6DS 1 lb (A).………..…………….	65	ab
Moncoat MZ 7.5DP 12 oz (A) ………..……………..	55	ab
Maxim MZ 6.2DP 0.5 lb (A) ………..……………..…	70	ab
Maxim 4FS 0.08fl oz (A) + Quadris 2.08FL 0.6 fl oz (B)………..……………..…	40	bc
Maxim 4FS 0.16fl oz (A) + Quadris 2.08FL 0.6 fl oz (B)………...……………….	55	ab
Ridomil Gold 4SL 0.42 fl oz (B)…………………..….	70	ab
Inoculated Check……………………..……………	95	a

[a] Disease incidence (%) is calculated as the ratio of tubers developing late blight symptoms. 20 potato seed pieces were harvested and incubated in plastic boxes lined with wet paper towels at 15°C in a controlled environmental chamber for 30 d.
[b] Application dates: A= 6 June (liquid formulations for seed piece application at 0.2 pt. H_2O/cwt); A= 6 June (dry formulation); B= 6 June (in-furrow).
[c] Values followed by the same letter are not significantly different at p = 0.05 (Least Square Means Tukey HSD).

Table 2. Effect of seed treatments, in furrow and early foliar treatments for control of seed-borne *Phytophthora infestans* (US- 22), 2013 on plant stand (%), relative area under emergence progressive curve values (RAUEPC; 0 - 100).

Treatment and rate/1000 row feet; Rate /cwt potato seed; and rate/A	Final Plant Stand %							RAUEPC[b] %
	15 DAP[a]	18 DAP	20 DAP	24 DAP	27 DAP	32 DAP	37 DAP	
Non-inoculated Check	21.0 a[d]	48.0 a	56.3 a	76.7 a	79.3 a	79.3 a	79.7 a	68.8 a
Nubark Mancozeb 6DS 1 lb (A[c])…..	3.0 b	10.7 bcd	20.0 bc	36.3 b	39.0 b	39.0 b	39.7 b	30.9 b
Revus 250SC 0.307 fl (A)………....	0.0 b	1.0 cd	2.3 e	5.3 e	6.7 e	7.0 d	7.0 d	5.0 e
Revus 250SC 0.614 fl oz (A)………	1.0 b	1.3 cd	2.0 e	3.7 e	4.7 e	4.7 d	4.7 d	3.6 e
Revus 250SC 0.307 fl oz (A) + Nubark Mancozeb 6DS 1 lb (A)…	2.3 b	17.3 b	27.0 b	36.3 b	38.3 b	38.3 b	38.7 b	32.0 b
Revus 250SC 0.614 fl oz (A) + Nubark Mancozeb 6DS 1 lb (A)…	3.7 b	12.0 bcd	17.7 bcd	25.7 bc	26.3 bc	26.3 bc	26.7 bc	22.1 bc
Moncoat MZ 7.5DP 12 oz (A)……	1.7 b	6.7 bcd	8.7 cde	16.3 cde	18.3 cde	18.7 cd	19.3 cd	14.6 cde
Maxim MZ 6.2DP 0.5 lb (A)………	5.0 b	14.7 bc	18.0 bcd	24.0 bcd	25.7 bcd	25.7 bc	25.7 bc	21.9 bcd
Maxim 4FS 0.08fl oz (A) + Quadris 2.08FL 0.6fl oz (B)………	1.0 b	3.0 cd	5.3 de	8.0 e	8.3 e	8.7 d	8.7 d	7.0 e
Maxim 4FS 0.16 fl oz (A) + Quadris 2.08FL 0.6fl oz (B)………	3.0 b	7.0 bcd	7.7 cde	10.0 de	11.0 cde	11.0 cd	11.0 cd	9.5 de
Ridomil Gold 4SL 0.42 fl oz (B)…	0.7 b	2.7 cd	6.3 de	10.0 de	10.7 de	11.0 cd	11.0 cd	8.7 de
Tenet 4WP 1.5 oz (B)……………	1.0 b	2.7 cd	3.7 e	6.3 e	7.7 e	7.7 d	8.0 d	5.8 e
Tenet 4WP 2.25 oz (B)……………	1.3 b	1.7 cd	2.7 e	5.7 e	6.7 e	7.0 d	7.7 d	5.4 e
Tenet 4WP 3 oz (B)………………	0.7 b	1.3 cd	2.7 e	4.0 e	4.0 e	4.3 d	5.0 d	3.6 e
Serenade Soil 1.34SC 8.8fl oz (B)…	1.0 b	2.7 cd	3.3 e	4.7 e	6.3 e	6.7 d	6.7 d	5.0 e
Inoculated Check…………………..	0.3 b	0.3 d	0.7 e	3.0 e	3.0 e	3.7 d	4.0 d	2.5 e

[a] DAP= days after planting

[b] RAUEPC = Relative area under the emergence progress curve measured from planting to 37 days after planting

[c] Application dates: A=6 June (liquid formulations for seed piece application at 0.2 pt H_2O/cwt); A=6 June (dry formulation); B= 6 June (in-furrow)

[d] Values followed by the same letter are not significantly different at p = 0.05 (Least Square Means Tukey HSD)

Funding: MPIC and Industry

In-furrow fungicide treatments for control of Verticillium wilt of potatoes, 2013.

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In-furrow fungicides were applied at the Michigan State University Potato Research Farm (MRC), Entrican, MI (sandy soil); 43.3526, -85.1761 deg; elevation 951 ft; and at the Michigan State University Potato Research Farm (CHES), Clarksville, MI (Capac loam soil); 42.8733, -85.2604 deg; elevation 895 ft. Potato seed ("Snowden") was prepared for planting by cutting two days prior to planting. Seeds were planted on 16 May (MRC) and 21 May (CHES) into two-row by 25-ft plots (~10-in between plants to give a target population of 60 plants at 34-in row spacing) replicated four times in a randomized complete block design. A 5-ft not-planted alley separated the two-row beds. In-furrow fungicides included in the trial were Inspire 2.08 lb/gal SC (7 fl oz/A), Maxim 4.0 lb/gal SC (24.5 fl oz/A), Quadris 2.08 lb/gal SC (11.6 fl oz/A), Moncut 50 %w/w WP (1.07 fl oz/A), Headline 2.08 lb/gal (12 fl oz/A), Luna Tranquility 4.16 lb/gal SC (11.2 fl oz/A), and Blocker 4F 4.0 lb/gal SC (160 fl oz/A). Vydate 3.77 lb/gal SC was applied with each treatment in-furrow (at planting; 34 oz/A), foliarly at hilling (17 oz/A) and foliarly 3 weeks after hilling (17 oz/A). In-furrow, at-planting applications of fungicide were delivered in 8 pt water/A in a 7 in. band using a single XR11003VS nozzle at 30 psi. Foliar applications of Vydate were applied with an R&D spray boom delivering 25 gal/A (80 psi) 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). Bravo WS 6SC 1.5 pt/A was applied on a seven-day interval, total of eight applications, for foliar disease control. Weeds were controlled by cultivation 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 6 Sep for both locations). Plots (1 x 20-ft row) were harvested on 17 Sep (MRC) and 19 Sep (CHES) and individual treatments were weighed and graded.

MRC Sampling

Soil samples were taken on 5 Jun (20 DAP; 1 day before first foliar Vydate application), 2 Jul (47 DAP; 12 days after final foliar Vydate application), 14 Aug (90 DAP; 55 days after final foliar Vydate application), and 5 Sep (112 DAP; 77 days after final foliar Vydate application). Soil was then plated on a *Verticillium dahliae* selective media and incubated for 21 days. Colony forming units (CFU) were counted on each plate. Five plants per plot were harvested on 14 Aug [90 days after planting (DAP); 55 days after the final Vydate application] and each plot was given a value from 0 to 11 using the Horsfall-Barratt rating scale (0=0%; 1=0.1-3%; 2=3.1-6%; 3=6.1-12%; 4=12.1-25%; 5=25.1-50%; 6=50.1-75%; 7=75.1-87%; 8=87.1-94%; 9=94.1-97%; 10=97.1-99.9%; 11=100%) based on the percent of stems which showed visual symptoms of Verticillium wilt. Following visual assessment, 0.5 mL of stem sap was extracted using a hydraulic plant sap press (Spectrum, Inc.). The sap was plated on selective *Verticillium dahliae* media and incubated for 21 days. Colony forming units were then counted on each plate. Randomly selected samples of 10 tubers per plot were washed and assessed for stem end vascular beading incidence (%) on 17 Oct 2013, 30 days after harvest (154 DAP).

Funding: MPIC and Industry

MRC Meteorological Data

Meteorological variables were measured with a Campbell weather station located at the farm from 1 May to the end of Sept. Average daily air temperature (^{o}F) from 16 May was 62.0, 66.1, 69.5, 67.3, and 60.47 and the number of days with maximum temperature >90^{o}F was 0, 0, 3, 0 and 0 (May, Jun, Jul, Aug, Sep, respectively). Average daily relative humidity (%) over the same period was 71.4, 70.7, 72.6, 72.0 and 74.1%. Average daily soil temperature at 4" depth (^{o}F) over the same period was 64.7, 72.6, 80.0, 75.8, and 67.6. Precipitation (in.) over the same period was 3.84, 2.26, 1.35, 4.06, and 1.33. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

MRC Results (Table 1)

No treatments were significantly different in percent of emergence or average number of stems per plant. No significant difference was found in the number of CFU at any of the four sampling dates. Though no significant difference was seen between treatments, the overall CFU decreased for most treatments from the time of the first sampling (5 Jun) to the time of the second soil sampling date (20 Jun). No significant difference in CFU levels was seen between treatments at the final two sampling dates (14 Aug and 5 Sep), but overall CFU levels did increase from the time of the second sampling (20 Jun). No treatments affected Verticillium wilt in the stems measured as visual stem symptoms or stem colony forming units measured through sap extraction. The untreated control showed significantly less tuber discoloration in comparison to Quadris. All other treatments showed no significant difference in tuber stem end discoloration in comparison to the untreated control. No in-furrow applied products increased total yield in comparison to the untreated control. Soil treatments were not phytotoxic in terms of plant stand or rate of emergence.

CHES Sampling

Soil samples were taken on 17 Jun (27 DAP; 1 day before first foliar Vydate application), 8 Jul (48 DAP; 5 days after final foliar Vydate application), 15 Aug (86 DAP; 43 days after final foliar Vydate application), and 6 Sep (108 DAP; 65 days after final foliar Vydate application). Soil was then plated on a *Verticillium dahliae* selective media and incubated for 21 days. Colony forming units were counted on each plate. Five plants per plot were harvested on 15 Aug [86 days after planting (DAP); 43 days after the final Vydate application] and each plot was given a value from 0 to 11 using the Horsfall-Barratt rating scale (0=0%; 1=0.1-3%; 2=3.1-6%; 3=6.1-12%; 4=12.1-25%; 5=25.1-50%; 6=50.1-75%; 7=75.1-87%; 8=87.1-94%; 9=94.1-97%; 10=97.1-99.9%; 11=100%) based on the percent of stems which showed visual symptoms of Verticillium wilt. Following visual assessment, 0.5 mL of stem sap was extracted using a hydraulic plant sap press (Spectrum, Inc.). The sap was plated on selective *Verticillium dahliae* media and incubated for 21 days. Colony forming units where then counted on each plate. Randomly selected samples of 10 tubers per plot were washed and assessed for stem end vascular beading incidence (%) on 19 Oct 2013, 30 days after harvest (151 DAP).

CHES Meteorological Data

Meteorological variables were measured with a Campbell weather station located at the farm from 1 May to the end of Sept. Average daily air temperature (^{o}F) from 21 May was 60.1, 65.8, 69.5, 67.1, and 59.7 and the number of days with maximum temperature >90^{o}F was 0, 0, 4, 0 and 0 (May, Jun, Jul, Aug, Sep, respectively). Average daily relative humidity (%) over the same period was 64.8, 71.4, 72.1, 72.7 and 74.7%. Average daily soil temperature at 4” depth (^{o}F) over the same period was 61.7, 70.3, 75.8, 69.7, 64.0 and 63.6. Average daily soil moisture at 4” depth (% of field capacity) over the same period was 37.4, 39.2, 37.8, 36.6 and 36.3. Precipitation (in.) over the same period was 4.22, 3.11, 3.31, 3.18, and 1.77. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation.

CHES Results (Table 2)

No treatments were significantly different in percent of emergence or average number of stems per plant. No significant difference was found in the number of CFU at any of the four sampling dates. Though no significant difference was seen between treatments, the overall CFU decreased for most treatments from the time of the first sampling (17 Jun) to the time of the second soil sampling date (8 Jul). No significant difference in CFU levels was seen between treatments at the final two sampling dates (15 Aug and 6 Sep), but overall CFU levels did increase from the time of the second sampling (8 Jul). The second sampling was done 5 days after the second and final foliar Vydate treatment and though there was no significant difference between treatments, the overall CFU decreased for every treatment from the time of the first sampling (17 Jun) to the time of the second soil sampling date (8 Jul). No significant difference in CFU levels was seen between treatments at the final two sampling dates (15 Aug and 6 Sep), but overall CFU levels did increase from the time of the second sampling (8 Jul). No treatments affected Verticillium wilt in the stems measured as visual stem symptoms, stem colony forming units measured through sap extraction or tuber discoloration in comparison to the untreated check. No in-furrow applied products increased total yield in comparison to the untreated control. Soil treatments were not phytotoxic in terms of plant stand or rate of emergence.

Conclusions

Environmental conditions were conducive to Verticillium wilt as was seen in the percentage of infected stems found at both locations. Data from both locations showed that no in-furrow, at planting fungicide applications was different from the untreated control in regards to Verticillium wilt control. Management of Verticillium wilt requires an integrated approach that combines the use of host resistance, cultural control methods, and chemical control. Further research is needed to identify what cultural and chemical control strategies may be effective against the disease

Funding: MPIC and Industry

Table 1. Effects of in-furrow, at planting fungicide treatments on emergence percent, stems per plant, *Verticillium dahliae* colony forming units (CFU), visual Verticillium wilt symptoms, number of CFU in 0.5 mL of stem sap, vascular beading, and yield in hundred weight per acre at CHES.

	Emergence %	Stems Number per Plant	CFU[b]/10g Soil June 5	CFU/10g Soil June 20	CFU/10g Soil Aug 14	CFU/10g Soil Sep 5	Average % of stems showing wilt Aug 14[b]	Average CFU/0.5 mL of Stem Sap Aug14[c]	Average % of vascular beading in tuber 17 Oct	Average Yield in Hundred Weight per Acre 17 Sept
Untreated Control	83.4 a[d]	1.80 a	1.75 a	1.75 a	14.5 a	12.9 a	79.1 a	88.5 a	17.5 a	153 a
Inspire 7 oz/A + Vydate 34 oz/A	82.7 a	1.80 a	7.03 a	1.75 a	24.3 a	10.8 a	73.6 a	48.3 a	25.0 ab	211 a
Maxim 24.5 oz/A + Vydate 34 oz/A	90.1 a	1.87 a	3.48 a	0.25 a	42.1 a	10.5 a	75.2 a	87.5 a	30.0 ab	228 a
Quadris 11.6 oz/A + Vydate 34 oz/A	83.3 a	2.05 a	3.58 a	1.00 a	16.5 a	11.9 a	64.7 a	59.4 a	55.0 b	210 a
MONCUT 1.07 lb/A + Vydate 34 oz/A	75.7 a	1.85 a	1.85 a	2.25 a	14.1 a	8.21 a	76.3 a	43.8 a	40.0 ab	189 a
Headline 12 oz/A + Vydate 34 oz/A	73.2 a	1.82 a	1.55 a	1.50 a	52.6 a	10.6 a	78.8 a	60.7 a	37.5 ab	210 a
Luna Tranquility 11.2 oz/A + Vydate 34 oz/A	75.2 a	2.25 a	2.58 a	0.25 a	29.7 a	7.35 a	82.1 a	159.7 a	27.5 ab	206 a
Blocker 4F 160 oz/A + Vydate 34 oz/A	83.7 a	1.87 a	2.40 a	1.75 a	28.4 a	8.55 a	83.0 a	50.6 a	37.5 ab	221 a
Vydate 34oz/A Only	83.3 a	1.90 a	2.05 a	3.00 a	9.56 a	8.98 a	75.1 a	5.95 a	32.5 ab	184 a
Tukey's $HSD_{0.10}$	21.9	0.68	7.28	3.60	61.4	12.5	25.5	200.0	30.9	74.4
ANOVA p-value[e]	0.37	0.54	0.45	0.37	0.24	0.92	0.58	0.58	0.06	0.23

[aa]in-furrow at planting application in 8 gal H_2O/A 21 May, 2013

[b]Average percent derived from using 0 to 11 using the Horsfall-Barratt rating scale (0=0%; 1=0.1-3%; 2=3.1-6%; 3=6.1-12%; 4=12.1-25%; 5=25.1-50%; 6=50.1-75%; 7=75.1-87%; 8=87.1-94%; 9=94.1-97%; 10=97.1-99.9%; 11=100%)

[c]Sap extracted from same stems which were rated by Horsfall-Barratt disease scale using hydraulic plant sap press (Spectrum, Inc.). Plated on *Verticillium dahliae* selective media and incubated for 21 days.

[c]CFU=colony forming units seen on selective *Verticillium dahliae* media

[d]Means followed by same letter do not significantly differ (α=0.10, Tukey's)

[e]Since most ANOVA p-values are greater than 0.10, LSD cannot be performed; must perform Tukey's HSD which is more conservative in reporting significant differences between treatment means

Funding: MPIC and Industry

Table 2. Table 1. Effects of in-furrow, at planting fungicide treatments on emergence percent, stems per plant, *Verticillium dahliae* colony forming units (CFU), visual Verticillium wilt symptoms, number of CFU in 0.5 mL of stem sap, vascular beading, and yield in hundred weight per acre at MRC.

Treatments and Rate/A[a]	Emergence %	Stems Number per Plant	CFU[b]/10g Soil June 17	CFU/10g Soil July 8	CFU/10g Soil Aug 15	CFU/10g Soil Sep 6	Average % of stems showing wilt Aug 15[b]	Average CFU/0.5 mL of Stem Sap Aug 15[c]	Average % of vascular beading in tuber Oct 19	Average Yield in Hundred Weight per Acre Sep 19
Untreated Control	75.0 a[d]	1.88 a	14.0 a	2.10 a	4.44 a	3.75 a	80.0 a	383.7 a	50.0 a	192.3 a
Inspire 7 oz/A + Vydate 34 oz/A	62.5 a	1.66 a	7.25 a	2.22 a	3.48 a	3.70 a	86.1 a	336.8 a	52.5 a	274.4 a
Maxim 24.5 oz/A + Vydate 34 oz/A	67.0 a	1.80 a	5.25 a	2.10 a	4.18 a	4.45 a	87.3 a	238.6 a	37.5 a	239.1 a
Quadris 11.6 oz/A + Vydate 34 oz/A	76.5 a	1.97 a	1.50 a	2.25 a	6.89 a	3.20 a	81.6 a	328.1 a	30.0 a	279.0 a
MONCUT 1.07 lb/A + Vydate 34 oz/A	65.5 a	1.90 a	5.50 a	2.10 a	6.23 a	4.40 a	88.9 a	157.4 a	40.0 a	265.5 a
Headline 12 oz/A + Vydate 34 oz/A	64.0 a	1.67 a	4.75 a	2.30 a	2.35 a	4.95 a	82.5 a	307.4 a	25.0 a	262.2 a
Luna Tranquility 11.2 oz/A + Vydate 34 oz/A	71.3 a	1.61 a	4.00 a	2.10 a	6.66 a	4.60 a	63.5 a	146.9 a	40.0 a	263.3 a
Blocker 4F 160 oz/A + Vydate 34 oz/A	65.8 a	1.87 a	2.0 a	2.40 a	11.14 a	5.10 a	67.8 a	155.0 a	40.0 a	241.5 a
Vydate 34oz/A Only	74.3 a	1.56 a	6.5 a	2.04 a	9.86 a	5.30 a	86.1 a	426.1 a	40.0 a	269.7 a
Tukey's $HSD_{0.10}$	14.97	0.60	14.0	0.74	10.12	5.93	48.64	622.0	37.75	153.0
ANOVA p-value[e]	0.08	0.40	0.0953	0.88	0.19	0.97	0.79	0.84	0.58	0.80

[a]in-furrow at planting application in 8 gal H_2O/A 21 May, 2013
[b]Average percent derived from using 0 to 11 using the Horsfall-Barratt rating scale (0=0%; 1=0.1-3%; 2=3.1-6%; 3=6.1-12%; 4=12.1-25%; 5=25.1-50%; 6=50.1-75%; 7=75.1-87%; 8=87.1-94%; 9=94.1-97%; 10=97.1-99.9%; 11=100%)
[c]Sap extracted from same stems which were rated by Horsfall-Barratt disease scale using hydraulic plant sap press (Spectrum, Inc.). Plated on *Verticillium dahliae* selective media and incubated for 21 days.
[c]CFU=colony forming units seen on selective *Verticillium dahliae* media
[d]Means followed by same letter do not significantly differ (α=0.10, Tukey's)
[e]Since most ANOVA p-values are greater than 0.10, LSD cannot be performed; must perform Tukey's HSD which is more conservative in reporting significant differences between treatment means.

The Influence of Variety, Sulfur, and Cultural Practices on Potato Common Scab Control

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Introduction

Potato common scab (PCS) in North America can be caused by several species of *Streptomyces*, including *S. scabies*, *S. acidiscabies*, *S. europaeiscabiei*, *S. turgidiscabies*, and *S. stelliscabiei*. There are hundreds of species of *Streptomyces* described in the literature, while only about 10 of these species are pathogenic and cause PCS worldwide (Lees and Wanner, 2012). PCS is a serious, recurrent, and important soil-borne disease of the potato (*Solanum tuberosum* L.) globally (Stevenson et al., 2001) particularly in Michigan (Wharton et al., 2007). PCS affects the cosmetic quality of the tuber and ultimately the market value of the crop. Economic losses are greatest for tubers intended for table stock, although significant losses have been reported for chipping varieties.

Potato scab lesions are variable. PCS is characterized by corky lesions on the tuber surface, which can be categorized into at least three symptomatic lesion types, including superficial, raised, or pitted. Scab lesions can be categorized further into discrete or coalescing. To further classify disease severity, an index of surface area infected using these categories can be used.

Incidence and severity of PCS vary based on location, from year to year, cultivar to cultivar, and from field to field. It is unclear as to what factors, strains, or species determine the type or severity of scab symptoms (Loria et al., 1997). The variability and severity of the disease is of importance to MI and the US, where environmental conditions are favorable and often conducive for PCS (Stevenson et al., 2001). These conditions are typically warm, dry seasons, with high soil temperatures and variable rainfall (Stevenson et al., 2001). Reasons for the variability are not well understood, although many hypotheses have been described, including environmental factors and differences in cultivar susceptibility (Stevenson et al. 2001).

PCS is an efficient saprophyte that can overwinter in the soil, on tubers, and on crop residuals for over a decade. Most potato soils have a resident population of *Streptomyces* spp., which can increase with each succeeding host crop. The population can be reduced by rotation with other non-host crops, but this practice does not eliminate the disease. Spores can persist in the soil for many years, and can germinate and infect in the presence of a suitable host. Infection of the potato tuber by *Streptomyces* spp. occurs primarily through the lenticels and wounds (Wanner, 2007). Therefore, tubers are most susceptible during the six-week period of tuber initiation and growth.

Managers often implement their management strategies in the fall prior to the potato crop. Essentially, fall strategies focus on creating an environment unfavorable for *Streptomyces* spp. and disease development. Management of PCS is one of the most important challenges managers are facing in potato production worldwide. Different management techniques often provide inconsistent or inadequate results when relating to PCS incidence and severity. Scientists still struggle and have little understanding of the exact conditions or factors that contribute to the differences and variation of disease seen in the field.

Cultural practices or management techniques are often implemented for control of PCS, but results are inconsistent, as with all management strategies. Acidic soils, with a level below 5.2 pH can significantly reduce the incidence and severity of PCS (Stevenson et al. 2001). This management strategy can fail because *Streptomyces acidiscabies* can survive and cause PCS disease under these acidic conditions. Achieving a lower pH can be accomplished in many different ways. One successful approach has been the addition of sulfur to reduce the soil pH. Historically, sulfur has been used for PCS control, but the mechanism is not well known or understood.

Tillage practices are essential in the proper preparation of the seedbeds to maximize potato quality and yields. Soil physical and chemical properties, moisture and temperature, root growth, and pathogen vectors are all influenced by tillage practice, and consequently pathogen virulence, diversity and host susceptibility are likewise influenced (Sumner et al., 1981). Tillage practices can negatively or positively affect potato diseases, depending on the disease of interest and the environment (Gudmestad et al., 2007). The impact of tillage on plant disease development has been highly variable, depending on the specific regional crop–pathogen–environment interactions (Sumner et al., 1981).

Chisel plowing, as opposed to the traditional tillage practice of moldboard plowing, is the most frequently used method of conservation tillage in potato. Generally the chisel plow provides less soil inversion and pulverizing than the moldboard plow. Tillage practices can bury plant residues and destroy plant pathogens mainly by solarization, which can reduce inoculum levels in the next growing season. Moldboard plowing has been shown to have positive effects in the management of some soilborne potato diseases including potato early dying, relative to conventional tillage (Gudmestad et al., 2007). However, Leach et al. (1993) showed that chisel compared to moldboard plowing resulted in a reduction of the incidence and severity of stem lesions caused by *Rhizoctonia solani* on the potato. Few studies have looked at the effect of tillage practices on incidence and severity of PCS. Peters et al, (2004) reported the severity of potato PCS was not influenced by tillage practices or rotation, although the severity was low in all years of the study.

Two trials were conducted which included:

1. To investigate the effects of applying elemental sulfur (ES; 0, 200, and 400 lb/A) in the fall, prior to the potato field season, on pH, its influence on incidence and severity of PCS and to determine if different tillage practices (minimal disturbance, chisel plow, and moldboard plow) influences incidence and severity of PCS;

2. To investigate the effects of potato cultivars with different susceptibility to PCS “Dark Red Norland”; (least susceptible), “Russet Norkotah” and “Snowden”; (moderately susceptible) on the incidence and severity of PCS and to determine if different cultural or tillage practices (minimal disturbance, chisel plow, and moldboard plow) influences incidence and severity of PCS.

Interaction between soil cultivation practices and application of elemental sulfur

The field trial was planted with the scab susceptible potato variety cv. “Snowden” at the Michigan State University Montcalm Potato Research Station, Entrican, MI (MRS) on 16 May 2013 into two-row by 30-ft plots (ca. 9-in between plants at 34-in row spacing) replicated four times within a complete randomized block design. The trial was repeated at the Michigan State University Clarksville Research Station, Clarksville, MI (CRS) and planted on 17 May 2013. Elemental sulfur (Tiger 90) was applied in the fall prior to the potato field season at rates of 0, 200, and 400 lb/A. The tillage treatments were done in the fall, following the application of

ES, and consisted of a moldboard plow (John Deere 3-bottom) to a 12” depth along the width of each replication, a chisel plow (Brillion 7-shank) to a 10” depth along the width of each replication, and a (minimal disturbance) disc plow (John Deere 210) to a 1” depth along the width of each treatment, for a total plot length of 270-ft. Fertilizer was drilled into plots before planting, formulated according to soil tests results. Additional nitrogen (final N 28 lb/A) was applied to the growing crop with irrigation 45 days after planting (DAP) for a total of 300 lb N/A. Weeds were controlled by hilling and Dual 8E at 2 pt/A 10 DAP and Poast at 1.5 pt/A 58 DAP. Insects were controlled with Admire Pro 2F at 1.25 pt/A at plating, and two applications of Baythroid XL at 1.6 oz/A at 60 and 90 DAP, or as needed based on commercial potato pest recommendations. Potato late blight and general foliar diseases were prevented with weekly applications of Bravo WS at 1.5 pt/A starting at early canopy closure.

Plots (2 x 30-ft rows) were harvested on 18 Sep, 2013 at MRS and 25 Sep, 2013 at CRS following plant desiccation (125 DAP and 131 DAP, respectively). Tubers were washed and assessed for PCS incidence and severity (see below) two weeks after harvest. Severity of PCS was measured as an index by rating 50 randomly selected tubers from each treatment and replication. The rating system classes were classified based on a 1 – 6 scale, falling into classes based on lesion type; 1 = superficial discrete, 2 = coalescing superficial, 3 = raised discrete, 4 = raised coalescing, 5 = pitted discrete, and 6 = pitted coalescing (Fig. 1). Tubers were further classified into (%) surface area covered with PCS tuber lesions using the Merz scale, with classes 0 – 6: 0= no scab, 1= 0.1 – 2.0%, 2= 2.1 – 5.0 %, 3= 5.1 – 10 %, 4= 10.1 – 25 %, 5= 25.1 – 50.0 %, and 6= > 50.0%. The number of each lesion class was multiplied by the % surface area classes. The result is multiplied by a constant (21) to express the severity index as a percentage index from 1-100. These combined rating scales provide a qualitative and quantitative measure of PCS incidence and severity.

Results Clarksville

There were no significant differences between plowing treatments and elemental sulfur (ES) treatments on scab incidence or severity and no significant effect on total yield (Table 1). Furthermore, there was no significant interaction between ES and tillage practices. PCS was severe in this trial and the incidence was 98% or greater for all treatments with overall severity ranging from 11.9 to 13.1. Severity within the SG6 (deep pitted and coalescing) on a quality scale would make those tubers hard to market. The pH ranged from 6.2 to 7.1 before the application of ES and ranged from 6.0 to 7.0 following the application of ES. Average pH was 6.8, 6.6, and 6.5 for 0, 200, and 400 lb/A, respectively (data not shown).

Results Montcalm

There were no significant differences between plowing treatments and elemental sulfur (ES) treatments on scab incidence or severity (Table 2). Tillage practices had a significant effect on total yield (Table 2). Moldboard plow treatments had significantly higher total yield compared to the minimal disturbance treatment, with chisel plow treatments not statistically different from the other two cultivation methods. Furthermore, there were no significant interaction between ES and tillage practices. PCS was severe in this trial and the incidence was 96% or greater for all treatments with overall severity ranging from 11.8 to 13.1. The pH ranged from 6.4 to 7.6 before the application of ES and ranged from 6.0 to 7.2 following the application of ES. Average pH was 6.8, 6.7, and 6.5 for 0, 200, and 400 lb/A, respectively (data not shown)

Interaction between soil cultivation practices and cultivars varying in susceptibility to PCS

The field trial was planted with three potato varieties, cvs. "Dark Red Norland, "Russet Norkotah" and "Snowden", at the Michigan State University Montcalm Potato Research Station, Entrican, MI (MRS) on 16 May 2013 into two-row by 30-ft plots (ca. 9-in between plants at 34-in row spacing) replicated four times within a complete randomized block design. The trial was repeated at the Michigan State University Clarksville Research Station, Clarksville, MI (CRS) and planted on 17 May 2013. Tillage treatments and PCS were measured as described above.

Results Clarksville

There were no significant differences between plowing treatments and cultivar on scab incidence or severity and no significant effect on total yield (Table 3). Furthermore, there was no significant interaction between variety and tillage practices. PCS was severe in this trial and the overall incidence was 96% or greater for all treatments with overall severity values ranging from 10.6 to 12.3.

Results Montcalm

There were significant differences between plowing treatments and cultivar on overall scab severity (Table 4). Moldboard plow significantly reduced scab overall severity compared to chisel and minimal disturbance treatments. Dark Red Norland had a significantly lower PCS overall severity compared to Snowden and Russet Norkotah. All three cultivars had significant differences in total yield, with Dark Red Norland performing the best, followed by Snowden, then Russet Norkotah. Upon analyzing the lesion classes individually, PCS severity and incidence of PCS within classification group 6 (SG6; described above) were significantly lower for Dark Red Norland compared to other cultivars (Table 4). PCS overall incidence was 96% or greater for all treatments with overall severity values ranging from 10.2 to 13.4. Furthermore there were significant interaction between cultivar and plowing treatments in relation to total yield and overall PCS severity (Table 4).

Conclusion

Environmental conditions were conducive for PCS during this field season and incidence and severity were at high levels (96% or greater incidence and an average 12.0 overall severity) for both trials at both locations. Results were inconsistent and varied depending on locations, similar to other studies, possibly due to different environmental conditions. The pH was lowered by the addition of ES in this study at both locations, although pH was not reduced to a level that is required to reduce the incidence or severity of PCS. Management of PCS requires an integrated approach that combines the use of host resistance, cultural control methods, and possibly chemical control method. Further research is needed to identify factors contributing to potato common scab and identifying management strategies for adequate control.

Table 1. Effects of tillage type (moldboard plow, chisel plow, and no till/minimal disturbance) and elemental sulfur (0, 200, 400 lbs/ A) on incidence and severity of potato common scab and total yield at Clarksville Research Station.

	Common scab incidence and severity index			
Treatment	Incidence SG6[a] (%)	Scab Index SG6[b] (0-100)	Scab Index Overall[d]	Total Yield
Chisel...............................	83.0 a[c]	68.1 a	13.1 a	176 a
Moldboard.......................	84.4 a	66.4 a	12.5 a	140 a
Minimal disturbance.......	76.5 a	57.2 a	11.9 a	137 a
0 lbs Sulfur.....................	80.5 a	65.4 a	12.8 a	164 a
200 lbs Sulfur.................	82.8 a	64.0 a	12.4 a	153 a
400 lbs Sulfur.................	80.5 a	52.3 a	12.3 a	136 a

[a] Severity of common scab was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0:0= 0%; 1:1 to 1:6; 2:1 to 2:6; 3.1 to 3:6; 4.1 to 4:6; 5.1 to 5:6; and 6.1 to 6:6 where the first number is the type of lesion (0= no lesions; 1= superficial discrete; 2= coalescing superficial; 3= raised discrete; 4= raised coalescing; 5= pitted discrete; 6=pitted coalescing surface area of tuber covered with tuber lesions (surface and pitted) and the second number is surface area affected (1= 1 lesion to 2%; 2= 2.1-5%; 3=5.1-10%; 4= 10.1-25%; 5=25.1%-50%; 6, > 50% surface area). These incidence data are for Scab Severity Group 6 only.

[b] Severity index data are for Scab Severity Group 6 only.

[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Honest Significant Difference; Tukey Multiple Comparison).

[d] Weighted Severity index data are for Scab Severity Groups 1 through 6; each severity index 1 through 6 was multiplied by 1, 2, 3, 4, 5 and 6, respectively then divided by a constant (21) to express the severity data as an index from 1–100.

Table 2. Effects of tillage type (moldboard plow, chisel plow, and no till/minimal disturbance) and elemental sulfur (0, 200, 400 lbs/ A) on incidence and severity of potato common scab and total yield at Montcalm Research Station.

	Common scab incidence and severity index			
Treatment	Incidence SG6[a] (%)	Scab Index SG6[b] (0-100)	Scab Index Overall[d]	Total Yield
Chisel................................	75.1 a[c]	63.5 a	13.1 a	224 ab
Moldboard........................	70.3 a	55.2 a	11.8 a	260 a
Minimal disturbance.......	79.5 a	65.4 a	12.9 a	186 b
0 lbs Sulfur......................	76.0 a	62.3 a	12.5 a	200 a
200 lbs Sulfur..................	73.2 a	60.9 a	12.9 a	220 a
400 lbs Sulfur..................	75.7 a	60.8 a	12.5 a	250 a

[a] Severity of common scab was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0:0= 0%; 1:1 to 1:6; 2:1 to 2:6; 3.1 to 3:6; 4.1 to 4:6; 5.1 to 5:6; and 6.1 to 6:6 where the first number is the type of lesion (0= no lesions; 1= superficial discrete; 2= coalescing superficial; 3= raised discrete; 4= raised coalescing; 5= pitted discrete; 6=pitted coalescing surface area of tuber covered with tuber lesions (surface and pitted) and the second number is surface area affected (1= 1 lesion to 2%; 2= 2.1-5%; 3=5.1-10%; 4= 10.1-25%; 5=25.1%-50%; 6, > 50% surface area). These incidence data are for Scab Severity Group 6 only.

[b] Severity index data are for Scab Severity Group 6 only.

[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Honest Significant Difference; Tukey Multiple Comparison).

[d] Weighted Severity index data are for Scab Severity Groups 1 through 6; each severity index 1 through 6 was multiplied by 1, 2, 3, 4, 5 and 6, respectively then divided by a constant (21) to express the severity data as an index from 1–100.

Table 3. Effects of tillage type (moldboard plow, chisel plow, and no till/minimal disturbance) and variety (Snowden, Russet Norkotah, and Dark Red Norland) on incidence and severity of potato common scab and total yield at Clarksville Research Station.

	Common scab incidence and severity index			
Treatment	Incidence SG6[a] (%)	Scab Index SG6[b] (0-100)	Scab Index Overall[d]	Total Yield
Chisel................................	42.3 a[c]	30.4 a	12.0 a	176 a
Moldboard.........................	33.7 a	21.5 a	11.7 a	160 a
Minimal disturbance........	36.4 a	44.4 a	10.8 a	148 a
Snowden...........................	54.6 a	47.1 a	11.4 a	140 a
Russet Norkotah...............	33.5 ab	26.2 a	12.3 a	162 a
Dark Red Norland............	24.3 b	23.0 a	10.6 a	178 a

[a] Severity of common scab was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0:0= 0%; 1:1 to 1:6; 2:1 to 2:6; 3.1 to 3:6; 4.1 to 4:6; 5.1 to 5:6; and 6.1 to 6:6 where the first number is the type of lesion (0= no lesions; 1= superficial discrete; 2= coalescing superficial; 3= raised discrete; 4= raised coalescing; 5= pitted discrete; 6=pitted coalescing surface area of tuber covered with tuber lesions (surface and pitted) and the second number is surface area affected (1= 1 lesion to 2%; 2= 2.1-5%; 3=5.1-10%; 4= 10.1-25%; 5=25.1%-50%; 6, > 50% surface area). These incidence data are for Scab Severity Group 6 only.
[b] Severity index data are for Scab Severity Group 6 only.
[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Honest Significant Difference; Tukey Multiple Comparison).
[d] Weighted Severity index data are for Scab Severity Groups 1 through 6; each severity index 1 through 6 was multiplied by 1, 2, 3, 4, 5 and 6, respectively then divided by a constant (21) to express the severity data as an index from 1–100.

Table 4. Effects of tillage type (moldboard plow, chisel plow, and no till/minimal disturbance) and variety (Snowden, Russet Norkotah, and Dark Red Norland) on incidence and severity of potato common scab and total yield at Montcalm Research Station.

	Common scab incidence and severity index			
Treatment	Incidence SG6[a] (%)	Scab Index SG6[b] (0-100)	Scab Index Overall[d]	Total Yield
Chisel	60.8 a[c]	47.7 a	12.1 a	206 a
Moldboard	50.2 a	34.8 a	10.6 b	258 a
Minimal disturbance	61.1 a	47.6 a	12.0 a	210 a
Snowden	73.2 a	51.5 a	10.8 b	215 b
Russet Norkotah	59.3 a	50.2 a	12.4 a	146 c
Dark Red Norland	39.5 b	28.4 b	11.5 ab	313 a
Moldboard * Red	37.0 c	24.6 d	10.9 bc	378 a
Chisel * Red	45.5 bc	35.1 bcd	12.4 ab	284 b
Minimal dist. * Red	36.0 c	25.7 cd	11.1 bc	278 b
Moldboard * Snowden	72.0 ab	49.6 abcd	10.2 c	249 b
Chisel * Snowden	78.0 a	54.2 ab	10.6 bc	199 bc
Minimal dist. * Snowden	69.5 ab	50.7 abc	11.5 abc	195 bc
Minimal dist. * Russet	77.5 a	66.4 a	13.4 a	157 c
Moldboard * Russet	41.5 c	30.3 bcd	10.6 bc	147 c
Chisel * Russet	59.0	54.0 ab	13.3 a	134 c

[a] Severity of common scab was measured as an index calculated by counting the number of tubers (n = 50) falling in class 0:0= 0%; 1:1 to 1:6; 2:1 to 2:6; 3.1 to 3:6; 4.1 to 4:6; 5.1 to 5:6; and 6.1 to 6:6 where the first number is the type of lesion (0= no lesions; 1= superficial discrete; 2= coalescing superficial; 3= raised discrete; 4= raised coalescing; 5= pitted discrete; 6=pitted coalescing surface area of tuber covered with tuber lesions (surface and pitted) and the second number is surface area affected (1= 1 lesion to 2%; 2= 2.1-5%; 3=5.1-10%; 4= 10.1-25%; 5=25.1%-50%; 6, > 50% surface area). These incidence data are for Scab Severity Group 6 only.
[b] Severity index data are for Scab Severity Group 6 only.
[c] Values followed by the same letter are not significantly different at $p = 0.05$ (Least Significant Difference; T-test Multiple Comparison).
[d] Weighted Severity index data are for Scab Severity Groups 1 through 6; each severity index 1 through 6 was multiplied by 1, 2, 3, 4, 5 and 6, respectively then divided by a constant (21) to express the severity data as an index from 1–100.

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First Report of Boscalid and Penthiopyrad-Resistant Isolates of *Alternaria solani* Causing Early Blight of Potato in Michigan

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Early blight of potato (*Solanum tuberosum*) is caused by *Alternaria solani* and occurs annually in Michigan. If left uncontrolled it can result in yield losses exceeding 20% and impact stored potatoes. The disease is commonly managed using succinate dehydrogenase inhibitor (SDHI) fungicides (1). Unfortunately, recent studies have shown that SDHI resistance has increased dramatically over the past two years in *A. solani* populations (1, 2). To investigate the presence of SDHI resistance in Michigan, potato leaves with early blight symptoms were collected from fields in Montcalm County and Ionia County, MI in 2012. To obtain *A. solani* isolates from these leaves, small pieces of leaf tissue (5 x 5 mm) were taken from the center of lesions and plated to water agar. Single germinated *A. solani* spores were transferred to PDA and incubated at 25°C. The identity of cultures was confirmed by colony and spore morphology as previously described (3). Nineteen *A. solani* isolates were obtained and each was screened for sensitivity to the SDHIs boscalid, penthiopyrad, and fluopyram, using a 50 ppm discriminatory dose based on EC_{50} values previously determined (2). Mycelial plugs (~5.5 mm) were transferred to amended and non-amended PDA plates that were incubated at 25°C for seven days. To assess sensitivity, the isolate was considered highly resistant if fungal growth relative to control plates exceeded 50%, moderately resistant if it was between 35-50%, and sensitive if it was less than 35%. A sensitive *A. solani* isolate (AS11) from Bonners Ferry, ID was used as a control in these experiments. Of the isolates tested, 11% were highly resistant to both boscalid and penthiopyrad and 5% were moderately resistant to both fungicides. Twenty-one percent were moderately resistant to penthiopyrad alone. The rest of the isolates (84 and 68% respectively) were sensitive to the two fungicides. None of the isolates tested were resistant to fluopyram. Recently, two major mutations H227R in *SdhB* and H133R in *SdhD* have been identified in highly resistant *A. solani* isolates in Idaho (2). Due to the fact that the majority of the identified mutations occur near the 3' end of each subunit this region was amplified and sequenced using the following primer sets: SdhB – (5'- TACTGGTGGAAC CAGGAGGAGTA -3' and 5'- CATACCACTCTAGGTGAAG -3'), SdhC – (5'-CCAAATCACCTGGTACGCCTCG-3' and 5'-TCATCCGAGGAAGGTGTAGTAAAGGCTG-3'), and SdhD – (5'-CCGACTCTATTCTCTGCGCCCT-3' and 5'-CTCGAAAGAGTAGAGGGCAAGACCCA-3'). In this study, all of the isolates that were highly resistant to both boscalid and penthiopyrad were found to contain the H133R mutation in *SdhD*, which correlated with the strongest resistance phenotype. To our knowledge, this is the first report of resistance to SDHIs in populations of *A. solani* on potato in Michigan. These data are concerning as they show that the highly resistant isolates have already developed cross resistance between boscalid and penthiopyrad, even though penthiopyrad has not come into regular use in Michigan yet. Although all of the isolates tested were sensitive to fluopyram, the discovery of isolates resistant to boscalid and penthiopyrad suggests that all SDHI fungicides should be considered at high risk of resistance development in Michigan.

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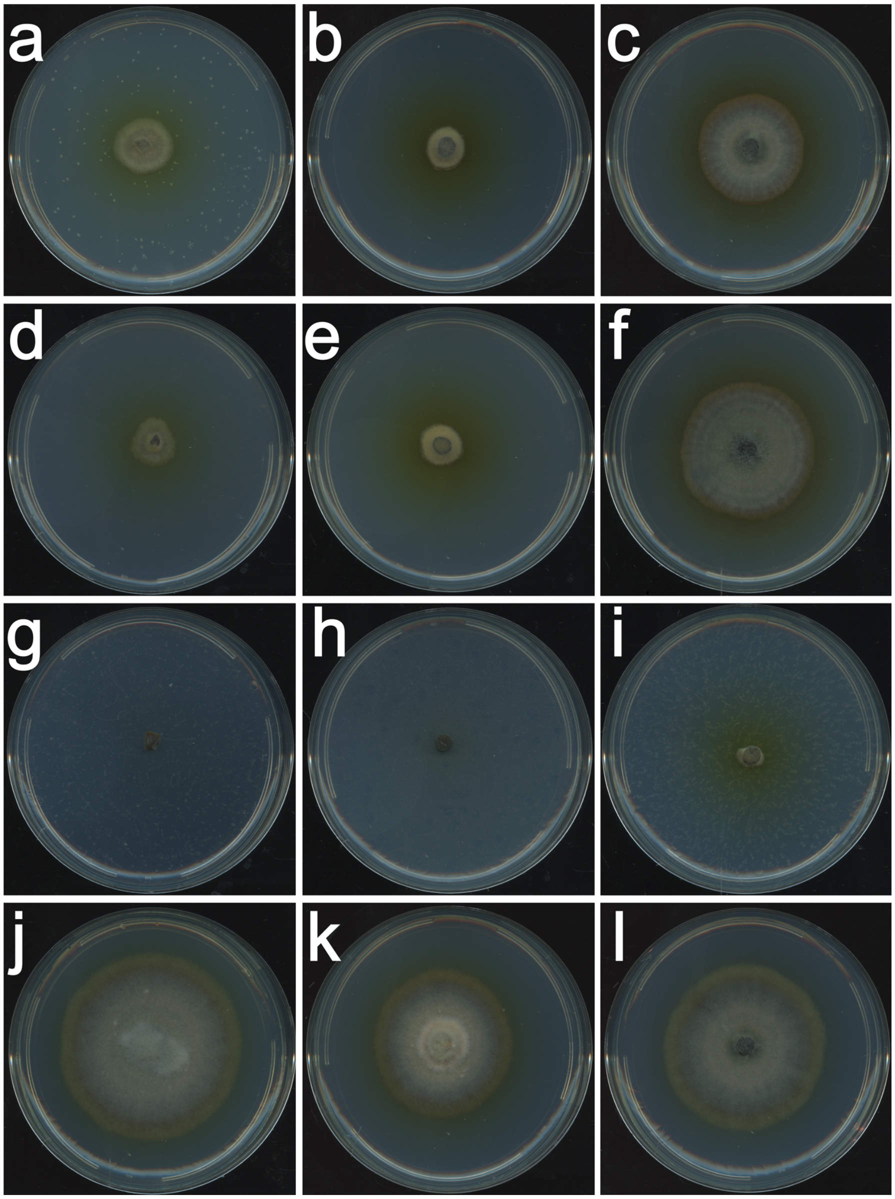

Fig. 1. *Alternaria solani* sensitivity to 50 ppm of boscalid (a-c), penthiopyrad (d-f), fluopyram (g-i) or non-amended (j-l) potato dextrose agar plates. Three representative isolates are depicted including AS11 from Bonners Ferry, ID (a, d, g, j), M-15 from Montcalm County, MI (b, e, h, k) and M-2 from Montcalm County, MI (c, f, i, l).

First Report of *Fusarium proliferatum* Causing Dry Rot in Michigan Commercial Potato (*Solanum tuberosum*) Production

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Fusarium dry rot of potato (*Solanum tuberosum* L.) is a postharvest disease caused by several *Fusarium* spp. Thirteen *Fusarium* spp. have been implicated in dry rot of potatoes worldwide. Among them, 11 species have been reported causing potato dry rot of seed tubers in the northern United States (1). Historically, *F. sambucinum* was the predominant species in Michigan potato production (3). Dry rot symptomatic tubers (n= 972) were collected from Michigan commercial potato storage facilities in 2011 and 2012 to determine the composition of *Fusarium* spp. Sections were cut from the margins of necrotic tissue with a sterile scalpel and surface disinfested in 0.6% sodium hypochlorite for 10 s, rinsed twice in sterile distilled water, and dried on sterile filter paper. The tissue sections were plated on half-strength potato dextrose agar (PDA) amended with 0.5 g/liter of streptomycin sulfate. Dishes were incubated at 23°C in the dark for 7 days. Putative *Fusarium* isolates were transferred onto water agar and hyphal tips from the margin of actively growing cultures were removed with a sterile scalpel and plated to carnation leaf agar (CLA) and half-strength PDA to generate pure cultures. Seven hundred and thirty *Fusarium* isolates were collected using these techniques. Preliminary identification of the 730 isolates was based on colony and conidial morphology on PDA and CLA, respectively. While *F. oxysporum* and *F. sambucinum* were isolated as expected from prior reports (3), three isolates of *F. proliferatum* were also identified. On CLA, macroconidia of *F. proliferatum* were sparse, slender, and mostly straight, with three to five septae (4). Microconidia were abundant, usually single celled, oval or club-shaped in short chains or false heads on monophialides and polyphialides (4) and chlamydospores were absent. On PDA, abundant white mycelium was produced and turned violet with age. Koch's postulates were confirmed through pathogenicity testing on disease-free potato tubers cvs. Atlantic and Russet Norkotah. Tubers were surface disinfested for 10 min in 0.6% sodium hypochlorite and rinsed twice in distilled water. Three tubers of each cultivar per isolate were wounded at the apical end of the tuber to a depth of 4-10 mm with a 4 mm diameter cork-borer. Tubers were inoculated by inserting a mycelial plug from a 7 d old culture grown on PDA into the wound and incubating the tubers at 20°C for 21 d. All *Fusarium* isolates were tested. Control tubers were inoculated by inserting a water agar plug. Pathogenicity and virulence testing were replicated 3 times and repeated. Tubers inoculated with *F. proliferatum* developed typical potato dry rot symptoms but no dry rot symptoms were observed on control tubers. *Fusarium proliferatum* was re-isolated from symptomatic tubers, confirming Koch's postulates. To our knowledge, this is the first report of *F. proliferatum* causing potato dry rot in Michigan.

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Identification of *Fusarium* spp. Causing Dry Rot of Potato Tubers in Michigan's Commercial Potato Production and their Sensitivity to Fungicides

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Introduction

Fusarium dry rot of potato is one of the most important postharvest diseases caused by several *Fusarium* species and is of worldwide importance (Secor and Salas, 2001). Infection of potato tubers by *Fusarium* spp. occurs through wounds or bruising to the periderm during harvesting, grading, loading, cutting, and handling (Secor and Salas, 2001). *Fusarium* can be a devastating pathogen affecting both tubers in storage and seed tubers in the field (Wharton et al., 2007). Dry rot of seed tubers can reduce crop establishment by affecting the development of potato sprouts, resulting in poor emergence and reduced plant stands (Wharton et al., 2007). Losses associated with dry rot have been estimated to range from 6 to 25 %, and occasionally storage losses as great as 60% have been reported (Secor and Salas, 2001). In the United States (US), losses attributed to dry rot in storage is estimated at $100 to $200 million annually (unpublished data from the United States Department of Agriculture, Schisler, D.).

Currently there are at least 13 known *Fusarium* spp. responsible for causing potato dry rot worldwide, and 11 of these species have been reported in the Northern US (Gachango et al., 2012). The most prevalent species reported by Hanson et al. (1996) were *F. sambucinum*, *F. solani*, and *F. oxysporum*. In addition, Lacy and Hammerschmidt (1993) reported that of these species, *F. sambucinum* is the most predominant species affecting potato in storage and causing seed piece decay after planting and that *F. sambucinum* was the most aggressive of these species. In a more recent survey conducted on Michigan (MI) potato seed stocks, a more diverse speciation of *Fusarium* was identified, with *F. oxysporum* reported to be the species recovered most frequently from dry rot symptomatic tubers and *F. sambucinum* the most virulent on potato tubers (Gachango et al., 2012). Additionally, Gachango et al. (2011) identified *F. torulosum* as a first report causing dry rot of potato tubers in the US. Many studies have determined the prevalence and virulence of *Fusarium* species differ among locations (Peters et al., 2008; Choiseul et al., 2006; Gachango et al., 2012).

There are no known commercially grown cultivars resistant to dry rot in North America, although the level of susceptibility varies between cultivars (Wharton et al., 2007). Most of the potato seed lots in MI (>50%) experience some level of dry rot in their seed tubers (Wharton et al., 2007). Cutting seed tubers can transmit pathogens such as *Fusarium* spp., which can lead to potato dry rot infection and development in the field or in storage. Fusarium dry rot on seed potato pieces can be controlled by applying fungicide seed treatments prior to planting or at planting (Wharton et al., 2007). Control of Fusarium dry rot in storage was primarily controlled by postharvest applications of thiabendazole, (TBZ or Mertec 340F™, Syngenta Crop Protection), although thiabendazole-resistant strains compromise the efficacy of dry rot control (Hanson et al., 1994: Gachango et al., 2012: Ocamb et al., 2007). Many strains of *F. sambucinum* are known to be resistant to TBZ and other benzimidazoles globally, while all *F. sambucinum* strains were resistant to TBZ in the survey of seed potato tubers in Michigan (Gachango et al., 2012).

Fludioxonil (Maxim™; Syngenta Crop Protection) can reduce seed piece decay as well as the incidence of diseased sprouts that develop into infected plants (Wharton et al., 2007). However, fludioxonil-resistant strains of *F. sambucinum*, *F. oxysporum*, and *F. coeruleum* were reported in MI and Canada (Gachango et al., 2012; Peters et al., 2008). Azoxystrobin (Quadris™, Syngenta Crop Protection) has been used to control soil-borne diseases when applied on freshly cut seed tubers, although no assessment has been made on the efficacy of azoxystrobin for Fusarium dry rot control. Difenoconazole (Inspire™; Syngenta Crop Protection), was more recently introduced into North America for Fusarium management, and has been recently registered for control of Fusarium dry rot and other potato diseases. Furthermore, a 3-way mixture of difenoconazole, azoxystrobin, and fludioxonil has recently been registered for managing decay caused by *Fusarium* species on potato and other tuber crops. This 3-way mixture (Stadium™) has been registered by Syngenta Crop Protection for potato dry rot and silver scurf management in storage.

There has been no systematic assessment of the *Fusarium* spp. responsible for causing potato dry rot in Michigan commercial potato storages. The objectives of this study were to (i) characterize *Fusarium* spp. responsible for dry rot of potato tubers in commercial storages in Michigan; and (ii) determine the baseline sensitivity of the *Fusarium* isolates collected in Michigan commercial potato production to TBZ, fludioxonil, difenoconazole, and azoxystrobin.

Materials and Methods

Tuber Collection: Dry rot symptomatic tubers (40-50) were collected from MI commercial potato production facilities in the Fall of 2011 and 2012. In 2011, nine cultivars were sampled from a total of 13 fields from seven farms in six counties. In 2012, 11 cultivars were sampled from a total of 19 fields from 11 farms in nine counties. The tuber samples included nine publicly available cultivars: 'Atlantic', 'Dark Red Norland', 'Goldrush', 'MI Purple', 'Norwis', 'Pike', 'Russet Burbank', 'Russet Silverton", and 'Snowden', as well as eight proprietary cultivars. All symptomatic tubers had shallow, sunken, and/or wrinkled necrotic areas on the surface of the tuber with internal symptoms characterized by light tan to dark brown areas often lined with variable mycelium pigmentation from yellow to pink to white.

Pathogen isolation and identification: Small sections were cut from the margins of necrotic or infected tissue and plated on potato dextrose agar (PDA) to identify the *Fusarium* spp. causing potato dry rot.

***Fusarium* Inoculation, Pathogenicity, and Virulence:** Tubers were inoculated with all identified *Fusarium* isolates to test pathogenicity and virulence.

Fungicide Sensitivity Assays: Fungicide sensitivity assays were conducted using two methods. Azoxystrobin insensitivity was defined as the effective concentration of the fungicide that inhibited 50% of the fungal growth (EC_{50}) > 10 mg/liter (Olaya and Holm, 2001). Fludioxonil insensitivity was defined as (EC_{50}) >100 mg/liter (Peters et al., 2008). TBZ and difenoconazole insensitivity was defined as (EC_{50}) > 5 mg/liter (Hanson et al., 1994; Ocamb et al., 2007). Each isolate was classified as sensitive or resistant based on these criteria for each fungicide.

Results

Survey: Symptomatic tubers (n = 1192) were collected from 32 commercial potato lots in MI, from which 730 isolates of *Fusarium* spp. were recovered and identified to 12 species (Fig. 1). *Fusarium oxysporum* was the most commonly isolated species (67.3%), followed by *F.*

equiseti (13.3%), *F. solani* (6.3%), *F. sambucinum* (5.7%), *F. proliferatum* (3.2%) and *F. acuminatum* (1.9%). Less prevalent species present at ≤1% included *F. sporotrichioides*, *F. avenaceum*, *F. culmorum*, *F. graminearum*, *F. cerealis*, and *F. lacertarum* (Fig. 2).

Pathogenicity and Virulence: Representative isolates of all species were pathogenic when inoculated onto potato tubers. Pathogenicity was evaluated on cvs. 'Snowden' and 'MSQ440-2' in 2011 and cvs. 'Atlantic' and 'Russet Norkotah' in 2012 (Figs. 3 and 4). Cvs. 'Snowden' and 'Atlantic' were significantly more susceptible based on percent area of infected tuber tissue. Isolates of *F. sambucinum*, *F. avenaceum*, and *F. acuminatum* were the most aggressive, but differed with cultivar (Fig. 5) and year (data not shown).

Fungicide Sensitivity Assay: In 2011, all isolates of *Fusarium* spp. were sensitive to thiabendazole (EC50<5 mg/L), except the isolates of *F. sambucinum* (EC50> 5 mg/L). Most isolates were sensitive to fludioxonil (EC50< 100 mg/L), few isolates were sensitive to azoxystrobin (EC50< 10 mg/L), and most were sensitive to difenoconazole (EC50< 5 mg/L) (Fig. 6). In 2012, all isolates were sensitive to thiabendazole, except for 80% of the *F. sambucinum* isolates and 50% of the *F. solani* isolates. Most isolates were sensitive to fludioxonil, some isolates were sensitive to azoxystrobin, and the majority of the isolates were sensitive to difenoconazole, except for *F. solani*. Sixteen *Fusarium* isolates showed reduced sensitivity to difenoconazole (EC50 values ranging from 0.08 mg/L to 8.37 mg/L), which is a first report of reduced sensitivity in the US. Furthermore, four isolates grew on PDA containing 20 mg/L of difenoconazole.

Mixed resistance to the fungicides tested was also observed (Table 1). Insensitivity to more than one fungicide was observed for isolates of *F. sambucinum, F. solani, F. oxysporum,* and *F. incarnatum/ equiseti*, except for the fungicide combination of difenoconazole and thiabendazole (Table 1). Furthermore, no isolates were insensitive to any 3-way combinations, including the difenoconazole, azoxystrobin, and fludioxonil combination.

Conclusion

Fusarium oxysporum was recovered most frequently from dry rot symptomatic tubers, which was similar to the study conducted on potato seed stocks from MI. Isolates of *F. sambucinum* were the most aggressive species isolated from potato seed stocks, while *F. sambucinum*, *F. avenaceum*, and *F. acuminatum* were the most aggressive species isolated from potato storage facilities. Fungicide resistant strains of *Fusarium* were identified to be similar to the potato seed stock study, with the addition of difenoconazole and azoxystrobin resistant isolates. Fungicide resistant strains of *Fusarium* continue to compromise the efficacy of dry rot control in storage and in the field. No isolates were insensitive to difenoconazole, azoxystrobin, and fludioxonil, so it appears the 3-way mixture (Stadium™) should be effective in Fusarium dry rot control. Additional testing is needed to determine the efficacy of fungicides on potato tuber slices.

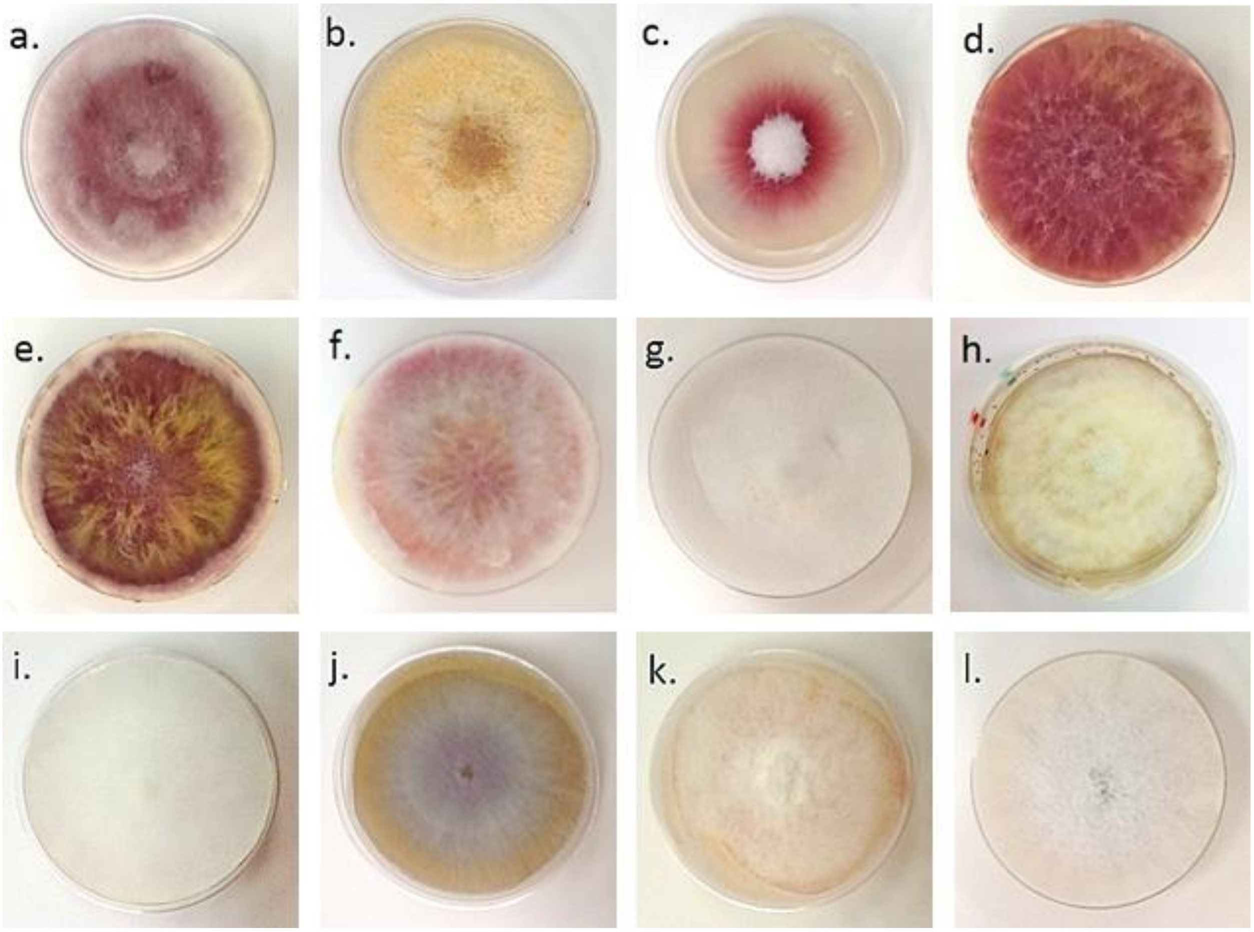

Fig. 1. *Fusarium* species recovered from infected potato tubers grown on full strength PDA; **a**. *F. avenaceum*; **b**. *F. sambucinum*; **c**. *F. acuminatum*; **d**. *F. graminearum;* **e**. *F. crookwellense*; **f**. *F. sporotrichioides*; **g**. *F. redolens*; **h**. *F. lacertarum;* **i**. *F. oxysporum*; **j**. *F. solani*; **k**. *F. incarnatum/equiseti*; **l**. *F. proliferatum.*

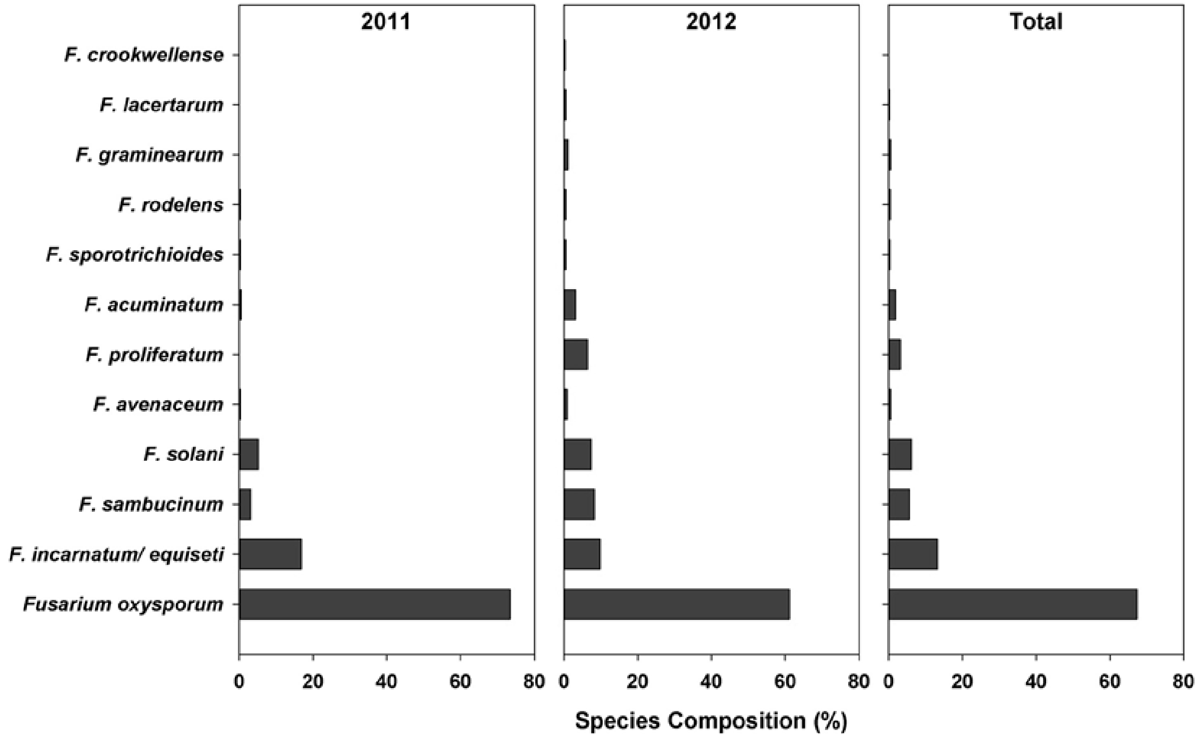

Fig. 2. Frequency distribution of *Fusarium* species recovered from dry rot symptomatic potato tubers. Species composition represent relative frequency calculated as percentage of isolates of a given species relative to the total number of isolates recovered in 2011 and 2012 (378 and 352 isolates), respectively.

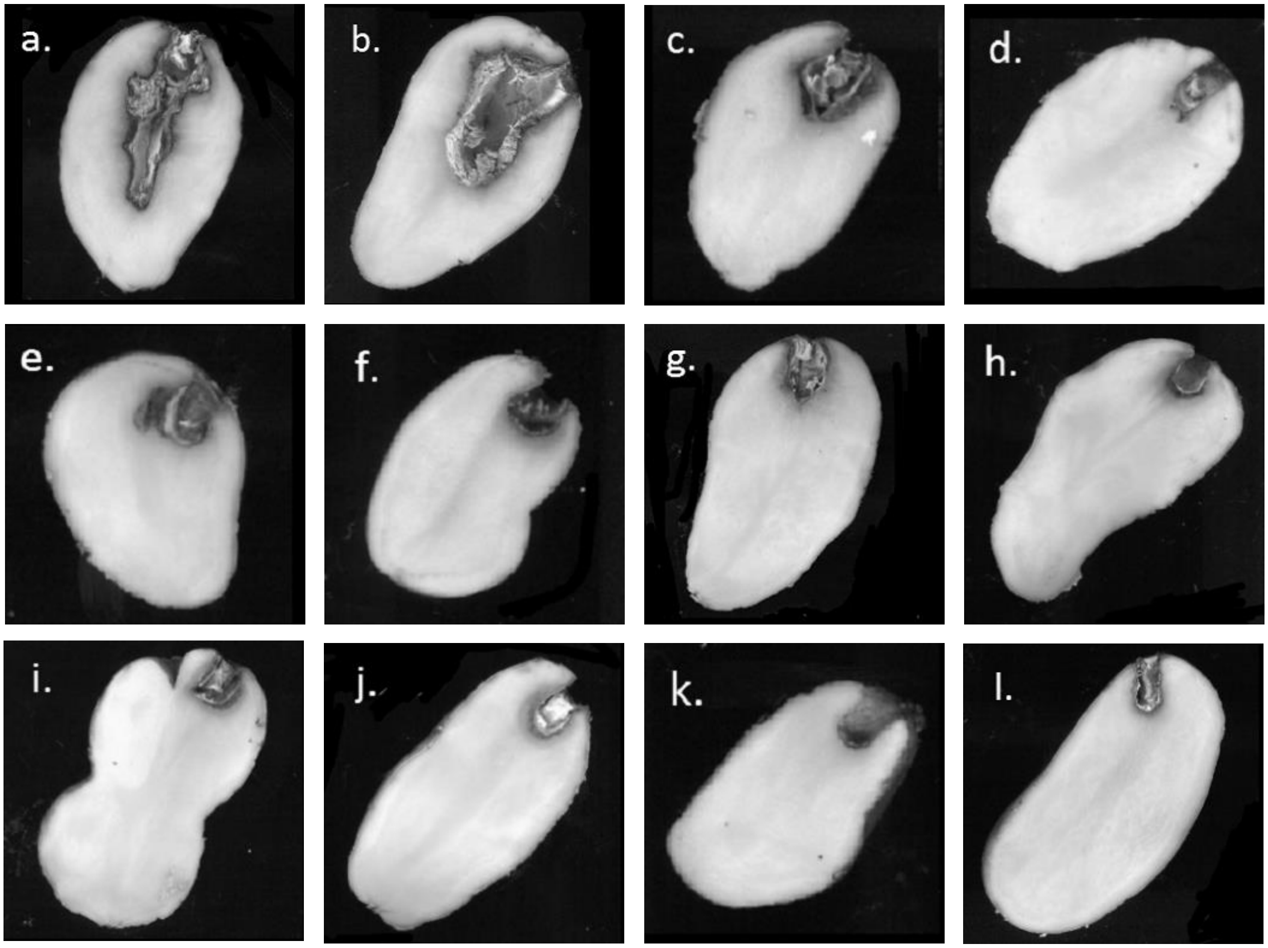

Fig. 3. Virulence of *Fusarium* isolates on potato tubers (cv. Russet Norkotah) inoculated with; **a**. *F. avenaceum*; **b**. *F. sambucinum*; **c**. *F. acuminatum*; **d**. *F. graminearum;* **e**. *F. crookwellense*; **f**. *F. sporotrichioides*; **g**. *F. redolens*; **h**. *F. lacertarum;* **i**. *F. oxysporum*; **j**. *F. solani*; **k**. *F. incarnatum/equiseti*; **l**. *F. proliferatum.*

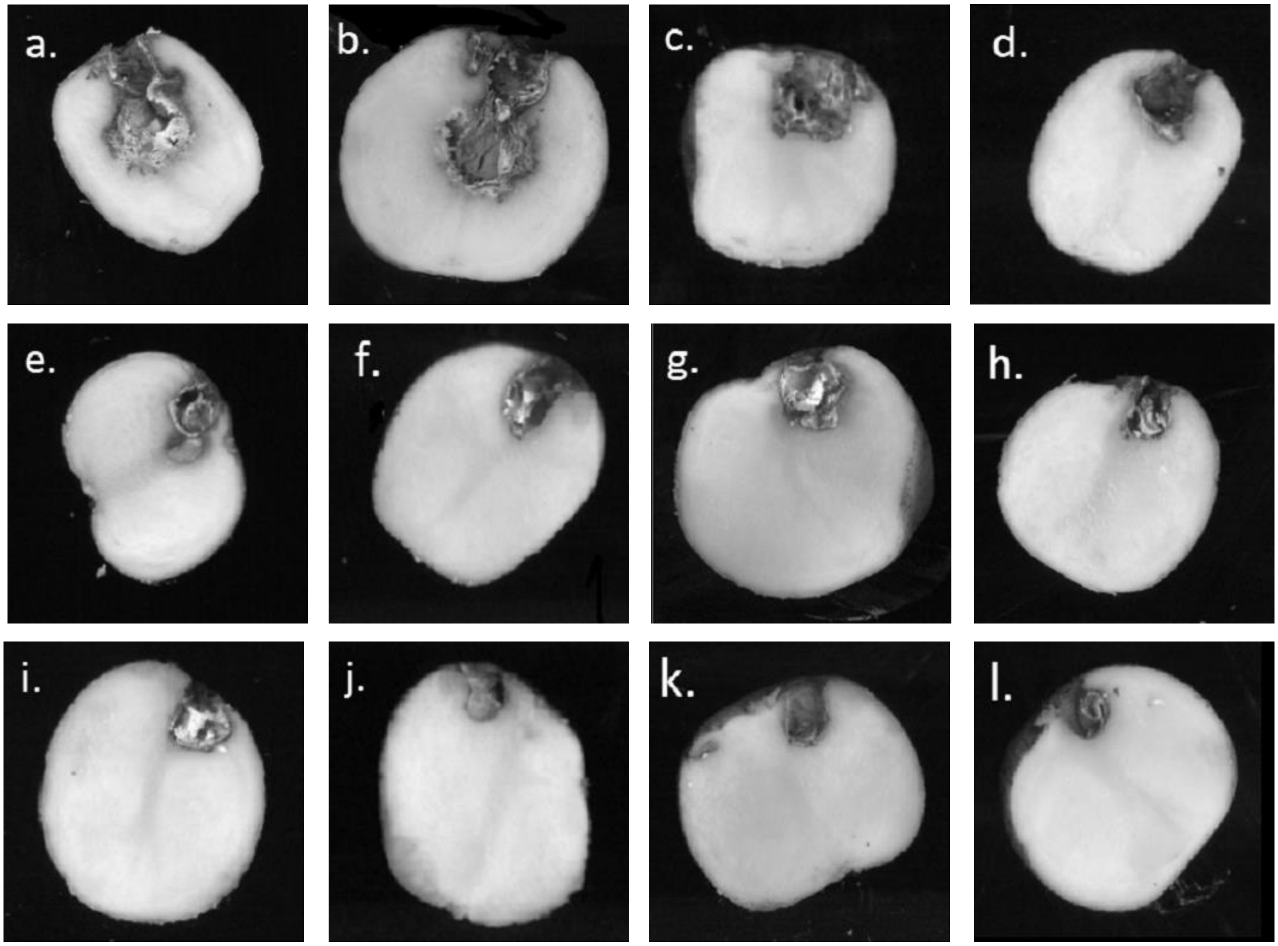

Fig. 4. Virulence of *Fusarium* isolates on potato tubers (cv. Atlantic) inoculated with;
a. *F. avenaceum*; **b**. *F. sambucinum*; **c**. *F. acuminatum*; **d**. *F. graminearum;* **e**. *F. crookwellense*; **f**. *F. sporotrichioides*; **g**. *F. redolens*; **h**. *F. lacertarum;* **i**. *F. oxysporum*; **j**. *F. solani*; **k**. *F. incarnatum/equiseti*; **l**. *F. proliferatum.*

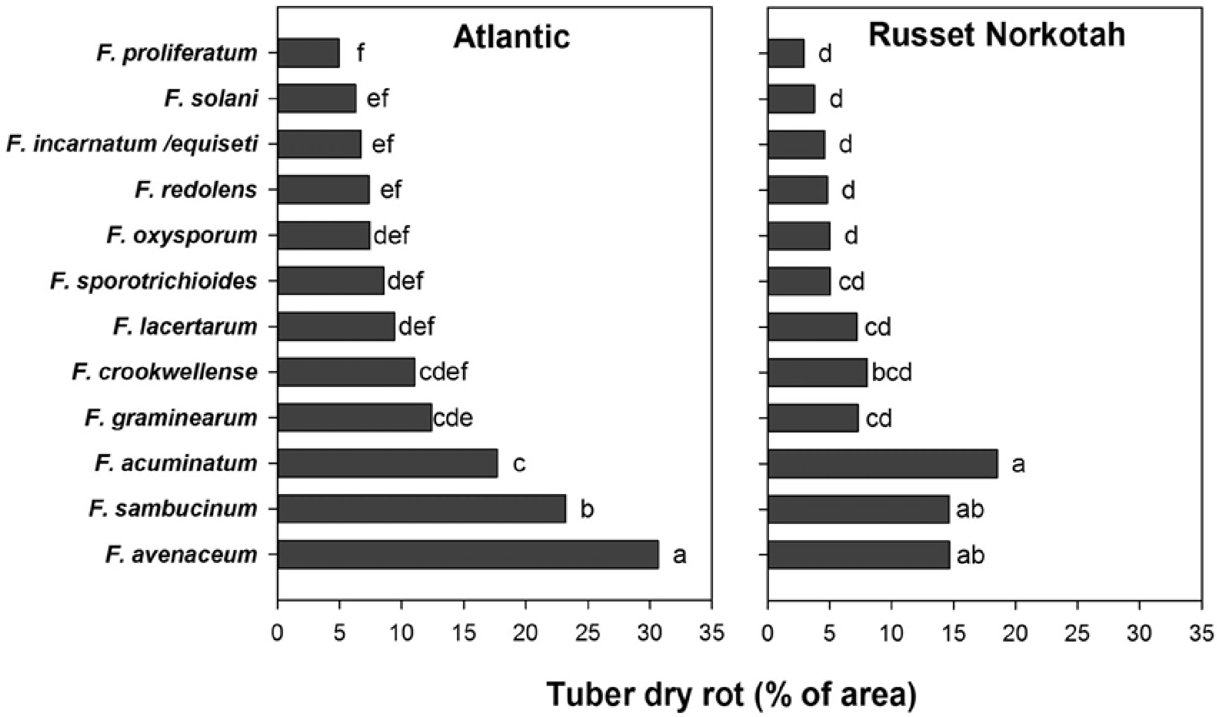

Fig. 5. Aggressiveness of *Fusarium* species causing dry rot on potato tubers (cvs. Atlantic and Russet Norkotah). Mean area of tuber dry rot (%) calculated as the total area of infected tissue relative to the total area of the potato tuber. *Fusarium* species followed by the same letter are not significantly different in aggressiveness (p = 0.05, Tukey test).

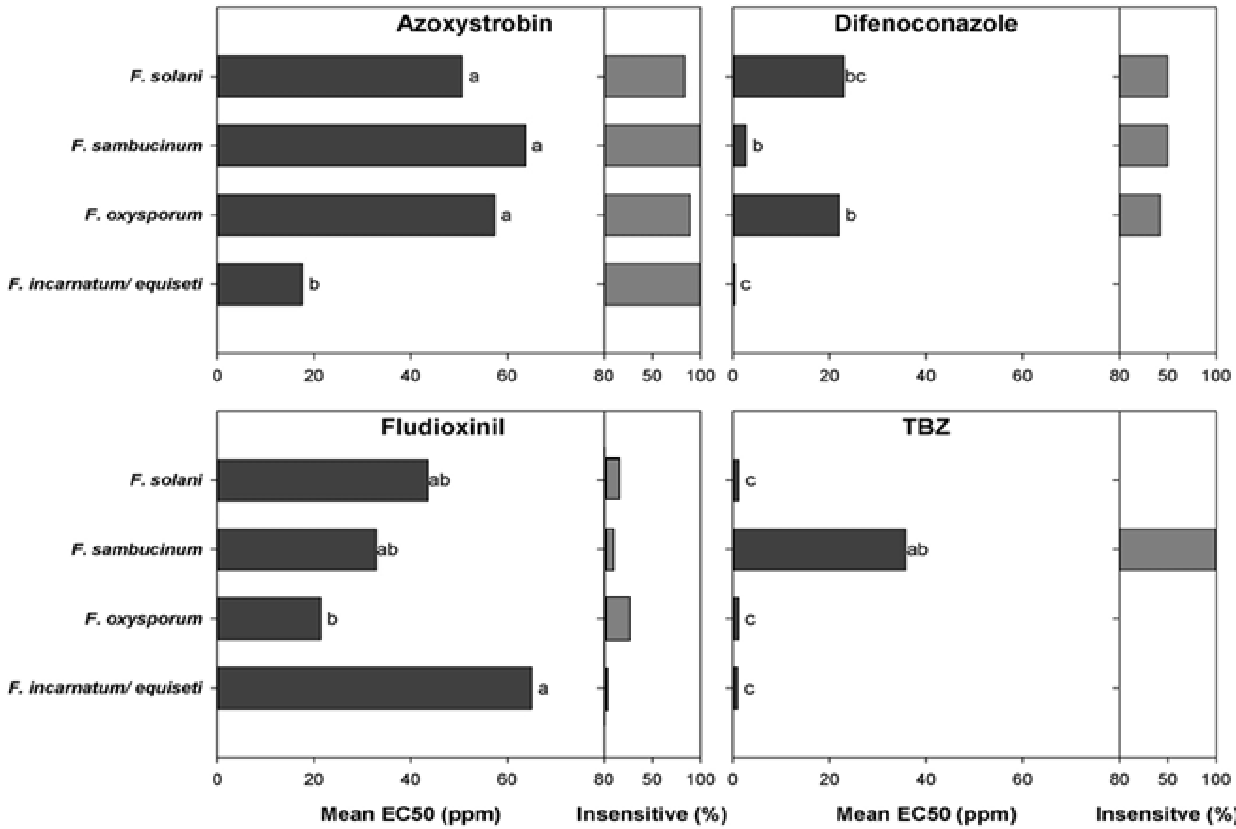

Fig. 6. Mean values (black bars) of the 50% effective concentration, EC50 values (mg/L or ppm), for inhibition of mycelial growth of *Fusarium*. Relative frequency (%) (grey bars) of *Fusarium* isolates insensitive to azoxystrobin, difenoconazole, fludioxonil, and thiabendazole (TBZ) in 2011.

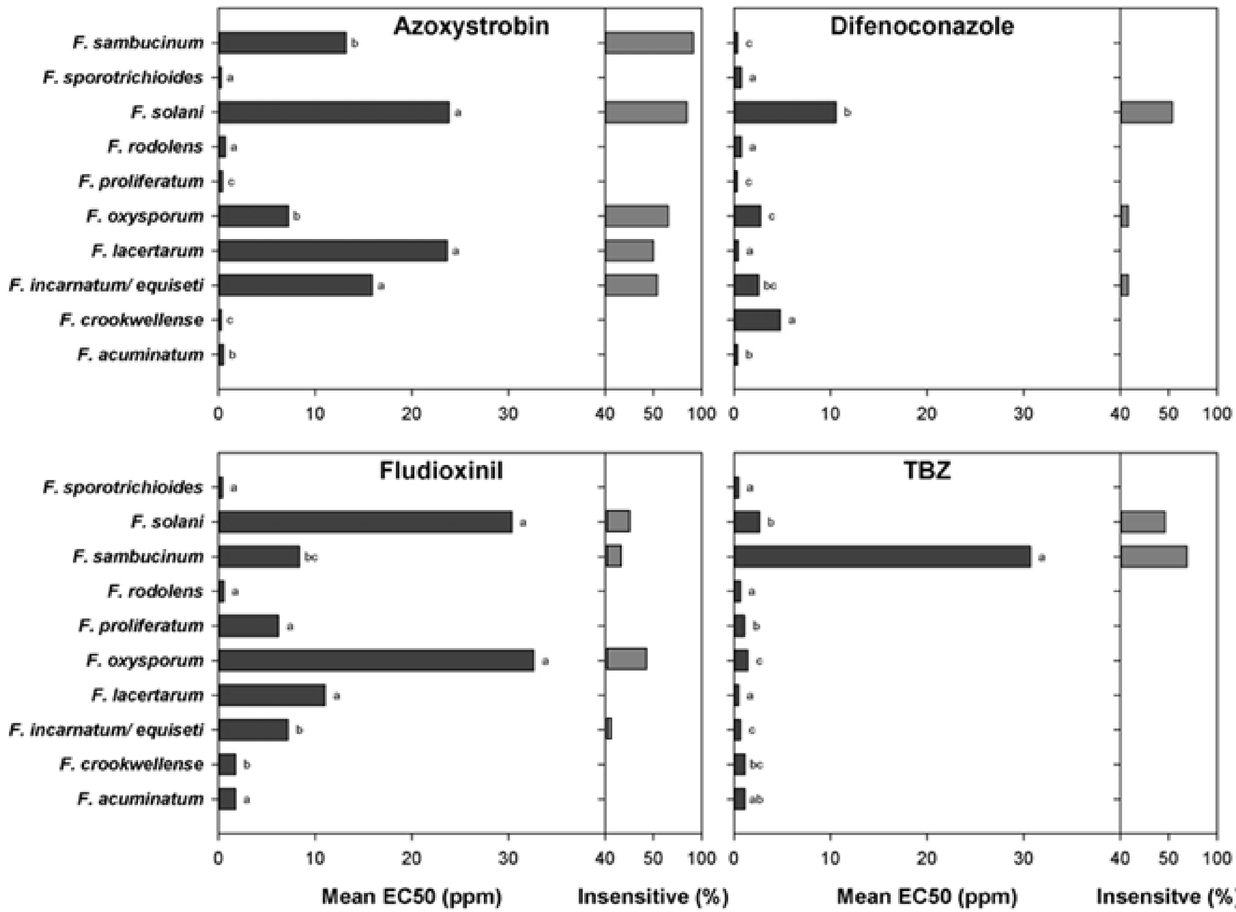

Fig. 7. Mean values (black bars) of the 50% effective concentration, EC50 values (mg/L or ppm), for inhibition of mycelial growth of *Fusarium* species. Relative frequency (%) (grey bars) of *Fusarium* isolates insensitive to azoxystrobin, difenoconazole, fludioxonil, and thiabendazole (TBZ) in 2012.

Table 1. Relative frequency of *Fusarium* spp. insensitive to multiple fungicides.
Relative frequency calculated as percentage of *Fusarium* isolates of a given spp. insensitive to fungicide combinations relative to the total number of isolates recovered for each species. Azo = azoxyxtrobin, Flu = fludioxonil, TBZ = thiabendazole, and Dif + difenoconazole.

		Relative frequency (%) of *Fusarium* spp. insensative to fungicide combinations					
***Fusarium* spp.**	**N isolates**	**Azo + Flu**	**TBZ + Flu**	**Dif + Flu**	**Dif + Azo**	**Dif + TBZ**	**Azo + TBZ**
F. acuminatum	4	0.0	0.0	0.0	0.0	0.0	0.0
F. crookwellense	1	0.0	0.0	0.0	0.0	0.0	0.0
F. incarnat./ equiseti	24	0.0	0.0	0.0	4.2	0.0	0.0
F. lacertarum	2	0.0	0.0	0.0	0.0	0.0	0.0
F. oxysporum	120	5.0	0.8	5.0	0.8	0.0	0.8
F. proliferatum	1	0.0	0.0	0.0	0.0	0.0	0.0
F. rodelens	1	0.0	0.0	0.0	0.0	0.0	0.0
F. sambucinum	23	0.0	8.7	0.0	0.0	0.0	21.7
F. solani	13	0.0	0.0	15.4	23.1	0.0	7.7
F. sporotrichioides	1	0.0	0.0	0.0	0.0	0.0	0.0

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Evaluation of fungicide programs for potato early blight and brown leaf spot control, 2013.

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Potatoes (cut seed, treated with Maxim FS at 0.16 fl oz/cwt) were planted at Michigan State University Horticultural Experimental Station, Clarksville, MI (Capac loam soil); 42.8733, -85.2604 deg; elevation 895 ft. on 30 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. Plots were irrigated as needed with sprinklers and were hilled immediately before sprays began. All fungicides in this trial were applied on a 7-day interval from 15 Jul to 3 Sep (8 applications) with an ATV rear-mounted R&D spray boom calibrated to deliver 25 gal (80 psi) using three XR11003VS nozzles per row. Potato late blight was prevented from movement into the plots from adjacent plots inoculated with *Phytophthora infestans* with bi-weekly applications of Previcur N 6SC at 1.2 pt from early canopy closure on 15 Jul to 3 Sep. Weeds were controlled by hilling and with Dual 8E (2 pt on 3 Jun), Poast 1.5EC (1.5 pt on 13 Jul). Insects were controlled with Admire 2F (20 fl oz at planting), Sevin 80S (1.25 lb on 13 and 29 Jul), Thiodan 3EC (2.33 pt on13 Aug) and Pounce 3.2EC (8 oz on 22 Jul). Plots were rated visually for combined percentage foliar area affected by early blight and brown leaf spot and Botrytis tan spot on 30 Aug and 5, and 11 Sep [8 days after final application (DAFA). The evaluations for early blight and brown leaf spot were combined into a single assessment. The relative area under the disease progress curve (RAUDPC; max = 100) was calculated for each disease and for each treatment from the date of appearance of symptoms (30 Aug) to 11 Sep, a period of 12 days. Vines were killed with Reglone 2EC (1 pt on 12 Sep). Plots were harvested on 10 Oct and tubers from individual treatments were weighed and graded. Meteorological variables were measured with a Campbell weather station located at the farm from 1 Jun to 31 Aug. Average daily air temperature (^{o}F) from 1 Jun was 65.8, 69.5, and 67.1 and the number of days with maximum temperature >90^{o}F was 0, 4 and 0 (Jun, Jul, Aug, respectively). Average daily relative humidity (%) over the same period was 71.4, 72.1, and 72.7. Average daily soil temperature at 4” depth (^{o}F) over the same period was 70.3, 75.8, and 69.7. Average daily soil moisture at 4” depth (% of field capacity) over the same period was 37.4, 39.2, and 37.8. Precipitation was 3.11, 3.31, and 3.18 in. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation. Early blight severity values accumulated from emergence on 10 Jun to 29 Sep (evaluation date) were 1276 P-days.

Weather conditions were moderately conducive for the development of early blight and brown leaf spot, but less conducive for Botrytis tan spot. Early blight and brown leaf spot developed steadily during Aug and untreated controls reached about 46.3% foliar infection by 11 Sep. Most treatments had significantly less combined early blight and brown leaf spot than the untreated control except those with greater than 32.5% affected foliage. The RAUDPC estimated progress of Alternaria diseases over the course of the epidemic and treatments with RAUPDC values less than 12.5 were significantly different form the untreated control (18.2). Botrytis tan spot developed slowly during Aug and untreated controls reached about 17.5% foliar infection by 11 Sep. No treatments had significantly less botrytis tan spot than the untreated control and ranged from 6.3 to 17.5% affected foliage. The RAUDPC estimated progress of botrytis tan spot over the course of the epidemic and treatments with RAUPDC values less than 4.9 were significantly different form the untreated control (7.5). Treatments with greater than US#1 yield of 269 cwt and total yield of 394 cwt were significantly different from the untreated control. Phytotoxicity was not noted in any of the treatments.

Funding: MPIC and Industry

Treatment and rate/A	EB/BLS[a] Final foliar severity (%)		EB/BLS[a] RAUDPC[b] 29 DAFE		Botrytis tan spot Final foliar severity (%)		Botrytis tan spot RAUDPC 29 DAFE		Yield (cwt) US1		Yield (cwt) Total	
Bravo WS 6SC 1.5 pt (A-I[c])……………..	26.3	c-f[d]	7.4	cd	12.5	a	3.3	bcd	238	a-d	330	bcd
Bravo WS 6SC 1.5 pt (ABCDG); Vangard 75WG 7.0 oz (EFHI)…………..	29.5	b-f	9.3	bcd	11.3	a	3.5	bcd	260	ab	381	abc
Bravo WS 6SC 1.5 fl oz (ABCDG); Inspire Super 383.3EW 20.0 fl oz (EFHI).	40.0	abc	12.2	bc	17.5	a	5.5	abc	243	abc	343	bc
Bravo WS 6SC 1.5 fl oz (ABCDG); Switch 62.5WG 11 oz (EFHI)…………...	25.5	c-f	8.0	cd	10.0	a	2.8	cd	272	a	343	bc
Bravo WS 6SC 1.5 fl oz (ABCDG); Switch 62.5WG 14.0 oz (EFHI)………...	42.5	ab	14.0	ab	17.5	a	5.7	ab	256	ab	356	bc
Tanos 50WG 6.0 oz + Manzate 75WG 1.5 lb (ACEGI); Vertisan 1.67EC 16 fl oz + NIS 90SL 8.0 fl oz a (BDFH)……………	33.8	a-d	10.9	bc	15.0	a	5.2	a-d	281	a	370	abc
Vertisan 1.67EC 1.0 pt (A-I)…………….	32.5	a-e	10.1	bcd	13.8	a	4.6	bcd	251	ab	316	cd
Echo ZN 4.17SC 32.0 fl oz (ABEFGH); Luna Tranquility 500SC 8.0fl oz (CD)….	18.0	ef	7.0	cd	6.3	a	2.5	d	269	ab	394	ab
Echo ZN 4.17SC 32.0 fl oz (ABEFGH); Luna Tranquility 500SC 11.2 fl oz (CD)..	15.3	f	4.6	d	7.5	a	2.6	d	280	a	436	a
Echo ZN 4.17SC 32 fl oz (ACEGH); Quash 50WG 2.5 oz (BDF)……………...	30.5	b-f	10.2	bcd	13.8	a	4.6	bcd	285	a	376	abc
Echo ZN 4.17SC 32 fl oz (ABEFGH); Quash 50WG 2.5 oz (CD)……………….	24.3	def	7.3	cd	11.3	a	3.7	bcd	236	a-d	367	abc
EF400 100L 12 fl oz + ExCit 100L 4 fl oz (A-I)…………………	36.3	a-d	12.5	abc	15.0	a	5.2	a-d	200	cd	261	d
Echo ZN 4.17SC 32 fl oz (ABEFGH); Topguard 1.04SC 14 fl oz (CD)…………	36.3	a-d	11.9	bc	13.8	a	4.9	a-d	191	d	265	d
Untreated Check…………………………	46.3	a	18.2	a	17.5	a	7.5	a	220	bcd	330	bcd

[a] Combination of foliar infection due to a combination of early blight [EB (*Alternaria solani*)] *and* Brown leaf spot [BLS (*A. alternata*)] on 12 Sep, 29 days after appearance of initial symptoms of *Alternaria* spp.
[b] RAUDPC, relative area under the disease progress curve calculated from day of appearance of initial symptoms to 14 Sep (29 days).
[c] Application dates: A= 15 Jul; B= 22 Jul; C= 29 Jul; D= 6 Aug; E= 13 Aug; F= 20 Aug; G= 27 Aug; H= 3 Sep
[d] Values followed by the same letter are not significantly different at $p = 0.05$ (Fishers LSD)

Funding: Industry and MPIC

Evaluation of fungicide programs for potato late blight control: 2013.

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Potatoes ('Atlantic', cut seed, treated with Maxim FS at 0.16 fl oz/cwt) were planted at Michigan State University Horticultural Experimental Station, Clarksville, MI (Capac loam soil); 42.8733, -85.2604 deg; elevation 895 ft. on 17 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. Plots were irrigated as needed with sprinklers and were hilled immediately before sprays began. All rows were inoculated (3.4 fl oz/25-ft row) with a zoospore suspension of *Phytophthora infestans* [US-22 biotype (sensitive to mefenoxam, A2 mating type)] on 31 Jul and [US-23 biotype (sensitive to mefenoxam, A1 mating type)] on 7 Aug at 10^4 spores/fl oz. Plots were irrigated as needed with sprinklers and were hilled immediately before sprays began. All fungicides in this trial were applied on a 7-day interval from 10 Jul to 28 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 unless stated. Weeds were controlled by hilling and with Dual 8E (2 pt/A on 5 Jun), Poast (1.5 pt/A on 17 Jul). Insects were controlled with Admire 2F (20 fl oz/A at planting), Sevin 80S (1.25 lb/A on 17 and 31 Jul), Thiodan 3EC (2.33 pt/A on14 Aug) and Pounce 3.2EC (8 oz/A on 17 Jul). Plots were rated visually for percentage foliar area affected by late blight on 15, 19, 23, 30 Aug, and 5 Sep [16, 20, 24, 31 and 37 days after the initial inoculation (DAI)] when there was about 100% foliar infection in the untreated plots. The relative area under the late blight disease progress curve was calculated for each treatment from the date of inoculation to 5 Sep, a period of 37 days. Vines were killed with Reglone 2EC (1 pt/A on 11 Sep). Plots (2 x 25-ft row) were harvested on 14 Oct and tubers from individual treatments were weighed and graded. A sample of 50 tubers was collected from each plot at harvest and stored at 50^oF and 95% RH in the dark for 28 days. The incidence of late blight affected tubers was evaluated at harvest and 28 days after harvest. Meteorological variables were measured with a Campbell weather station located at the farm from 1 May to the final evaluation (30 Aug). Average daily air temperature (^oF) from 1 Jun was 65.8, 69.5, and 67.1 and the number of days with maximum temperature >90^oF was 0, 4 and 0 (Jun, Jul, Aug, respectively). Average daily relative humidity (%) over the same period was 71.4, 72.1, and 72.7. Average daily soil temperature at 4" depth (^oF) over the same period was 70.3, 75.8, and 69.7. Average daily soil moisture at 4" depth (% of field capacity) over the same period was 37.4, 39.2, and 37.8. Precipitation was 3.11, 3.31, and 3.18 in. Plots were irrigated to supplement precipitation to about 0.1 in./A/4 day period with overhead sprinkle irrigation. The total number of late blight disease severity values (DSV) over the disease development period from 31 Jul (inoculation date) to 30 Aug was 35 using 90%RH (ambient air) as a basis for DSV accumulation.

Late blight developed steadily after inoculation due to extended leaf wetness periods and moderate air temperature during Aug and untreated controls reached on average 100% foliar infection by 5 Sep. Up to 30 Aug, all fungicide programs with less than 35.0% foliar late blight had significantly less foliar late blight than the untreated control (50.0%). By 5 Sep, all programs had significantly better foliar late blight than the untreated control (100 %). All fungicide programs had significantly lower RAUDPC values in comparison to the untreated control (19.2). At harvest, the percent incidence of infected tubers from untreated plots was 3.0% but no treatments were significantly different in comparison to the untreated control and ranged from 0.5 to 3.0%. On 11 Nov (28 days after harvest) the percent incidence of infected tubers from untreated plots was 2.8% but no treatments were significantly different in comparison to the untreated control and ranged from 3.0 to 2.8%. Treatments with greater than US1 yield of 289 and total yield of 281 cwt/A, respectively were significantly different from the untreated control (US1 = 158 and total yield = 226 cwt/A). Phytotoxicity was not noted in any of the treatments.

Funding: Industry and MPIC

Treatment and rate/A	Foliar potato late blight (%) 30 Aug 31 DAI[a]		5 Sep 37 DAI		RAUDPC[b] 37 DAI		Yield (cwt/A) US1		Total		Tuber blight (%)[c] 150 DAP[d]	178 DAP
Elixir 75DF 1.5 lb (A,B,D,F,H,J,L,N[e])……….	7.5	efg[f]	28.8	f-j	3.9	d-i	263	a-e	317	a-d	2.0	1.0
Elixir 75DF 1.8 lb (A,B,D,F,H,J,L,N)………..	3.3	fg	17.5	g-l	2.1	f-i	277	a-d	332	a-d	2.0	0.8
KFD-107-01 75DF 2 lb (A,B,D,F,H,J,L,N)…..	6.8	efg	16.8	h-l	2.9	e-i	259	a-e	322	a-d	1.8	1.3
Bravo WS 6SC 1.5 pt (A,B,D,F,H,J,L,N)…….	0.5	g	0.8	l	0.2	i	303	a	360	a	1.0	0.8
Bravo WS 6SC 1.5 pt (A,D,H,L)……………..	12.5	d-g	32.5	d-h	5.8	c-h	299	ab	353	ab	1.5	1.5
Bravo WS 6SC 1.5 pt (A,D,H,L); CX-10250 100WG 1.25 oz (B,F,J,N)………..	3.3	fg	8.0	kl	1.6	f-i	272	a-e	332	a-d	1.8	2.5
Revus 249FS 5.5 fl oz (A,D,H,L); Bravo WS 6SC 1.5 pt (B,F,J,N)……………...	1.0	g	1.3	l	0.4	i	269	a-e	323	a-d	3.3	1.5
A18269 100OD 0.6 fl oz (A,D,H,L); Bravo WS 6SC 1.5 pt (B,F,J,N)……………..	0.6	g	1.0	l	0.2	i	307	a	362	a	1.0	1.5
A20638 250SC 0.92 fl oz (A,D,H,L); Bravo WS 6SC 1.5 pt (B,F,J,N)……………..	0.9	g	1.0	l	0.4	i	289	abc	354	ab	3.0	0.3
A20638 250SC 0.82 fl oz (A,D,H,L); Revus 249FS 5.5 fl oz + Bravo WS 6SC 1.5 pt (B,F,J,N)……………..	1.1	g	2.5	kl	0.5	i	294	ab	345	abc	3.0	0.8
A20638 250SC 0.82 oz + Quadris 2.08FL 6.84 fl oz (A,D,H,L); Bravo WS 6SC 1.5 pt (B,F,J,N)………………	1.8	g	3.8	kl	0.7	hi	253	a-e	315	a-d	1.3	0.5
Bravo WS 6SC 1 pt (A,D,H,L); Ranman 3.33SC 2.08 fl oz + Penncozeb 4F 42.6 fl oz + NIS (B,F,J,N)…….	3.0	g	20.0	g-k	2.3	f-i	217	c-f	263	de	2.0	1.5
Bravo WS 6SC 1.0 pt (A,D,H); Ranman 3.33SC 2.73 fl oz + Penncozeb 4F 1.8 pt + NIS[g] (B,F,J,N)………..	6.5	efg	30.0	e-i	3.7	d-i	295	ab	369	a	1.3	0.0
Bravo WS 6SC 16 fl oz (A,B,D); Ranman 3.33SC 2.73 fl oz + NIS (F,H,J)…….	2.0	g	6.3	kl	1.0	ghi	237	a-e	281	b-e	1.3	1.0
Ranman 3.33SC 2.08 fl oz + Bravo WS 6SC 16 fl oz (A,B,D); Gavel 75DF 2 lb (F); Ranman 3.33SC 2.08 fl oz (H,J); Penncozeb 4F 2.66 pt + NIS 100SL (I,K)…….	5.5	efg	11.3	jkl	2.3	f-i	229	b-f	278	b-e	0.8	1.8
Ranman 3.33SC 2.08 fl oz + Bravo WS 6SC 16 fl oz (A,B); Gavel 75DF 2 lb (D); Ranman 3.33SC 2.08 fl oz + Penncozeb 4F 42.6 oz + NIS (F,H,J)…………	4.0	fg	12.5	i-l	1.8	f-i	203	ef	261	de	1.8	1.5
SA-011404 100WG 20 oz (A,B,D,F,H,J,L,N)..	20.3	b-f	51.3	bc	8.1	b-e	239	a-e	299	a-e	2.0	1.5
SA-0350102 100F 1.2 pt (A,B,D,F,H,J,L,N)…	4.0	fg	11.3	jkl	1.8	f-i	247	a-e	305	a-d	0.5	0.5
SA-0011402 100F 2 pt + SA-0280101 100F 20 fl oz (A,B,D,F,H,J,L,N).	16.3	c-g	35.0	c-g	6.1	c-g	244	a-e	297	a-e	1.3	0.3
SA-0280101 100F 20 fl oz (A,B,D,F,H,J,L,N).	35.0	ab	62.5	b	12.6	b	201	ef	256	de	1.5	1.3
SA-0011402 100F 2 pt (A,B,D,F,H,J,L,N)…...	21.3	b-e	47.5	b-e	8.8	bcd	261	a-e	314	a-d	1.8	0.3
SA-011403 100F 3.2 fl oz + SA-0280102 100F 28 fl oz (A,B,D,F,H,J,L,N).	12.5	d-g	40.0	c-f	6.3	c-f	213	def	273	cde	2.0	0.5
SA-0280102 100F 28 fl oz (A,B,D,F,H,J,L,N).	30.5	bc	60.0	b	11.7	b	209	def	267	de	0.8	0.8
SA-0011402 100F 2 pt (A,C,E,J,I,K,M)……...	26.3	bcd	50.0	bcd	10.5	bc	221	c-f	283	b-e	1.0	0.3
Inoculated Check……………………………...	50.0	a	100.0	a	19.2	a	158	f	226	e	3.0	2.8

[a] Days after inoculation of *Phytophthora infestans* (US-22, A2 mating type, mefenoxam sensitive) on 31 Jul.
[b] RAUDPC, relative area under the disease progress curve calculated from day of appearance of initial symptoms to 5 Sep (37 days).
[c] Incidence of tuber late blight at harvest (150 DAP) and after storage for 28 days at 50°F (178 DAP).
[d] Days after planting.
[e] Application dates: A= 10 Jul; B= 17 Jul; C= 18 Jul; D= 24 Jul; E= 26 Jul; F= 31 Jul; G= 3 Aug; H= 7 Aug; I= 11 Aug; J= 14 Aug; K= 19 Aug; L= 21 Aug, M= 27 Aug; N= 28.
[f] Values followed by the same letter are not significantly different at $p = 0.05$ (Fishers LSD).
[g] NIS = Non Ionic Surfactant applied at 0.25% v/v.

Tuber Blight Development in Potato Cultivars in Response to Different Genotypes of *Phytophthora infestans*

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Introduction

The oomycete *Phytophthora infestans* (Mont.) de Bary is the causal agent of late blight, which is the most devastating disease on potato worldwide (Fry, 2008). Since the disease was first reported in the 1840s (de Bary, 1876), outbreaks have occurred intermittently with different degrees of impact. Since the global re-emergence of late blight in the 1980s (Fry and Goodwin, 1997b), new and more aggressive genotypes have impacted potato (Hu et al., 2012) and tomato crops (Chowdappa et al., 2013). One genotype designated as US-1, dominated the global *P. infestans* population until the last decade of the 20th century. Several genotypes then appeared, and caused comparatively more severe losses than US-1 (Goodwin et al., 1994, Spielman et al., 1991, Fry, 2008, Fry and Goodwin, 1997a).

Vleeshouwers *et al.* (2010) documented the recent impact of late blight during the epidemics in the US and Europe from 2005 to 2008, showing the capacity of this pathogen to adapt and evolve causing disease. The genotype US-8 (mating type A_2, mefenoxam-insensitive, GPI 100/110/122) has been described as one of the most aggressive genotypes to date, due to the aggressiveness of isolates on foliage (Goodwin et al., 1996, Kirk et al., 2001a). US-8 isolates also proved more aggressive on potato tubers causing faster appearance of tuber rot symptoms than isolates observed previously (Kirk et al., 2009, Kirk et al., 2010). The US-8 genotype quickly became predominant in potato cropping systems following its first detection in 1989 in north and central Mexico (Goodwin et al., 1998, Goodwin et al., 1992). The appearance of US-8 and the displacement of US-1 were characterized by an increase in the severity of tuber blight (Lambert and Currier, 1997).

A similar case was observed recently in Europe: the genotype 13_A2, also known as Blue-13, appeared during 2006 to 2008, and became the dominant genotype in Great Britain and mainland Europe (Lees et al., 2008, Cooke et al., 2011, Cooke et al., 2012) and since then in India (Chowdappa et al., 2013). Genotype 13_A2 characteristically has an increased aggressiveness on potato foliage and tubers in comparison to previous genotypes detected in the region (Cooke et al., 2011). New introduced genotypes can quickly affect epidemic development in a production region, and since the development of resistant host material is historically a lengthy process disease management becomes very challenging (Lees et al., 2008).

The impact of tuber late blight on potato production occurs at different levels: on seed production as the potential source of new epidemics; on volunteers that serve as sources of inoculum for tomato and potato crops; and, on quality and yield of seed, table-stock and processing tubers (Bonde and Schultz, 1943, Kirk et al., 2009). Latent infections on seed and volunteer tubers are an important mechanism of long-term dispersion and introduction of new genotypes of *P. infestans* (Abad and Abad, 1997, Nyankanga et al., 2010). The resistance of tubers against *P. infestans* and development of tuber blight are conditioned by the ability of the pathogen to penetrate the tuber tissue and the localization of the infection within the tuber. The tuber has different components involved in resistance including the periderm, outer cortical cells, medulla, lenticels and eyes (meristematic tissue) and all may respond differently to the pathogen (Pathak and Clarke, 1987, Flier et al., 2007, Nyankanga et al., 2008). Different cultivars also vary in these resistance components, and there is variation in the aggressiveness of *P. infestans* genotypes (Kirk et al., 2010, Kirk et al., 2009, Kirk et al., 2001a). Potato breeding has focused on resistance of foliage with little effort on tuber blight resistance. This trend has changed over time due to the importance of tuber blight that can result in storage rot losses and transmission from season-to-season through seed (Johnson and Cummings, 2009, Kirk et al., 2009, Kirk et al., 2010). Therefore, it is important to compare tuber disease development caused by isolates of new genotypes of *P. infestans* with isolates of the existing genotypes to commonly produced cultivars and those with known tuber resistance to *P. infestans*.

The late blight epidemics of 2009 - 2010 in the Eastern US were characterized by the appearance of a new genotype; designated as US-22. The genotype US-22 was initially reported in Florida in 2007 (Ristaino, 2010; Hu et al., 2012), and then found on infected potato and tomato along the Eastern US coast (Hu et al., 2012). This new genotype is complex and temporally displaced the US-8 genotype in Michigan (Rojas and Kirk, 2011). The change in the genetic structure of the *P. infestans* population in Michigan necessitates the evaluation of currently available cultivars and recently released late blight resistant cultivars from breeding programs. Therefore, the aim of this study was to compare the ability of the new genotype, US-22, as well as other *P. infestans* genotypes to cause tuber breakdown at 10°C, the storage temperature typically used for chip processing.

Materials and Methods

Germplasm selection

Six cultivars of potato were selected for evaluation. The tubers for this study were obtained from the Michigan State University potato breeding and genetics program and commercial potato fields in Michigan. The MSU potato breeding and genetics program has identified potato cultivars with different responses against the US-8 genotype of *P. infestans*; the cultivars included in this study with their respective foliar and tuber ratings in parentheses were Jacqueline Lee [Resistant (R), Moderately Resistant (MR); (Douches et al., 2001)] and Missaukee [R, Intermediate (I); (Douches et al., 2010)]. Other cultivars used in this study were FL1879 [Susceptible (S,S)], Russet Burbank [Moderately Susceptible (MS),S], Red Norland (S,S) and Monticello (S,S) (Douches et al., 1997, Porter et al., 2004). Potato tubers were stored at 3°C in the dark at 90% relative humidity (RH) until used. Tubers were warmed to 15°C in incremental steps of 2°C for 7 d before inoculation. Tubers for the experiments were within the size grade range 50-150 mm diameter (any plane). Visual examination of a random sample of tubers from each entry for disease symptoms indicated that tubers were free from late blight. The samples were further tested with an ELISA immunodiagnostic for *Phytophthora* sp. (Alert Multiwell Kit - *Phytophthora sp.* Neogen Corporation, Lansing, MI, USA) according to the manufacturer's instructions; *P. infestans* was not detected in any of the tubers. Prior to inoculation, all tubers were washed with water to remove soil. The tubers were surface disinfested by soaking in a 2% sodium hypochlorite solution for 30 min. Tubers were dried in a controlled environment chamber with continuous airflow at 15°C in dry air (30% RH) for 4 h prior to inoculation. After inoculation tubers were stored at 10°C and maintained for 30 days in the dark in a controlled environment chamber at 90% RH.

Isolates and inoculum preparation.

Characteristics of the twelve different *P. infestans* isolates used in this study are summarized in Table 1. The selected Michigan isolates were from the collection of W.W. Kirk (Michigan State University, USA), US-8 and US-22 reference isolates were provided by Dr. W.E. Fry (Cornell University, USA), Colombian isolates were provided by Dr. Silvia Restrepo (LAMFU, Los Andes University, Colombia) and UK isolates by Dr. David Cooke (The James Hutton Institute, Scotland, UK). For lenticel infection experiment, isolates US-8F and Pi10-012 were selected due to their virulence on tuber tissue. The isolates were re-activated on inoculated leaf tissue and transferred into rye B media for 14 days in the dark at 18°C for sporangia production, and transferred to the light for 2 d to encourage sporulation. Sporangia and mycelium were harvested by flooding with cold sterile water (4°C) and gentle scraping of the surface of the culture using a rubber policeman. The mycelium/sporangia suspension was stirred with a magnetic stirrer for 1 h. The suspension was strained through four layers of sterile cheesecloth and the sporangia concentration was measured with a hemacytometer and adjusted to about 1 x 10^4 total sporangia·ml^{-1} (discharged and non-discharged). The sporangial suspensions were stored for 4 h at 4°C to encourage zoospore release from the sporangia.

Whole tuber inoculation with *P. infestans*.

Tuber late blight development caused by the different *P. infestans* genotypes on the tuber cultivars was evaluated at 10°C storage temperature using whole tuber sub-peridermal inoculation. The washed, surface-disinfested tubers were inoculated by removing a 5-mm diameter potato plug using a sterile cork borer, and placing 2 x 10^{-5} ml of sporangia suspension (delivering zoospores released from about 20 sporangia per inoculation) with a hypodermic syringe and needle at the apical end of the tuber about 1 cm from the dominant sprout to a maximum depth of 1 cm. The potato plug was returned to close the wound and it was sealed with petroleum jelly. A complete randomized block design with three experimental repeats consisted of 10 tubers per cultivar, 6 different cultivars and 12 different isolates representing 4 genotypes. A total of 3 replicates were inoculated for each of the cultivar - isolate combination. Ten control tubers per cultivar were inoculated with cold (4°C) sterile distilled H_2O. After inoculation, tubers were placed in the dark in sterilized covered plastic crates and returned to controlled environment chambers [Percival Incubator (Model I-36LLVL, Geneva Scientific, LLC, Fontana, WI)]. The chambers were set at 10°C and 95% humidity and the sample tubers were incubated for 30 d until evaluation.

Eye and lenticel susceptibility to *P. infestans* genotypes

Tubers of three different cultivars with different responses to *P. infestans* were obtained from MSU potato breeding program to evaluate periderm susceptibility. The three cultivars with different tuber blight ratings were Atlantic (S), Jacqueline Lee (MR) and Stirling (R) (Kirk et al., 2009). Tubers were prepared as described above. Tubers were submerged in a sporangial suspension containing about 1 x 10^4 total sporangia·ml^{-1} for 48 h at room temperature. After inoculation, tubers were placed in the dark in sterilized covered plastic crates with damp towels to maintain high humidity, and then placed in controlled environment chambers at 10°C. The experimental design encompassed 2 different *P. infestans* genotypes (US-8F and Pi10-012), 3 cultivars and 12 tubers per cultivar. Arbitrary samples of 3 tubers per genotype-cultivar combination were sampled at 3, 6, 10 and 15 d post inoculation for evaluation. The experiment was conducted four times and the replicates were analyzed together, blocking by repeat. At each time the number of eyes and lenticels infected were assessed under the dissecting microscope at 20X magnification (Olympus SZX10, Olympus America Inc., Lake Success, NY) and light microscope at 200X magnification (Olympus CX22, Olympus America Inc.).

Evaluation of tuber blight

A digital image analysis technique (Kirk et al., 2001b, Niemira et al., 1999) was used to assess tuber tissue infection. The image files were analyzed using SigmaScan V3.0 (Jandel Scientific, San Rafael, CA). The area selection cut-off threshold was set to 10 light intensity units, limiting the determination to the non–dark parts of the image. The average reflective intensity (ARI) of all the pixels within the image gave a measurement of infection severity of the tuber tissue of each sample. The ARI was measured in sections from the apical, middle and basal regions of the tuber. The amount of late blight infected tissue per tuber was expressed as a single value (Mean ARI) calculated as the average ARI of the apical, middle and basal sections evaluated 30 days after inoculation (DAI) (Fig. 1).

Late blight infection confirmation

Tissue samples (5 mm diameter plugs) were taken from infected tubers. A rapid DNA extraction protocol proposed by Wang *et al.* (1993) and modified by Trout *et al.* (1997) for potato tissue was used. Samples were homogenized with a plastic micropestle in 100 μL 0·5 N NaOH, centrifuged at 8000 x g for 5 min, and 20 µL of the supernatant was diluted with 80 µL of Tris (pH 8·0). PCR was done using 2 μL of this extract. The primers PINF and ITS5 were used as reported by Trout *et al.* (1997), PCR conditions were standardized to initial denaturation at 94°C for 2 min, followed by 35 cycles of 94°C for 1 min, 55°C for 1min and 72°C for 1 min, and final extension at 72°C for 10 min. PCR products were visualized in agarose gels (1%) stained with (ethidium bromide) for the detection of the 600 bp band, as determined for positive amplification of *P. infestans*.

Data Analysis

The severity of tuber tissue infection was expressed relative to the ARI (described above) of the control tubers for each cultivar. The relative ARI (RARI) was calculated as:

$$RARI(\%) = \left(1 - \frac{mean\ \ ARI\ \ treatment}{mean\ \ ARI\ \ control}\right) \times 100$$

RARI (%) has a minimum value of zero (no symptoms) and a maximum value of one hundred (black tuber surface). Data for all experiments were analyzed by analysis of variance (least squares method) using the JMP program version 9.0 (SAS Institute Inc., Cary, North Carolina, USA). Treatment effects were determined by a three-way factorial ANOVA, where the main effects corresponded to cultivar and *P. infestans* genotype and the two-factor interaction. Principal component analysis (PCA; JMP software; SAS Institute) was done to describe variability among cultivars and *P. infestans* isolates.

The effect of *P. infestans* genotype on eye and lenticel infection was reported as area under the disease progress curve values (AUDPC) as described by Shaner and Finney (1977). Two-way ANOVA was calculated to determine differences among the genotypes of *P. infestans* and cultivars evaluated using the JMP program.

Results
Whole tuber inoculation

Whole tuber inoculation using different genotypes of *Phytophthora infestans* showed significant differences for the two main factors (genotype and cultivar) and the two-way interaction (Table 2). Among the cultivars evaluated, Dark Red Norland, Russet Burbank and Monticello were the most susceptible, but not significantly different from each other. Jacqueline Lee was the least susceptible of the six cultivars evaluated, but still had tuber blight. Among the different genotypes of *P. infestans* evaluated several responses were observed. Isolate Pi97-5 (genotype US-8) was the most aggressive, while isolate US-8F, also classified as genotype US-8, had a lower mean RARI (Table 3). The second most aggressive isolate was an isolate designated as genotype US-22, Pi10-012, isolated from potato in 2010 from St. Joseph county, MI. The European lineages, designated as 13_A2 (also known as Blue-13), were also moderately aggressive on tuber tissue, with mean RARI values between 16.7 and 13.9. Along with Blue-13 genotypes, the isolate Pi09-011 (genotype US-22) obtained during the epidemics on 2009 from potato was moderately aggressive.

The rest of the isolates used in this study caused less tissue darkening on the cultivars tested. The isolates Pi98-1 (US-14 genotype) and US-22F (US-22 genotype) had slightly lower aggressiveness in comparison to the more aggressive isolates. Michigan *P. infestans* isolates Pi10-023 and Pi09-021, characterized as genotype US-22 and isolated from tomato were significantly different from the aggressive isolate US-8 (Pi97-5); and grouped with isolates from Colombia, as low aggressive isolates on tuber tissue (Table 3).

The two-way interaction visualized as principal components analysis showed that for cultivars axis 1 and axis 2 accounted for 56.9 and 14.6% of the variability, respectively. With respect to the *P. infestans* isolates axis 1 and axis 2 accounted for 36.4 and 13.1% of the variability, respectively (Fig. 2). Jacqueline Lee was the least variable of the cultivars due to its reduced susceptibility to most of the genotypes of *P. infestans* evaluated. The other cultivars behaved in a similar fashion, where Dark Red Norland, Russet Burbank, FL1879 and Monticello were the most susceptible. Isolates of *P. infestans* were variable, but isolates assigned to genotype US-22 (Table 1) had reduced variability, which indicated that they had a diminished impact on tuber blight among the different cultivars evaluated (Fig. 2). Nonetheless, the isolates Pi09-011 and Pi10-012 identified as genotype US-22 obtained from potato were more aggressive on tuber tissue overall in comparison to other US-22 isolates. Also, the isolates Pi09-021 and Pi10-023 (US-22 genotype) from tomato were less aggressive than isolates US-8F and Pi97-5 (US-8 genotype) and 07-39 and 3298 (Blue-13). In general, Pi97-5 (US-8), 07-39 and 3298 (Blue-13) contributed most to variability among isolates and cultivars.

The interactions between cultivars and isolates of the different genotypes of *P. infestans* were shown in Table 4. The isolate Pi97-5 (US-8) was highly aggressive in the different cultivars with mean RARI values ranging from 10 to 27%, this isolate was chosen as an aggressive control in these studies. With respect to the US-22 isolates obtained in Michigan, Pi10-012 was moderately aggressive on most of the cultivars evaluated, with values 14.6 – 29.0%; but the isolates Pi09-021 and Pi10-023 isolated from tomato had consistently lower aggressiveness among cultivars (3.5 - 5.9 and 4 - 6.6%, respectively), which agreed with the PCA analysis. Overall, the US-22 genotype isolates from potato were more aggressive than those from tomato. The local isolate Pi97-5 (US-8) was the most aggressive isolate in most of the of potato cultivars.

Tuber eyes and lenticel infection

The infection of periderm was evaluated in terms of the number of eyes and lenticels infected using isolates representing genotypes US-8 and US-22 of *P. infestans* to determine if the new introduced genotype in Michigan was likely to infect tubers through the periderm without wounding. The isolates Pi97-5 (US-8) and Pi10-012 (US-22) (Table 1) previously identified as aggressive strains on tuber tissue were selected to infect three potato cultivars with different levels of resistance. In general, moderate lenticel infection was observed, but infected tubers had mycelial growth on the surface 10 d after inoculation [DAI (Fig. 3)]. The ANOVA analysis of the main effects resulted in a significant difference between the genotypes US-8 and US-22 but not for cultivars. Also the interaction of genotype and cultivar for lenticel infection rated as AUDPC was not significant (Table 5). Mean values for AUDPC for genotype US-22 were lower in all cultivars, but the lowest were from cvs. Atlantic and Stirling. In contrast, the US-8 isolates were more aggressive on Atlantic and less aggressive on Stirling (Fig. 4).

Discussion

The impact of tuber blight on epidemics caused by *Phytophthora infestans* emphasizes the importance of characterizing the interaction of different genotypes against different cultivars and the effect that new genotypes could have on the existing host-plant material. Tuber blight importance has been identified previously as a critical factor in storage and season-to-season transmission (Johnson & Cummings, 2009; Nyankanga et al., 2010, Kirk et al., 2010, Kirk et al., 2009).

The resistance of six different cultivars against twelve isolates representing five different genotypes of *P. infestans* was assessed in this study. The newly identified genotype US-22 was compared with other genotypes already identified and collected from the field. We focused on the resistance responses in medullar tissue and periderm, to determine the risk of the new genotype US-22 to potato growers. Large differences in susceptibility measured as medullar tissue darkening were observed among the different isolates of *P. infestans* on the potato cultivars.

The evaluation of tuber blight on medullar tissue revealed that isolates of genotype US-8 were the most aggressive in medullar tuber tissue in comparison to the other genotypes tested. Colombian isolates of *P. infestans* were less aggressive, probably due to a lack of pathogenic fitness to infect tubers, a phenomenon that has been observed previously in other lineages found in South America (Oyarzún et al., 2005). The UK isolates designated as genotype Blue-13 were highly aggressive and similar in aggressiveness in medullar tuber tissue to US-8 genotypes of *P. infestans*. These isolates impacted potato crops in Europe during 2007 to 2008 (Gisi et al., 2010, Cooke et al., 2011). The variability observed among the genotype US-22 isolates used could be due to different factors, mainly due to recent introduction of this genotype to the region. For instance, isolates of genotype US-22 obtained from potato were more aggressive on potatoes than those obtained from tomato. This could be explained by host specificity, similar to what has been observed previously in some isolates of *P. infestans* (Cooke et al., 2006). The degree of aggressiveness of the isolates on the tuber could be an important factor for transmission as aggressive isolates may not be spread from season-to-season due to reduced number of shoots killed by virulent *P. infestans* strains. (Montarry et al., 2007). Therefore, isolates of genotype US-22 might survive better than more aggressive strains by overwintering in seed or volunteer tubers, as it has been shown that transmission after overwintering tends to be low and varies according to the season (Montarry et al., 2007, Kirk, 2003).

Periderm responses (evaluated as incidence of eyes and lenticels infected) were similar among cultivars for the two *P. infestans* genotypes evaluated, but genotype US-8 was more aggressive and effective in terms of infection. One isolate of each genotype (US-8 and US-22) was used to inoculate tubers, however these isolates were identified as the most aggressive strains on tuber tissue during this research. The establishment of infection during the season is an important step in an epidemic. Infection of potato tubers during the growing season by *P. infestans* may occur when inoculum (sporangia, zoospores or mycelia) is washed from the foliage into the soil (Andrivon, 1995). Unwounded tubers would only be infected through natural openings like lenticels and eyes (Lacey, 1967). Tuber resistance to *P. infestans* in cultivars is related to tuber maturity and therefore also to resistance of the periderm (Walmsley-Woodward and Lewis, 1975). Genotype US-8 was more likely to infect through the periderm than genotype US-22. The AUDPC for lenticel infection incidence was low overall, which could have been related to the maturity of the tubers that were harvested about three weeks after desiccation [an adequate duration to promote periderm maturation (Johnson and Powelson, 2008)]. The inoculation method used assures that the tuber eyes and lenticels were "open", which would promote infection; this has been done previously using high humidity to promote infection (Montarry et al., 2007). Tubers with intact skin are less susceptible to infection by *P. infestans* than those with open eyes and lenticels, but those with fresh wounds are most likely to be infected (Darsow, 2004). Using intact tubers in this experiment gives a good indication of likely tuber response to infection with *P. infestans* in the field.

Generally, the aggressiveness of isolates of US-22 genotype measured across different cultivars was lower in comparison to the previously predominant US-8 genotype. The reduced aggressiveness disagrees with population changes observed during recent years in Europe and the US (Lambert and Currier, 1997, Cooke et al., 2011). The consistent aggressiveness of isolates of the US-8 genotype agrees with previous studies and such aggressive isolates can be considered as references for breeding programs to determine tuber resistance. To our knowledge, this was the first study to compare aggressiveness of US-22 across tubers of different potato cultivars. However, the aggressiveness of the US-22 genotype and potential overwintering properties of isolates should not be underestimated since there is little information on the epidemiology of this genotype and its impact could become a greater issue for potato growers in the future.

Tuber blight caused by newly introduced genotypes of *P. infestans* may impose a change in emphasis of breeding efforts to generate more tolerant cultivars. The variability of susceptibility observed among the cultivars to the different isolates of US-22 could have implications for breeding programs especially given the limited number of cultivars screened in these tests and the capacity for mutation in *P. infestans* (Catal et al., 2010).

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Table 1 Characteristics of *Phytophthora infestans* isolates used for tuber late blight study including country, state and county of origin, original host, mitochondrial haplotype, glucose-6-phosphate isomerase profile, metalaxyl resistance and genotype

Origin	Year	Isolate	Host	Location[a]	Mating Type	Mt Hap[b]	*Gpi* [c]	Met[d]	Genotype
Michigan, US	2009	Pi09-011	*Solanum tuberosum*	Mecosta	A2	Ia	100/122	I	US-22
Michigan, US	2009	Pi09-021	*Solanum lycopersicum*	Ingham	A2	Ia	100/122	S	US-22
Michigan, US	2010	Pi10-023	*Solanum lycopersicum*	Mecosta	A2	Ia	100/122	S	US-22
Michigan, US	2010	Pi10-012	*Solanum tuberosum*	St Joseph	A2	Ia	100/122	I	US-22
North Dakota, US	1998	Pi98-1	*Solanum tuberosum*	US	A2	Ia	100/122	I	US-14
Michigan, US	1997	Pi97-5	*Solanum tuberosum*	US	A2	Ia	100/111/122	R	US-8
Colombia	-	2568	*Physalis peruviana*	COL	A2	Ia	100/111/122	I	US-8
Colombia	-	1810	*Solanum tuberosum*	COL	A1	IIa	100/100	I	CO-2
UK	-	07-39	*Solanum tuberosum*	UK	A2	Ia	100/100	I	Blue-13
UK	-	3298A	*Solanum tuberosum*	UK	A2	Ia	100/100	I	Blue-13
New York, US	-	US-8F	*Solanum tuberosum*	NY	A2	Ia	100/111/122	R	US-8
New York, US	-	US-22F	*Solanum tuberosum*	NY	A2	Ia	100/122	S	US-22

[a] Michigan location names refer to counties.
[b] Mt Hap corresponds to mitochondrial haplotype.
[c] *Gpi*, Glucose-6-phosphate isomerase profile.
[d] Mefenoxam response: (S) sensitive, (I) intermediate, and (R) resistant based on Therrien et al. (1993).

Table 2 Two-way factorial ANOVA for the effect of isolate of *Phytophthora infestans* and cultivars on whole tuber late blight as revealed by mean Relative Average Reflection Intensity [RARI (%)]*. Results represent the combined dataset for three repetitions

Source of Variation	df[a]	Sum of Squares	F Ratio[b]	P-Value[c]
Cultivar	5	8129.21	52.32	<0.001*
Isolates	11	67168.73	196.49	<0.001*
Cultivar X Isolates	55	20849.30	12.20	<0.001*

[a] Degrees of freedom.
[b] F ratio = the model mean square divided by the error mean square.
[c] *P* = Probability value (Significance level or $\alpha = 0.05$;).

- Relative RARI (%) has a minimum value of zero (no symptoms) and a maximum value of 100 (black tuber surface).

Table 3 Effect of different isolate of *Phytophthora infestans* on extent of tuber tissue affected by late blight as mean Relative Average Reflection Intensity [RARI (%)] in different potato cultivars; results represent the combined dataset for three repetitions of the experiment

	Tuber tissue darkening caused by different genotypes of *P. infestans*						
Cultivar	Mean RARI (%)		Isolate	Genotype	Mean RARI (%)	
Dark Red Norland	13.56	a[b]	Pi97-5	US-8	21.93	a
Russet Burbank	13.18	a	Pi10-012	US-22	20.45	a
Monticello	12.82	a	3298A	Blue-13	16.79	b
Missaukee	10.75	b	US-8F	US-8	14.16	c
FL 1879	9.67	b	07-39	Blue-13	13.96	c
Jacqueline Lee	7.74	c	Pi09-011	US-22	13.04	c
$LSD_{0.05}$	2.85		Pi98-1	US-14	8.62	d
			US-22F	US-22	5.87	e
			2568	US-8	5.69	e
			Pi10-023	US-22	5.29	e
			Pi09-021	US-22	5.22	e
			1810	CO-2	5.10	e
			$LSD_{0.05}$		3.27	

[a] Normalized tuber tissue darkening score expressed as RARI (%) = [1- Mean ARI treatment / Mean ARI control] x100; % 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).

[b] Values followed by the same letter are not significantly different at $\alpha = 0.05$ for comparisons of mean RARI values within different *P. infestans* genotypes of cultivar combination (Based on Fishers protected LSD).

Table 4. Effects of different isolates of *Phytophthora infestans* on extent of tuber tissue affected by late blight revealed by as mean Relative Average Reflection Intensity [RARI (%)] in different potato cultivars

P. infestans isolates	Mean RARI (%)[a] FL 1879	Jacqueline Lee	Missaukee	Monticello	Dark Red Norland	Russet Burbank
07-39	8.5 l-v[b]	5.5 p-v	13.4 i-o	17.8 e-i	21.6 c-f	16.9 f-j
1810	4.1 t-v	4.9 q-v	2.7 v	6.6 p-v	6.5 p-v	5.8 p-v
2568	3.2 uv	4.1 t-v	4.6 s-v	5.7 q-v	7.4 n-v	9.1 l-u
3298A	12.5 i-p	7.4 n-v	11.4 j-q	18.6 e-i	21.5 c-f	29.4 a
Pi09-021	5.5 q-v	4.7 r-v	5.9 p-v	5.9 p-v	5.9 p-v	3.5 uv
Pi10-023	4.0 s-v	4.9 r-v	5.0 q-v	5.4 q-v	6.6 p-v	5.9 p-v
Pi10-012	29.0 ab	14.1 h-m	21.1 c-g	23.5 a-e	20.3 d-h	14.6 h-l
Pi98-1	6.3 p-v	7.0 o-v	6.9 o-v	10.1 k-t	11.0 j-r	10.5 k-s
US-22F	3.3 uv	8.2 m-v	8.7 l-v	3.7 u-v	6.9 p-v	4.4 t-v
US-8F	5.8 p-v	14.4 h-m	13.6 i-n	20.1 d-h	15.1 g-k	15.9 f-k
Pi97-5	22.4 b-f	10.8 j-s	26.0 a-d	20.8 d-g	24.5 a-d	27.0 a-c
Pi09-011	15.2 g-k	7.2 n-v	10.1 k-t	14.8 g-l	15.2 g-k	15.7 f-k

[a] Normalized tuber tissue darkening score expressed as RARI (%) = [1- Mean ARI $_{treatment}$ / Mean ARI $_{control}$] x100; % 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).
[b] Values followed by the same letter are not significantly different at α = 0.05 for comparisons of mean RARI of cultivars with the different *P. infestans* genotypes (Based on Fishers protected LSD).

Table 5. Two-way factorial ANOVA of three different cultivars evaluated for tuber eye and lenticel infection against two genotypes of *Phytophthora infestans* (US-8 and US-22) expressed as area under disease progress curve values (AUDPC); results represent the combined dataset for three repetitions

Source of Variation	df[a]	Sum of Squares	F Ratio[b]	P-Value[c]
Isolate	1	1669.136	7.944	0.016*
Cultivar	2	1117.355	2.659	0.111
Isolate X Cultivar	2	573.373	1.364	0.292

[a] Degrees of freedom (df).
[b] F ratio = the model mean square divided by the error mean square.
[c] *P* = Probability value (Significance level or α = 0.05)

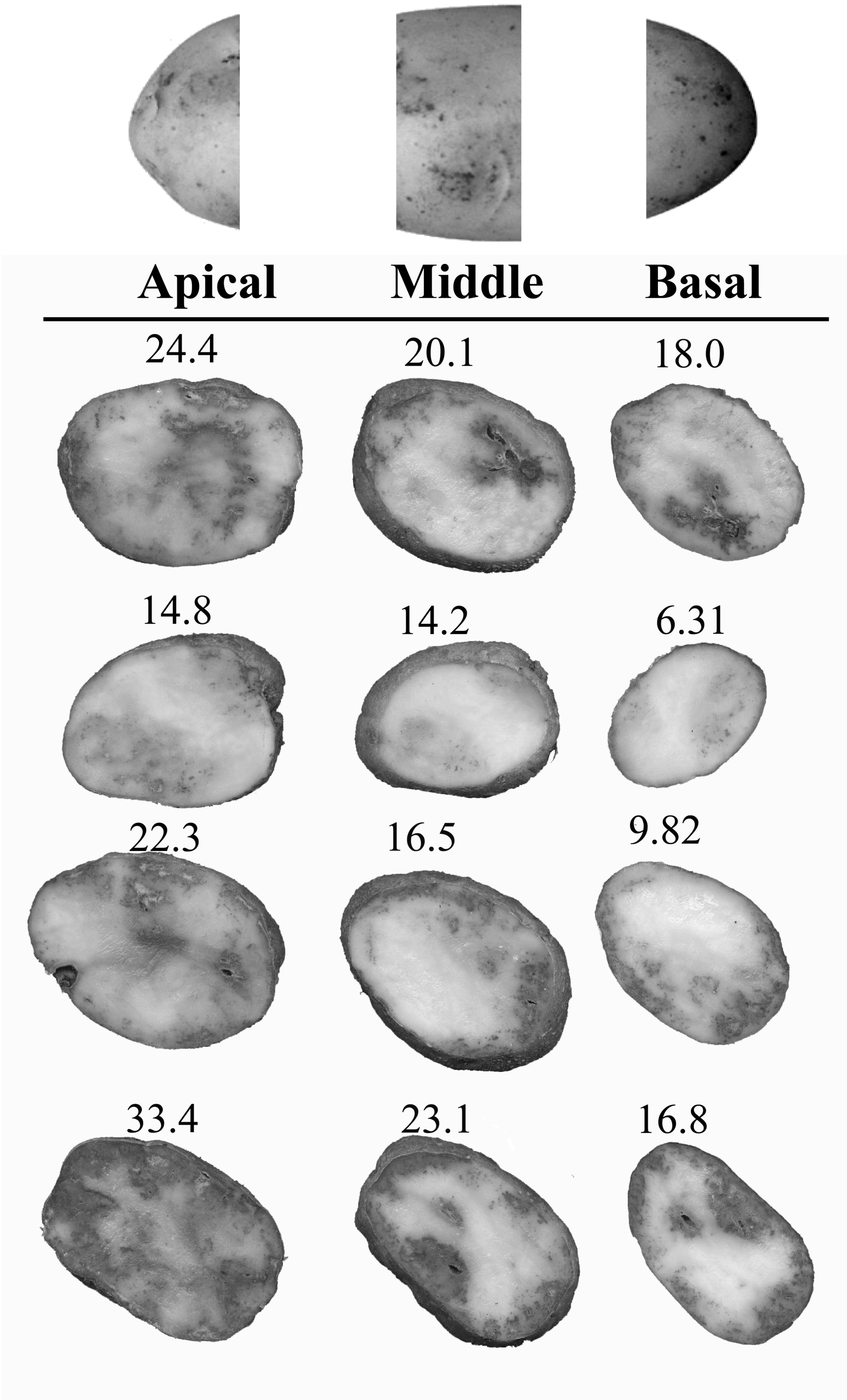

Figure 1. Digital image of three sections of a tuber inoculated with *P. infestans* US–8 genotype. Numbers indicate RARI (%) for apical, middle, and basal sections.

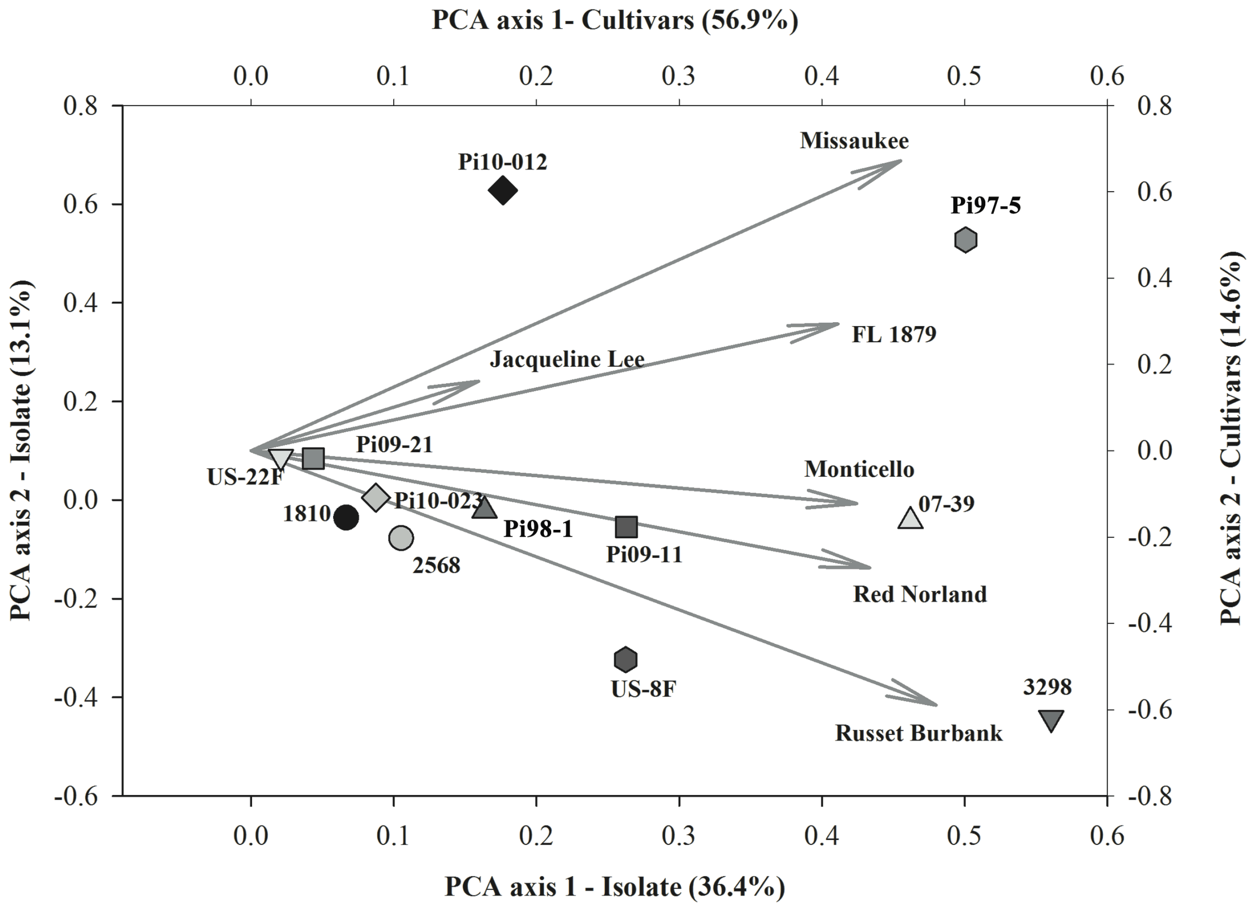

Figure 2. Principal component analysis (PCA) for potato cultivar and genotype of *Phytophthora infestans* isolates in evaluations of tuber late blight of mean Relative Area Under the Disease Progress Curve RARI (%). Cultivars are represented by lines; isolates by symbols.

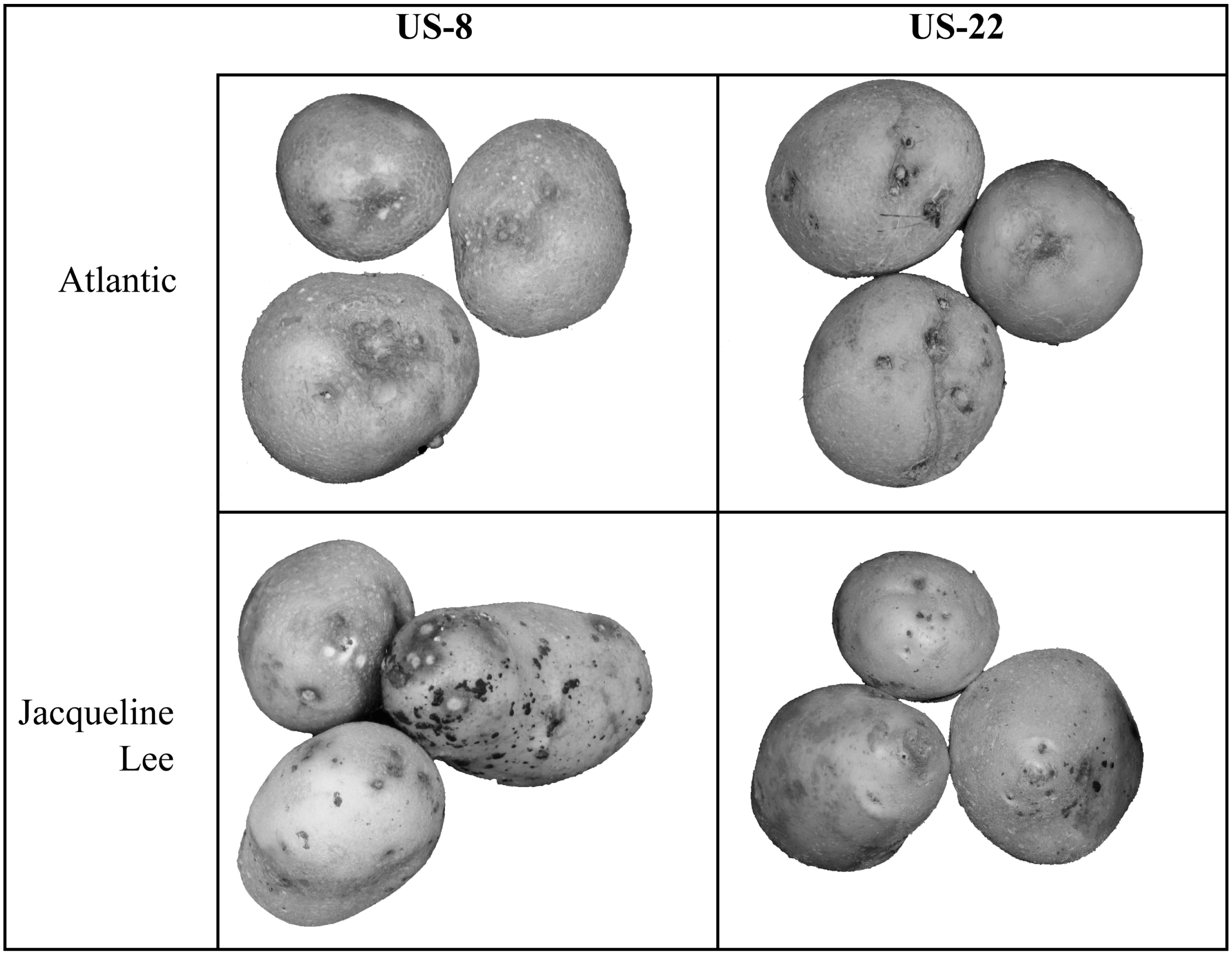

Figure 3. Periderm infections on lenticels and eyes of two different potato cultivars infected by *Phytophthora infestans* genotypes US-8 and US-22.

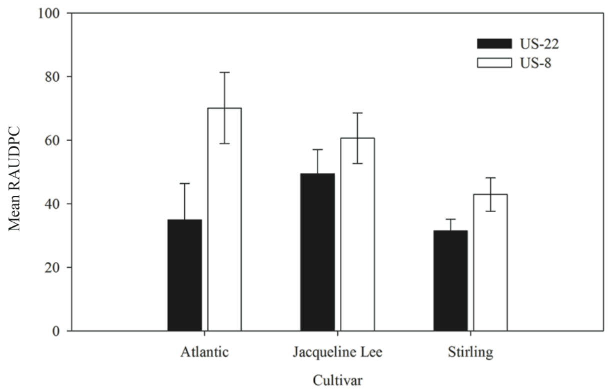

Figure 4. Mean area under the disease progress curve values for progression of eyes and lenticel infection caused by *Phytophthora infestans* genotypes US-8 and US-22 on three different cultivars of potato. Non-overlapping error bars indicate significant differences among genotypes within the three cultivars ($P < 0.05$) as calculated using 2-way ANOVA.

Effects of in-season crop-protection combined with postharvest applied fungicide on suppression of potato storage diseases caused by Fusarium pathogens

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Abstract

The effects of fungicides and biofungicides applied as foliar sprays to potatoes during the growing season in combination with storage loading applications to control Fusarium dry rot in stored potato tubers were evaluated. The in-season treatments included in-furrow and foliar application of mefenoxam or phosphorous acid and foliar application of *Bacillus subtilis*. Storage treatments included phosphorous acid, *B. subtilis* and a 3-way mixture of azoxystrobin, fludioxonil and difenoconazole. The experiment utilized two storage temperatures, 10 °C (on cv. FL1879) and 4 °C (on cv. Goldrush). There was a significant interaction between field and storage treatment for Fusarium dry rot incidence. Field treatment with *B. subtilis* or mefenoxam followed by storage treatment with *B. subtilis*, the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole or phosphorous acid resulted in reduced dry rot incidence. Field treatment strategies combined with storage applied fungicides and biofungicides were viable options for controlling dry rot incidence and could be adopted in potato production.
Key words: In-season; storage; biocontrol; postharvest; potato dry rot

1. Introduction

Fusarium dry rot of potato (*Solanum tuberosum* L.) is a devastating postharvest disease worldwide and is caused by several *Fusarium* species (Boyd, 1972; Secor and Salas, 2001; Gachango et al., 2011a, 2012b) with *Fusarium sambucinum* Fuckel. being the most aggressive species in Michigan (Wharton et al., 2007b; Gachango et al., 2012b). The first symptoms of Fusarium dry rot are usually dark depressions on the surface of the tuber (Peters et al., 2008). In large lesions, the skin becomes wrinkled in concentric rings as the underlying dead tissue desiccates (Fig. 1). Necrotic areas shaded from light to dark chocolate brown or black characterize internal symptoms. This necrotic tissue is usually dry (hence the name “dry rot”) and may develop at an injury such as a cut or bruise. The pathogen enters the tuber, often rotting out the center (Fig. 1). Rotted cavities are often lined with mycelia and spores of various colors from yellow to white to pink. Dry rot diagnosis may be complicated by the presence of other tuber pathogens. Soft rot bacteria (*Pectobacterium* spp.) often colonize dry rot lesions, especially when tubers have been stored under conditions of high relative humidity or tuber surfaces are wet (Secor and Salas, 2001).. *Fusarium* species are common in most soils where potatoes are grown and can survive as resistant spores free in the soil. There are two main opportunities in the potato crop cycle for *Fusarium* species to infect potato tubers in the spring and in the fall (Fig. 2). *Fusarium sambucinum* and *F. solani* are commonly found on seed tubers in the spring. Potato seed tubers are maintained in storage at 3 °C, which is approximately the temperature at which *F. sambucinum* is dormant, and consequently, there is minimal development of dry rot in storage. However, some level of Fusarium dry rot is almost always present in commercially available seed. During the pre-planting phase of potato production, seed tubers are warmed to about 12 °C, then cut into seed pieces prior to planting. Tubers infected with *F. sambucinum* are particularly susceptible to the development of seed piece decay during this phase. In cases of severe disease, seed pieces may rot completely before planting. Alternatively, after planting, more than 50 percent of sprouts developing on infected tubers may become diseased and killed outright before emergence (Choiseul et al., 2001). Damage at this stage results in delayed or non-emergence and is usually expressed as poor and uneven stands with weakened plants. Reduction in crop vigor then results from expenditure of seed energy used to produce secondary or tertiary sprouts to compensate for damage to primary sprouts.

Progeny tubers may become contaminated with *Fusarium* spores as they develop in the late summer and early fall. Tubers are not usually infected until harvest because the pathogen cannot cause infection unless the potato skin is ruptured, which rarely occurs during the growing season. Wounds caused during harvest and handling provide dormant spores on the tuber surface with multiple points of entry into the tuber. Once the pathogen has penetrated the tuber skin, it begins to grow in the tuber tissue, causing dry rot lesions at the point of entry. In storage, dry rot develops most rapidly at about 90 – 95% relative humidity and temperatures of 15° to 20°F. Lower humidity and temperatures retard infection and disease development. However, dry rot may continue to develop at the lowest temperatures safe for storage of potatoes (Wharton et al., 2007a, 2007b).

Dry rot affects both tubers in storage and seed tuber pieces in the field (Wharton et al., 2007a). Losses associated with dry rot have been estimated from 6 to 25%, and occasionally losses as high as 60% have been reported during long-term storage (Chelkowski, 1989; Secor and Salas, 2001). In addition to the damage inflicted on tubers, *Fusarium* species also produce toxins such as trichothecenes, harmful to humans and animals (Desjardins and Plattner, 1989). In Michigan potato production, *F. sambucinum* was the predominant species affecting potatoes in storage and causing seed piece decay after planting (Lacy and Hammerschmidt, 1993) and since then dry rot has been reported in most of the seed lots (Kirk and Wharton, 2008) and additionally causing sprout rotting in seed tubers (Wharton et al., 2006). *F. oxysporum* was the predominant species isolated from seed tubers in Michigan in a survey conducted between 2008 and 2009 by Gachango et al. (2012b).

Measures for controlling dry rot in storage are limited. There is no commercially grown potato cultivar that is resistant to dry rot in North America (Wharton et al., 2007a). However, the level of susceptibility varies from one cultivar to the other and clones with a high level of resistance to *F. sambucinum* and *F. solani* have been reported (Leach and Webb, 1981). Integrating storage technologies with physical methods and chemical treatments either at harvest or as tubers enter into storage or before planting could reduce the losses caused by *Fusarium* spp. Dry rot has been managed primarily by reducing tuber bruising, providing conditions for rapid wound healing (Secor and Salas, 2001; Secor and Johnson, 2008) and by applying thiabendazole (TBZ), a benzimidazole fungicide as tubers enter into storage or before planting (Hide et al., 1992). However, isolates of *F. sambucinum* resistant to TBZ and other benzimidazoles were discovered in

Europe in 1973 (Hide et al., 1992) and in the United States in 1992 (Desjardins, 1995), thus rendering this chemical less effective in controlling dry rot (Staub, 1991).

Gachango et al. (2012b) reported that all samples of *F. sambucinum* isolated from Michigan potato seed were resistant to TBZ. Other fungicides used to control Fusarium dry rot in US include fludioxonil alone (Maxim™ Seed Potato, Syngenta Inc. Greensboro, NC, USA) or in combination, fludioxonil + mancozeb (Maxim® MZ, Syngenta); (Zitter, 2010). Fludioxonil is able to reduce seedpiece decay as well as disease on sprouts (Wharton et al., 2007b), which can help produce healthy progeny tubers. Fludioxonil has a single site mode of action hence a high probability of development of insensitive strains (Brent and Hollomon, 2007). Fludioxonil-resistant strains of *Fusarium* spp. were reported in Canada and the US and included *F. sambucinum and F. coeruleum* (Peters et al., 2008) and *F. oxysporum* (Gachango et al., 2011b). This has resulted in fewer alternatives for controlling potato seedpiece decay caused by *F. sambucinum, F. oxysporum,* and *F. coeruleum*.

Use of fungicides has been the primary disease management practice in potato production (Hamm et al., 2008). In-furrow application of systemic fungicides that are taken up by the roots and are able to move to the shoots, and protect the crops from foliar diseases also promote healthy tuber development (Hamm et al., 2008). Some of the fungicides registered in the US for in-furrow application to control potato diseases include mefenoxam (Ridomil Gold™), phosphorous acid (Phostrol™), azoxystrobin (Amistar™; Quadris™) and mefenoxam + chlorothalonil (Ridomil Bravo™) (Zitter, 2010). No fungicide has been registered for in-furrow application to prevent Fusarium dry rot. However, azoxystrobin has been used to control Fusarium seed piece decay when applied on freshly cut seed tubers (Powelson and Rowe, 2008).

To counteract the lack of effectiveness of TBZ, additional registration of postharvest fungicides is needed and some have already been proposed including a 3-way mixture of difenoconazole, azoxystrobin and fludioxonil for managing decays caused by *Fusarium* species on potato and other tuber crops (Adaskaveg and Förster, 2010). This 3-way mixture (Stadium™) has recently been registered by Syngenta Crop Protection, Inc. Greensboro, NC for potato dry rot and silver scurf management in storage.

Recently a study was reported to evaluate the effect of growing season tuber protection strategies, in-furrow and foliar applications of crop protectants, in combination with storage application of fungicides and biofungicides on tuber health during storage against oomycete diseases (Gachango et al. 2012a). Some of the active ingredients included in this study such as azoxystrobin and *B. subtilis* were reported to have acceptable efficacy against Fusarium dry rot when applied to potato tubers in storage (Gachango et al., 2012c). However, so far no study has been published to evaluate the effect of such a strategy on Fusarium dry rot. Hence, the objective of this study was to determine the effects of combinations of in-season applied crop protection strategies with storage application of fungicides and biofungicides on reduction of disease incidence caused by *Fusarium sambucinum* (Fusarium dry rot).

2. Materials and Methods

2.1 Field Treatment

Two field trials were conducted at Michigan State University, Montcalm Research Farm, Entrican, MI, in 2008 and 2009 as described in Gachango et al (2012a). The 2008 trial was planted on May 15th, and the 2009 trial was planted on May 21st. Two potato cultivars, cv. FL1879, a chip processing cultivar and cv. Goldrush, a table-stock cultivar, were planted 12.5-cm deep in 0.9-m row spacing and 28-cm within rows. Plots of 100 x 50-m were laid out in a split plot block design (the main split was cultivar) and further subdivided with each plot representing a crop protection regime field treatment (described below) and replicated three times in a randomized complete block design to give a total of 12 plots per cultivar. Nine rows of each cultivar were planted resulting in 18 rows per plot/field treatment. At harvest, tubers from the replicated treatments were combined by cultivars and stored as described below.

Field treatments consisted of a) in-furrow application at-planting of mefenoxam [Ridomil Gold SL® (4.1mL/100 row meters); Syngenta Crop Protection, Inc. Greensboro, NC], followed by foliar applications of mefenoxam (Ridomil Gold SL® 2.24 kg ai/ha) at canopy closure (on June 26th in 2008 and on July 2nd in 2009) and repeated a further two times at 14 d intervals; b) in-furrow at-planting application of phosphorous acid [Phostrol 53.6SC (6.4 mL/100 row meters), Nufarm Americas Inc. Houston, TX], followed by foliar applications of phosphorous acid (11.7 L/ha) at canopy closure (on June 26th in 2008 and on July 2nd in 2009) and repeated a further two times at 14 d intervals; c) foliar applications of *Bacillus subtilis*; [Serenade ASO 1.34SC (14 L/ha), AgraQuest Inc. Davis, CA] at canopy closure (on June 26th in 2008 and on July 2nd in 2009) and repeated a further two times at 14 d intervals and d) the control plot, treated only with chlorothalonil [Bravo WS 6SC (1.75 L/ha), Syngenta] on a 7 d schedule initiated at canopy closure (on June 26th in 2008 and on July 2nd in 2009) for a total of seven applications prior to desiccation. Fungicide/biofungicide treated plots were also treated with chlorothalonil on a 7 d schedule (as described above) in addition to the experimental treatments for late blight protection. Crop protection maintenance treatments were described in Gachango et al (2012a). Plots, 9 rows per cultivar (100-m), were harvested on September 17th 2008 and on October 13th 2009. The crops experienced 1072 and 1029 °C day^{-1} (day degrees accumulated above base temperature of 4 °C) in 2008 and 2009, respectively. The 2008 crop was therefore more mature than the 2009 crop however this may not be a great enough difference to impact the physiological age of the tubers. Tubers were harvested using a single row Lenco potato research plot harvester fitted with star rollers on the sorting chain to channel potatoes across a built-in grading table that separates tubers into size grades roughly equivalent to <50 g, 50 to 250 g and > 250 g tubers (Advanced Farm Equipment, LLC 5773 Crystal Rd. Vestaburg, MI). Tuber pulp temperature was monitored during harvest and plots were harvested when tubers had temperatures between 12 and 20 °C to avoid bruising. The harvested tubers were placed in 450 kg aerated wooden boxes and labeled according to the field treatment. The tubers were transported to a curing facility, which was maintained at 10 °C, 90% relative humidity in darkness for three weeks prior to administration of the storage inoculation and treatments.

2.2 Storage experiment

2.2.1 Preparation of tubers

The storage experiment was initiated on October 22nd for the 2008 trial and on November 10th for the 2009 trial. The harvested potato tubers grown under the field treatments described above were stored at 20 °C and 95% RH for 10 d and temperatures reduced by

1 °C/day to 15 °C to enhance wound curing and suberization prior to inoculation. Tubers free from any defect or visible disease symptoms were selected and washed by slowly passing them through a conveyor lined with nozzles, which sprayed water on the tubers thus washing off soil. The clean tubers were put in clean plastic crates and allowed to dry for 24 h. The tubers were then 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 over an area of about 300 mm^2. The wounded tubers were then soaked in the inoculum (described below) for 48 h. The tests were carried out at two storage temperatures used in the potato industry, 10 °C (chip processing, cv. FL1879) and 4 °C (table stock and seed, cv. Goldrush). After inoculation and treatment the storage temperatures were reduced by 1 °C/day to the target temperatures.

2.2.2 Preparation of inoculum and tuber inoculation

Fusarium sambucinum previously isolated from potato tubers in Michigan was grown for 10 d prior to the preparation of inoculum. The pathogen was grown on potato dextrose agar (PDA; Difco, Detroit, Michigan). A suspension containing macroconidia of *F. sambucinum* was prepared, and the concentration was adjusted to 1,000 macroconidia/mL by use of a hemacytometer. Two untreated controls, either inoculated with the pathogen or a non-inoculated control were included in the trial for every treatment combination (field treatment x storage treatment) and tubers treated for the storage component of the trials (25/replicate/treatment). Based on the results of an inoculation optimization experiment (data not reported), the wounded tubers were exposed to an inoculum suspension for 48 h. After inoculation, tubers were removed and placed in plastic crates, 25 tubers per crate. The inoculated tubers were stored for 24 h at 10 °C before treatment with fungicides or biofungicides (Table 1). The azoxystrobin + fludioxonil + difenoconazole treatment was applied as a three way mixture of the individual fungicides. Fungicides were applied as liquid treatments in a water suspension using a precision plot sprayer system from R&D sprayers (Bellspray Inc., Opelousas, LA 70570) with a single R&D XR11003VS spray nozzle attached to a lance suspended over a 0.5 m wide roller table at a rate of 1L/ton at 344.74 Kpa onto the tuber surfaces, with the entire tuber surface being coated. Treated tubers were incubated in the dark in plastic crates at 10 °C (cv. FL1879) or 4 °C (cv. Goldrush).

2.3 Evaluation of dry rot and data analysis

Experiments at 10 °C (cv. FL1879) and 4 °C (cv. Goldrush) were analyzed separately as both variety and temperature were considered potentially confounding effects. Variety was considered confounding as the varieties may differ in susceptibility to *F. sambucinum*. Temperature was considered confounding as disease development at 4 °C will be less than at 10 °C. The tubers were evaluated on March 9th in 2008, and March 10th in 2009, after about 120 d in storage. Tubers were cut longitudinally into four slices and evaluated for presence of symptoms of dry rot. Tubers with symptoms of dry rot were counted and disease incidence determined as percentage of symptomatic tubers relative to the number of tubers in each replicate. Data were tested for assumptions of normality and analyzed using the analysis of variance platform (ANOVA) and the Tukey's HSD test in JMP (JMP © 2008. SAS Institute Inc., SAS Campus Drive, Cary, NC, USA 27513).

3. Results

There were significant differences between results from each year for disease incidence at 10 °C on cv. FL 1879 and at 4 °C on cv. Goldrush as determined by F-tests, therefore data from each year were analyzed separately (Table 2). A lower level of dry rot incidence was observed in 2008 than in 2009. Tuber dry rot incidence generally increased with temperature. Although cultivars were not compared statistically due to the confounding effect of temperature, the role of cultivar susceptibility may not be ruled out as a factor. In 2008, less disease development was observed at both temperatures on both cultivars. Dry rot did not develop on the non-inoculated checks in either year or cultivar experiment combination and were subsequently left out of the analyses.

3.1 Evaluation of dry rot at 10 °C on cv. FL1879

At 10 °C on cv. FL1879, the variable, "field treatment" which was analyzed as a main effect and consisted of all treatments applied in the field, had a significant effect on dry rot incidence in 2008 and 2009 (Table 3). A comparison of the effect of the field treatments can be measured by comparing the mean incidence of Fusarium dry rot development among the inoculated check treatments originating from field treatments indicated by the sub-caption in each sub-figure [Fig. 3 (A1 and B1= Phosphonic Acid; A2 and B2= Mefenoxam; A3 and B3= *B. subtilis*; A4 and B4= untreated field plots; A= 2008 and B= 2009)]. Field treatment with *B. subtilis* or mefenoxam significantly reduced dry rot incidence and differed from the untreated field treatment, but not from field treatment with Phosphorous acid in 2008 (Fig. 3A1 – 3A4). No field treatment significantly reduced dry rot incidence in comparison to the untreated field treatment in 2009 (Fig. 3B1 – 3B4).

"Storage treatment" analyzed as a main effect had a significant effect on dry rot incidence in 2008 and 2009 (Table 3). In 2008, storage treatment with phosphonic acid, the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole or *B. subtilis* had a significant effect on dry rot incidence compared to the inoculated control (Fig 3A1 – A4). In 2009, storage treatment with phosphorous acid or the the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole significantly reduced dry rot incidence compared to the inoculated control.

The interaction of the main effects of the field and storage variables had a significant effect on disease incidence in 2008 and 2009, respectively (Table 3). All inoculated controls from plots treated with phosphorous acid, *B. subtilis* or mefenoxam resulted in significantly lower dry rot incidence compared to the inoculated control from the untreated plot in 2008 (Fig. 3). However, in 2009, all the inoculated controls from all plot treatments did not differ significantly from each other with respect to dry rot incidence. The interaction of plot treatment, *B. subtilis*, with phosphorous acid applied as a storage treatment, significantly reduced dry rot incidence in 2009 compared to the interaction of untreated plot and storage treatment with phosphorous acid (Fig. 3).

3.2 Evaluation of dry rot at 4 °C on cv. Goldrush

At 4 °C on cv. Goldrush, very low dry rot disease incidence was observed in 2008 compared to 2009 (Table 3). The variable, field, only had a significant effect on dry rot incidence in 2009 but not in 2008 (Table 3). Field treatment with mefenoxam had a significant effect on dry rot incidence compared to the untreated field plots in 2009. Storage treatment had a significant effect on dry rot incidence in 2008 and 2009, respectively (Table 3). The storage treatments, *Bacillus subtilis*, phosphorous acid or the the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole significantly reduced dry rot incidence compared to the inoculated control in 2008 and 2009. The interaction between field and storage treatments had a significant effect on dry rot incidence in 2009 but not in 2008 (Table 3). The inoculated control from fields treated with mefenoxam or *B. subtilis* differed significantly from the inoculated controls from the untreated field treatment (Fig. 4).

3.3 Evaluation of storage treatments on dry rot

Dry rot incidence was lower in 2008 in both cultivars and excluding the effect of the field treatment in Goldrush only the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole significantly reduced dry rot incidence compared to the inoculated control (Fig. 5). In FL1879, only Phosphorous acid and *B. subtilis* reduced dry rot incidence compared to the inoculated control. In 2009, dry rot incidence was severe and the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole. Phosphorous acid and *B. subtilis* significantly reduced dry rot incidence compared to the inoculated control in both cultivars (Fig. 5).

4. Discussion

The results from the trials over two years demonstrated that in-season crop protection strategies, e.g. in-furrow and foliar applications combined with storage treatment using fungicides and biofungicides is a viable option for increasing tuber protection against *Fusarium sambucinum* a potato dry rot storage pathogen. The test was conducted at two storage temperatures, 10 and 4 °C, on two different cultivars to simulate dry rot development on tubers destined for chipping (cv. FL 1879) and table-stock or seed (cv. Goldrush), respectively. Tuber dry rot incidence generally increased with temperature. Although cultivars were not compared statistically due to the confounding effect of temperature, the role of cultivar susceptibility may not be ruled out as a factor. The high disease frequencies observed in 2009 may reflect actual storage losses when no postharvest treatments are used. In 2008, less disease development was observed at both temperatures on both cultivars. Little dry rot developed at 10 °C on cv. FL 1879 in 2008, unlike in 2009 where it developed at both temperatures on both cultivars. The failure for dry rot development was unclear, although the low disease development in 2008 could have been due to field conditions affecting the maturity of the tubers. In 2008, the crop experienced more accumulated day degrees than in 2009 and tubers may have been physiologically more mature and less susceptible to *F. sambucinum*. Although infection of tubers by *F. sambucinum* can take place in the field, due to strict selection of the sample, the tubers that were used in the current study had no naturally occurring infection from the field.

Control and management of fungal diseases in potatoes relies on cultural practices such as crop rotation, use of disease-free seed, wound-healing of stored potatoes and minimizing wounds and injuries during harvesting and handling (Secor and Gudmestad, 1999). Since cultural practices alone are not always sufficient to effectively control this disease, alternative strategies are needed. Limited availability of postharvest products and development of resistance to thiabendazole (Desjardins, 1995) and fludioxonil (Peters et al., 2008; Gachango et al., 2011b) necessitates alternative strategies for control of Fusarium dry rot. Crop protection during the growing season has been widely practiced to control tuber rots caused by the oomycete pathogens in foliar stages of crop and tuber development (Johnson et al., 2004; Platt et al., 2004) and during storage (Porter et al., 2006; Al-Mughrabi et al., 2007). Recently a combination of strategies where specific fungicides and biofungicides were applied either during the season or at storage was shown to provide some control of oomycetes under conducive conditions (Gachango et al., 2012a). Other studies have focused on postharvest application of fungicides for control of tuber rots caused by oomycete pathogens (Miller et al., 2006; Johnson, 2008) or fungal pathogens (Secor and Gudmestad 1999; Miller al., 2011). However, no work has been done to evaluate the effects of combining in-season crop protection strategies with postharvest applied fungicide on control of Fusarium dry rot during storage.

Fusarium dry rot developed at both temperatures in both cultivars in 2009 whereas in 2008 the incidence was more pronounced at the higher temperature. Potato tubers used were wounded as *Fusarium* spp. cannot infect intact tuber periderm or lenticels (Secor and Salas, 2001). Lulai (2001) reported that the wound healing process in potatoes requires a relative humidity of 90-95% and levels above this or presence of a film of water may delay the process due to restricted oxygen supply and cell enlargement leading to further infection. Extended soaking of wounded tubers in the inoculum led to severe disease development in 2009 but not 2008 suggesting another factor decreased disease development in 2008.

The interaction of field and storage applied fungicides and biofungicides significantly reduced the development of dry rot. The inoculated control from the untreated field had significantly higher disease incidence compared to the inoculated controls from fields treated with *B. subtilis* or mefenoxam. Although mefenoxam is registered only for control of oomycetes, there was a reduction of dry rot incidence on tubers from the field treated with mefenoxam. Barak et al., (1984) reported that tubers from a field treated with metalaxyl had a high resistance to tuber decay caused by *F. sambucinum* and *F. culmorum* although this resistance decreased gradually with storage time. Resistance to mefenoxam was not tested in our current study, but as mefenoxam is active specifically against oomycetes it is unlikely to have a direct effect on *Fusarium* spp. and possibly the effect may be indirect through a plant regulated systemic process. Field treatment with mefenoxam followed by storage application of either the 3-way mixture of azoxystrobin, fludioxonil and difenoconazole or phosphorous acid gave the best control of dry rot. The 3-way mixture of azoxystrobin, fludioxonil and difenoconazole (Stadium™) has now been registered by Syngenta Crop Protection or control of dry rot and silver scurf and might become an alternative for controlling dry rot, since thiabendazole has limited control over dry rot caused by *F. sambucinum* (Ocamb et al., 2007). *F. sambucinum* is the most aggressive *Fusarium* spp. in Michigan (Wharton et al., 2007a; Gachango et al 2012b) and control is challenging. In addition, the recent discovery of fludioxonil-resistant *Fusarium* spp. in Canada (Peters et al., 2008) and in Michigan (Gachango et al., 2011b) complicates strategies for controlling dry rot. Despite phosphorous acid being registered for control of the oomycete pathogens (Brunings et al., 2005) but not Fusarium dry rot, the storage application reduced dry rot development on tubers from fields treated with mefenoxam, *B. subtilis* or phosphorous acid. These results agree with those of Lobato *et al.* (2010) who found that phosphorous acid could reduce disease development caused by *F. solani*, *Phytophthora infestans* and *Rhizoctonia solani*.

From this study we can therefore conclude that combination of in-season application and storage application of fungicides and biofungicides effectively increased tuber protection against Fusarium dry rot. There is need to further test the mechanism being utilized in controlling dry rot. The combination of in-season application and postharvest application of fungicides and biofungicides effectively increased tuber protection against storage pathogens. Any synergistic effect of the strobilurins with the phenylyrolles and the triazoles warrants further investigation.

Acknowledgements

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Table 1

Storage treatments (fungicides and biofungicide) used for potato storage diseases caused by *Fusarium sambucinum* pathogen trials at MSU[a] from 2008 to 2009.

	Treatments	Formulation[b]	Rate g ai/ 100 kg[c]	Manufacturer
1	Not-inoculated check			
2	Inoculated check			
3	*Bacillus subtilis*	1.34SC	11.2	AgraQuest, Inc. Davis CA
4	Phosphorous acid	53.6SC	44.7	NuFarm Americas, Inc. Burr Ridge, IL
5	Azoxystrobin +	250SC	1.7	Syngenta Crop Protection, Inc.
	Fludioxonil +	250SC	5.2	Greensboro NC
	Difenoconazole[d]	250SC	0.9	

[a] MSU= Michigan State University.

[b] Formulation= products added to the active ingredient to change its physical characteristic and allow compatibility with the machinery; SC= Suspension Concentrates.

[c] Rate represents g active ingredient of the product per 100 kg of potato tubers.

[d] The azoxystrobin + fludioxonil + difenoconazole treatment was applied as a three way mixture of the individual fungicides.

Table 2

Main effects analyses of field and storage treatments on Fusarium dry rot incidence on tubers stored at 10 °C (cv. FL1879) and 4 °C (cv. Goldrush) as impacted by the year in which the experiments were carried out, 2008 and 2009.

				Year of Trial			
Variable Measured	Temperature (cv.)	F Ratio	Prob > F	2008		2009	
Incidence[a]	10 °C (cv. FL 1879)	625.9211	<0.0001	3.8	b[b]	32.4	a
	4 °C (cv. Goldrush)	214.0969	<0.0001	2.1	b	13.4	a

[a] Incidence was calculated as number of tubers showing Fusarium dry rot symptoms relative to the number of tubers per treatment.

[b] Numbers followed by the same letter within a row are not significantly different at $P = 0.05$ (LS means differences Student t).

Table 3

Main effects analyses of field and storage treatments and interactions between these variables on Fusarium dry rot incidence on tubers stored at 10 °C (cv. FL1879) and at 4 °C (cv. Goldrush) for 120 d in 2008 and 2009.

Source of variation	df[d]	Incidence[a] (%)			
		10 °C (cv. FL1879)		4 °C (cv. Goldrush)	
		Prob >F		Prob >F	
		2008	2009	2008	2009
Field[b]	3	<0.0001	0.0177	0.2694	0.0213
Storage[c]	3	<0.0001	<0.0001	0.0215	<0.0001
Storage*Field	9	0.0046	0.0158	0.1490	0.0001

[a] Incidence was calculated as number of tubers showing Fusarium dry rot symptoms relative to the number of tubers per treatment.

[b] Field (plot) represented a treatment; phosphorous acid, mefenoxam, *Bacillus subtilis* and untreated control.

[c] Storage treatment consisted of inoculated control, not-inoculated control, phosphorous acid, *B. subtilis*, and a 3-way mixture of azoxystrobin, fludioxonil and difenoconazole.

[d] df = degrees of freedom.

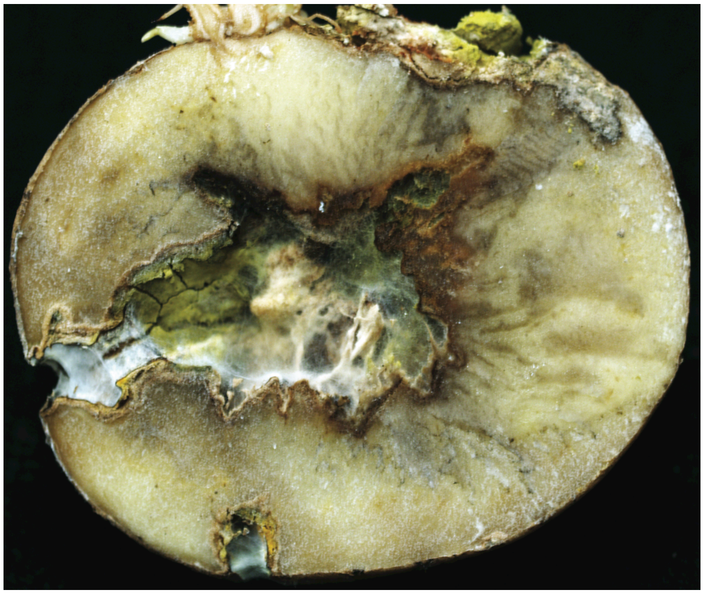


Figure 1

Symptoms of dry rot caused by *Fusarium sambucinum* on cv. Snowden tuber (from Wharton et al. 2007a).

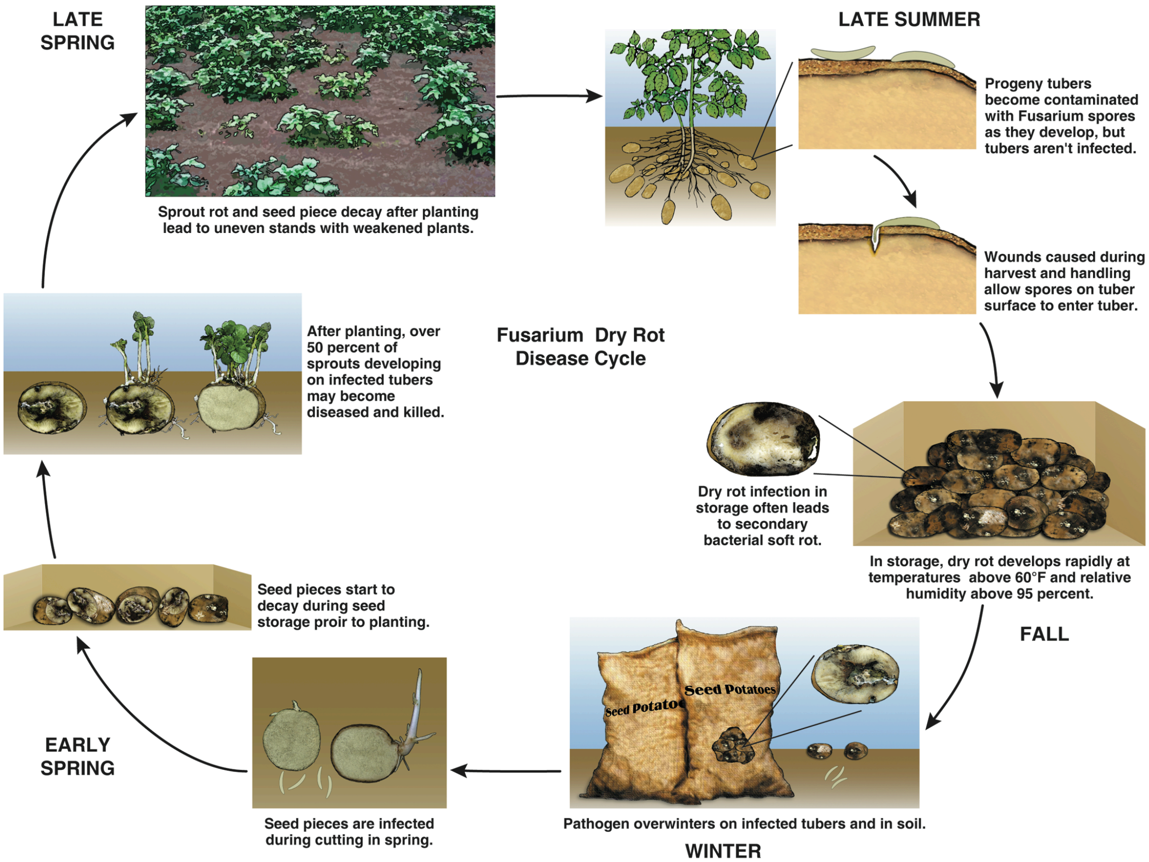
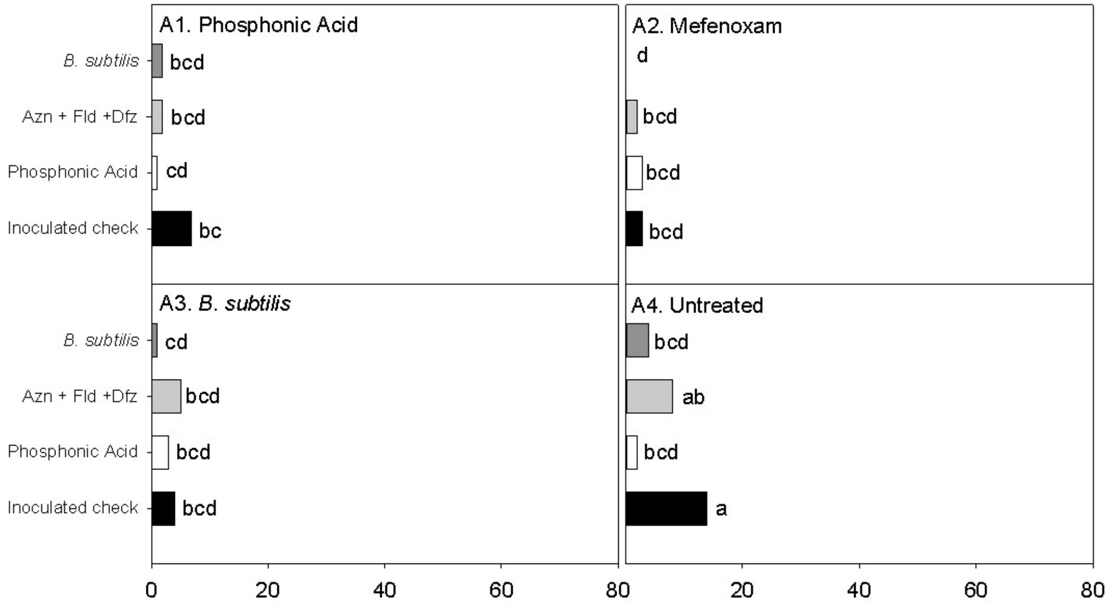


Figure 2

Fusarium dry rot disease cycle (from Wharton et al. 2007a).


A1. Phosphonic Acid
A2. Mefenoxam
A3. B. subtilis
A4. Untreated
B. subtilis
Azn + Fld +Dfz
Phosphonic Acid
Inoculated check
bcd
bcd
cd
bc
d
bcd
bcd
bcd
cd
bcd
bcd
bcd
bcd
ab
bcd
a
0
20
40
60
80

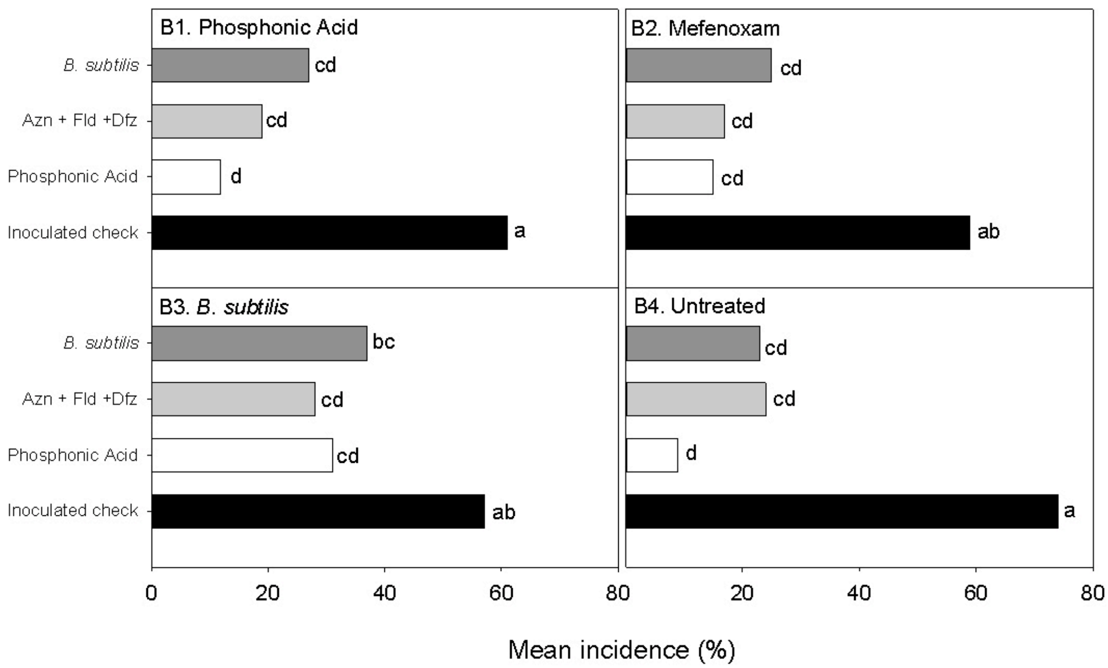
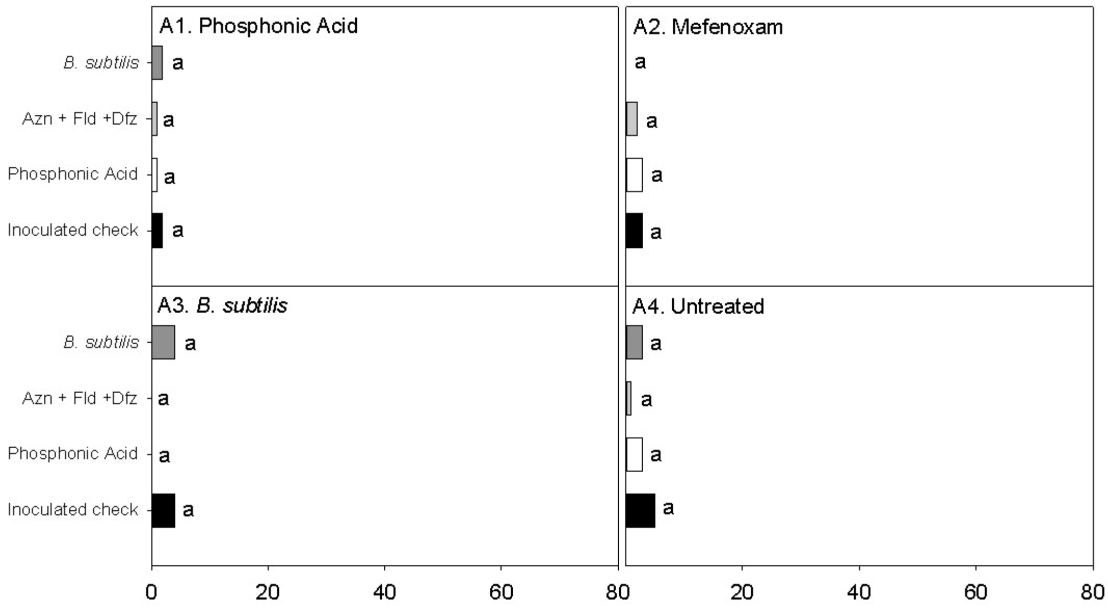

B1. Phosphonic Acid
B2. Mefenoxam
B3. B. subtilis
B4. Untreated
B. subtilis
Azn + Fld +Dfz
Phosphonic Acid
Inoculated check
cd
cd
d
a
cd
cd
cd
ab
bc
cd
cd
ab
cd
cd
d
a
0
20
40
60
80
Mean incidence (%)

Figure 3

Effects of field and storage treatments and interactions on Fusarium dry rot incidence on tubers stored at 10 °C (cv. FL1879; 2008, A1 – A4; 2009, B1 – B4) for 120 d. Variables consisted of field treatments (A1, B1 - phosphorous acid; A2, B2 – mefenoxam; A3 – B3 - *Bacillus subtilis* and A4, B4 - untreated control) application timings and rates as in the text and storage treatment (inoculated control, not-inoculated control, phosphorous acid *Bacillus subtilis* and a 3-way mixture of azoxystrobin, fludioxonil and difenoconazole [Azn + Fld + Dfz]) and their interactions (rates of application detailed in Table 1). Incidence was calculated as number of tubers showing Fusarium dry rot symptoms relative to the number of tubers per treatment. Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (HSD = Honestly significant difference).


A1. Phosphonic Acid
A2. Mefenoxam
A3. B. subtilis
A4. Untreated
B. subtilis
Azn + Fld +Dfz
Phosphonic Acid
Inoculated check
a
0
20
40
60
80

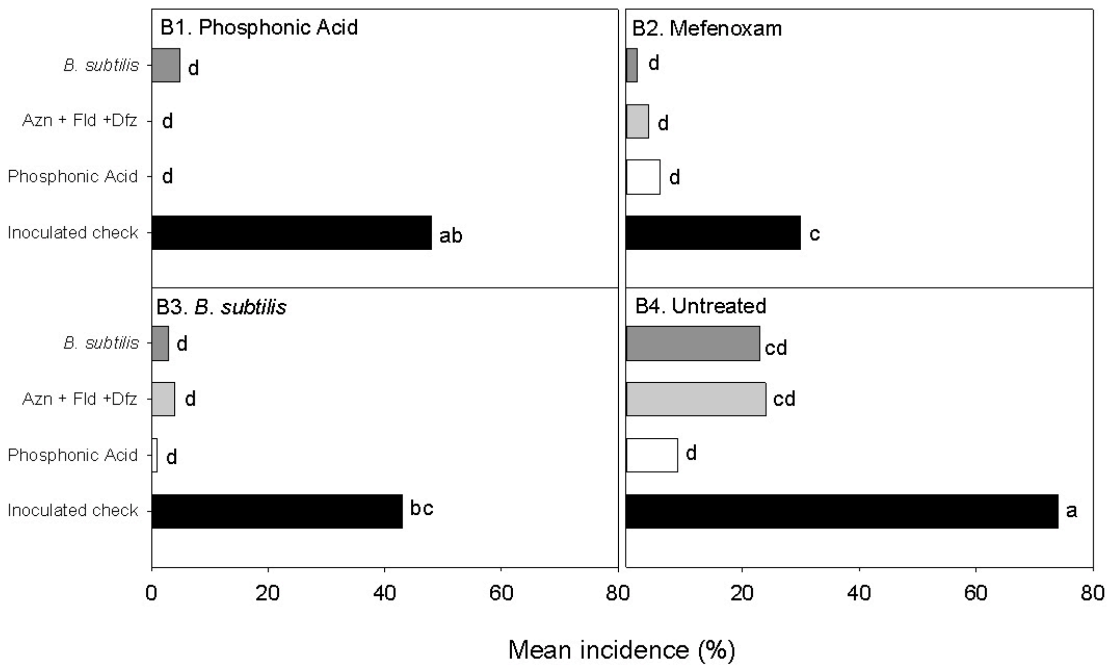

B1. Phosphonic Acid
B2. Mefenoxam
B3. B. subtilis
B4. Untreated
B. subtilis
Azn + Fld +Dfz
Phosphonic Acid
Inoculated check
d
ab
c
bc
cd
a
0
20
40
60
80
Mean incidence (%)

Figure 4

Effects of field and storage treatments and interactions on Fusarium dry rot incidence on tubers stored at 4 °C (cv. Goldrush; 2008, A1 – A4; 2009, B1 – B4) for 120 d.Variables consisted of field treatments (A1, B1 - phosphorous acid; A2, B2 – mefenoxam; A3 – B3 - *Bacillus subtilis* and A4, B4 - untreated control) application timings and rates as in the text and storage treatment (inoculated control, not-inoculated control, phosphorous acid *Bacillus subtilis* and a 3-way mixture of azoxystrobin, fludioxonil and difenoconazole [Azn + Fld + Dfz]) and their interactions (rates of application detailed in Table 1). Incidence was calculated as number of tubers showing Fusarium dry rot symptoms relative to the number of tubers per treatment. Numbers followed by the same letter within a column are not significantly different at $P = 0.05$ (HSD = Honestly significant difference).

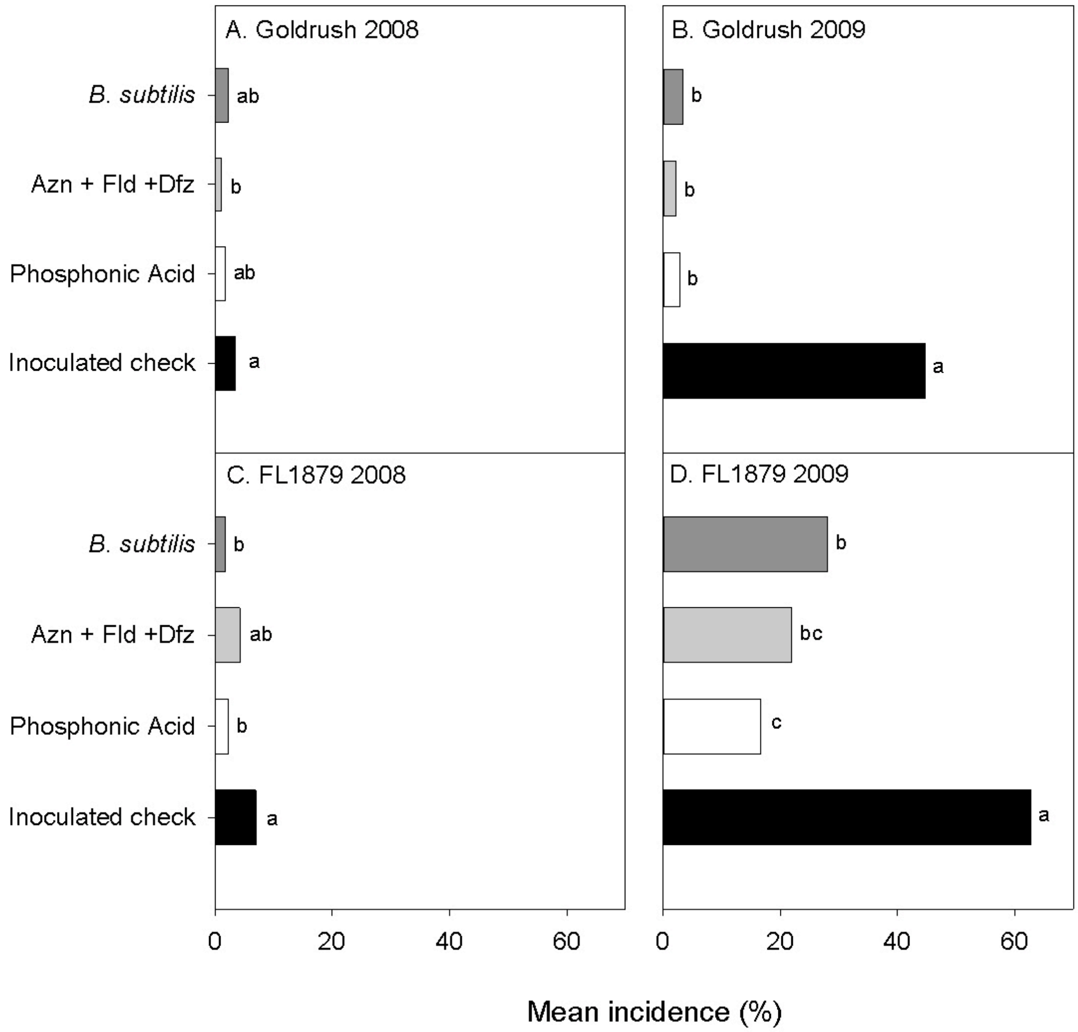

A. Goldrush 2008
B. Goldrush 2009
C. FL1879 2008
D. FL1879 2009
B. subtilis
Azn + Fld +Dfz
Phosphonic Acid
Inoculated check
ab
b
ab
a
b
b
b
a
b
ab
b
a
b
bc
c
a
0
20
40
60
Mean incidence (%)

Figure 5

Effects of storage treatments on Fusarium dry rot incidence on tubers stored at A. 4 °C (cv. Goldrush; 2008); B. 4 °C (cv. Goldrush; 2008); C. 10 °C (cv. FL1879; 2008); D. 10 °C (cv. FL1879; 2009); A1 – A4; 2009, B1 – B4) for 120 d. Variables consisted of storage treatment (inoculated control, not-inoculated control, phosphorous acid *Bacillus subtilis* and a 3-way mixture of azoxystrobin, fludioxonil and difenoconazole [Azn + Fld + Dfz]), the rates of application detailed in Table 1. Incidence was calculated as number of tubers showing Fusarium dry rot symptoms relative to the number of tubers per treatment. Numbers followed by the same letter within a column are not significantly different at *P* = 0.05 (HSD = Honestly significant difference).

2012-2013 MICHIGAN POTATO DEMONSTRATION STORAGE ANNUAL REPORT MICHIGAN POTATO INDUSTRY COMMISSION

Chris Long, Coordinator and Andrew Camp

Introduction and Acknowledgements

Round white potato production for chip processing continues to lead the potato market in the state of Michigan. Michigan growers continue to look for promising, new, round white varieties that will meet necessary production and processing criteria. There are many variety trials underway in Michigan that are evaluating chipping varieties for yield, solids, disease resistance and chipping quality with the hope of exhibiting to growers and processors the positive attributes of these lines. Extended storage chip quality and storability are areas of extreme importance in round white potato production. Due to the importance of these factors, any new chip processing varieties that have the potential for commercialization will have storage profiles developed. Being able to examine new varieties for long-term storage and processing quality is a way to keep the Michigan chip industry at the leading edge of the snack food industry. The information in this report can position the industry to make informed decisions about the value of adopting these varieties into commercial production.

The Michigan Potato Industry Commission (MPIC) Potato Demonstration Storage Facility currently consists of two structures. The first building, the Dr. B. F. (Burt) Cargill Building, constructed in 1999, provides the Michigan potato industry with the opportunity to generate storage and chip quality information on newly identified chip processing clones. This information will help to establish the commercial potential of these new varieties. This demonstration storage facility utilizes six, 550 cwt. bulk bins (bins 1-6) that have independent ventilation systems. The second structure, built in 2008, has three, 600 cwt. bulk bins that are independently ventilated. The first of these bulk bins, bin 7, has been converted into box bin storage that holds 36, 10 cwt. box bins to provide storage profiles on early generation potato varieties. The box bin is an entry level point into storage profiling that allows the industry to learn about a varieties' physical and chemical storability before advancing to the bulk bin level. We typically have 4-6 years of agronomic data on a variety before entering box bin testing. In the variety development process, little information has been collected about a varieties' physical storability or chemical storage profile prior to being included in the box bin trial. A storage profile consists of bi-weekly sampling of potatoes to obtain; sucrose and glucose levels, and chip color and defect values. In addition, each variety is evaluated for weight loss or shrinkage and pressure bruise. With this information, the storage history of a variety can be created, providing the industry with a clearer picture of where a line can or cannot be utilized in the snack food industry. The Michigan potato industry hopes to use these storage profiles to improve in areas such as long-term storage quality, deliverability of product and, ultimately, sustained market share.

The two remaining 600 cwt. bulk bins in the second structure are designed to be used to evaluate the post-harvest physiology of the potato. The facility can be used to evaluate storage pathology or sprout inhibitor products. The Michigan industry recognizes the importance of being able to control disease and sprout development in storage and is committed to doing research in these areas.

This twelfth annual Demonstration Storage Report contains the results of the storage work conducted in the facility during the 2012-2013 storage season. Section I, "2012-2013 New Chip Processing Variety Box Bin Report", contains the results and highlights from our 10 cwt. box bin study. Section II, "2012-2013 Bulk Bin (500 cwt. bin) Report", shows bulk bin results, including information from commercial processors regarding these new varieties.

The storage facility, and the work done within it, is directed by the MPIC Storage and Handling Committee and Michigan State University (MSU) faculty. The chair of the committee is Brian Sackett of Sackett Potatoes. Other members of the committee include: Bruce Sackett, Steve Crooks, Todd Forbush, Chris Long, Troy Sackett, Dennis Iott, Keith Tinsey, Mike Wenkel, Duane Anderson, Stephanie Anderson, Loren Wernette, Tim Wilkes, Larry Jensen, Chase Young and Tim Young. The funding and financial support for this facility, and the research that is conducted within it, is largely derived from the MPIC. The committee occasionally receives support for a given project from private and/or public interests.

We wish to acknowledge all the support and investment we receive to operate and conduct storage research. First, we express our gratitude for the partnership we enjoy between the MPIC and Michigan State University. Thank you to the MPIC Storage & Handling Committee

for their investment of time, guiding the decisions and direction of the facility. Steve, Norm and John Crooks, Crooks Farms, Inc.; Brian, Jeff and Alan Sackett, Sackett Potatoes; Jason Walther, Karl Ritchie and Keith Tinsey, Walther Farms; and Tim, Todd and Chase Young, Sandyland Farms; these are the growers that provided the material to fill the bulk bins this year; and without their willingness to be involved, we could not have accomplished our objectives. Equal in importance are the processors who invested in this research. They are Mitch Keeney, Jim Fitzgerald and Jack Corriere of UTZ Quality Foods, Inc., Hanover, PA; Gene Herr of Herr Foods, Inc., Nottingham, PA; Dave Smith of Mike-Sell's Potato Chip, Co., Dayton, OH; and Al Lee and Phil Gusmano of Better Made Snack Foods, Detroit, MI. It has been a great pleasure to work with all of you. Special thanks to Butch Riley (Gun Valley Ag. & Industrial Services, Inc.) for his annual investment in the sprout treatment of the storage facility. We would also like to acknowledge a long list of additional contributors who invested much time to help foster a quality storage program: Dr. Dave Douches and the MSU Potato Breeding and Genetics Program, Todd Forbush (Techmark, Inc), Larry Jensen (Chief Wabasis Potato Growers), and Tim Wilkes (Potato Services of Michigan). All played a role in making this facility useful to the Michigan potato industry.

Overview of the production season *

The overall 6-month average maximum temperature during the 2012 growing season was five degrees higher than the 6-month average maximum temperature for the 2011 season and was four degrees higher than the 15-year average (Table 1). The 6-month average minimum temperature for 2012 was one degree lower than the 15-year average. There were 15 days with recorded temperature readings of 90 °F or above in 2012. There were 143 hours of 70 °F temperatures between the hours of 10 PM and 8 AM which occurred over 30 different days, April to September (Data not shown). There were no days in May that the minimum air temperature was below 32 °F. The average maximum temperature for July 2012 was eight degrees higher than the 15-year average (Table 1). In October 2012, during the period from the 1st to the 20th, there were seven days with no measureable rainfall. For the period from September 15th to October 20th, there were eight days that the minimum air temperature was below 32 °F.

Rainfall for April through September was 12.02 inches, which was 6.6 inches below the 15-year average (Table 2). In October 2012, 4.85 inches of rain was recorded. Irrigation at MRC was applied 13 times from May 24th to September 24th, averaging 0.77 inches for each application. The total amount of irrigation water applied during this time period was 9.95 inches.

* Weather data collected at the MSU, Montcalm Research Center, Entrican, MI.

I. 2012-2013 New Chip Processing Variety Box Bin Report

(Chris Long, Andrew Camp and Brian Sackett)

Introduction

The purpose of this project is to evaluate new chip processing varieties from national and private breeding programs for their ability to process after being subjected to storage conditions. A variety's response to pile temperature, as reflected in sucrose and glucose levels, is evaluated. Weight loss and pressure bruise susceptibility of each variety is also evaluated. Bin 7 contained 36, 10 cwt. boxes. Thirty-six boxes were placed in six stacks of six. The boxes were designed for air to travel in from a header, or plenum wall, through the forklift holes of each box, up through the potatoes within it and onto the next box above until the air reaches the top and is drawn off the top of the chamber, reconditioned and forced back through the header wall plenums and up through the boxes again. Each box contains a sample door facing the center aisle from which tubers can be removed to conduct bi-weekly quality evaluations.

Procedure

Fourteen new varieties were evaluated and compared to the check variety Snowden in 2012. The 15 varieties were chosen by the MPIC Storage and Handling Committee. Once the varieties were chosen, 1 cwt. of each variety was planted in a single 34 inch wide row, on May 7th at the MSU, Montcalm Research Center, Entrican, MI. The varieties were all planted at a 10" in-row seed spacing. All varieties received a rate of fertilizer recommended to achieve a 375 to 425 cwt./A yield (270 lb. N/Acre). The varieties were vine killed after 125 days and allowed to set skins for 14 days before harvest on September 20, 2012; 137 days after planting. Variety maturity is not taken into account in the harvest timing due to storage and handling restrictions.

Approximately ten cwt. of each variety were placed in each box bin, labeled and stacked in bin 7. The average storage temperature for all the box bins (box bin 7) was 54.0 ºF for the 2012-2013 season. At harvest, nine, 20 lb. samples from each variety were collected for weight loss and pressure bruise evaluation. A description of the varieties tested, their pedigree and scab ratings are listed in Table 1. Yield, size distribution, chip quality, and specific gravity were recorded at harvest (Table 2). All 15 varieties were graded to remove all “B” size tubers and pickouts and entered the storage in good physical condition.

The storage season began September 20th, 2012, and ended June 3rd, 2013. Bin 7 was gassed with CIPC on October 19th, 2012, and January 30th, 2013. Variety evaluation began October 22nd, 2012, followed by a bi-weekly sampling schedule until early June. Thirty tubers were removed from each box every two weeks and sent to Techmark, Inc. for sucrose, glucose, chip color and defect evaluation. Nine pressure bruise sample bags were taken for each variety, weighed and placed in one of the bulk bins at the storage facility. Three bags were placed at each of 3’, 8’ and 14’ from the pile floor. When that bin was unloaded, the sample bags were weighed and percent weight loss was calculated. A 25 tuber sample was taken from each of the nine bags and was evaluated for the presence or absence of pressure bruise. The number of tubers and severity of bruise was recorded. All pressure bruises were evaluated for discoloration.

This report is not intended to be an archive of all the data that was generated for the box bin trial, but a summary of the data from the most promising lines. The purpose of this report is to present a summary of information from 2-5 lines from this trial that will be moved along the commercialization process. If more detailed information is desired, please contact Chris Long at Michigan State University in the Department of Plant, Soil and Microbial Sciences for assistance (517) 355-0271 ext. 1193.

Table 1. 2012 MPIC Demonstration Box Bin Variety Descriptions

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

Entry	Pedigree	2012 Scab Rating*	Characteristics
Lamoka (NY139)	NY120 X NY115	1.5	High yield, mid-late season maturity, medium specific gravity, oval to oblong tuber type, low internal defects, long term chip quality
Snowden (W855)	B5141-6 X Wischip	2.6	High yield, late maturity, mid-season storage, reconditions well in storage, medium to high specific gravity
Manistee (MSL292-A)	Snowden X MSH098-2	2.5	Above average yield, common scab susceptible, late blight susceptible, medium specific gravity, long storage potential, uniform tuber type, heavy netted skin, excellent late season chip quality
AF4157-6	Yankee Chipper X Dakota Pearl	1.5	Medium-early maturity, round to oblong netted tubers, good specific gravity, good chip color from the field and storage, common scab susceptible
CO02321-4W	NY115 X BC0894-2W	3.0	Average yield potential, average specific gravity, medium maturity, common scab susceptibility
MSL007-B	MSA105-1 X MSG227-2	1.5	Average yield potential , early to mid-season maturity, uniform tuber type, medium specific gravity, scab tolerant, heavy netted skin
MSN190-2	MSI234-6Y X MSG227-2	1.5	High specific gravity, earlier maturity, black spot bruise resistant, average yield
MSQ086-3	Onaway X Missaukee (MSJ461-1)	1.9	Good yield potential, nice round white tuber type, medium maturity, late blight resistance, good internal quality, medium-low specific gravity
MSQ089-1	A91790-13 X Missaukee (MSJ461-1)	1.9	Above average yield, full season maturity, uniform round tuber type, netted skin
MSR127-2	MSJ167-1 X MSG227-2	1.5	Scab resistant, high specific gravity, good chip quality from storage, above average yield potential, medium-late maturity

*Scab rating based on 0-5 scale; 0 = most resistant and 5 = most susceptible.
Common scab data provided by MSU Potato Breeding and Genetics Program.

Table 1. continued

Entry	Pedigree	2012 Scab Rating*	Characteristics
MSR169-8Y	Pike X MSJ126-9Y	0.8	Below average yield, medium maturity, yellow flesh, average specific gravity, common scab resistant
MSS165-2Y	MSM188-1 X MSL159-AY	1.9	High yield, above average specific gravity, late maturity, uniform round tuber type, heavy netted skin, yellow flesh, good internal tuber quality
NY140	NY121 X NY115	2.8	Late season chip quality, dual purpose chip and table stock, high yields of large tubers, buff textured skin, medium specific gravity
NY148	NY128 X Marcy	1.8	Late season maturity, high specific gravity, scab-resistant chip stock, good yield potential, medium to late season storage quality, black spot bruise susceptible
W4980-1	B0692-4 X W1355-1	2.0	Medium-early maturity for out-of-the-field chipping, moderate yield potential, low set

Common scab data provided by MSU Potato Breeding and Genetics Program.

Table 2. 2012 Michigan Potato Industry Commission Box Bin Processing Potato Variety Trial

2012 Box Bin Processing Potato Variety Trial
MSU Montcalm Research Center, Montcalm County, MI

Harvest 20-Sep-12 136 Days

DD, Base 40[6] 3312

	CWT/A		PERCENT OF TOTAL[1]						CHIP	TUBER QUALITY[2]				TOTAL	VINE	VINE		CHIP
LINE	US#1	TOTAL	US#1	Bs	As	OV	PO	SP GR	SCORE[3]	HH	VD	IBS	BC	CUT	VIGOR[4]	MATURITY[5]	COMMENTS	COMMENTS
NY140	447	492	91	9	85	6	0	1.077	1.0	0	8	0	0	10	3.0	4.0	2.0 scab, bright appearance, large tuber size	8 chips with SED
MSR127-2	440	485	90	10	81	9	0	1.087	1.0	1	2	0	0	10	3.0	3.5	0.5 scab	sl SED in 4 chips, 2 chips with internal browning
MSQ089-1	377	426	88	12	87	1	0	1.073	1.0	0	4	0	0	10	3.0	3.5	3.0 scab	SED in 2 chips
MSS165-2Y	356	400	88	12	85	3	0	1.086	1.5	0	1	1	0	10	2.5	4.5	0.5 scab, yellow flesh	4 chips with SED, obvious yellow color
MSQ086-3	353	426	83	16	82	1	1	1.077	1.0	0	5	0	0	10	2.5	4.0	2.0 scab, bright appearance, gc in pickouts	6 chips with SED
MSL007-B	351	426	82	18	82	0	0	1.076	1.0	0	2	0	0	10	2.0	3.5	0.5 scab, heavy netted skin	10 chips with SED
CO02321-4W	318	401	79	19	79	0	2	1.084	1.0	0	1	0	0	10	3.0	1.5	3.0 scab, bright appearance, round tuber type, misshapen tubers in pickouts	6 chips with SED
NY148	317	448	71	28	69	2	1	1.096	1.0	0	1	0	0	10	3.5	4.0	0.0 scab	8 chips with SED
MSL292-A	315	356	89	11	87	2	0	1.079	1.0	0	5	0	0	10	2.5	2.0	2.0 scab	4 chips with tr SED
W4980-1	313	382	82	17	81	1	1	1.080	1.0	1	1	3	0	10	4.0	2.0	2.0 scab, heat necrosis in three tubers	severe SED in many chips
Snowden	**305**	**423**	**72**	**28**	**70**	**2**	**0**	**1.086**	**1.0**	**0**	**6**	**0**	**0**	**10**	**3.5**	**3.5**	**3.0 scab**	**SED in 2 chips**
Lamoka	297	330	90	7	72	18	3	1.082	1.0	0	8	0	0	10	3.0	3.0	gc in pickouts, 1.0 scab	4 chips with SED
AF4157-6	247	301	82	18	82	0	0	1.083	1.0	0	9	0	0	10	2.5	1.5	2.0 scab	clean
MSN190-2	223	311	71	28	67	4	1	1.091	1.0	0	7	0	0	10	2.0	2.0	0.5 scab, misshapen tubers in pickouts	2 chips with sl SED
MSR169-8Y	145	224	65	35	65	0	0	1.072	1.5	1	0	0	0	10	2.0	1.5	0.0 scab, small tuber type	6 chips with SED
MEAN	**320**	**389**						**1.082**										

tr = trace, sl = slight, N/A = not applicable

SED = stem end defect, gc = growth crack

[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 Association Scale
(Out of the field)
Ratings: 1 - 5
1: Excellent
5: Poor

[4]VINE VIGOR RATING
Date Taken: 6-Jun-12
Ratings: 1 - 5
1: Slow Emergence
5: Early Emergence (vigorous vine, some flowering)

[5]VINE MATURITY RATING
Date Taken: 22-Aug-12
Ratings: 1 - 5
1: Early (vines completely dead)
5: Late (vigorous vine, some flowering)

Planted:	7-May-12
Vines Killed:	6-Sep-12
Days from Planting to Vine Kill:	122
Seed Spacing:	10"
No Fumigation	

[6]MAWN STATION: Entrican
Planting to Vine Kill

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Results: 2012-2013 New Chip Processing Box Bin Highlights

Lamoka (NY139)

In the 2012 Box Bin Trial, Lamoka yielded just below the trial average at 297 cwt./A US#1 with a specific gravity of 1.082 (Table 2). This Cornell University developed clone can have a slightly elongated and pear shaped tuber type in the larger oversized tubers, but has great yield potential, excellent chip quality and some moderate common scab tolerance.   NY139 expresses better common scab tolerance and longer term chip quality than the check variety Snowden.   The vine maturity for NY139 in the 2012 Box Bin trial was medium-late. A nine to ten inch in-row seed spacing in central Michigan would be recommended for this variety because it can oversize. Even with the reduced yield in the 2012 trial, Lamoka recorded 18 percent of the total yield as oversize tubers. Out-of-the-field chip quality was good with only a trace of stem end defect reported. NY139 was placed into storage on September 20th, 2012. The first sugar measurement was taken on October 22nd and was recorded as follows; 0.694 percent sucrose (X10) and a 0.001 percent glucose. The sucrose and glucose levels were at their lowest in early February at 0.408 percent (X10) and 0.001, respectively. The picture above shows NY139 in late April 2013 with a 0.727 percent (X10) sucrose and a 0.001 glucose value. From mid to late May 2013, the sugar levels in storage rose significantly, affecting chip quality in a negative manner. The storage pulp temperature in this bin remained around 54.0 °F season long. Lamoka performed well even at this warm storage temperature. This variety continues to exhibit excellent chip quality from storage late in the season and this will only be extended with cooler storage temperatures. The tuber percent weight loss was not reported, but 24.4 percent of the tubers were recorded as having bruise and discoloration under the skin. These tubers were stored in a bulk bin that contained another experimental line which had 6.7 percent pressure bruise with discoloration. The bin was unloaded on June 3rd, 2013, and the pressure bruise evaluations were performed on June 10th, 2013. NY139 appears to be as susceptible as other varieties to pressure bruise. Overall, this variety has great commercial potential. Its' yield and chip quality provide the industry with some potential improvements in duration of storability and common scab tolerance. Some questions have been raised regarding this varieties' potential susceptibility to storage rots. NY139's response to storage rot under commercial storage conditions will need to be tested in subsequent years and variety commercialization advanced slowly.

MSL007-B

This Michigan State University (MSU) chip processing variety has common scab tolerance and a uniform round tuber type with a heavy netted skin. The specific gravity for this variety was 6 points below the trial average at 1.076. The recorded US#1 yield for this variety was above the trial average in the 2012 Box Bin Trial at 351 cwt./A (Table 2). The variety appears to have a medium maturity with a good set of medium sized tubers (Table 1). The internal quality was good with no hollow heart reported at harvest in the raw tubers. Moderate stem end defect (SED) was reported in the out-of-the-field chip sample. The out-of-the-field chip color appeared to be good, scoring a 1.0 SFA score (Table 2). During the 2012-2013 storage season, MSL007-B was placed into storage on September 20th, 2012. A sugar reading was recorded for the first time on October 22nd at a percent (X10) sucrose value of 0.585 and a glucose value of 0.003 percent. The sucrose values remained stable until mid-April when they began to increase until the end of the storage season in early June. The percent glucose remained relatively high all season, ranging from 0.003 in late October 2012 to 0.016 in early June, 2013. A chip picture is included from April 22nd, 2013, to show the chip quality during this period. The sucrose and glucose values on this day were 0.636 percent (X10) and 0.005 percent, respectively and rising. This variety appears to have a significant stem end reaction most growing seasons. The percent weight loss recorded for this variety at the time of bin unloading was 3.83, with 12.2 percent of the tubers evaluated expressing bruise with discoloration under the surface of the skin. These numbers are average with respect to other varieties evaluated this season. Overall, this variety performed well agronomically, but the chip quality, this season, appears to be marginal. Further testing of this clone will continue in hopes of replacing Snowden acreage with a variety that has common scab resistance. Concern is warranted when considering commercialization of this clone based on the amount of stem end defect present from year to year.

Manistee (MSL292-A)

This Michigan State University (MSU) chip processing variety has excellent late season chip quality, a uniform round tuber type with a good netted skin. The specific gravity for this variety was slightly below the trial average at 1.079. The recorded US#1 yield for this variety was at the trial average in the 2012 Box Bin Trial at 315 cwt./A (Table 2). The internal quality was excellent with no hollow heart reported at harvest in the raw tubers. Only a trace of stem end defect (SED) was reported in the out-of-the-field chip sample. The out-of-the-field chip color appeared to be good, scoring a 1.0 SFA score (Table 2). MSL292-A was placed into storage on September 20th, 2012. The first sugar data was recorded on October 22nd, 2012, and was reported as having a percent (X10) sucrose value of 0.735 and a glucose value of 0.002 percent. The sucrose values decreased slowly October 2012 through February 2013, reaching the lowest point in late February at 0.441 percent (X10) sucrose value. The percent glucose remained low season long, ranging from 0.002 in late October 2012 to 0.003 in late May 2013. A chip picture is included from April 22nd, 2013, to show the chip quality during this period. The sucrose and glucose values on this day were 0.772 percent (X10) and 0.001 percent, respectively. Chip quality was excellent on this day, but went off shortly after given the warm storage temperature of 54.0 °F. The percent weight loss recorded for this variety at the time of bin unloading was 3.11, with 5.1 percent of the tubers evaluated expressing bruise with discoloration under the surface of the skin. These numbers are lower than the majority of the varieties evaluated this season. Overall, this variety performed well agronomically with excellent late season chip quality observed. Further testing of this clone will continue in hopes of replacing Snowden acreage from late storage.

MSR127-2

This Michigan State University (MSU) chip processing variety has common scab tolerance and a uniform round tuber type. The specific gravity for this variety was 1.087. The recorded US#1 yield for this variety was above the trial average in the 2012 Box Bin Trial at 440 cwt./A (Table 2). The variety appears to have a medium-late maturity with a good set of tubers. The internal quality was good with one hollow heart and no vascular discoloration reported at harvest in the raw tubers. Moderate stem end defect (SED) was reported in the out-of-the-field chip sample. The out-of-the-field chip color appeared to be good, scoring a 1.0 SFA score (Table 2). A few minor chip defects were noted. During the 2012-2013 storage season, MSR127-2 was placed into storage on September 20th, 2012 and evaluated a month later for sugar stability. On October 22nd, 2012, MSR127-2 had a percent (X10) sucrose value of 0.460 and a glucose value of 0.001 percent. The sucrose percent (X10) values remained somewhat flat, ranging from 0.460 in late October to 0.507 in mid-March. The percent sucrose increased steadily from late March to the end of the storage season. The percent glucose remained low all season until early April 2013 at which time it rose quickly. A chip picture is included from March 18th, 2013, to show the chip quality during this period. The sucrose and glucose values on this day were 0.507 percent (X10) and 0.001 percent, respectively. MSR127-2 appears to have good mid-season chip processing quality. The percent weight loss recorded for this variety at the time of bin unloading was 3.4, with 12.0 percent of the tubers evaluated expressing bruise with discoloration under the surface of the skin. These numbers are similar to the majority of the varieties evaluated this season. Overall, this variety performed well, attaining the second highest US#1 yield in the 2012 trial. This variety is on track for larger scale testing in 2015.

NY148 (NYE106-4)

This Cornell University developed variety exhibited an above average specific gravity in the 2012 Box Bin Trial. The specific gravity was the highest in the trial at 1.096. The recorded yield for NY148 was 317 cwt./A US#1 (Table 2). This variety exhibits a stronger than normal vine vigor, resulting in what appears to be a late vine maturity. The out-of-the-field chip sample scored a 1.0 SFA score with some stem end defect reported. On October 22nd, 2012, the percent sucrose (X10) was 0.802 and percent glucose was 0.005. Sucrose and glucose levels came down to their lowest points in mid-February at 0.473 percent (X10) and 0.001, respectively. At this point in storage, the sucrose values began to rise to 1.017 percent (X10) in late May 2013. From mid-January 2013 until late April 2013, the glucose level remained at or below 0.002 percent. Total defects recorded for this variety in late April 2013 were 5.7 percent. The picture above captured NY148 at its latest acceptable chip quality point from storage on April 22nd, 2013. The percent sucrose (X10) and glucose were 0.662 and 0.002 on this date. The percent weight loss recorded at the time of bin unloading for this variety was 3.78, with 32.7 percent of the tubers evaluated expressing bruise with discoloration under the surface. This variety has exhibited a very high level of susceptibility to pressure bruising. This variety has excellent yield potential and moderate common scab tolerance, but chip quality appears to be questionable out of storage due to the accumulation of physical defects. Further storage and chip quality testing is required before this clone should be considered for commercialization.

Snowden

This variety is included as a reference point for the 2012 Box Bin Trial. The recorded yield for the Snowden variety was 305 cwt./A US#1 with a 1.086 specific gravity (Table 2). This variety yielded below the trial average in 2012. On September 20^{th}, 2012, this variety was put into storage and a month later was analyzed for sucrose and glucose concentration. On October 22^{nd}, 2012, a 0.658 percent sucrose (X10) and a 0.002 percent glucose value was recorded. Sucrose and glucose levels came down to their lowest points in mid-January at 0.378 percent (X10) and 0.001, respectively. From this point in storage, the sucrose values began to rise to 1.062 percent (X10) in mid-April 2013. The percent glucose level was at 0.008 on this date. The chip picture above depicts Snowden during its last acceptable chip quality period in 2013. Total defects recorded for this variety on March 18^{th}, 2013, were 8.7 percent with a percent sucrose (X10) of 0.811 and a percent glucose of 0.002. The percent weight loss recorded at the time of bin unloading for this variety was 7.85, with 4.4 percent of the tubers evaluated expressing bruise with discoloration under the surface.

II. 2012 - 2013 Bulk Bin (500 cwt. Bin) Report

(Chris Long, Brian Sackett and Andrew Camp)

Overview

The goal of the MPIC Storage and Handling Committee for the 2012-2013 bulk bin storage season was to develop storage profiles on three promising advanced clones (Section A. of this report) and begin the evaluation of Ozone gas injection into bulk piled potatoes as a means of stopping or slowing the development of storage pathogens (Section B. of this report). Four fungi that are commonly implicated in potato storage breakdown are; Soft Rot (*E. c. atroseptica*), Dry Rot (*Fusarium spp.)*, Pink Rot (*P. erythroseptica*), and Pythium Leak (*P. ultimum*). These four pathogens were inoculated into bulk piles and challenged with Ozone gas. The severity of tuber rot was subsequently evaluated. The Storage and Handling Committee has made these two areas, variety development and storage pathology, the focal points of the 2012-2013 storage research season.

Section A. Introduction to Variety Commercialization

The first variety tested for storage profiling in the 2012-2013 storage season was Lamoka (NY139), a clone from the potato breeding program at Cornell University, Ithaca, NY. This variety has a strong yield potential, specific gravity, great late-season chip quality and good common scab tolerance. As the tubers become larger, they tend to be more pear to oval shaped. More stem end defects are present in the larger tubers, so managing tuber size profile is important in this variety. Lamoka has a thin, smooth skin. The second variety tested was MSL292-A, a new long-term storage, chip processing variety from the Potato Breeding and Genetics Program at Michigan State University. This clone has a high, overall average yield of US#1 size tubers, with a uniformly netted skin. The specific gravity is medium. Tuber type can be compressed, apical to stem end, but in general this occurs only in a small percentage of the total tuber number. The variety has a common scab susceptibility similar to Snowden. The final variety tested was MSJ126-9Y. This variety has been in the facility previously, but due to a variety mix, was not able to complete the storage profile process. MSJ126-9Y is a mid-season storage variety with an average yield of uniform round, netted tubers. The specific gravity is medium. The flesh color of this clone is light yellow to yellow. The tuber size profile is generally medium and the variety has excellent common scab resistance.

For each of the varieties listed above, a brief description of agronomic and storage performance is provided. In addition, a short description of pressure bruise susceptibility, chip color and color defects, sugar accumulation and overall chip quality is given. With this information, a clearer perspective can be obtained regarding the viability of these varieties in commercial production.

Procedure

Each bin was filled under contract with potato producers in the state of Michigan. The MPIC paid field contract price for the potatoes to be delivered to the demonstration storage. Pressure bruise samples were collected for each bulk bin and designated bulk bins were filled. The varieties and their storage management strategies were established by the MPIC Storage and Handling Committee. For each bulk bin filled, a corresponding box bin containing 10 cwt. was filled and placed into bin 7. Bin 7 was held at a warmer temperature, in most cases, than the corresponding bulk bin of the same variety. This allowed the committee to see if the warmer storage temperature in the box bin would reduce storage life and provided information as to how the bulk bin might physiologically age.

In the 2012-2013 storage season; bins 1, 2, 3 and 4 were filled with Lamoka (NY139); bin 5 was filled with MSL292-A (Manistee); and bin 6 with MSJ126-9Y. The Lamoka's in bulk bins 1-2 were grown by Walther Farms. Sackett Potatoes produced the Lamoka's in bulk bins 3-4 and Sandyland Farms grew the MSL292-A (bulk bin 5) and MSJ126-9Y (bulk bin 6).

Bin 1 was filled on September 21st, 2012. The seed was planted April 24th, 2012, and vine killed on September 4th, 2012 (134 DAP, 3987 GDD_{40}). The variety was harvested September 21st, 2012; 151 days after planting. The pulp temperature for bulk bin 1 Lamoka's, at the time of bin loading, was 57.7 ºF. Average to above average tuber size, oval to oblong tuber appearance and minor tuber skinning was observed at the time of bin loading. The planting, vine kill and harvest dates for bin 2 are identical to that reported for bin 1. The pulp temperature for bulk bin 2 Lamoka's, at the time of bin loading, was 57.0 ºF. Tuber condition reported in bin 1 was similar in bulk bin 2.

Bin 3 was filled on September 25th, 2012. They were planted May 14th, 2012, and vine killed on September 4th, 2012 (114 DAP, 3134 GDD_{40}). The variety was harvested September 21st, 2012; 135 days after planting. The pulp temperature for bulk bin 3 Lamoka's, at the time of bin loading, was 55.2 ºF. The planting, vine kill and harvest dates for bin 4 are identical to that reported for bin 3. The pulp temperature for bulk bin 4 Lamoka's, at the time of bin loading, was 55.7 ºF.

Bin 5 was filled on October 17th, 2012. They were planted May 22nd, 2012, and vine killed on September 17th, 2012 (109 DAP, 3244 GDD_{40}). The variety was harvested October 17th, 2012; 149 days after planting. The pulp temperature for bulk bin 5, containing MSL292-A, at the time of bin loading was 51.2 ºF.

Bin 6 was filled on October 17th, 2012. They were planted May 22nd, 2012, and vine killed on September 17th, 2012 (109 DAP, 3244 GDD_{40}). The variety was harvested October 17th, 2012; 149 days after planting. The pulp temperature for bulk bin 6, containing MSJ126-9Y, at the time of bin loading was 55.2 ºF. Black spot bruise samples were taken on each bin at the time of bin loading. The results indicated that the tubers in bin 1 were 88% bruise free, the tubers in bin 2 were 74% bruise free, the tubers in bin 3 were 92% bruise free, the tubers in bin 4 were 86% bruise free, the tubers in bin 5 were 62% bruise free and the tubers in bin 6 were 80% bruise free.

Bins 1, 2, 3 and 4 were gassed with CIPC on October 18th, 2012. Bins 5 and 6 were gassed with CIPC November 7th, 2012. On December 7th, 2012, bins 1, 2, 3 and 4 were gassed for a second time with CIPC. Bin sugar monitoring began the day the tubers were placed into storage and was evaluated on a two week sampling schedule thereafter. Forty tubers were removed from the sample door in each bin every two weeks and sent to Techmark, Inc. for sucrose, glucose, chip color and defect evaluation. The sample door is located in the center back side of each storage bin and is an access door that allows samples to be taken from the pile three feet above the bottom of the pile. Pressure bruise evaluation began by collecting nine, 20 to 25 lb. tuber samples as each bin was being filled. Three samples were placed at each of three different levels within the bulk bin pile at 3, 8, and 14 feet from the storage floor.

The pressure bruise samples were evaluated 3 to 5 days after the bin was unloaded. A set of 25 tubers was randomly selected from each bag and visually inspected for pressure bruise. Each bruise was evaluated for discoloration by removing the tuber skin with a knife. A visual rating was given to the bruise for the presence or absence of flesh color (blackening of flesh). Percent weight loss in each tuber sample was calculated as it was removed from the storage.

Objective

The Storage and Handling Committee's objective in testing the Lamoka in bulk bins 1-4 was to: a.) determine the effect of in-row seed spacing on tuber size and evaluate the effect of tuber size on stem end defect formation (bulk bins 1-2); b.) determine the optimal storage temperature for Lamoka, while maintaining acceptable storage and chip quality (bulk bins 3-4). Also of interest was the level of pressure bruise damage that may be incurred at a given storage temperature. For bulk bins 5 and 6, the objective was to determine the optimal storage temperature for both varieties (MSL292-A and MSJ126-9Y) that produce the best chip quality at the latest possible point in the storage season. Weight loss and pressure bruise will be evaluated in each of these bins also.

Bulk Bin 1, Lamoka (NY139)

Lamoka is a common scab tolerant, round to oval shaped chip processing variety from Cornell University. The variety produces good chip quality from 48 ºF long-term storage. In the 2012 on-farm variety trials, this line yielded 422 cwt./A US#1. The specific gravity of this variety averages between 1.078-1.085. Potential drawbacks of this variety could be Black Leg, Pythium Leak, Pink Rot and Black Heart susceptibility. These defects need to be evaluated more extensively over different environments and years.

Figure 1. Techmark-Inc. chip picture, bulk bin 1 Lamoka, 2.18.13

For the 2012-2013 storage season, this variety was grown by Walther Farms, Three Rivers, Michigan, which is located in St. Joseph County. The tuber pulp temperature upon arrival at the storage was 57.7 ºF. The variety was tested and found to be 88 percent black spot bruise free after bin loading. The tuber quality was generally good with some slight skin feathering present. The larger tubers were oval to oblong in appearance. Subjectively, the tubers appeared to have a smaller general size profile than bin 2. The potatoes in bulk bin 1 were planted with a 9 inch in-row seed spacing. This bin was held for a period of suberization (57-58 °F) before cooling. Some internal sugar color and sugar related defects were present from the time of bin loading until early December, 2012, consequently the pile temperature was maintained around 56.0 °F until sugar related defects decreased in late December. Early January, 2013, sugar levels were monitored as the pile was cooled to a target storage temperature of 50.0 °F.

At the time of bin loading on September 21st, 2012, the tuber sucrose and glucose concentrations were 0.935 percent (X10) and 0.003 percent, respectively. In early December, 2012, the sucrose value had dropped to 0.492 percent (X10) with 11.7 percent total defects reported. The pile was allowed to continue to cool. The Lamoka's in this bin recorded their lowest sucrose and glucose values of the season at 0.350 percent (X10) sucrose and 0.001 percent glucose on February 18th, 2013, with a pile temperature of 49.8 °F. See the Techmark Inc. February 18th generated photo which correlates to these sugar numbers (Figure 1). One chip in this photo does show a trace of stem end defect. Bin 1 was chip processed on February 18th, 2013, due to the presence of wet breakdown in the bulk pile related to what was thought to be tuber Black Leg or bacterial rot. The pile ending pulp temperature was 49.8 °F when shipped on February 18th, 2013, to Better Made Inc., Detroit, MI. At the time of bin unloading, tuber weight loss was 7.18 percent, with 3.0 percent of the tubers that expressed pressure bruise having discoloration under the skin. This variety appears to pressure bruise similarly to other varieties, but the discoloration under the pressure bruise area was observed at a very low incidence level. When processed at Better Made Inc. on February 18th, the Lamoka's were reported to have a 1.080 specific gravity. Better Made scored the finished chips with 7 percent total defects, 2 percent sugar related, 2 percent internal and 3 percent external. Ten percent bruising and two percent Dry Rot were reported in the raw tuber grade report. The Agtron score was reported to be 79.1. Figure 2 represents a chip quality grade sample conducted

Figure 2. MSU grade sample from bin 1 processed at Better Made, Inc. on 2.19.13

on finished product from the Better Made processing run of Lamoka by Michigan State University Potato Extension based on MSU evaluation criteria. Our color defects and internal defects scores were similar to Better Made data, but our external finished chip score was closer to 8-9 percent.

Lamoka continues to exhibit good agronomic quality, such as high yield potential, common scab tolerance and good chip quality in small test plots. Encouraging this variety to set good skins before harvest and storage will be important for its commercialization. Managing diseases such as Soft Rot, Dry Rot and Pythium Leak in the field will be important for the future of this variety also. The high degree of stem end defects observed in this variety from bulk bin 1 finished chips (Figure 2) was believed to be due to poor irrigation management on a large sand knoll that created a very stressful environment for the tubers to grow under, resulting in the on-set of this defect. Lamoka has shown to be a 130 day potato, slightly later than the standard chipping variety Snowden. Managing nitrogen application may also help to ensure a better skin set on this variety at harvest. Overall, this variety has many great qualities and needs to be evaluated in more large acreage trials for a number of years to better understand its physical and chemical storability.

Bulk Bin 2, Lamoka (NY139)

Figure 1. Techmark-Inc. chip picture, bulk bin 2 Lamoka, 5.6.13

Lamoka in bulk bin 2 was grown under identical conditions as the tubers in bulk bin 1, both bulk bins being produced by Walther Farms, Three Rivers, MI. The tuber pulp temperature of the Lamoka tubers in bin 2 upon arrival on September 21st, 2012, was 57.0 ºF. The sucrose and glucose levels at the time of bin loading were 0.802 percent (X10) and 0.002 percent, respectively. The tubers were tested and found to be 74 percent black spot bruise free after bin filling. The tuber quality was acceptable, but moderate skin feathering was observed at the time of bin loading. Similar to bulk bin 1, bin 2 was held at 58.0 ºF for wound healing until early November. There were significant amounts of internal and external chip related defects early in the storage season resulting in the bin's holding temperature remaining around 55.0-56.0 °F until early December 2012. From mid-December, the pile was cooled slowly until reaching the desired holding temperature of 49.8 °F in early February 2013. Sugar levels were monitored as the pile was cooled. Sucrose and glucose levels reached their lowest levels early February 2013, through mid-March 2013, ranging from 0.415 to 0.391 percent (X10) sucrose with a constant 0.001 percent glucose level during this same time period. The sucrose and glucose levels began rising in mid-April and continued until the time of bin shipping in early May. The sucrose and glucose values just prior to processing were 0.591 percent (X10) and 0.003 percent, respectively. See the Techmark Inc. May 6th generated photo which correlates to these sugar numbers (Figure 1). Some severe stem end defect was still present at the time of processing.

Bin 2 was chip processed at Mike-Sell's Potato Chip Co. on May 7th. No further processing information was available from this load of potatoes. At the time of bin unloading, tuber weight loss was 13.52 percent, with 7.1 percent of the tubers expressing pressure bruise and discoloration under the skin. This variety appears to pressure bruise similarly to other varieties, and the discoloration under the pressure bruise area was observed at a more moderate rate than in bin 1. The number of pressure bruises with discoloration under the skin may have been elevated due to the duration of the tubers in storage and the high air volume in the storage bin causing a higher percentage of tuber dehydration.

Lamoka has exhibited great agronomic quality as previously mentioned. Encouraging good skin set will be very important prior to harvest and before storage to ensure physical storability. Managing nitrogen application may help to reduce excess vine growth. Managing in-field bacterial diseases such as aerial vine rot will be important to reduce inoculum load brought into storage. Seed spacing will be a good tool to use to manage overall tuber size, thus reducing internal tuber defects such as stem end. In southern Michigan counties, this variety would best be planted at an 8-9 inch in-row seed spacing. In Central Michigan, the in-row seed spacing can be widened to a 9-10 inch in-row seed spacing.

Bulk Bin 3, Lamoka (NY139)

For the 2012-2013 storage season, the potatoes in bin 3 were grown by Sackett Potatoes, Mecosta, Michigan. The tuber pulp temperature upon arrival at the storage was 55.2 ºF. The variety was tested and found to be 92 percent black spot bruise free after bin loading. The tuber quality was good with a medium tuber size profile of round to oval shaped tubers. The potatoes in bulk bin 3 were planted with a 10 inch in-row seed spacing. This bin was held for a two week period of suberization (57-58 °F) before cooling. Some internal sugar color and sugar related defects were present from the time of bin loading until early December 2012. The pile temperature was cooled slowly to 52.0 °F as not to impede reparation of the free sugar present. Upon reaching 52.0 °F in early December and seeing that defect levels continued to decline, the pile temperature was cooled to 50.0 °F in mid-late December and held there for the season.

Figure 1. Techmark-Inc. chip picture, bulk bin 3 Lamoka, 2.18.13

At the time of bin loading on September 25th, 2012, the tuber sucrose and glucose concentrations were 0.553 percent (X10) and 0.001 percent, respectively. In early December, 2012, the sucrose value had remained stable at 0.557 percent (X10). The Lamoka's in this bin recorded their lowest sucrose and glucose values of the season at 0.434 percent (X10) sucrose and 0.001 percent glucose on February 18th, 2013, with a pile temperature of 49.6 °F. See the Techmark Inc. February 18th generated photo which correlates to these sugar numbers (Figure 1). The chip quality at this time in storage was excellent. Most of the external defects, mainly stem end defect had conditioned out of the tubers by this date. This was very exciting to see Lamoka metabolize out these free sugars. Bin 3, like bin 1 was shipped for processing on February 18th, 2013, due to the presence of wet breakdown in the bulk pile which was related to tuber Black Leg and general bacterial rot. The pile ending pulp temperature was 49.8 °F when shipped on February 18th, 2013, to Herr Foods, Inc., Nottingham, PA. At the time of bin unloading, tuber weight loss was 3.84 percent, with 1.8 percent of the tubers that expressed pressure bruise having discoloration under the skin. This variety appears to pressure bruise similarly to other varieties, but the discoloration under the pressure bruise area was observed at a very low incidence level. When processed at Herr Foods on February 19th, the Lamoka's were reported to have a 1.080 specific gravity. The Agtron score was reported to be 64.3. Herr's reported the finished product to have good overall color with a total defect score of 4-5 percent. Figure 2 represents a chip quality grade sample conducted on finished product from the Herr's processing run of Lamoka by Michigan State University Potato Extension based on MSU evaluation criteria. Our color defects and internal defects scores were similar to Herr's data, but our external finished chip score was 6 percent. The MSU total defect score was 10 percent.

Figure 2. MSU grade sample from bin 3 processed at Herr Foods, Inc. on 2.19.13

These potatoes had a low incidence of black spot bruising at the time of bin loading which makes it difficult to understand what drove the tubers to wet breakdown. Lamoka continues to show that it has susceptibility to storage rot. Tuber skin set did not appear to be a problem at the time of harvest. The 2012 growing season was hot and the potato crop did experience a lot of heat stress which most likely drove the stem end issues observed this year, but the storage rot continues to be a concern. Increasing fungicide applications at the time of blossom drop may be helpful to reduce vine rots. Lamoka has many great qualities and needs to be evaluated in more large acreage trials for a number of years to better understand its physical and chemical storability.

Bulk Bin 4, Lamoka (NY139)

Figure 1. Techmark-Inc. chip picture, bulk bin 4 Lamoka, 4.1.13

For the 2012-2013 storage season, the potatoes in bin 4 were grown by Sackett Potatoes, Mecosta, Michigan. The tuber pulp temperature upon arrival at the storage was 55.7 ºF. The variety was tested and found to be 86 percent black spot bruise free after bin loading. The tuber quality was good with a medium tuber size profile of round to oval shaped tubers. The potatoes in bulk bin 4 were planted with a 10 inch in-row seed spacing. This bin was held for a two week period of suberization (57-58 °F) before cooling. A minor amount of sugar related defects were present from the time of bin loading until mid-November 2012. This bin contained surprisingly fewer chip defects early in storage when compared to the potatoes in bin 3 that were from the same field. The pile temperature was cooled from 56.6 °F in late October to a holding temperature of 47.0 °F in early February 2013. No sharp increase in sucrose was observed over this cooling period. Total chip defects were minimal after the 1st of December.

At the time of bin loading on September 25th, 2012, the tuber sucrose and glucose concentrations were 0.553 percent (X10) and 0.001 percent, respectively. In early December, 2012, the sucrose value had remained stable at 0.548 percent (X10). The Lamoka's in this bin recorded their lowest sucrose and glucose values of the season of 0.432 percent (X10) sucrose and 0.001 percent glucose on March 18th, 2013, with a pile temperature of 46.8 °F. The Techmark Inc. April 1st, generated photo represents the chip quality of Lamoka at this period in storage (Figure 1). The sucrose value rose from 0.432 percent (X10) on March 18th, to 0.452 percent (X10) on April 1st. The glucose reading of 0.001 percent did not change over this same time frame. The chip quality at this time in storage was excellent. Most of the external defects, mainly stem end defect had conditioned out of the tubers by mid-November 2012. Based on the need to meet shipping requirements of participating entities, this bin was shipped on April 1st. Little, if any, bacterial breakdown was observed in this bin and was not the factor that pushed the processing date of this bin. The bin was shipped to meet cooperator scheduling. The pile ending pulp temperature was 46.8 °F when shipped on April 1st, 2013, to Shearer's Foods, Brewster, OH. At the time of bin unloading, tuber weight loss was 4.50 percent, with 3.1 percent of the tubers that expressed pressure bruise having discoloration under the skin. These values were excellent. The fewer defects in the potato tubers allowed the cooling of the bin to be a colder holding temperature than bins 1-3. Tuber quality was generally better in bin 4 than the other Lamoka bins and this was clearly reflected in the April chip quality data. When processed at Shearer's on April 1st, the Lamoka's were reported to have a 1.075 specific gravity. The Agtron score was reported to be 64.0. Shearer's reported the finished product to have a total defect score of 4 percent. One percent was color related defects and three percent were external and stem end related defects. Figure 2 represents a chip quality grade sample conducted on finished product from the Shearer's processing run of Lamoka by Michigan State University Potato Extension based on MSU evaluation criteria. The MSU total defect score is slightly higher for the continuous fry process.

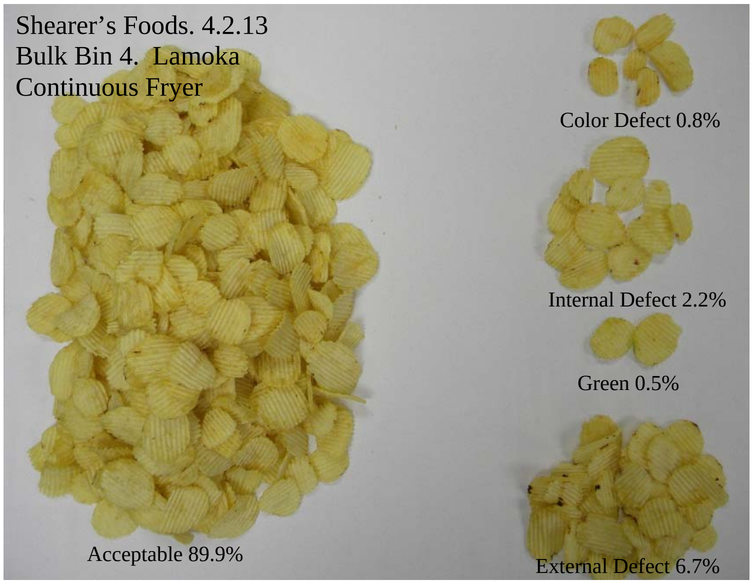

Figure 2. MSU grade sample from bin 4 processed at Shearer's Foods on 4.2.13

These potatoes had the best chip processing quality of the four Lamoka bins evaluated in 2012-2013. Small tuber size and less heat stress under Central Michigan production conditions played a role in the improved chip quality. The tubers physically held-up better in bin 4 than any of the other bins, providing more time to condition out any free sugars. Lamoka processed well at Shearer's both under the continuous and kettle fry process. When processed on

Figure 3. MSU grade sample from bin 4 processed at Shearer's Foods on 4.2.13

the kettle fryer, this bin of Lamoka's had only 2 percent total defects recorded at Shearer's. MSU chip evaluation produced a slightly higher number of total defects (Figure 3).

Bulk Bin 5, MSL292-A (Manistee)

MSL292-A is a Michigan State University developed variety. In the 2012 on-farm trials, this variety yielded 400 cwt./A US#1 when averaged over eight locations. The specific gravity ranges from 1.075 to 1.085. This variety also has a uniform round tuber type. A small percentage of tubers may be compressed, apical to stem end. The skin has a uniform heavy netted appearance. MSL292-A exhibits moderate common scab suceptibility similar to Snowden. An in-row seed spacing of 10 to 12 inches is recommended. The tuber set per plant is approximately 10-16 tubers.

Figure 1. 6.3.13 Techmark Inc. chip picture of MSL292-A just prior to processing

The MSL292-A potatoes in bin 5 were grown by Sandyland Farms in Montcalm County, Michigan and were harvested and loaded into storage on October 17th with a pulp temperature of 51.2 ºF. The overall size profile of the tubers was good. The potatoes were determined to be only 62% bruise free after bin loading. The tubers were warmed to 55.0 °F after arrival and allowed to remain at this temperature to suberize for two weeks. The percent sucrose reading in early November 2012 was 0.871 percent (X10). The glucose value was 0.002 percent at this same time. After suberization, the tubers were then cooled slowly until the potatoes reached a pulp temperature of 50.0 ºF in early February 2012, at which time the sucrose and glucose levels were evaluated. In early February, the sucrose value was 0.641 (X10) percent and the glucose was 0.001 percent. The pulp temperature was held at 50.0 °F February through early May 2013. In mid-March 2013, the sucrose and glucose reached their lowest levels of the season at 0.434 percent (X10) and 0.001 percent, respectively. From mid-March, sucrose levels rose steadily into early June 2013. MSL292-A was shipped to Utz Quality Foods, Hanover, PA on June 3rd, 2013. The sucrose and glucose readings at the time of shipping were 0.613 percent (X10) and 0.003 percent glucose. The pile temperature was 52.0 ºF on the date of shipping. Figure 1 depicts the chip quality of the MSL292-A tubers on the day of bin unloading. Chip processing quality was exceeded in these potatoes by 7-10 days based on the sucrose values. Pressure bruise data from this bin at the time of bin unloading indicated that 6.7 percent of the tubers evaluated exhibited pressure bruise with discoloration under the skin.

Figure 2. Raw tuber quality as observed at Utz Quality Foods, bin 5 MSL292-A on 6.4.13

Figure 2 depicts the overall raw tuber quality prior to processing at Utz on June 4th, 2013. Pressure bruising was evident on about 10 percent of the MSL292-A tubers. Specific gravity was reported to be 1.074 at Utz. The tubers had a good average size profile. Figure 3 depicts the finished chip quality from the processing of MSL292-A at Utz on June 3rd, 2013. The average percent total chip defects was 4 percent. This consisted of 2 percent external defects, which were mainly pressure bruise, and 2 percent internal defects, mostly internal discoloration and hollow heart. The chip quality performance of this load of MSL292-A was compared to fresh crop Atlantic that were processed at Utz during this same time frame in early June 2013. The Atlantic's had an average reported Hunter value of 62.2 compared to the Hunter value of 61.9 on this load of MSL292-A from 7.5 months of storage at the MPIC Demonstration Storage Facility. The Atlantic's averaged 9.6 percent total defects. Figure 4 represents a chip quality grade sample conducted on finished product from the Utz processing run of Atlantic's by Michigan State University Potato Extension based on MSU

Figure 3. Finished chip quality as observed at Utz Quality Foods, bin 5 MSL292-A on 6.4.13

evaluation criteria. The MSU total defect score is higher than that reported by Utz. It appears the majority of the Atlantic chip defects are external, possibly Pinkeye or bacterial rot and related heat stress.

MSL292-A appears to have very good late season chip quality as confirmed by this processing run at Utz on June 4th, 2013. The chip quality may have been slightly better if this load was processed 7-10 days earlier. The physical tuber quality of this variety held-up season long with no rot observed at the time of bin unloading. Overall, the general agronomic qualities of MSL292-A appear to be good. Some common scab susceptibility has been observed. Tuber shape did not appear to be a concern in this processing run.

Figure 4. Finished chip quality as observed at Utz Quality Foods, fresh crop Atlantic's on 6.4.13

Bulk Bin 6, MSJ126-9Y

MSJ126-9Y is a variety from the Potato Breeding and Genetics program at Michigan State University. This variety has medium tuber size with a uniform round tuber appearance and light yellow flesh. The common scab tolerance of this variety is very good, similar to, and possibly slightly better than Pike. This variety has an average yield of uniformly shaped tubers. The specific gravity, on average, ranges from 1.074 to 1.082 in Michigan. The MSJ126-9Y in bin 6 was

Figure 1. Techmark Inc. chip picture of MSJ126-9Y just prior to processing at Shearer's on 4.2.13

grown in Montcalm County, Michigan by Sandyland Farms. The storage was filled on October 17th with a pulp temperature of 55.2 ºF. The variety was evaluated to be 80 percent black spot bruise free after bin loading. Tuber size, skin type and overall appearance was very nice at the time of bin loading.

The variety was warmed to 57 ºF after arrival to encourage wound healing and suberization. The tubers arrived with a significant amount of stem end and vascular discoloration, consequently the pile temperature was maintained at 56.0 ºF to encourage the metabolism of free sugar. In early November, bin 6 recorded a 0.849 percent (X10) sucrose and a 0.003 percent glucose level with 42.4 percent total chip defects. In early December, the percent (X10) sucrose and glucose levels decreased to 0.611 and 0.001, respectively, with 18.8 percent total defects reported. The pile temperature was cooled to 52.0 °F in late December, 2012, resulting in a slight rise in the sucrose level which remained elevated during the month of January 2013. In early February, the sucrose concentration further declined along with the total defect score and the pile was cooled to 50.0 °F. A sucrose rise was observed again as the pile was cooled and the cooling process was halted. In early March, the pile temperature was stabilized at 51.0 °F. The lowest sucrose and glucose values were recorded in late February with a 0.516 percent (X10) sucrose level and a 0.001 percent glucose value. Total defects were reported at 9.6 percent on this date. Sucrose levels were quite variable through

Figure 2. MSU grade sample from bin 6 processed at Shearer's Foods on 4.2.13

Figure 3. MSU grade sample from bin 6 processed at Shearer's Foods on 4.2.13

the month of March 2013, resulting in the discussion to process the bin of MSJ126-9Y.

Figure 1 depicts the chip quality in early April 2013 just prior to processing of the MSJ126-9Y at Shearer's Foods in Brewster, OH. Tuber weight loss could not be calculated at the time of bin unloading, but 2.7 percent of the tubers were expressing pressure bruise and discoloration under the skin. Figure 2 represents a chip quality grade sample conducted on finished product of MSJ126-9Y. This picture depicts potatoes that were processed on a continuous feed fryer at Shearer's Foods and graded by Michigan State University Potato Extension based on MSU evaluation criteria. The MSU total defect score of 14 percent is much higher than the 2.5 percent total defects reported by Shearer's. Figure 3 represents a chip quality grade sample conducted on finished product of MSJ126-9Y as well. This sample was processed on a kettle fryer at Shearer's Foods and graded by Michigan State University Potato Extension based on MSU evaluation criteria. The MSU total defect score of 20 percent is much higher than the 8.0 percent total defects reported by Shearer's.

MSJ126-9Y has shown to have an average agronomic performance with a slightly lower than desired specific gravity for processing. The common scab tolerance of this variety is excellent and this trait alone gives the variety some merit. The variety appears to be a mid-season chip processing variety. The light yellow flesh does not appear to detract from the finished chip quality. Potential tuber immaturity could have been the primary cause for the stem end defects that were present at the time of harvest. The May 22nd planting date was potentially too late for this variety, resulting in chemical immaturity within the tubers. The sucrose levels were reported to be 1.101 on the 4th of September, prior to vine kill on September 17th, 2012. An earlier planting may improve chemical maturity at the time of harvest. The market window for best processing quality of this variety appears to be February or March, similar to Snowden. Overall, the agronomic performance of MSJ126-9Y needs to be further assessed to determine the economic viability of the variety.

Section B. Introduction to Storage Pathology and Ozone Utilization

The Storage and Handling Committee has been working with Guardian Integrated Technologies Co. and Techmark Inc. during the 2012-2013 storage season to evaluate the effectiveness of Ozone application to bulk potato piles to reduce the inoculum load from rot pathogens. Bins 8 and 9 were both filled with the variety Pike and inoculated with four common rot pathogens, Dry Rot, Pink Rot, Pythium Leak and Soft Rot. In all, roughly 1 percent of the 600-620 cwt. of potatoes in each of these bulk bins were inoculated with a rot pathogen. Ozone application was made at a measured rate to bin 9 beginning at the time of bin loading in 2012. Bin 8 was used as the control bin. Our results at this time, from this seasons experiment, are preliminary and we are not prepared to present any conclusions at this time. As we work closely with Guardian and Techmark, we hope to refine our experimental protocol to achieve a more accurate evaluation of the efficacy of Ozone application to bulk potatoes. Currently, we plan to make modifications to our experimental protocol for the 2013-2014 storage season and then reevaluate the efficacy of the product. We are planning to change our test variety, reduce the number of pathogens being used, reduce the amount of inoculated tubers in each bulk pile and reduce the rate and volume of Ozone that is being applied to the treated bin. Tuber injury was observed in bin 9 as a result of overexposure to ozone, thus causing injury to the tuber periderm and increased vulnerability of the tubers to storage breakdown (Figure 1.). Great effort will be made to eliminate this effect in 2013-2014, at which time we hope to present our conclusions from this study.

Figure 1. Pressure bruise-like injury observed in bulk bin 9 (Ozone treated).

Guidelines for Stadium Application to Potato Tubers

Willie Kirk (PSMS, MSU), David Ross (Syngenta crop Protection), Phillip Wharton and Nora Olsen (University of Idaho)

Potatoes are susceptible to a variety of storage pathogens, including Fusarium dry rot (*Fusarium sambucinum*), silver scurf (*Helminthosporium solani*), late blight (*Phytophthora infestans*), Pink rot (*Phytophthora erythroseptica*), Pythium leak (*Pythium ultimum*) and black dot (*Colletotrichum coccodes*). Current recommendations for potato storage diseases include sanitation and exclusion as the primary controls for these pathogens in storage facilities. Few 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.

Several commercial storage products Phostrol (sodium, potassium and ammonium phosphates), and Storox (hydrogen peroxide/peroaxyacetic acid mixture) are registered for control of storage pathogens. Recently, Stadium a new product from Syngenta Crop Protection was registered for use as a pre-storage treatment for management of Fusarium dry rot and Silver Scurf in storage. Stadium is a three way mixture of azoxystrobin (Quadris), fludioxonil (Maxim) and difenoconazole (Inspire) and the application rate is 1.0 fl. oz. per 20 cwt (ton) of potato tubers carried in 0.5 gal H_2O per ton of tubers. Results form trial at MSU and University of Idaho show that Stadium provided effective disease control.

How to achieve optimum coverage with Stadium on potato tubers entering storage.

Key Points

a. Insure consistent uniform spray coverage of tubers.
b. Position the spray nozzles at a point where tubers are rotating, turning or dropping during the application.
c. The proper spray volume will allow full coverage without leaving the tubers dripping wet.
d. Check calibration regularly during application.
e. Constant agitation of spray liquid is required to maintain product in suspension.

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1. **Evaluate the treatment system**:
    a. Storage facilities, storage processes and storage conveyer systems can vary greatly as to setup, volume and quality of the crop being stored.

   b. Before application, it is important to evaluate each location and design an application system to meet the needs of the specific conditions.
      i. Configuration of unloading, sorting conveyor systems: Is there adequate space available for the application?
      ii. Note positions along the line where a spray may be applied to the tubers (e.g. drop points, spread points, room for a spray table along the line).
      iii. Tonnage/hour being stored – This will dictate the type and volume of the application system.

2. **Position**:
   a. The treatment site should be easily accessible to allow calibration, inspecting spray and coverage, and for cleaning nozzles and maintenance.
   b. The treatment site should be at a point where tubers are rotating, turning or dropping to insure coverage.

3. **Spray Volume**:
   a. Strive to achieve optimum spray volume for each storage facility:
      i. Too high of a carrier volume will leave the tubers wet and encourage bacterial rot.
      ii. Too low or a carrier volume will prohibit adequate coverage and limit protection.
      iii. Tubers should look uniformly "damp", but not "dripping wet".
      iv. Use 0.25 to 0.5 gal/ton.
      v. Note - The target volume (spray per ton of tubers) can vary with tuber size. Smaller tubers have more surface area and may require slightly more carrier volume per ton.

0.25 gal/ton 0.5 gal/ton 1.0 gal/ton 2.0 gal/ton

(Picture Credit - Lynn Woodell, Univ. Idaho)

4. **Tonnage:**
   a. For high tonnage systems (resulting in multiple layers of tubers on conveyers) – A "drop" application method is appropriate.

b. For lower tonnage (Single layer of tubers) - Roller tables or conveyors may be considered.
c. If tonnage and space allow, roller tables and/or toll-booth application positions (where multiple layers of tubers are allowed to spread out into a single layer) may be appropriate.
d. Where space does not allow for roller tables, positioning nozzles at a logical drop point is probably the best option.

5. Type of application system:

a. The objective of tuber application is to apply Stadium uniformly across the surface of the tuber in adequate carrier volume to ensure good coverage, but without leaving the tubers visibly "wet". Two primary configurations exist:

b. Application Table Application:
   i. If space allows, a roller-application table or roller-toll-booth-spreading system can be used for application. This would ideally be positioned just after the final sorting tables.
   ii. Shielding is required to reduce exposure close to the sorting workers.
   iii. Rollers are required to ensure that tubers are rotating or turning during application.
   iv. If the tubers are in a single layer, a roller table is appropriate.
   v. If the tubers are typically 2-deep or more, a spreading system may be required to reduce their depth to a single layer.
   vi. Nozzles are positioned above the line to spray down onto the rotating tubers.

c. Drop-point Application:
   i. If space or other considerations do not allow for a roller table application, a drop-point application may be used.
   ii. The spray is applied to tubers as they fall from one conveyor to another, or off the end of the piler.
   iii. Chose a natural drop-point where tubers fall in a single layer, and where nozzles can be positioned for best coverage.
   iv. Note that for high tonnage operations, where falling tubers remain in multiple layers, nozzles must be positioned both above and below the falling tubers.

(Picture Credit - Nora Olsen, Univ. Idaho)

v. If conveyor to conveyor drop points are shielded, or where tubers "flow" several tuber deep from one conveyor to another, then the only choice may be to position the sprayer at the end of the piler. This is not ideal as and certain factors should be recognized:
   1. It will be difficult to inspect, clean and maintain such a system,
   2. The risk of pile contamination or over application exists, in case of breakage or a system blow-out.

6. **Recommended Spray Location:**
   a. We recommend that Stadium be applied at each drop at the end of a star-roller system, before dropping to the conveyor system into the storage facility. The tubers will be cleaned as much as possible and will still be spread out in a thin layer prior to hitting the conveyor. Two spray bars approximately 2' apart will ensure best coverage.

7. **Mixing and Calibration**:
   a. Once setup, tonnage & application volume has been determined, proper calibration is critical.
   b. Calibration procedure:
      i. Measure the tonnage throughput per hour.
      ii. Calculate the spray volume/minute required to apply the volume/ton of tubers (for example: 7.5 gal/hr for 0.5 gal/ton).
      iii. Measure and verify that the spray application system can deliver the amount required/minute or that it can be adjusted if necessary.
      iv. Calibration example: (Note – gallon spray/hr should be the sum of the volumes from ALL nozzles delivered per hour):

         1. Higher tonnage/hour:
            a. Target tons/hr = 30 (0.5 tons/minute)
            b. Gal/ton = 0.5
            c. Gal spray/hr = 15 (0.25 gal spray/minute)
               (30 tons/hr x 0.5 gal/hr)
         2. Lower tonnage/hour:
            a. Target tons/hr = 15 (0.25 tons/minute)
            b. Gal/ton = 0.5
            c. Gal spray/hr = 7.5 (0.25 gal spray/minute)
               (15 tons/hr x 0.5 gal/hr)

8. **General Guidelines and Considerations:**

a. ALWAYS FOLLOW LABEL INSTRUCTIONS.
   Read the label in its entirety.
   Instruct and demonstrate the label to all people mixing, handling or applying Stadium fungicide.
b. CONSTANT AGITATION of the slurry is important during the application process.
c. Does the operator/facility have appropriate certifications?
d. Where will the treatment area be situated relative to the pile and workers?
   All treatment areas should be enclosed or shielded, where possible, or otherwise setup to prevent drift of spray mist.
e. Check calibration regularly to insure proper dosage delivery.
f. Application volumes must be adjusted to the capacity of the line and tuber volume being treated.
g. Position drip trays below the treatment site to catch waste chemical.
h. Does the application system have an automatic cut-off to stop the applicator if tuber flow ceases?
   It should be possible to stop all machinery on the line via one switch in case of emergency.
i. What is the anticipated throughput in tons/hour?
   Can a constant throughput be maintained?
   Can all parts of the line handle the throughput?
j. Can any treatment table be consistently filled across its width?
k. Will the applicator deliver the desired output and maintain an effective spray pattern?
l. If a conveyor/elevator/piler application system is used, is the “drop” great enough to achieve coverage while small enough to minimize damage?