2014 MSU 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 Chip Processing Trial (NCPT) 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 as 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. 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.

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 2014 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 2014 harvest, over 1,200 selections were made from the 60,000 seedlings produced. In addition, about 40 third 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 2014 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 120 selections were made, respectively; based upon chip quality, specific gravity, scab resistance, late blight resistance and DNA markers for PVY and golden nematode resistance. 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 tested the removal of PLRV in 2014 and succeeded.

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), MSQ086-3, (verticillium wilt 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 2014, while others were tested under replicated conditions at the Montcalm Research Center. Promising tablestock lines include MSL211-3, MSQ440-2, MSQ086-3, MSS487-2 and MSQ131-A. We have a number of tablestock selections with late blight resistance (MSS576-5SPL, MSQ131-A, MSS487-2 and MSS176-1). MSL211-3 has earliness and a bright skin. 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 Purple Sport 1. MSQ558-2RR and MSR226-ARR are red-fleshed chippers. We are increasing seed of Missuakee for international markets due to its late blight resistance and Golden nematode resistance.

Disease and Insect Resistance Breeding

Scab: In 2014 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 1**. The susceptible checks of Snowden and Atlantic were highly infected with pitted scab. Promising resistant selections were McBride,

MSL007-B, MSR061-1, MSR127-2, MSU383-A, MSQ440-2, MST252-1Y, MSV179-1, MST424-6 as well as the Z-series selections from the commercial scab site. 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. 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

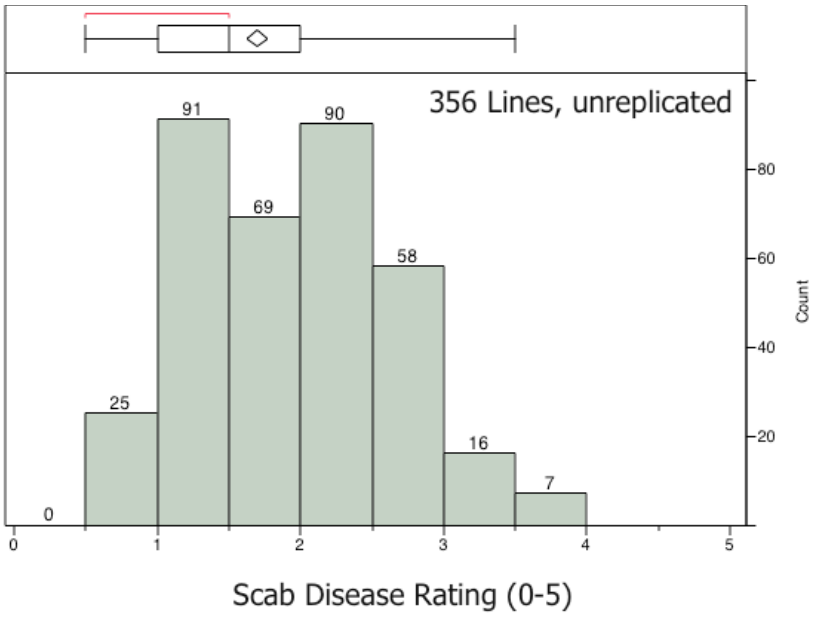
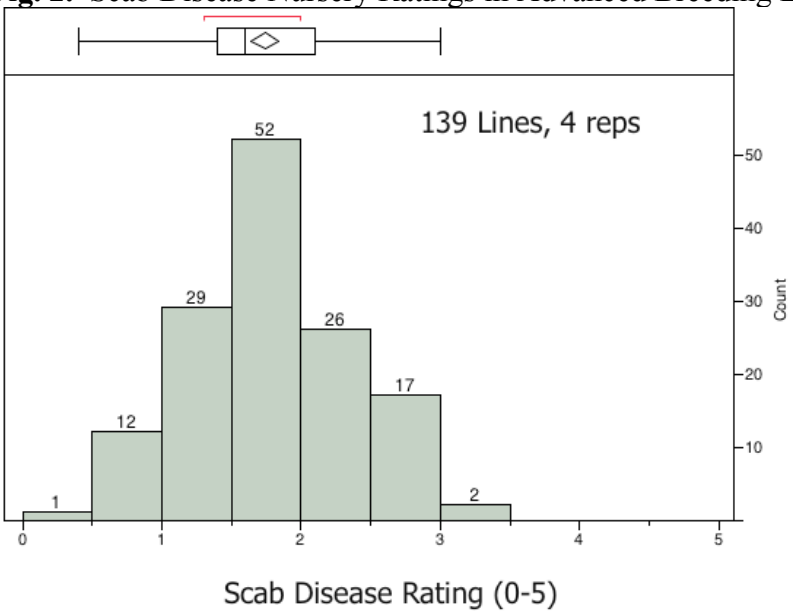


Fig. 2. Scab Disease Nursery Ratings in Advanced Breeding Lines



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.

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 2014 we also made 40 scab-resistant chip-processing selections. The most most-promising selections are listed in Table 1. These lines are being placed in tissue culture for further testing.

Table 1. *Streptomyces* Scab Trial Results from On-Farm trial location.

Priority	Line	Scab	Total	US#1	US#1	Bs	As	OV	PO	SPGR
Check	Kalkaska	1.0	315	282	90	10	74	15	1	1.084
Check	Lamoka	1.3	345	319	93	7	93	0	0	1.089
Check	P270-1	0.5	144	114	79	21	79	0	0	1.079
1	Z022-07	0.8	352	328	93	7	85	8	0	1.085
1	Z052-11	0.8	438	402	91	9	88	3	0	1.082
1	Z052-13	0.3	332	313	94	6	88	6	0	1.088
1	Z062-10	0.5	355	325	92	8	91	1	0	1.091
1	Z062-50	0.5	332	320	97	3	75	22	0	1.083
1	Z068-02	1.0	345	319	93	6	86	7	1	1.091
1	Z096-03	1.0	406	370	91	9	83	8	0	1.087
1	Z118-19	0.5	282	275	98	2	58	40	0	1.084
1	Z169-01	0.8	425	371	87	12	75	12	2	1.082
1	Z219-01 PVYR	0.3	319	299	94	5	91	3	1	1.085
1	Z219-13 PVYR	1.0	352	334	95	4	87	8	1	1.094
1	Z219-14 PVYR	0.5	403	382	95	5	91	4	0	1.090
1	Z219-46 PVYR	0.3	268	251	94	5	61	33	1	1.082
1	Z242-03	0.8	399	369	93	7	88	5	0	1.090
1	Z242-12	1.5	373	332	89	11	85	4	0	1.099
1	Z242-13	0.8	288	261	92	7	91	1	1	1.104
1	Z242-14	1.3	306	284	93	5	90	3	2	1.083
1	Z242-15	0.8	308	295	96	4	95	1	0	1.094
1.5	Z020-08	0.5	282	270	96	4	82	14	1	1.081
1.5	Z052-40	1.0	352	294	83	16	75	8	1	1.086
1.5	Z062-31	1.0	416	378	91	9	82	9	0	1.080
1.5	Z222-19	1.8	325	303	93	6	82	11	1	1.093
1.5	Z242-07	1.5	323	301	93	7	87	6	0	1.099

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 2014 we conducted late blight trials at the Clarksville Research Center. We inoculated with the US23 genotype, 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 (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 2014 trials is summarized in Figures 3 and 4.

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

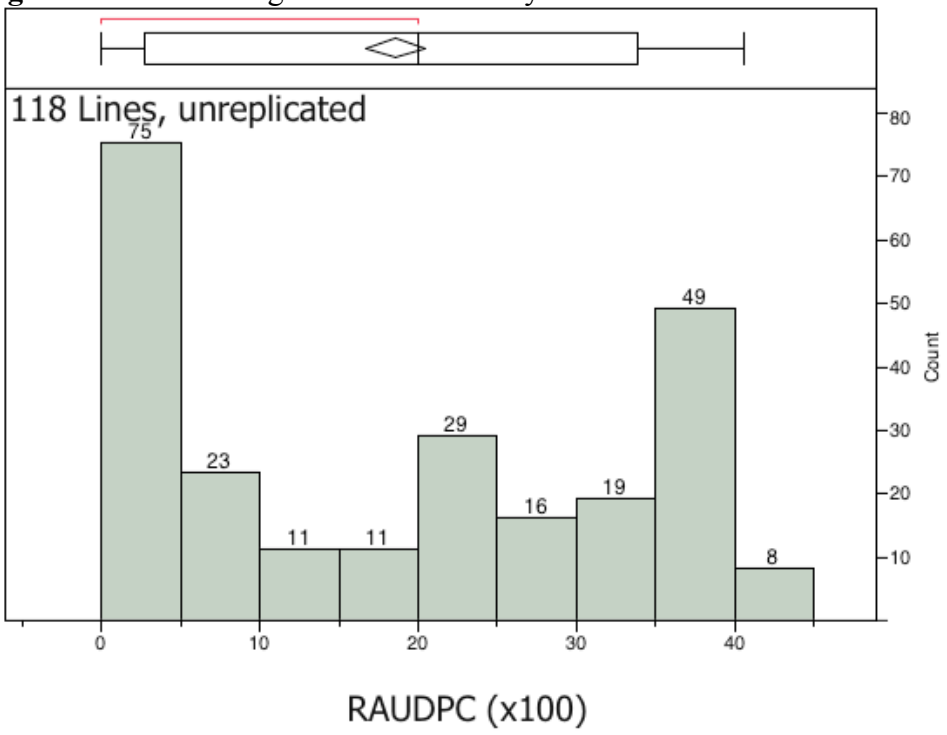
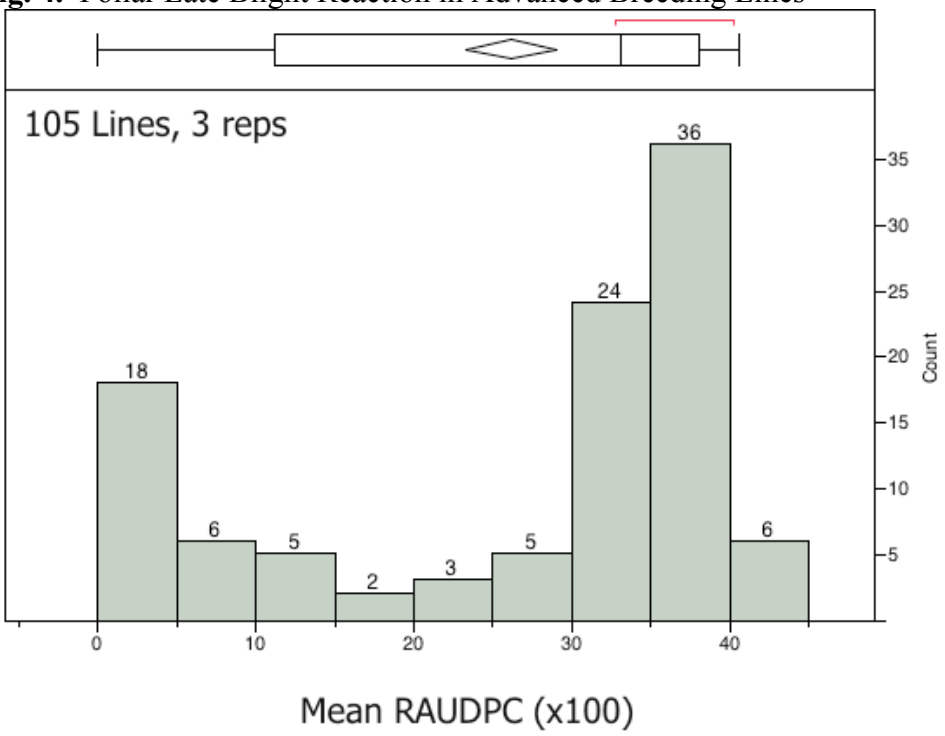


Fig. 4. Foliar Late Blight Reaction in Advanced Breeding Lines



MSU Lines with Commercial Tracking

McBride (MSJ126-9Y)

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

Strengths: McBride is a chip-processing potato with an attractive round appearance with shallow eyes. McBride has a medium vine and an early to mid-season maturity. This variety has resistance to *Streptomyces scabies* (common scab) stronger than Pike. McBride 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.

Manistee (MSL292-A)

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

Strengths: Manistee is a chip-processing potato with an attractive round appearance with shallow eyes. Manistee has a full-sized vine and an early to mid-season maturity. Manistee 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. We now have DNA SNP markers linked to late blight resistance, scab resistance, chip color, tuber asparagine and specific gravity. We will now start using this linkage information to assist us in breeding.

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 previous 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 *S. 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. This new diploid potato breeding project is expanding to develop promising lines to use as parents in the future.

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 agronomic trials were conducted in 2014. The best performing lines are being advanced for more testing. In an inoculated field test in Idaho the MSE149-5Y line was 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 were conducted for a subset of these lines in 2014. The best lines will be re-tested in 2015. Lastly, we have some lines with the vacuolar acid invertase silencing that were field tested in 2014. There are three MSE149-5Y lines with good silencing that maintain low reducing sugars in 4C storage. We have generated a few Kalkaska invertase silencing lines that are being grown to produce tubers for cold storage testing.