

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-compatibility), *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 compatibility (*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-cry11a1*), 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 Missaukee 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.

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Table 1 Early Observation Trial: Most promising lines.

Line	Plot Yield (cwt/a)	Specific Gravity	OTF 8/5/13		Pedigree	
			SFA Chip Score	Merit ¹	Female	Male
<i>Chip-processing</i>						
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		

¹Merit 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

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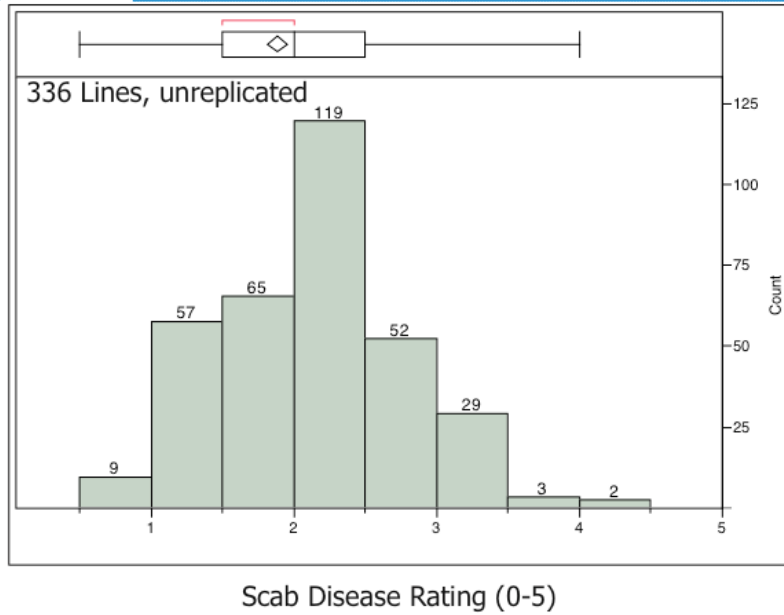
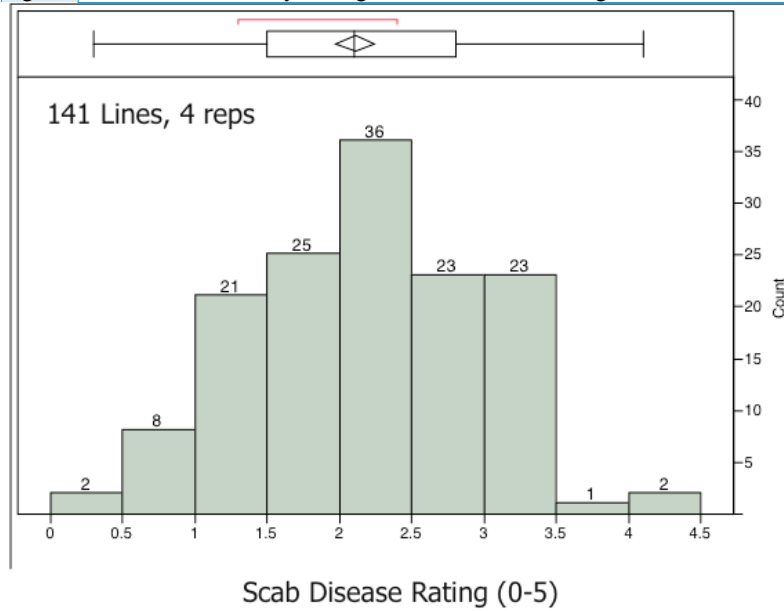


Fig. 2. Scab Disease Nursery Ratings in Advanced Breeding Lines

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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.

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

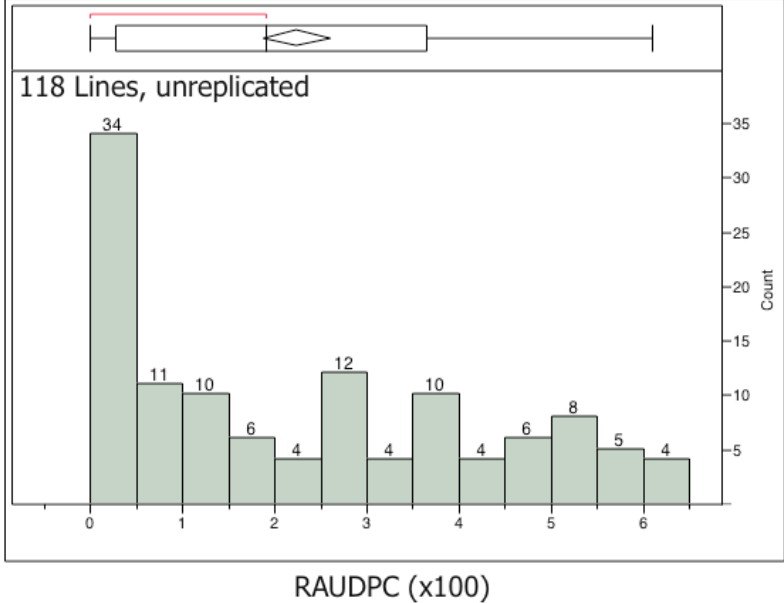
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Line	Female	Male	2013 Tuber Appearance	2012 Scab Rating	Field	Washed	2013 SPGR	OTF CHIP 9/19/13	SED 2013
					Scab Rating 9/18/13	Scab Rating 9/19/13			
Z052-31	Pike	R127-2	1	1.0	0.5	0.5	1.079	1.0	0.0
Z062-10	R127-2	McBride	2	1.0	0.5	0.5	1.083	1.0	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 GREEN-fund project. In 2013 we

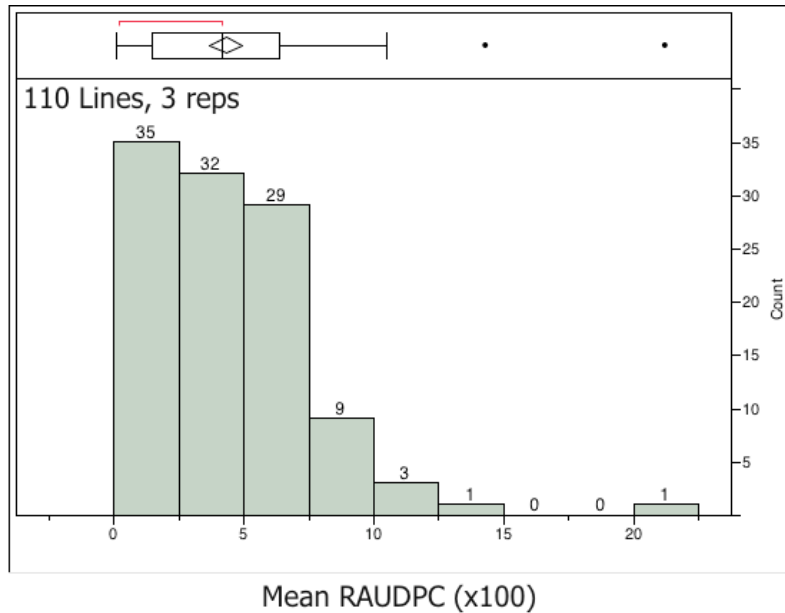
conducted late blight trials at the Clarksville Research Center. We inoculated with the US22 and US23 genotypes, but the foliar reaction to the *Phytophthora infestans* has been different from all previous years using US8. In some cases lines that were classified as resistant were susceptible. On the 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. 1 and 2). 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.

Fig. 1. Foliar Late Blight Reaction in Early Generation Lines



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Fig. 2. Foliar Late Blight Reaction in Advanced Breeding Lines



Colorado potato beetle: With support from project GREEN 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. Five lines showed significant reduction to defoliation. These lines are being used to make further crosses to advance this beetle resistance trait. 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.

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 14 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 20 lines and four 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 half 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.

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

Line	Resistance	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							
		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
	MR ScabR								
MSQ035-3	LBR	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: Chip-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 GREEN 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.